2015 Climate Change Action Plan Update

August 2016

Presented to:
Governor Tom Wolf

Presented by:

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

The Pennsylvania Climate Change Act (Act 70 of 2008, or Act) provides for a report on potential climate change impacts and economic opportunities for the Commonwealth. The Act 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. This document is the second update to the original Climate Change Action Plan that was issued by DEP in December 2009.

In addition to the Action Plan, the DEP provides a report on the potential impact of climate change on human health, the economy and the management of economic risk, forests, wildlife, fisheries, recreation, agriculture and tourism in Pennsylvania. This report was completed for DEP by Penn State University's Environment and Natural Resources Institute in May 2015. Also required of DEP is a report on the economic opportunities for the Commonwealth created by the potential need for alternative sources of energy, climate-related technologies, services and strategies, carbon sequestration technologies, capture and utilization of fugitive GHG emissions from any source and other mitigation strategies. This report is provided as a macroeconomic analysis of the individual work plans contained in the Action Plan. The analysis was prepared under contract for DEP by the Center for Climate Strategies.

The Pennsylvania Climate Change Advisory Committee (CCAC) provided advice to DEP for the preparation of this Plan. The CCAC was composed of 18 members during the development of this Plan. The 2009 Climate Change Action Plan was developed by DEP, CCAC and an outside contractor with over 50 concepts for GHG reductions described in work plans. In 2013, the Climate Change Action Plan Update focused on updating 28 work plans that were most feasible for implementation. For this 2015 Update, DEP and the CCAC focused on updating work plans that needed additional explanation related to implementation. Primarily, DEP and CCAC members selected work plans to include in the latest update based on the largest GHG emissions reductions.

The 13 work plans, contained in this report, for reducing GHG emissions were discussed and evaluated, including cost-effectiveness, with the CCAC over a two-year period. Each work plan identifies the costs, benefits and co-benefits of the plan and is included in the Appendix. The Center for Climate Strategies provided assistance to DEP by performing a macroeconomic analysis of the work plans to account for potential costs and benefits provided to the gross state product and employment impacts of each individual plan.

Work Plans Ranked by Potential Reduction		
Work Plan Title	**Potential Reductions through 2030 (MMTCO2e)**	**Cost-Effectiveness through 2030 ($/MMTCO2e)**
10. Energy Efficiency Financing in Pennsylvania	**Not Quantified***	**Not Quantified***
7. High Performance Buildings	**97.9**	**-89.8**
8. Re-Light PA	**71.2**	**-71.6**
5. Heating Oil Conservation and Fuel Switching	**43.49**	**-90.92**
4. Geoexchange Systems (Ground Source Heat Pumps)	**35.1**	**-204**
3. Adopt Current Building Energy Codes	**32.2**	**-85**
2. Act 129 of 2008 Phase IV & V	**18.1**	**-218.6**
1. Coal Mine Methane Recovery	**12.6**	**12.42**
6. Combined Heat and Power (CHP)	**8.2**	**-27.5**
12. Urban & Community Forestry	**7.3**	**-59**
9. Manufacturing Energy Technical Assistance	**7.1**	**-83.1**
13. Manure Digesters	**2.4**	**3.72**
11. Semi-Truck Freight Transportation	**2.1**	**-309**
Total	**337.69**	**-1222.38**

Work Plans Ranked by Cost-Effectiveness		
Work Plan Title	**Potential Reductions through 2030 (MMTCO2e)**	**Cost-Effectiveness through 2030 ($/MMTCO2e)**
10. Energy Efficiency Financing in Pennsylvania	**Not Quantified***	**Not Quantified***
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* Reductions and cost-effectiveness were not calculated for the Energy Efficiency Work Plan due to the uncertainty of available funding and program design.

Based on the costs and savings analysis developed by DEP for 12 of the 13 work plans the macroeconomic analysis of those work plans shows that the majority have real potential to generate not only GHG reductions but also significant improvements in total employment, total income and real disposable personal income. The results suggest that implementing all 12 work plans would result in significant employment gains, while reducing energy use enough to actually lower total gross domestic product (GDP).

Importantly, this analysis shows that climate change policies, like initiatives in any other area of public policy, will vary dramatically in their impact on economic activity, as well as on equity concerns. Further, policies can be designed and redesigned to achieve their climate goals while also tending to concerns about overall economic health of a region. Both observations help to erode the assumption that climate policy is at odds with economic development – indeed, efficiencies such as those sought by most of the work plans covered here are projected by this analysis to drive increases in jobs and incomes more often than not.

This Action Plan summarizes Pennsylvania GHG emissions and sinks for the base year 2000 through 2012, along with the GHG emissions projections from 2015 through the target year of 2030. The total statewide gross GHG emissions for Pennsylvania in 2012 were 287.38 MMTCO2e compared to 322.96 MMTCO2e in 2000, a relative decrease of 11.02 percent.

Overall, Pennsylvania's gross GHG emissions are projected to be lower in 2030 than in 2000, with reductions in the residential, commercial, transportation, agriculture and waste sectors. The total statewide emissions sinks are expected to remain stable, creating consistent net GHG benefits through 2030. The benefits of emission sinks are mostly attributed to Pennsylvania's forestry sector.

The Commonwealth of Pennsylvania possesses abundant energy resources which contribute to electricity generation, such as natural gas, coal, nuclear, hydropower, wind, solar and other renewables. Pennsylvania is a national leader in both energy production and resource diversity. There are immense opportunities for renewable energy in Pennsylvania, such as wind and solar. With the improvement of battery storage technology, wider deployment of renewable energy can be achieved. As a leading state in gas and coal production, Pennsylvania is uniquely positioned to be a national leader in addressing climate change.

Pennsylvania currently has approximately 200 major electric generation facilities. While coal, oil and natural gas comprise the greatest number of facilities, the output of the state's five zero-carbon emitting nuclear power plants will continue to generate over one-third of Pennsylvania's electricity into the future.

Pennsylvania has traditionally been an electricity exporting state due to the strength of its coal and nuclear fleet. However, greater diversity in the market place due to an alternative portfolio standard, implementation of widespread energy efficiency and conservation as well the rise of natural gas use have resulted in a variable and changing generation portfolio. In the midst of this change, Pennsylvania still operates as a significant electricity exporting state within the Mid-Atlantic region. According to the U.S. Energy Information Administration (EIA), in 2012, Pennsylvania ranked 1st nationally in electricity export and 2nd in electricity production. Energy efficiency also plays a significant role in Pennsylvania with the adoption of Act 129 of 2008, which requires electricity distribution companies to implement energy efficiency and conservation plans aimed at reducing customers' energy use. According to the EIA, Pennsylvania ranks 31st in total energy consumed per capita.

Methane has been identified by the EPA as the second most prevalent GHG emitted in the United States from human activities, accounting for 10 percent of domestic GHG.[1] According to

[1] *U.S. Greenhouse Gas Inventory Report: 1990-2013*, http://www.epa.gov/climatechange/GHGemissions/gases.html

EPA, methane is estimated to have a global warming potential of 28-36 over 100 years.[2] This reflects the fact that methane emitted today will persist in the atmosphere for about a decade on average. The key sources of methane include landfills, coal mines, agriculture, and oil and gas operations.[3] Pennsylvania is an economic leader in each of these industries and is committed to curbing methane emissions from these sectors.

The Pennsylvania General Assembly has provided DEP with powers and duties to control air pollution through the Pennsylvania Air Pollution Control Act. Through the use of current statutes, regulations and permitting requirements, Pennsylvania has already demonstrated that technology and best practices to deliver substantial reductions in methane emissions exist and can be accomplished cost-effectively.

The transportation sector contributes 27 percent of the total U.S. GHG emissions. In Pennsylvania, the 2012 transportation sector contributed 25.5 percent to the total GHG emissions. This is due to the scale of the activities encompassed and the intensity and inefficiency with which liquid fuels are consumed. According to the U.S. Department of Transportation (DOT), "transportation is the largest end-use sector emitting CO2" and 97 percent of the emissions from the transportation sector come from direct combustion of liquid fuels.[4]

The impacts of the transportation sector on the overall GHG emissions in Pennsylvania can be reduced through four primary strategies:

1. Increase fuel efficiency and improve technology and design;
2. Reduce demand for travel or share travel modes among public;
3. Switch to cleaner, less GHG intensive fuels; and
4. Improve operating practices and educate drivers.[5]

Various federal and state programs exist to allow for the reduction of emissions from the transportation sector. These programs would allow DEP to examine the gains achieved so far and identify room for improvement. It's easier for the Commonwealth to impact some areas, such as investment in transit services, than others, such as switching to an alternative fuel vehicle, which is a personal choice which the Commonwealth can only encourage through incentives.

Forests play an important role in mitigating the impacts of climate change. Healthy, productive forests store and sequester carbon. Sustainable timber harvesting can not only improve the health of the forests and encourage the growth of young, vigorous trees; it can also result in durable wood products, which continue to store carbon for long periods of time.

Pennsylvania has a 2.2-million-acre state forest system which is an important reservoir for both storing carbon and sequestering it from the atmosphere. In 2015, state forests are expected to

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[2] *Understanding Global Warming Potential*, http://epa.gov/climatechange/GHGemissions/gwps.html
[3] *The White House Climate Action Plan: Strategy to Reduce Methane Emissions*, March 2014, https://www.whitehouse.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf
[4] U.S. DOT, Transportation and Climate Change Clearinghouse, Transportation's Role in Climate Change, http://climate.dot.gov/about/transportations-role/overview.html retrieved on 8/21/15
[5] U.S. EPA, Sources of Greenhouse Gas Emissions, http://www.epa.gov/climatechange/GHGemissions/sources/transportation.html updated on 5/7/15, retrieved on 8/24/15

sequester 4.7 million tons of carbon and store, above ground, 143 million tons. Pennsylvania's 11.5 million acres of privately owned forestland also provide carbon storage and sequestration, although rates vary depending on how well they are managed and developed. Forests also help to combat the effects of climate change by providing key ecosystem services, such as improving rising stream temperatures, reducing runoff during heavy rain events, and taking up excess nutrients to keep water clean.

The agriculture sector is one of the many industries that release GHGs into the atmosphere. Agricultural activities are one of the most important and necessary contributions made to society and have the potential to act as both producer and reducer of GHG emissions. GHG emissions from farms can be summarized into the categories of energy consumption activities and livestock emissions. Within Pennsylvania, emissions from agriculture are estimated to be less than 3 percent of the state's total emissions.[6] Pennsylvania is home to 58,800 farm operations operating 7,720,000 acres of farmland.[7]

GHG emissions in the waste management sector primarily come from three sub-groups; landfill gas, solid waste combustion, and wastewater treatment. Landfill gas, methane, is generated by the decomposition of solid waste within a landfill. Some solid waste in the Commonwealth is combusted in waste-to-energy plants, thus reducing the amount of methane that is emitted but increasing the amount of carbon dioxide. Both municipal wastewater treatment and industrial wastewater treatment are accounted for in the third sub-group. In 2012 the waste management sector contributed 1.4 percent of the total Pennsylvania GHG emissions.

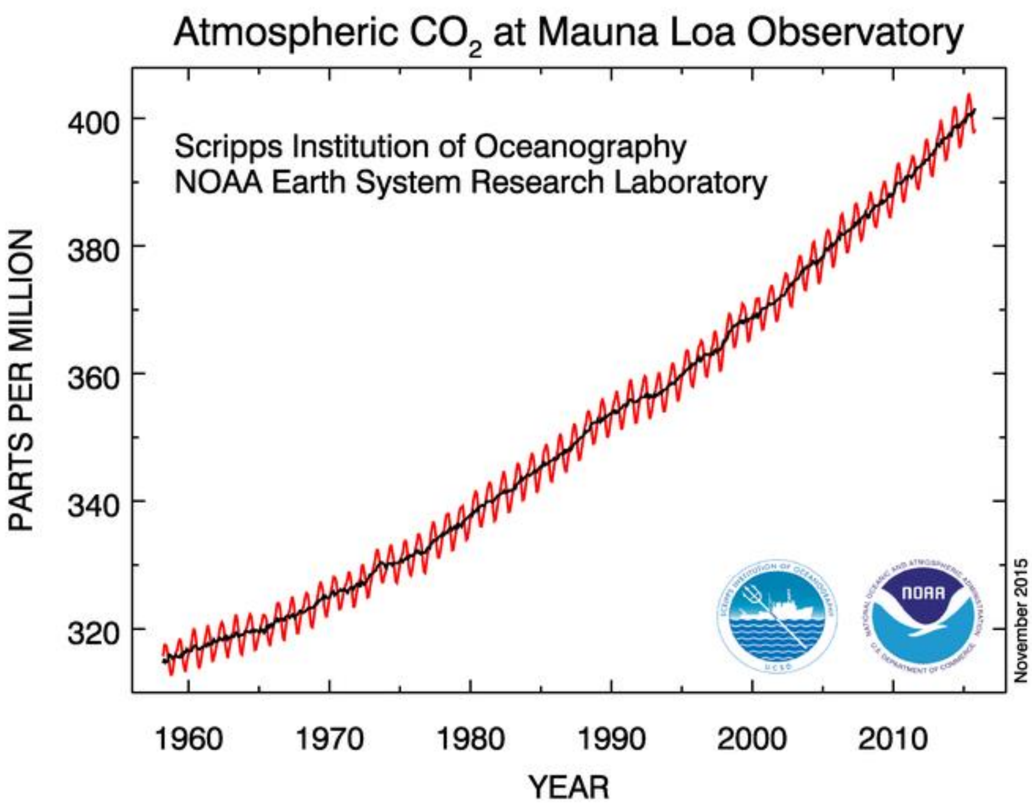
With this Action Plan, DEP is recommending 12 actions to the Pennsylvania Legislature.

[6] 2009 Climate Change Action Plan, 9-1
[7] http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA

Chapter 1: Overview and Introduction

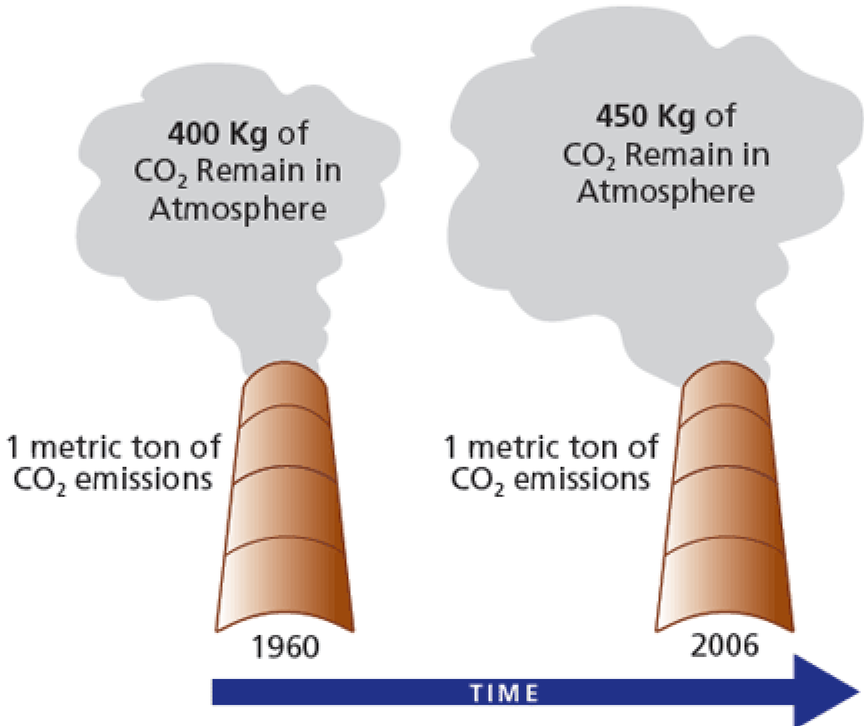
One of the most serious issues facing the world is climate change (or climate disruption). Since at least the 1970s, scientists have warned that human activities are impacting global climate patterns. Increasing levels of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), have led to a warming of the Earth's atmosphere. On a global scale, every single year for the past 37 years has been warmer than the 20th century average. When too much carbon enters the atmosphere, the gas acts like a blanket around the Earth, not allowing the heat received from the sun to escape back into space. This is where the term "global warming" stems from.

The need for energy is the primary driver of these GHG emissions, and Pennsylvania is the third largest emitter of carbon dioxide in the country. It is irresponsible to continue these known activities and same patterns that are impacting our health, our communities, and our environment. Melting ice caps, sea level rise, wildfires, extended heat waves, extreme storms and flooding events are the consequences and they are happening now. Yet atmospheric CO_2 levels have increased every year.[8]



[8] National Oceanic and Atmospheric Administration. "Earth System Research Laboratory: Global Monitoring Division." http://www.esrl.noaa.gov/gmd/ccgg/trends/ff.html

Global deforestation has reduced the amount of carbon that is absorbed through natural processes. The ocean is also a major carbon dioxide sink. Over time, excessive CO_2 has made the ocean more acidic and warmer and therefore unable to continue its absorption rate. This means that a higher percentage of the CO_2 emitted remains in the atmosphere today than decades ago.



Source: UCS; Data from Canadell et al. 2007, PNAS

Fortunately, there are practical solutions that can be easily deployed to reduce GHG emissions and slow the pace of climate change. These solutions are not just good for mitigating GHG emissions, but will strengthen our energy security, create jobs, and improve our health through an improved environment. As most GHGs remain in the atmosphere for decades or even centuries, it is impossible to immediately reverse the damage that has already been done. This Action Plan provides concepts and options that can be implemented immediately in Pennsylvania to ensure that we're doing our part to slow the progression of climate change.

Pennsylvania has made strides in the past few years to reduce GHG emissions in several areas. In the electricity production sector, preliminary EPA data show the GHG emissions from electricity generation decreasing by nearly 8 MMTCO2e from 2012 to 2014. Data provided by the U.S. Energy Information Administration show that Pennsylvania experienced a 29 percent increase in the electrical production by renewable energy sources between 2012 and 2013. According to the Phase II Year Five Statewide Evaluator report for the Act 129 program, over three quarters of an MMTCO2e of GHG emission is saved annually by business and citizen participation in Act 129. In the industrial sector, approximately 50 Pennsylvania manufacturing plants underwent energy use assessments by U.S. Department of Energy (DOE) Industrial Assessment Centers from 2013 to 2015. In the transportation sector, the Act 13 Natural Gas Energy Development Program has helped deploy over 2,000 vehicles statewide which run on some form of natural gas. DEP, through the Alternative Fuels Incentive Grant Program, has awarded $6.8 million for over 1,000 natural gas, propane, and electric vehicles in the Commonwealth since 2013.

The Pennsylvania Climate Change Act (Act 70 of 2008) requires the DEP to submit to the Governor a Climate Change Action Plan (Action Plan or Plan) that is revised every three years. This document is the second update to the original Climate Change Action Plan that was issued by DEP in December 2009.

The Climate Change Advisory Committee (CCAC) provided advice to DEP for the completion of this Plan. The 13 work plans for reducing GHGs that are referenced throughout this document and included in the Appendix were discussed and evaluated, including the cost-effectiveness, and voted on by the CCAC. Each work plan identifies costs, benefits, and co-benefits. The Center for Climate Strategies also provided assistance to DEP by analyzing the work plans for potential costs and benefits provided to the Gross State Product and employment impacts.

A Note About the Federal Clean Power Plan

On August 3, 2015, President Barack Obama released the final rule regulating carbon emissions from existing power plants. Known as the Clean Power Plan, the federal rule requires states to submit plans that demonstrate the achievement by 2030 of carbon emission reduction targets established by the U.S. Environmental Protection Agency (EPA). Final state plans were originally to be submitted by September 2016 with an alternative option of states requesting an extension until September 2018. The United States Supreme Court issued a stay on the Clean Power Plan on February 9, 2016, and is expected to hear arguments on the case at some point in 2017. Currently there is no timetable for the submission of state plans.

In September 2015, Pennsylvania opened a 60-day public comment period on the Commonwealth's implementation of the Clean Power Plan. In addition, the state held a series of 14 listening sessions across the state to solicit stakeholder input. DEP hopes to use the information gathered to develop a draft state plan by early 2016.

Pennsylvania's compliance with the Clean Power Plan will clearly be a major component of its approach to climate change. As noted below, electricity production is the largest source of carbon emissions in the state. The final state plan, with compliance requirements beginning in 2022, will reduce the carbon intensity of the state's electric generating fleet. However, because the Commonwealth is still in the early stages of developing its final implementation plan, it is not a component of this Climate Change Action Plan. However, many of the carbon strategies for electricity within this document should ultimately support the development of the state's plan.

Chapter 2: Climate Change Impacts

The consequences of inaction on mitigating the causes of climate change will be felt by all Pennsylvanians. Some of those consequences are already being felt through extreme weather events such as Superstorm Sandy and excessive heat waves. This chapter presents the expected impacts of climate change, as identified in the legislatively required Climate Impacts Assessment Update.

DEP contracted with the Environment and Natural Resources Institute at Penn State University to complete the original 2009 Climate Impacts Assessment, a 2013 Update, and a recently released 2015 Update. The 2009 Pennsylvania Climate Impacts Assessment and subsequent updates present simulations of the impacts of global climate change on Pennsylvania's climate in the 21st century. Each update has revised the conclusions of the 2009 study based on updated and new scientific findings, data and analysis.

The Impacts Assessment provides an overview of the potential impacts of global climate change on Pennsylvania over the next century, including specific impacts on climate sensitive sectors and the general economy. The Commonwealth faces two fundamental threats related to climate: 1) Sea level rise and its impact on communities and cities in the Delaware River Basin, including the city of Philadelphia; and 2) more frequent extreme weather events, including large storms, periods of drought, heat waves, heavier snowfalls, and an increase in overall precipitation variability. The 2015 Update shows that Pennsylvania has undergone a long-term warming of more than 1°C over the past 110 years. The models used in the Update suggest this warming is a result of anthropogenic influence, and that this trend is accelerating. Projections in the 2015 Update show that by the middle of the 21st century, Pennsylvania will be about 3°C warmer than it was at the end of the 20th century.

Also over the past century, there has been a 10 percent increase in annual precipitation in Pennsylvania and, even more noteworthy, an increase in the number of extreme precipitation events. The models predict a decreasing number of very dry months and an increasing number of very wet months in the agriculturally productive southeastern portion of the state. Additional precipitation will result in increased runoff in the eastern part of Pennsylvania – which will have a negative impact on the Chesapeake Bay through additional nitrogen, phosphorus, and sediment loading to the Bay. The projections provided in the Impacts Assessment Update show an increase in annual precipitation of 8 percent, with a winter increase of 14 percent.

Sector Assessments

Agriculture

Agricultural land represents 27 percent of all land use in Pennsylvania. Climate change will have impacts on this industry, but will also present opportunities. Pennsylvania farmers will not only be impacted by changes in climatic conditions in Pennsylvania, but also changes in price and technology induced by global climate change. Specifically, climate change is likely to have mixed impacts on crop production.

The increase in average temperature may mean longer growing seasons and thus higher crop yields. New crops may also be grown. Double cropping may be employed in the southeastern portion of the state, but doing so will require changes to supply chains to accommodate planting, harvesting, transportation, and storage of different grains. However, climate change will also bring more favorable conditions for pests, insects, and weeds – including new types, which could require increased use of agrochemicals. Genetic engineering could improve the pest resistance of crops, reducing the need for chemicals.

The increase in precipitation and its variability could lead to higher plant disease, increased risk of flooding, difficulty in the timing of planting, and increased demand for irrigation. Extreme temperatures will stress grain crops and fruit crops that flower in the summer months (such as grapes). Pennsylvania's wineries may choose to plant European varieties of grapes, which are better suited for warmer climates, but this could lead to increases in the cost of wine.

Pennsylvania dairy production will experience a negative impact through reduced milk yields, a result of heat stress. Additional capital expenditures for cooling equipment will be necessary to reduce the heat stress on cows. The same is true for poultry and egg production. Investments in insulation, ventilation, fans, and air conditioning will be necessary to prevent heat stress to the birds. Currently, a large portion of poultry and hog production takes place in warmer, southern states like North Carolina and Georgia, showing these production processes can still be viable with the increased costs of cooling. However, there may be a northward movement of these animals, bringing with them an increase in nutrient production.

Climate change poses some economic opportunities for the agriculture community, through energy crop production. Perennial shrub willow, perennial grasses such as miscanthus and switchgrass, and biomass sorghum or winter rye are options that can be grown for energy use.

Energy

Due to significant growth in natural gas production, Pennsylvania is now the third-largest energy producing state in the U.S. behind Texas and Wyoming. Pennsylvania is the largest exporter of electric power in the U.S., with approximately one-third of the electricity generated in the state consumed elsewhere. Coal and nuclear are the predominant fuels for generating electricity, but natural gas is steadily replacing coal-fired electricity production. Because of the increase in natural gas production, the price has fallen. Since 2011, overall energy use has decreased in Pennsylvania.

The primary sources of energy-related GHGs are electricity, transportation, and industrial uses. Pennsylvania's coal plants emit on average more than one ton of $CO2$ per megawatt-hour generated, while natural gas emits half as much. Overall, the impacts of higher temperatures are likely to lead to increased demand for electric power. Roughly 30 percent of households use electricity for home heating; while nearly all households use electricity for cooling. As temperatures rise, use of fans and air conditioners is likely to rise as well, leading to increased demand for electricity in hot months.

Extreme weather events can affect the reliability of energy delivery. Hurricanes, polar vortexes, and ice storms can damage infrastructure. Increased cooling demands can also stress energy delivery systems during times of high demand and could lead to electrical blackouts. The need for distributed generation to provide electricity in the event of natural disasters becomes more critical.

Forests

Climate change is already having an impact on forests around the world and Pennsylvania's diverse and productive forests will likely also undergo change. New research added to this Update substantially reinforces key findings of the previous Impact Assessments. Tree species are expected to shift to higher latitudes and elevations for suitable habitat. Mortality rates are expected to rise and regeneration is expected to decline. Rising temperatures increase insect reproductive rates, making pest outbreaks more destructive and harder to control. Additionally, pests that impact the forests of southern states could make their way into Pennsylvania forests.

Longer growing seasons, warmer temperatures, higher rainfall, increased CO_2, and nitrogen deposition may increase overall forest growth rates. Increased growth rates for some species will be offset by increased mortality for others. Forests can help to mitigate climate change by sequestering carbon, but it would be difficult to substantially increase the growth rates of hardwoods. The best opportunity lies in preventing forest loss.

According to the Impacts Assessment Update, the most significant opportunity for forests related to climate change are: 1) carbon trading, 2) increased markets for low-use wood for energy production, and 3.) potentially renewed interest and will to manage forests for their long-term health and resiliency.

Human Health

People with few resources and/or poor access to health care are particularly vulnerable to the health impacts of climate change. The overall warming trend will increase heat-related deaths but will decrease cold-related deaths in Pennsylvania. By 2100, the number of excessive heat days is projected to increase by a factor of 10 in Pittsburgh and Philadelphia. Risks for heat-related deaths are the highest for the elderly and those with cardiovascular disease.

Climate change could impact air quality by increasing ground-level ozone, small airborne particulates, and pollen and mold concentrations. Ozone is an irritant that causes respiratory issues, aggravates asthma, causes respiratory infections, and increases mortality. Ozone concentrations are highest in the summer, when warm temperatures and sunshine create volatile organic compounds (VOCs). Higher plant growth, more pollen produced by each plant, increased allergenicity of the pollen grains, and a longer pollen season can also be expected.

Water quality will also pose threats to human health, through increased water-borne pathogens and increased occurrence of harmful algal blooms. These are both caused by the increased runoff during heavy rain events, increased nutrient runoff, and warmer waters. Flooding from tropical storms and hurricanes also pose a threat to human health. Increased rainfall poses a threat to human health through vector-borne diseases, such as West Nile disease. An increase in the temperature of Pennsylvania will make it better suited for the deer-tick, the most important vector for Lyme disease.

Outdoor Recreation

Climate change will impact outdoor recreation in several ways. Higher spring and fall temperatures will lengthen the outdoor recreation season. Higher summer temperatures will increase demand for water-based recreation, but will decrease the amount of suitable habitat for trout and other species which thrive in cold water. Stream flows in the summer could be reduced and negatively affect sport fishing. Swimming in lakes and rivers could be limited by poor water quality, the result of higher temperatures, low summer flows, and nutrient and pathogen loadings.

Warmer winter temperatures and reduced snowfall will negatively impact snow-based recreation. Pennsylvania's ski resorts will experience shorter seasons, higher snow making costs, and lower profits as a consequence of climate change. Research also suggests that dispersed winter recreation, such as cross country skiing and snowmobiling, will decline because of less snowfall and fewer extended periods of cold weather.

Water

Compared to western states, Pennsylvania's seasonal variation in precipitation is much higher, increasing the potential for flooding. Extreme flows have become more common throughout most of Pennsylvania. The changes in flow volumes are most substantial in small to medium streams, while larger streams saw moderate increases. Consistent with the previous Impacts Assessments, this Update predicts higher flood potential due to more precipitation. Larger stream power leads to increased in-channel erosion potential (leading to river bed degrading and bank failures) and higher sediment output. Bank erosion causes stream health degradation and loss of habitat, in addition to impaired water quality. Climate change will intensify risks to water resources that are already stressed.

Other potential impacts are decreased water quality, urban flooding, and reduced water supplies for urban areas, and irrigation. Decreased water quality poses risks to drinking water, even with conventional treatments due to increased temperature, increased sediment and nutrient loadings from heavy rainfall, increased concentration of pollutants during droughts, and a disruption of treatment facilities during floods.

Warmer temperatures may mean less winter thermal stress on fish, but higher summer temperatures could have an impact on salmon spawning. However, more research is needed in this area.

Wetlands and Aquatic Ecosystems

Pennsylvania is home to a wealth of freshwater resources, with streams and wetlands being the most significant features. Wetlands remove excess nitrate and sediment in runoff and groundwater from upland sources, preventing eutrophication in lakes and rivers. They also serve as spawning and nursery grounds for fish and habitat for shore and wading birds and amphibians.

Headwater streams set the biogeochemical state of downstream river networks. Headwater streams account for 60 to 75 percent of the nation's total stream and river lengths, making their riparian communities extremely important for overall water quality.

More severe storm events and dry periods will change flow patterns, resulting in major changes to channel morphology and aquatic habitat. Changes in temperature, water quality, and water quantity will impact stream and wetland biological communities. The largest negative impact may be in lost biodiversity as fish and other species' populations shift northward. However, habitat fragmentation from development creates migration barriers that will prevent many species from moving to colder climates.

Temperature is crucial to both physiological and behavioral influence on the survival and growth of nearly all macroinvertebrate and fish species. Because of the potential for warmer water temperatures, Pennsylvania could see a decline in more valued cold-water communities and an increase in the abundance of less desirable biological assemblages, such as invasive species that can decimate native populations.

Coastal Resources

Pennsylvania's coastline on the Delaware Estuary is composed of 56 miles of rare and diverse freshwater flora and fauna. The freshwater tidal wetlands are estimated to cover 1,195 acres on Pennsylvania's southeastern coast. The report predicts that water temperatures in the summer could increase 2.7–3.5° F. This warming will cause a decrease in the solubility of oxygen and an increase in respiration rates, resulting in decline of the dissolved oxygen concentration.

Salt intrusion associated with a sea level rise will also put stress on the coastal resources of Pennsylvania. By mid-century, the sea level will rise by 0.4 m. Coupled with a predicted summer stream flow decrease of 19 percent, a modest increase in salinity is expected. While salinity is a threat, the predicted sea-level rise has the potential to drown the already-stressed wetlands if their growth rates are less than the rates of the rise.

Chapter 3: Inventory and Projections

Greenhouse Gas Inventory

Pennsylvania has several sectors which contribute to greenhouse gas (GHG) emissions, and each of these sectors has undergone fluctuations since 2000. Changes in amount and type of fuel consumption, growth and slow-downs in the economy, and duration of severe weather events all have a role in the trends observed in the Commonwealth's GHG emissions.

The following sectors have a GHG emission total associated with them within the Commonwealth: residential, commercial, industrial, transportation, electricity production, agriculture, waste management, forestry, and land use. Data for this inventory were primarily obtained from the EPA State Inventory Tool (SIT). SIT is an interactive spreadsheet model designed to help states develop GHG emissions inventories, and provides a streamlined way to update an existing inventory or complete a new inventory.

The SIT consists of 11 estimation modules applying a top-down approach to calculate GHG emissions, and one module to synthesize estimates across all modules. The default data are gathered by federal agencies and incorporates reported data from private, state, and local sources covering fossil fuels, electricity consumption, agriculture, forestry, waste management, and industry. As is customary, the units for the GHG emissions are given in million metric tons of carbon dioxide equivalent (MMTCO2e). A metric ton is equal to 2,204.6 pounds or approximately 1.1 short tons (US tons). The greenhouse gases typically accounted for in the SIT are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Each GHG has a different global warming potential (GWP), which is accounted for when converting emissions to MMTCO2e. The default GWP used by the SIT for CO_2 is 1.0, CH_4 = 25, and N_2O = 298. The GWP of a GHG will vary depending on the time scale selected. The default time scale for the SIT is 100 years. In order to provide consistency with previous updates and other state inventories using the SIT, the default values were not changed in compiling the inventory.

As shown in Table 3.1, the total statewide gross GHG emissions for Pennsylvania in 2012—the latest year with complete data available from the SIT—were 287.38 MMTCO2e. . Pennsylvania's forestry and land use sector provides a carbon sink for GHG emissions, absorbing approximately 34.26 MMTCO2 in 2012, and lowering the Commonwealth's net GHG emission for 2012 to 253.12 MMTCO2. Table 3.1. also shows a relative decrease of 11.02 percent in the gross emission and 15.93 percent in the net emission totals for 2012 relative to 2000.

Also shown in Table 3.1, the sectors with the largest contribution to the Commonwealth's GHG emissions are the transportation, industrial, and electricity production sectors. The relative change for each of these sectors between 2000 and 2012 was a decrease of 8.97 MMTCO2e for the transportation sector, a decrease of 3.99 MMTCO2e for the industrial sector, and a decrease of 10.76 MMTCO2e for the electricity production sector. Together, these three sectors annually account for over 85 percent of Pennsylvania's GHG emissions.

The residential, commercial, and agriculture sectors also experienced declines in GHG emissions during the time period from 2000 to 2012. The residential, commercial, and agriculture sectors had decreases in GHG emissions of approximately 8.37, 3.99, and 0.16 MMtCO2e respectively, during this time period.

GHG emissions from the waste management sector experienced an approximately 0.58 MMTCO2e increase from 2000 to 2012. During this same period, the GHG emissions sequestered (absorbed) by the forest and land use sector increased by approximately 12.38 MMTCO2e.

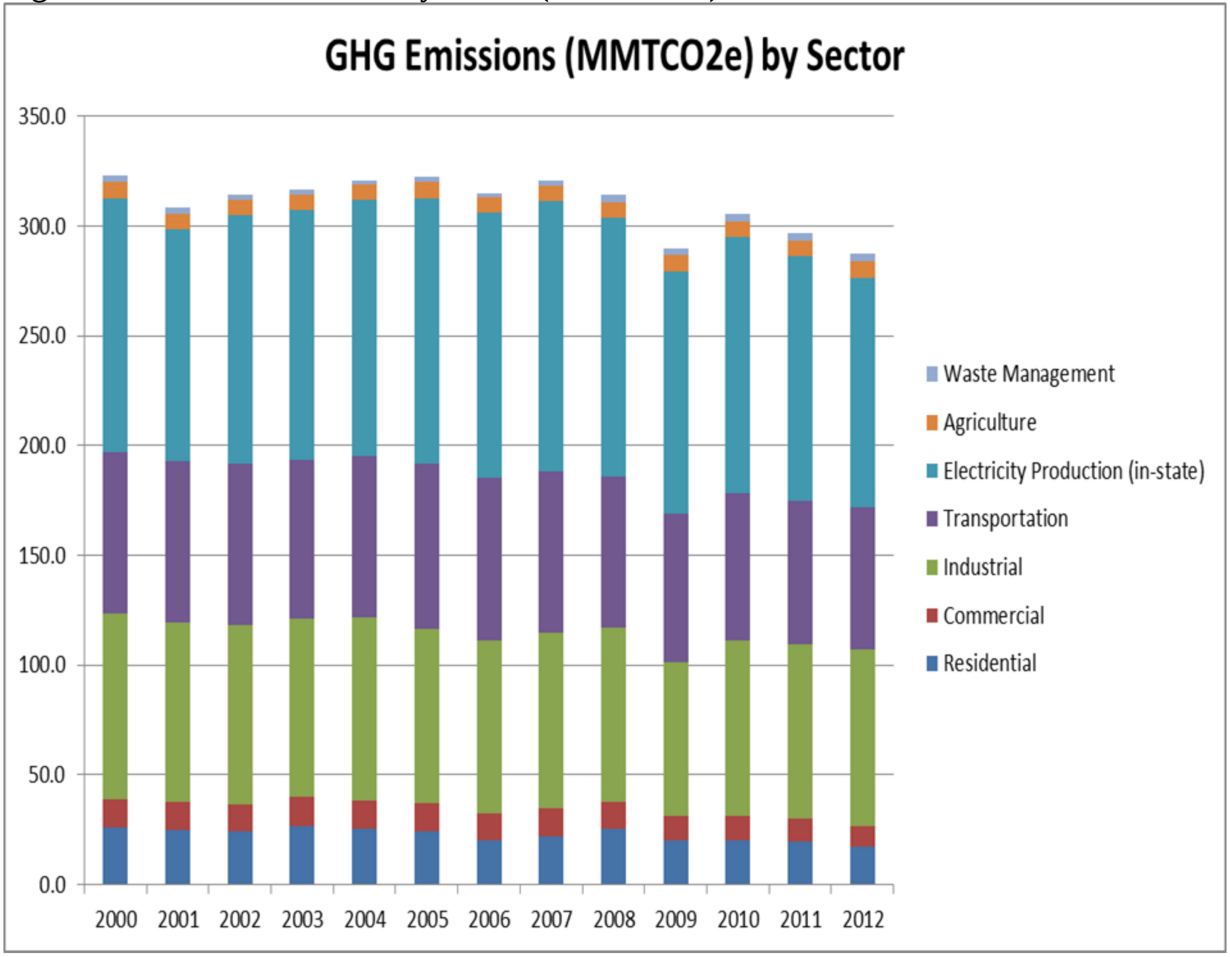
A brief discussion of each individual sector will occur later in the chapter. The discussion will focus on the trends of various components within each sector, such as fuel mix or subgroups of the sector. The chapter will conclude with estimated projections of GHG emissions for each sector out to year 2030. The projections are calculated using the U.S. EPA Projection Tool, which is used in combination with the SIT that was used to determine the values given in Table 3.1.1.

Table 3.1. – GHG Emissions by Sector

Sector / Emission Source ($MMTCO_2e$)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residential	**25.93**	**24.67**	**24.01**	**26.62**	**25.49**	**24.13**	**20.47**	**21.98**	**25.73**	**20.17**	**20.50**	**19.78**	**17.56**
Commercial	**13.02**	**12.80**	**12.78**	**13.50**	**13.06**	**13.01**	**11.85**	**12.55**	**11.77**	**10.91**	**10.64**	**10.42**	**9.14**
Industrial	**84.32**	**81.85**	**81.43**	**81.30**	**83.01**	**79.57**	**78.88**	**79.95**	**79.73**	**70.32**	**80.04**	**78.97**	**80.33**
Combustion of Fossil Fuels	49.08	47.78	47.36	48.34	48.42	46.46	46.45	45.76	44.87	35.55	40.60	41.04	42.46
Industrial Process	15.61	13.56	13.97	13.40	14.51	13.96	14.20	13.96	13.70	12.45	18.16	18.39	18.20
Coal Mining and Abandoned Coal Mines	12.78	11.73	10.81	10.70	10.50	9.40	8.19	9.92	10.54	11.53	11.78	9.11	9.10
Natural Gas and Oil Systems	6.86	8.78	9.29	8.86	9.58	9.75	10.04	10.32	10.63	10.79	9.50	10.43	10.57
Transportation	**73.71**	**73.38**	**73.47**	**72.18**	**73.75**	**74.92**	**74.29**	**73.84**	**68.86**	**67.62**	**67.09**	**65.61**	**64.74**
Petroleum	71.58	71.51	71.40	70.30	72.12	73.20	72.76	71.90	66.79	65.31	64.46	62.76	62.66
Natural Gas	2.14	1.87	2.07	1.88	1.64	1.72	1.53	1.94	2.07	2.30	2.63	2.85	2.08
Electricity Production (in-state)	**115.53**	**105.68**	**112.95**	**113.46**	**116.39**	**120.98**	**120.38**	**122.81**	**117.49**	**110.42**	**116.58**	**111.41**	**104.77**
Coal	111.04	101.48	107.76	107.35	108.58	112.34	114.01	113.88	109.01	98.23	102.70	94.32	82.93
Natural Gas	1.13	1.24	2.74	2.27	4.19	4.43	5.53	7.86	7.73	11.48	13.37	16.70	21.57
Oil	3.37	2.96	2.45	3.84	3.62	4.21	0.84	1.08	0.76	0.71	0.51	0.40	0.27
Agriculture	**7.37**	**7.22**	**7.22**	**6.92**	**7.13**	**7.19**	**7.00**	**7.32**	**7.34**	**7.36**	**7.29**	**7.28**	**7.21**
Enteric Fermentation	3.51	3.45	3.44	3.27	3.31	3.37	3.34	3.49	3.49	3.46	3.49	3.50	3.52
Manure Management	1.18	1.22	1.27	1.16	1.21	1.26	1.21	1.25	1.26	1.23	1.24	1.24	1.24
Agricultural Soil Management	2.67	2.54	2.50	2.48	2.60	2.55	2.45	2.58	2.58	2.65	2.55	2.53	2.44
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Waste Management	**3.06**	**3.07**	**2.45**	**2.53**	**1.59**	**2.43**	**1.93**	**2.05**	**3.51**	**3.17**	**3.19**	**3.39**	**3.64**
Solid Waste and Combustion	1.40	1.42	0.79	0.87	-0.07	0.77	0.25	0.36	1.81	1.47	1.47	1.67	1.91
Wastewater	1.66	1.65	1.66	1.66	1.66	1.66	1.68	1.69	1.70	1.70	1.72	1.72	1.73
Total Statewide Gross Emissions (Prod)	**322.96**	**308.66**	**314.30**	**316.51**	**320.41**	**322.23**	**314.80**	**320.50**	**314.43**	**289.98**	**305.33**	**296.86**	**287.38**
Increase relative to 2000		-4.43%	-2.68%	-2.00%	-0.79%	-0.23%	-2.53%	-0.76%	-2.64%	-10.21%	-5.46%	-8.08%	-11.02%
Forestry and Land Use	-21.88	-21.92	-27.69	-34.06	-34.01	-34.22	-33.93	-34.00	-33.76	-34.05	-33.97	-34.19	-34.26
Total Statewide Net Emissions (Prod. with sinks)	**301.08**	**286.74**	**286.61**	**282.45**	**286.40**	**288.01**	**280.87**	**286.50**	**280.67**	**255.93**	**271.36**	**262.67**	**253.12**
Increase relative to 2000		-4.76%	-4.81%	-6.19%	-4.88%	-4.34%	-6.71%	-4.84%	-6.78%	-15.00%	-9.87%	-12.76%	-15.93%
Sector / Emission Source ($MMTCO_2e$)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**

Figure 3.1 displays the total contribution to the Commonwealth's GHG emissions for the residential, commercial, industrial, transportation, electricity production, agriculture, and waste management sectors.

Figure 3.1 – GHG Emissions by Sector (MMTCO2e)



Residential Sector

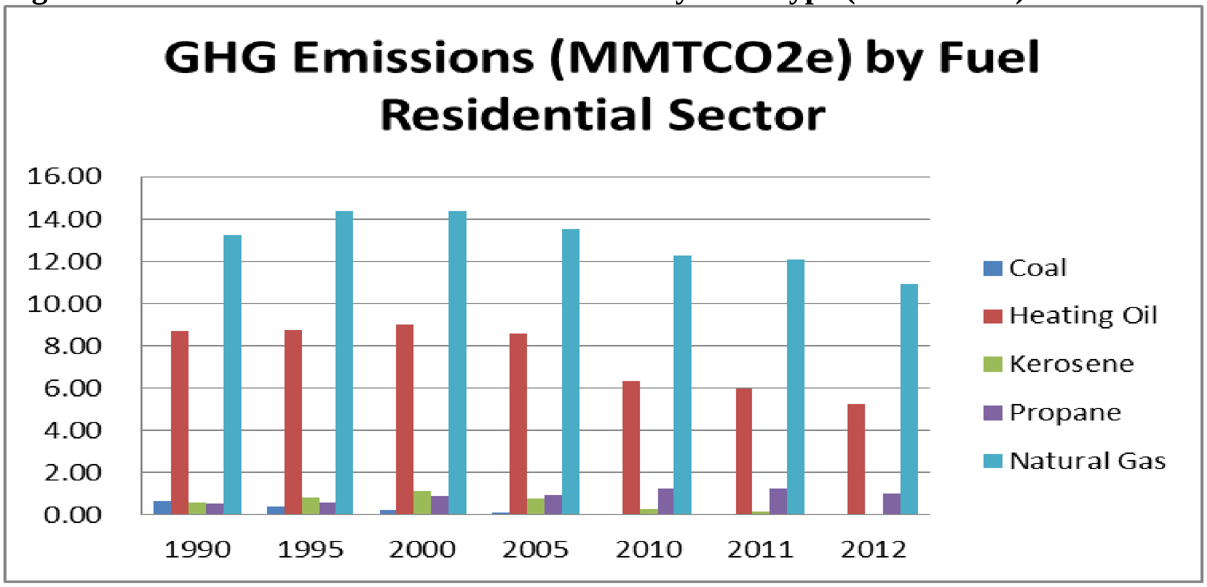
The emissions attributed to the residential sector result from fuels combusted to provide heat and hot water to residential homes within the Commonwealth. These fuels, in order of decreasing use in 2012, are natural gas, heating oil, wood, propane, and kerosene. Table 3.2 shows the amount of each fuel used (billion Btu) in residential homes within the Commonwealth. Several factors will have an effect on the amount of a fuel being used; including the severity of the weather, efficiency of the heating/cooling system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 3.2 – Residential Sector Fuel Consumption (Billion Btu)

Billion Btu	1990	1995	2000	2005	2010	2011	2012
Coal	6,570	3,836	2,154	1,253	-	-	-
Heating Oil	117,704	118,291	121,803	115,893	86,172	81,336	71,493
Kerosene	7,810	11,702	15,822	10,330	4,211	2,572	1,076
Propane	8,286	10,107	14,687	15,102	20,815	20,081	16,902
Natural Gas	249,467	271,374	271,994	255,038	231,854	228,119	205,991

Each fuel used in residential homes will have different rates of GHG emissions. Figure 3.2 shows the GHG emission (MMTCO2e) attributed to each fuel used in the residential sector. The emissions from burning firewood to heat residential homes are accounted for in the land use change sector. The emissions related to electricity use for residential homes using electricity for heating or cooling purposes are accounted for in the electricity production sector.

Figure 3.2 – Residential Sector GHG Emissions by Fuel Type (MMTCO2e)



Commercial Sector

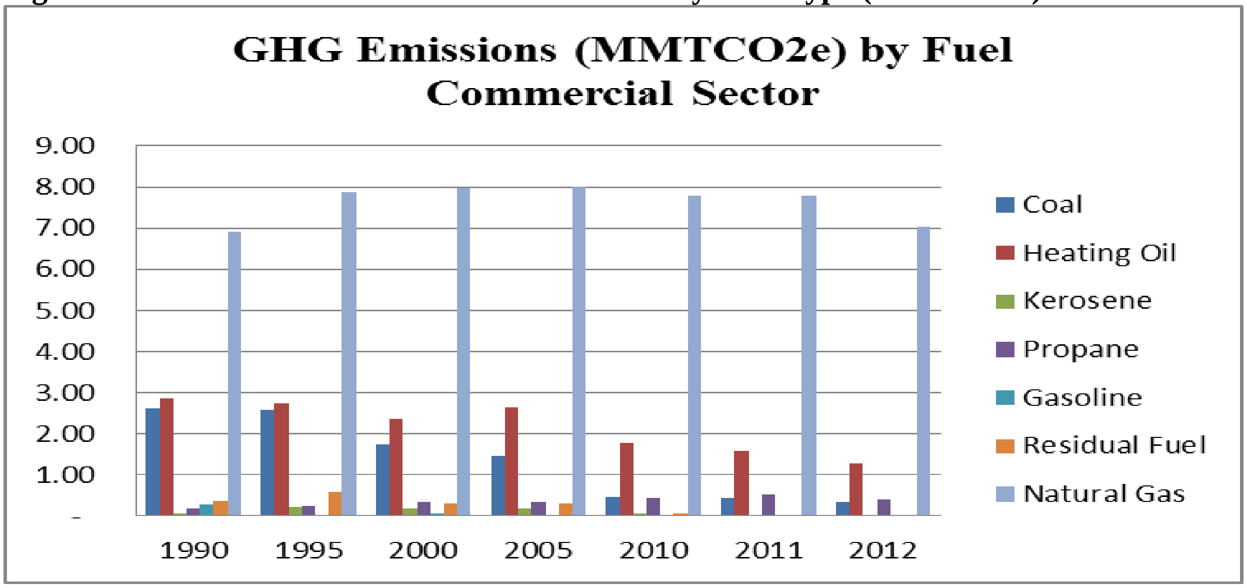
The emissions attributed to the commercial sector result from fuels combusted to provide heat and hot water to commercial buildings within the Commonwealth. These fuels, in order of decreasing use in 2012, are natural gas, heating oil, propane, coal, wood, gasoline, residual oil, and kerosene. Table 3.3 shows the amount of each fuel used (billion Btu) in commercial buildings within the Commonwealth. Several factors will have an effect on the amount of a fuel being used; including the severity of the weather, efficiency of the heating/cooling system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 3.3 Commercial Sector Fuel Consumption (Billion Btu)

Billion Btu	1990	1995	2000	2005	2010	2011	2012
Coal	26,279	25,669	17,427	14,407	4,729	4,343	3,275
Heating Oil	38,676	36,894	32,011	35,675	23,830	21,242	17,254
Kerosene	851	2,992	2,307	2,610	755	198	67
Propane	3,143	3,834	5,571	5,473	6,865	8,242	6,540
Gasoline	3,683	453	761	464	440	443	441
Natural Gas	130,622	148,806	150,410	150,849	146,902	146,752	132,519
Residual Oil	4,992	7,679	3,985	3,934	570	254	163
Wood	2,841	3,212	2,269	2,475	3,361	3,236	2,834

As in the residential sector, each fuel used in commercial buildings will have different rates of GHG emissions. Figure 3.3 shows the GHG emissions (MMTCO2e) attributed to each fuel used in the commercial sector. The emissions from burning firewood to heat commercial buildings are accounted for in the land use change sector. The emissions related to electricity use for commercial buildings using electricity for heating or cooling purposes are accounted for in the electricity production sector.

Figure 3.3 – Commercial Sector GHG Emissions by Fuel Type (MMTCO2e)



Industrial Sector

Greenhouse gas emissions from the industrial sector differ from the residential and commercial sectors in that the emissions come from four separate sub-groups; combustion of fossil fuels, the industrial process, activities involving coal mining and abandoned coal mines, and activities involving natural gas and oil systems. Within the four sub-groups, combustion of fossil fuels consistently accounts for over 50 percent of the annual GHG emissions from the industrial sector.

Combustion of Fossil Fuels in the Industrial Sector

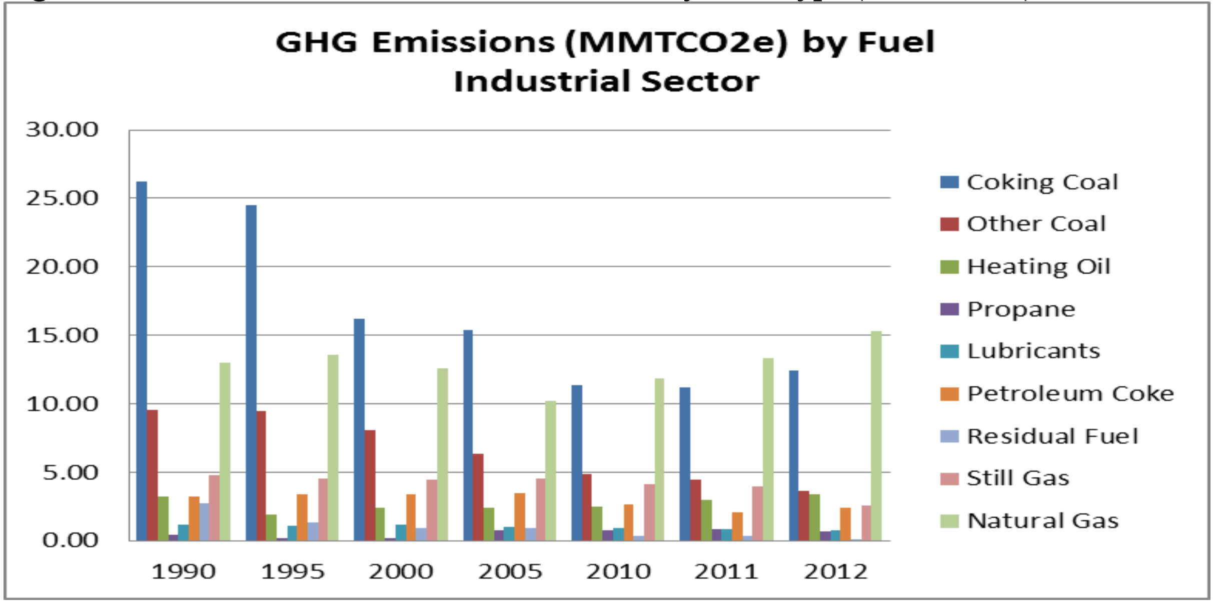
The emissions attributed to the industrial sector result from fuels combusted to heat and cool industrial buildings and equipment within the Commonwealth. These fuels, in order of decreasing use in 2012, are natural gas, coal/coke, heating oil, coal, and various other fuels. Table 3.4.1 shows the amount of each fuel used (billion Btu) in the industrial sector within the Commonwealth. Several factors will have an effect on the amount of a fuel being used; including the severity of the weather, efficiency of the heating/cooling system, and the price/availability of a particular fuel.

Table 3.4.1 Industrial Sector Fuel Consumption (Billion Btu)

Billion Btu	1990	1995	2000	2005	2010	2011	2012
Coking Coal	280,218	261,897	173,020	164,228	121,445	119,431	132,211
Other Coal	101,704	101,143	85,359	67,654	51,240	47,564	38,897
Heating Oil	43,482	25,496	32,294	32,926	34,119	40,766	45,537
Propane	6,641	3,436	3,313	12,030	12,464	13,026	11,277
Lubricants	15,577	14,861	15,875	13,392	12,495	11,855	10,907
Petroleum Coke	31,513	32,927	32,961	34,433	25,763	20,099	23,758
Residual Fuel	36,050	18,158	12,538	12,039	4,272	4,376	1,287
Still Gas	71,842	68,368	66,807	67,662	61,778	58,929	38,293
Natural Gas	245,738	255,702	237,183	193,374	223,481	251,294	288,558

As in the residential and commercial sectors, each fuel used in the industrial sector will have different rates of GHG emissions. Figure 3.4.1 shows the GHG emissions (MMTCO2e) attributed to each fuel used in the industrial sector. The emissions related to electricity within the industrial sector are accounted for in the electricity production sector.

Figure 3.4.1 – Industrial Sector GHG Emissions by Fuel Type (MMTCO2e)



Industrial Process

Some of the industrial processes that are accounted for in this group include cement manufacturing, lime manufacturing, limestone and dolomite use, iron and steel production, substitutes for ozone-depleting substances (ODS), and electric power transmission and distribution systems. The GHG emissions attributed to ODS substitutes are determined using a national emission total and then assigning a state value based on population. For example, in 2012 the United States experienced over 146 MMTCO2e of GHG emissions in the production and use of ODS substitutes. Pennsylvania’s population in 2012 was 4.07 percent of the national population, therefore 4.07 percent of 146 MMTCO2e (5.97 MMTCO2e) was assigned to

Pennsylvania's inventory. Table 3.4.2 shows the GHG emissions (MMTCO2e) attributed to each of the processes included within the industrial sector.

Table 3.4.2 – Industrial Sector Process Emissions (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Cement Manufacture	2.66	3.08	3.36	3.13	2.96	2.83	2.89
Lime Manufacture	1.13	1.07	1.19	0.85	1.72	1.79	1.68
Limestone and Dolomite Use	-	0.58	0.39	0.55	0.87	0.81	0.59
Iron & Steel Production	-	-	6.33	4.48	6.36	6.65	6.66
ODS Substitutes	0.02	1.44	3.43	4.34	5.65	5.79	5.97
Electric Power Transmission and Distribution Systems	1.18	0.94	0.60	0.47	0.30	0.30	0.25
Total	**4.99**	**7.10**	**15.31**	**13.81**	**17.87**	**18.17**	**18.04**

Please note that tracking of GHG emissions for limestone and dolomite use did not begin in the Commonwealth until 1994 and for iron and steel production until 1997.

Coal Mining and Abandoned Coal Mines

The GHG emissions associated with coal mining, both underground and surface mine, and processing coal are accounted for in this section. The GHG emissions coming from abandoned coal mines are also included. The majority of emissions come from underground mining activity. The results are determined by measurements of ventilation air from underground mines and by applying emission factors for surface mines, abandoned mines, and for coal processing. Table 3.4.3 shows the GHG emission (MMTCO2e) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

Table 3.4.3 – Coal Mining-Related Process Emissions (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Underground Mining	7.98	9.91	9.57	6.64	9.39	6.69	6.89
Surface Mining	1.65	1.14	0.97	0.73	0.61	0.67	0.54
Underground Processing	0.86	0.88	1.23	1.16	1.01	1.01	0.96
Surface Processing	0.27	0.18	0.16	0.12	0.10	0.11	0.09
Abandoned Mines	0.50	1.24	0.84	0.87	0.66	0.64	0.62
Total	**11.25**	**13.35**	**12.78**	**9.52**	**11.78**	**9.11**	**9.10**

Natural Gas and Oil Systems

The GHG emissions associated with natural gas production, transmission, and distribution are accounted for in this section. Emission factors are used in determining the total GHG emissions based on the number of natural gas wells, miles of transmission pipeline, and the number and types of services used for distribution in the Commonwealth. The natural gas transmission data became available in 2001 while the distribution data became available in 1997. DEP began to collect site specific emission data from natural gas production in 2010. In order to provide consistency from previous years, this inventory continues to use default SIT emission factors for natural gas production for all years. An emission factor is also used to determine the GHG emissions based on the total oil production within the Commonwealth. Table 3.4.4 shows the GHG emission (MMTCO2e) attributed to natural gas production, transmission, and distribution, and oil production.

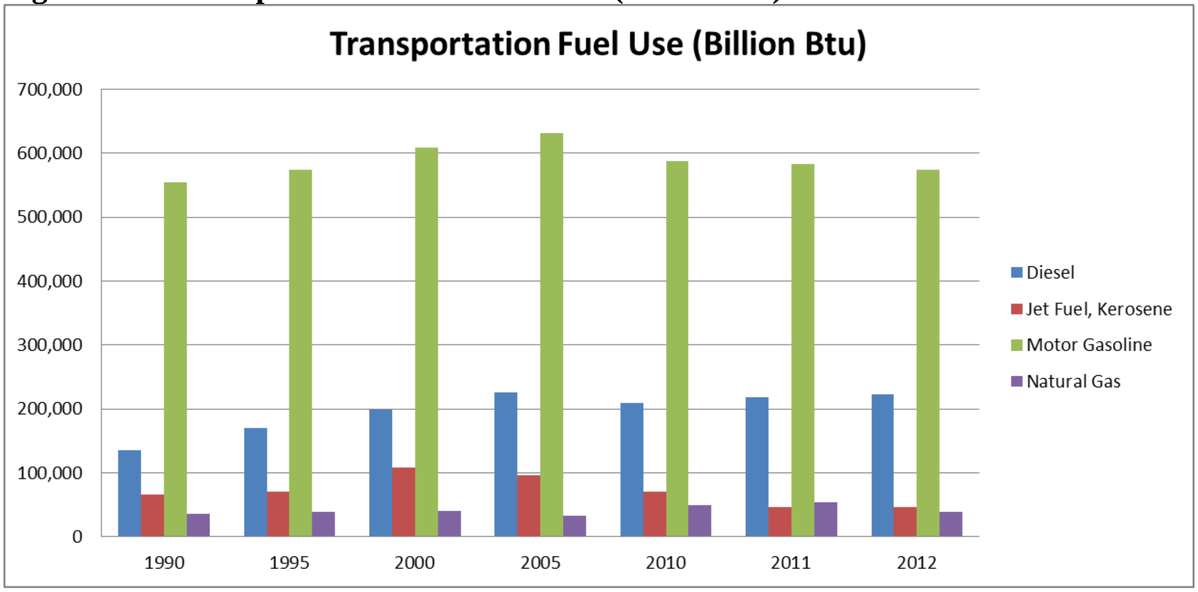
Table 3.4.4 – Natural Gas Production Process Emissions (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Natural Gas Production	3.05	3.15	3.67	4.78	4.56	5.57	5.65
Natural Gas Transmission	-	-	-	1.92	1.97	1.89	1.94
Natural Gas Distribution	-	-	3.16	3.01	2.92	2.92	2.91
Oil Production	0.04	0.03	0.03	0.04	0.06	0.06	0.07
Total	**3.09**	**3.18**	**6.86**	**9.75**	**9.50**	**10.43**	**10.57**

Transportation Sector

The emissions attributed to the transportation sector result from fuels combusted to provide transportation for various types of vehicles within the Commonwealth. These fuels, in order of decreasing use in 2012, are gasoline, diesel, jet fuel, and natural gas. Figure 3.5 shows the amount of each fuel used (billion Btu) in transportation within the Commonwealth. Several factors will have an effect on the amount of a fuel being used; including the mode of transportation, efficiency of the vehicle, and the price/availability of a particular fuel. The emissions related to electricity use in transportation purposes are accounted for in the electricity production sector.

Figure 3.5 – Transportation Sector Fuel Use (Billion Btu)



As in the previous sectors, each fuel used in transportation will have different rates of GHG emissions. Table 3.5 shows the GHG emissions (MMTCO2e) attributed to each fuel used in the transportation sector.

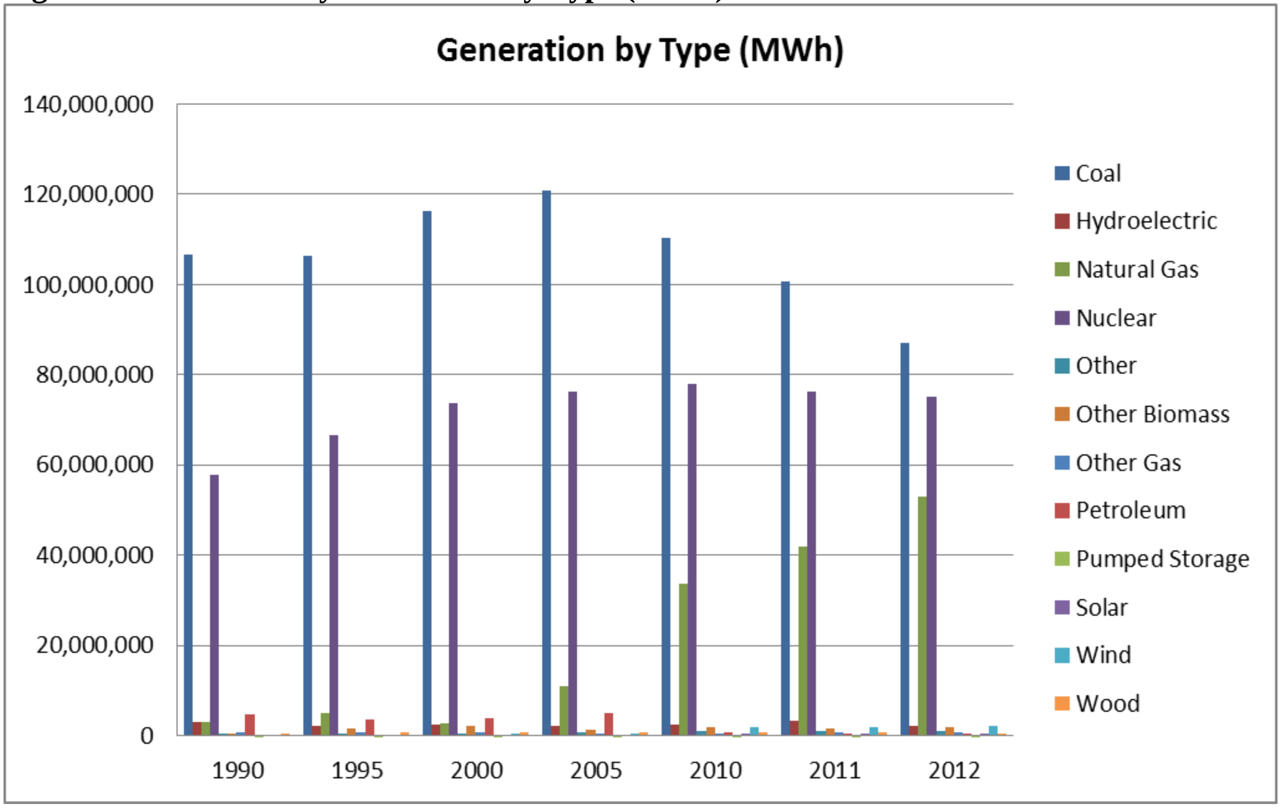
Table 3.5 – Transportation Sector Emissions by Fuel Consumption (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Diesel	9.99	12.60	14.65	16.72	15.54	16.18	16.49
Jet Fuel, Kerosene	4.81	5.04	7.91	7.01	5.21	3.44	3.44
Motor Gasoline	42.33	44.09	46.21	46.77	42.84	42.43	41.70
Natural Gas	1.90	2.09	2.13	1.72	2.63	2.85	2.08
Total	**59.03**	**63.81**	**70.91**	**72.22**	**66.21**	**64.90**	**63.72**

Electricity Production Sector

The emissions attributed to the electricity production sector result from fuels combusted to generate electricity within the Commonwealth. The electricity production sector has historically been the largest contributor of GHG emissions; over one third of the statewide gross emissions in 2012 came from this sector however, a sizable percentage of these emissions are associated with electricity that is produced and exported to meet the needs of surrounding states. Electricity is produced several different ways within the Commonwealth. The three primary forms of electricity generation in Pennsylvania are coal, nuclear, and natural gas. Figure 3.6.1 shows the electricity generation (MWh) in Pennsylvania by fuel.

Figure 3.6.1 - Electricity Generation by Type (MWh)



The largest changes in the production of electricity since 1990 have occurred in the use of coal and natural gas. Table 3.6.1 gives the relative percentages of each fuel used to generate electricity in Pennsylvania.

Table 3.6.1 – Electricity Generation by Fuel Type (%)

% MWh Generation	1990	1995	2000	2005	2010	2011	2012
Coal	60.74%	57.34%	57.62%	55.45%	48.04%	44.26%	39.01%
Hydroelectric	1.63%	1.09%	1.14%	1.02%	1.02%	1.42%	1.00%
Natural Gas	1.61%	2.66%	1.34%	4.96%	14.68%	18.39%	23.75%
Nuclear	32.90%	35.84%	36.58%	34.98%	33.87%	33.50%	33.65%
Other	0.00%	0.02%	0.03%	0.34%	0.37%	0.39%	0.40%
Other Biomass	0.17%	0.89%	1.00%	0.62%	0.74%	0.73%	0.79%
Other Gas	0.48%	0.42%	0.30%	0.25%	0.24%	0.27%	0.27%
Petroleum	2.65%	1.97%	1.86%	2.27%	0.25%	0.19%	0.13%
Pumped Storage	-0.50%	-0.67%	-0.20%	-0.33%	-0.31%	-0.22%	-0.20%
Solar	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
Wind	0.00%	0.00%	0.00%	0.13%	0.81%	0.79%	0.95%
Wood	0.31%	0.44%	0.34%	0.32%	0.29%	0.28%	0.24%

Since electricity produced from nuclear fuel, hydroelectric, solar, and wind create no direct GHG emissions, the primary fuels associated with GHG emissions from electricity production are coal, natural gas, and oil. Table 3.6.2 shows the amount of each of these fuels consumed (billion Btu) in generating electricity in Pennsylvania.

Table 3.6.2 – Fuel Use for Electricity Generation (Billion Btu)

Billion Btu	1990	1995	2000	2005	2010	2011	2012
Coal	1,054,707	1,062,368	1,210,638	1,224,911	1,119,758	1,028,374	904,245
Natural Gas	13,972	40,618	21,298	83,531	252,182	314,973	406,963
Oil	54274	38551	44930	51792	6847	5359	3591

As in the previous sectors, each fuel used in electricity production has different rates of GHG emissions. Figure 3.6.2 shows the GHG emissions (MMTCO2e) attributed to the three primary fuels used in the electricity production sector.

Figure 3.6.2 – GHG Emissions by Fuel Type

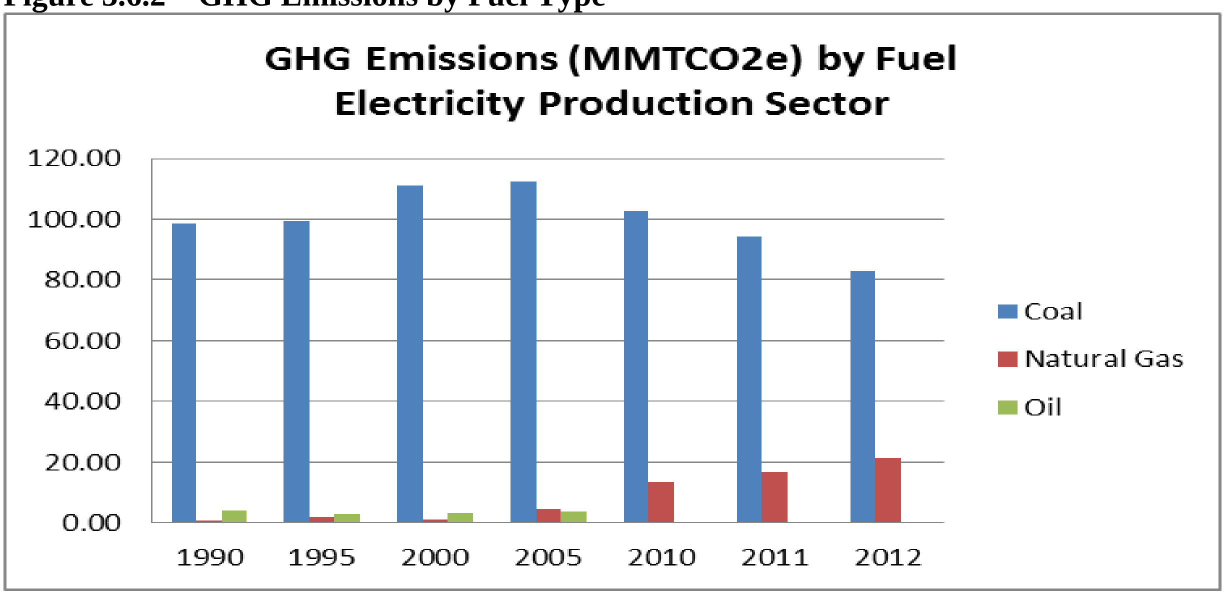


Table 3.6.2 gives the relative percentage of GHG emissions attributed to the three primary fuels used in the electricity production sector.

Table 3.6.2 – Contribution to GHG Emissions, Fuel Type, in the Electricity Sector (%)

	1990	1995	2000	2005	2010	2011	2012
Coal	95.4%	95.2%	96.1%	93.1%	88.1%	84.7%	79.2%
Natural Gas	0.7%	2.1%	1.0%	3.7%	11.5%	15.0%	20.6%
Oil	3.9%	2.8%	2.9%	3.2%	0.4%	0.4%	0.3%

As noted in Tables 3.6.1 and 3.6.2, for Pennsylvania's electricity generation sector in 2012 coal produced over 79 percent of the GHG emissions while producing 39.0 percent of the electricity, natural gas produced approximately 21 percent of the GHG emissions while producing approximately 24 percent of the electricity petroleum resources produced less than one-half of one percent of the GHG emissions while producing about one-tenth of one percent of all electricity generated in the Commonwealth. Nuclear fuel which produces no GHG emissions, was responsible for generating 33.65 percent of the electricity.

As will be discussed in Chapter 4, Pennsylvania has historically been and is projected to remain a net exporter of electricity to neighboring states. Table 3.6.6 shows the total consumption of electricity in gigawatt hours in Pennsylvania from the residential, commercial, industrial, and transportation sectors.

Table 3.6.3 – Electricity Consumption by Sector (GWh)

GWh	1990	1995	2000	2005	2010	2011	2012
Residential	38.17	42.80	45.01	53.66	55.26	54.80	52.88
Commercial	30.20	35.54	42.99	45.78	47.37	43.54	42.92
Industrial	45.99	47.53	45.45	47.95	45.46	49.59	48.04
Transportation	0.40	0.38	0.40	0.88	0.89	0.84	0.88
Line Loss	6.41%	6.41%	6.41%	6.41%	5.82%	5.82%	5.82%
Total	**122.62**	**134.90**	**143.02**	**158.44**	**158.18**	**157.96**	**153.66**

Table 3.6.4 gives the total amount of electricity consumed in Pennsylvania and the total amount of electricity generated. The difference between the two values is the total amount of electricity exported from Pennsylvania.

Table 3.6.4 – Electricity Generated, Consumed and Exported (GWh)

GWh	1990	1995	2000	2005	2010	2011	2012
Electricity Consumed	122.62	134.90	143.02	158.44	158.18	157.96	153.66
Electricity Generated	175.62	185.45	201.69	218.09	229.75	227.31	223.42
Electricity Exported	53.01	50.55	58.67	59.66	71.57	69.35	69.75

Agriculture Sector

At consistently less than 8 MMTCO2e annually, the GHG emissions from the agriculture sector are significantly lower than emission from the industrial, transportation, and electricity production sectors.. Like the industrial sector, GHG emissions in the agriculture sector are broken down into smaller groups: enteric fermentation, manure management, and soil management. Table 3.7.1 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

Table 3.7.1 – Animal Populations Contributing to GHG Emissions (1,000 Head)

Thousands of Head	1990	1995	2000	2005	2010	2011	2012
Dairy Cows	694	639	619	566	540	543	540
Dairy Replacement Heifers	285	275	285	275	300	310	315
Beef Cows	166	171	151	154	160	157	160
Beef Replacement Heifers	39	42	35	40	40	40	45
Heifer Stockers	28	24	20	55	50	50	55
Steer Stockers	199	188	165	170	150	140	145
Feedlot Heifers	22	25	25	24	24	24	24
Feedlot Steer	44	47	44	44	46	46	46
Bulls	29	27	25	25	25	25	25
Sheep	134	110	90	100	100	98	89
Goats	10	23	37	52	59	59	59
Swine	943	1,028	1,028	1,088	1,133	1,115	1,115
Horses	61	83	108	115	118	119	119

The enteric fermentation group includes animals that produce methane emissions as a result of their unique digestive process. Each type of farm animal has an associated methane emission factor associated with the enteric fermentation process. The total estimated GHG emissions from enteric fermentation is the summation of the product of the size of the statewide herd of each particular farm animal and the associated emission factor for that animal. Table 3.7.2 shows the GHG emissions (MMTCO2e) attributed to each animal in the agriculture sector due to enteric fermentation.

Table 3.7.2 – GHG Emissions, by Livestock Type, from Enteric Fermentation (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Dairy Cows	2.253	2.098	2.136	1.936	1.949	1.960	1.949
Dairy Replacement Heifers	0.492	0.452	0.471	0.440	0.495	0.511	0.519
Beef Cows	0.366	0.388	0.341	0.357	0.402	0.394	0.402
Beef Replacement Heifers	0.058	0.066	0.055	0.065	0.071	0.071	0.080
Heifer Stockers	0.035	0.033	0.030	0.082	0.080	0.080	0.088
Steer Stockers	0.270	0.264	0.240	0.245	0.233	0.217	0.225
Feedlot Heifers	0.022	0.024	0.025	0.024	0.026	0.026	0.026
Feedlot Steer	0.043	0.043	0.042	0.042	0.048	0.048	0.048
Bulls	0.065	0.063	0.058	0.060	0.065	0.065	0.065
Sheep	0.027	0.022	0.018	0.020	0.020	0.020	0.018
Goats	0.001	0.003	0.005	0.006	0.007	0.007	0.007
Swine	0.035	0.039	0.039	0.041	0.042	0.042	0.042
Horses	0.027	0.037	0.049	0.052	0.053	0.053	0.054
Total	**3.695**	**3.533**	**3.507**	**3.370**	**3.493**	**3.496**	**3.524**

The second sub-group of the agriculture sector is the manure management group. As with the enteric fermentation sub-group, each type of livestock has an associated emission factor for the GHG emission (CH_4 and N_2O), based on the amount of manure that the animal produces. The total GHG emissions from the manure management is equal to the summation of the product of the statewide livestock herd size, by animal and the emission factor for that animal. Table 3.7.3 shows the GHG emission (MMTCO2e) attributed to each animal in the agriculture sector due to manure management. The "other" category includes sheep, goats, and horses.

Table 3.7.3 – GHG Emissions, by Livestock Type, from Manure Management (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Dairy Cattle	0.598	0.578	0.640	0.658	0.639	0.644	0.643
Beef Cattle	0.048	0.049	0.048	0.048	0.050	0.050	0.051
Swine	0.247	0.290	0.273	0.318	0.324	0.323	0.322
Poultry	0.229	0.236	0.211	0.227	0.210	0.210	0.209
Other	0.006	0.008	0.010	0.010	0.011	0.011	0.011
Total	**1.129**	**1.162**	**1.183**	**1.262**	**1.235**	**1.239**	**1.237**

The third sub-group of the agriculture sector is the soil management group. GHG emissions (N_2O) from agricultural soils are calculated from the direct and indirect biochemical interactions of fertilizers, livestock, and crop residues with the soil. Table 3.7.4 below shows the estimated GHG emissions (MMTCO2e) resulting from agriculture soils management.

Table 3.7.4 –GHG Emissions from the Management of Agricultural Soils (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Direct	2.16	2.17	2.23	2.13	2.13	2.11	2.05
Indirect	0.41	0.44	0.44	0.42	0.42	0.42	0.38
TOTAL	**2.57**	**2.61**	**2.67**	**2.55**	**2.55**	**2.53**	**2.44**

Waste Management

GHG emissions in the waste management sector primarily come from three sub-groups; landfill gas, solid waste combustion, and wastewater treatment. Landfill gas, which is approximately 50% methane, is generated by the decomposition of solid waste within a landfill. Some solid waste in the Commonwealth is combusted in waste-to-energy plants, avoiding the production of methane would otherwise be produced in a landfill but which also results in the release of carbon dioxide. Both municipal wastewater treatment and industrial wastewater treatment are accounted for in the third sub-group.

Data in the SIT regarding the amount of landfilled solid waste in the Commonwealth was used to calculate potential landfill methane emissions. The methane avoided value in table 3.8.1 was calculated using data in the SIT and reflects the amount of methane that otherwise could have entered the atmosphere, but instead was combusted in either a flare or a landfill gas-to-energy project. A small amount (10 percent) of the landfilled solid waste is assumed to oxidize each year and thus would not contribute to the amount of methane emitted. Table 3.8.1 shows the GHG emissions (MMTCO2e) attributable to the potential landfill gas, the avoided methane emissions, and the avoided emissions due to solid waste oxidation.

Table 3.8.1[9] - GHG Emissions Associated with Landfilling Operations (MMTCO2e)

MMTCO2E	1990	1995	2000	2005	2010	2011	2012
Potential Landfill CH4	8.205	8.617	8.658	8.915	10.143	10.392	10.632
CH4 Avoided	-2.061	-3.819	-8.311	-9.850	-11.014	-11.093	-11.093
Oxidation	0.614	0.480	0.035	-0.094	-0.087	-0.070	-0.046
Total CH4 Emissions (Landfills)	**5.530**	**4.318**	**0.313**	**-0.842**	**-0.784**	**-0.630**	**-0.415**

The GHG emissions in the solid waste combustion sub-group result from the combustion of certain types of solid waste (plastics, synthetic rubber, and synthetic fibers). To avoid the potential for double counting, the emissions from the combustion of natural or biogenic materials, such as cotton, paper, etc. are omitted because these items would decompose naturally and therefore, no additional CO2 is emitted from the combustion of these materials. This section also accounts for N_2O and CH_4 gases that are generated in the waste combustion process. Data from the SIT for total solid waste combusted and the relative percentage of each of the materials listed previously was used in the calculation. Table 3.8.2 shows the GHG emission (MMTCO2e) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers of the waste combustion portion of the waste management sector.

Table 3.8.2 – GHG Emissions Associated with Waste Combustion (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
CO2	0.222	0.670	1.059	1.580	2.213	2.256	2.283
N2O	0.008	0.021	0.027	0.034	0.043	0.043	0.043
CH4	0.000	0.001	0.001	0.001	0.001	0.001	0.001
CO2, N2O, CH4 Emissions (Waste Combustion)	**0.231**	**0.692**	**1.087**	**1.615**	**2.257**	**2.301**	**2.328**

[9] EPA has recently updated the databases used for calculations in the waste management sector and these changes will be reflected in the 2016 Emissions Inventory.

The GHG emissions from the wastewater portion of the waste management sector are a combination of municipal wastewater treatment (CH_4 and N_2O) and some particular (red meat, poultry, pulp and paper) types of industrial wastewater treatment. The SIT was used to calculate the municipal wastewater and industrial wastewater GHG emissions. Production data was collected for the poultry and pulp and paper industrial wastewater treatment sector and multiplied by the SIT-supplied emission factors to determine the total GHG emissions. Table 3.8.3 shows the GHG emissions (MMTCO2e) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

Table 3.8.3 – GHG Emissions Associated with Wastewater Treatment (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Municipal CH4	0.953	0.964	0.984	0.989	1.018	1.020	1.022
Municipal N2O	0.311	0.322	0.338	0.334	0.354	0.355	0.357
Industrial CH4	0.030	0.034	0.336	0.338	0.344	0.342	0.348
Total Emissions Wastewater Treatment	**1.293**	**1.321**	**1.657**	**1.661**	**1.715**	**1.717**	**1.726**

Table 3.8.4 shows the GHG emission (MMTCO2e) totals for the solid waste and wastewater treatment portions of the waste management sector.

Table 3.8.4 – Total GHG Emissions from the Waste Management Sector (MMTCO2e)

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Solid Waste	5.760	5.010	1.400	0.773	1.473	1.670	1.913
Wastewater	1.293	1.321	1.657	1.661	1.715	1.717	1.726
Total Waste Management	**7.053**	**6.331**	**3.057**	**2.435**	**3.189**	**3.388**	**3.639**

Forestry and Land Use

The forestry and land use sector is very important in its ability to sequester (absorb) carbon dioxide, reducing the net GHG emission in the Commonwealth. In 2012, over 34 $MMTCO_2$ of GHG was sequestered in the forestry and land use sector, more than the GHG emissions from the residential, commercial and agricultural sectors combined. This sector includes forested lands and soils, liming and fertilization of agricultural soils, trees located in urban settings, yard waste, and forest fires. Data from the SIT was the primary source of information for this section. Data concerning forest fires was collected and used dating back to 2002. Table 3.9.1 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) (MMTCO2e) for the forestry and land use sector.

Table 3.9.1 – GHG Emissions Associated with Forestry and Land Use Practices

MMTCO2e	1990	1995	2000	2005	2010	2011	2012
Forest Carbon Flux	-19.82	-18.52	-18.52	-30.54	-30.31	-30.31	-30.31
Liming of Agricultural Soils	0.18	0.15	0.12	0.02	0.21	0.11	0.12
Urea Fertilization	0.03	0.03	0.04	0.02	0.03	0.02	0.02
Urban Trees	-2.48	-2.79	-3.11	-3.42	-3.74	-3.8	-3.87
Landfilled Yard Trimmings and Food Scrap	-1.1	-0.61	-0.45	-0.39	-0.43	-0.44	-0.51
Forest Fires	-	-	-	0.05	0.23	0.19	0.26
N2O from Settlement Soils	0.03	0.04	0.04	0.04	0.04	0.04	0.03
Total	**-23.16**	**-21.72**	**-21.88**	**-34.22**	**-33.97**	**-34.19**	**-34.26**

Projections

The estimated GHG emissions for Pennsylvania during the years 2015 through 2030 were calculated using the EPA's Projection Tool. The Projection Tool was designed as a companion to the SIT, which was used to determine the emission estimates in the previous sections. The Projection Tool uses historical GHG emission results from the SIT and forecasted estimates of various factors including fuel cost, population, industrial trends, and others. The Projection Tool does not incorporate any future policy changes that may have an impact on future GHG emissions. The results of the Projection Tool should be considered very rough estimates of what the GHG emissions would be in a "business as usual" scenario.

As shown in Table 3.10.1, the total statewide projected gross GHG emissions for Pennsylvania in 2030 is estimated to be 296.05 MMTCO2e, an increase of almost 9 MMTCO2e since 2012. No projections were made in the land use sector, so the 2012 value of 34.26 MMTCO2e was used for each year from 2015 to 2030. The Commonwealth's estimated net GHG emission for 2030 would be 261.79 MMTCO2e.

Also shown in Table 3.10.1, the sectors with the largest contribution to the Commonwealth's GHG emissions are the transportation, industrial, and electricity production sectors. The relative change for each of these sectors between 2015 and 2030 are an annual decrease of 0.9 percent for the transportation sector, an annual increase of 0.9 percent for the industrial sector, and no relative change for the electricity production sector. Together, these three sectors annually will still account for over 85 percent of Pennsylvania's GHG emissions.

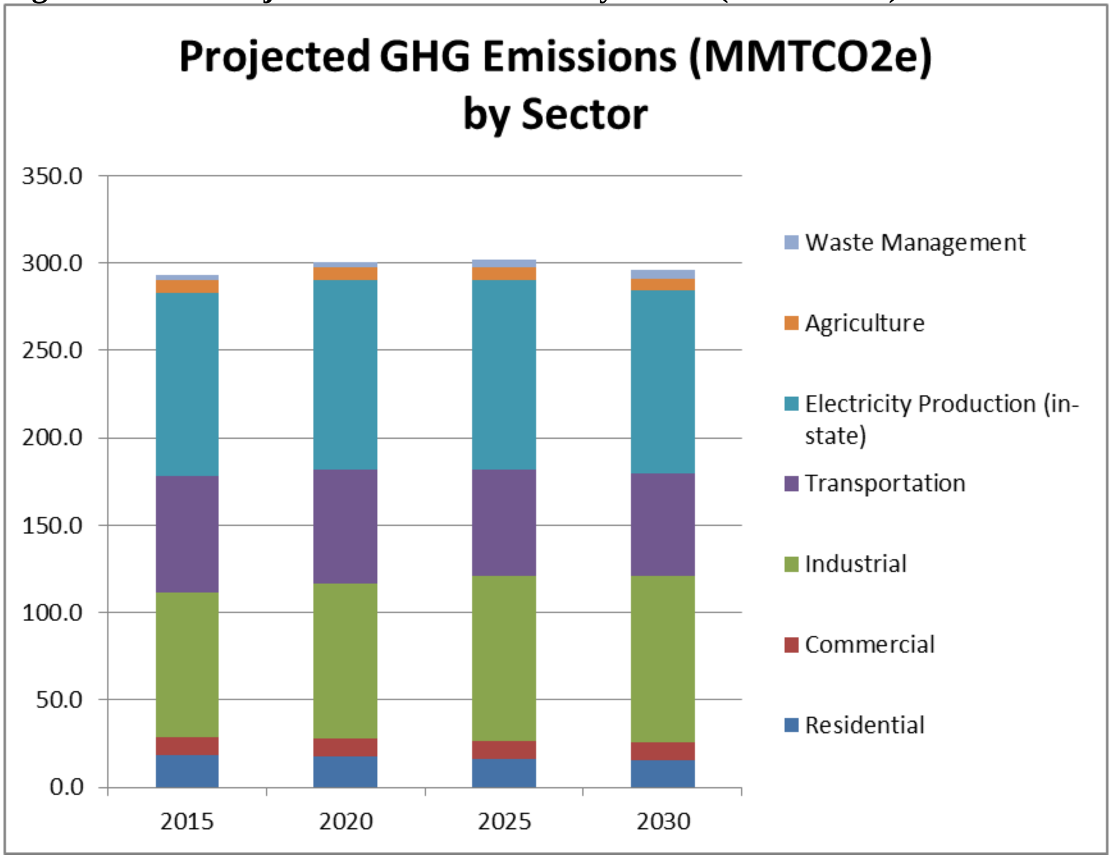
The residential, commercial, and agriculture sectors are also projected to experience slight declines in GHG emissions from 2015 to 2030. The residential sector will see an annual decrease in GHG emissions of approximately 1.0 percent, the commercial sector an annual decrease of approximately 0.1 percent, and the agriculture sector an annual decrease of approximately 0.1 percent. GHG emissions from the waste management sector are projected to experience approximately a 3.4 percent annual increase from 2015 to 2030.

Table 3.10.1 – Protected Estimated GHG Emissions by Sector and Source

Sector / Emission Source ($MMTCO_2e$)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	**18.03**	**17.93**	**17.81**	**17.66**	**17.48**	**17.31**	**17.12**	**16.94**	**16.76**	**16.59**	**16.40**	**16.22**	**16.04**	**15.86**	**15.68**	**15.50**
Commercial	**10.36**	**10.41**	**10.48**	**10.50**	**10.51**	**10.52**	**10.49**	**10.47**	**10.45**	**10.43**	**10.40**	**10.36**	**10.33**	**10.32**	**10.30**	**10.29**
Industrial	**82.89**	**84.93**	**86.32**	**87.26**	**88.08**	**89.05**	**89.27**	**90.27**	**91.17**	**91.99**	**94.01**	**93.06**	**93.04**	**93.00**	**92.91**	**95.01**
Combustion of Fossil Fuels	45.80	47.33	48.18	48.58	48.86	49.30	49.60	50.01	50.31	50.53	50.73	50.68	50.33	49.96	49.54	49.09
Industrial Process	14.54	14.94	15.38	15.82	16.25	16.68	17.15	17.61	18.06	18.52	18.97	19.36	19.74	20.12	20.50	20.87
Coal Mining and Abandoned Coal Mines	9.48	9.48	9.48	9.49	9.49	9.50	8.76	8.71	8.65	8.60	9.79	8.50	8.45	8.39	8.34	10.51
Natural Gas and Oil Systems	13.08	13.18	13.28	13.37	13.47	13.57	13.77	13.95	14.14	14.33	14.52	14.53	14.53	14.53	14.53	14.54
Transportation	**66.96**	**66.73**	**66.39**	**65.89**	**65.28**	**64.64**	**63.99**	**63.34**	**62.70**	**62.03**	**61.32**	**60.64**	**59.98**	**59.40**	**58.90**	**58.49**
Petroleum	64.26	64.05	63.61	62.99	62.26	61.53	60.82	60.09	59.36	58.60	57.82	57.11	56.45	55.83	55.29	54.85
Natural Gas	2.70	2.69	2.79	2.90	3.02	3.11	3.17	3.25	3.35	3.43	3.50	3.53	3.53	3.57	3.61	3.65
Electricity Production (in-state)	**104.72**	**105.46**	**105.88**	**107.53**	**108.61**	**108.49**	**109.82**	**110.17**	**108.93**	**108.82**	**108.34**	**107.98**	**106.85**	**105.84**	**105.65**	**104.77**
Coal	85.78	85.72	85.31	86.28	87.61	87.98	90.56	91.84	90.42	90.62	90.71	90.93	91.24	91.22	91.39	91.30
Natural Gas	18.46	19.29	20.21	20.88	20.66	20.18	18.92	18.00	18.17	17.86	17.30	16.73	15.29	14.30	13.93	13.14
Oil	0.48	0.45	0.36	0.36	0.34	0.33	0.34	0.34	0.34	0.34	0.34	0.33	0.32	0.33	0.33	0.33
Agriculture	**7.31**	**7.30**	**7.30**	**7.31**	**7.30**	**7.30**	**7.30**	**7.24**	**7.23**	**7.22**	**7.22**	**7.21**	**7.20**	**7.20**	**7.19**	**7.18**
Enteric Fermentation	3.45	3.45	3.45	3.46	3.46	3.46	3.46	3.39	3.39	3.38	3.38	3.37	3.37	3.36	3.35	3.35
Manure Management	1.34	1.34	1.35	1.35	1.36	1.36	1.36	1.37	1.38	1.38	1.39	1.39	1.40	1.40	1.41	1.41
Agricultural Soil Management	2.50	2.50	2.49	2.48	2.48	2.47	2.46	2.46	2.45	2.45	2.44	2.43	2.43	2.42	2.42	2.41
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Waste Management	**2.93**	**3.05**	**3.18**	**3.30**	**3.43**	**3.55**	**3.68**	**3.80**	**3.93**	**4.05**	**4.18**	**4.30**	**4.43**	**4.55**	**4.68**	**4.80**
Solid Waste and Combustion	1.05	1.15	1.25	1.35	1.45	1.55	1.65	1.75	1.85	1.95	2.05	2.15	2.25	2.35	2.45	2.55
Wastewater	1.87	1.90	1.93	1.95	1.98	2.00	2.03	2.05	2.08	2.10	2.13	2.15	2.18	2.20	2.23	2.25
Total Statewide Gross Emissions (Prod)	**293.19**	**295.82**	**297.36**	**299.44**	**300.69**	**300.86**	**301.65**	**302.22**	**301.18**	**301.13**	**301.86**	**299.78**	**297.87**	**296.17**	**295.31**	**296.05**
Increase relative to 2000	-9.22%	-8.40%	-7.93%	-7.28%	-6.90%	-6.84%	-6.60%	-6.42%	-6.74%	-6.76%	-6.53%	-7.18%	-7.77%	-8.29%	-8.56%	-8.33%
Forestry and Land Use	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26	-34.26
Total Statewide Net Emissions (Prod. with sinks)	**258.93**	**261.56**	**263.10**	**265.18**	**266.43**	**266.60**	**267.39**	**267.96**	**266.92**	**266.87**	**267.60**	**265.52**	**263.61**	**261.91**	**261.05**	**261.79**
Increase relative to 2000	-14.00%	-13.13%	-12.62%	-11.92%	-11.51%	-11.45%	-11.19%	-11.00%	-11.35%	-11.36%	-11.12%	-11.81%	-12.45%	-13.01%	-13.30%	-13.05%

Figure 3.10.2 displays the projection data from Table 3.10.1 for the residential, commercial, industrial, transportation, electricity production, agriculture, and waste management sectors.

Figure 3.10.2 – Projected GHG Emissions by Sector (MMTCO2e)



Chapter 4: Energy

The Commonwealth of Pennsylvania is home to abundant energy resources that contribute to electricity generation and help us meet our thermal energy needs. Resources such as natural gas, coal, nuclear, hydropower, wind, solar and other renewables have positioned Pennsylvania as a national leader in both energy production and resource diversity. Some of these resources are more carbon intensive than other energy sources. Investments into less carbon intensive sources of energy should be prioritized to ensure that Pennsylvania maintains a stable economy well into the future.

According to the United States Bureau of Labor and Statistics, Pennsylvania had over 85,000 people employed in Green Goods and Services (Utilities, Construction, Manufacturing, Trade, Transportation, and Warehousing of) in 2011, the last year such data is available. The Bureau of Labor and Statistics defines Green Goods and Services as jobs that produce goods and provide services that benefit the environment or conserve natural resources.[10] There are immense opportunities for renewable energy in Pennsylvania, such as wind and solar. With the improvement of battery storage technology wider deployment of renewable energy can be achieved.

Pennsylvania currently has approximately 200 major electric generation facilities. While coal, oil and natural gas comprise the greatest number of facilities, the output of the state's five zero-carbon emitting nuclear power plants will continue to generate over one-third of Pennsylvania's electricity into the future.

The significant and immediate impact of the unconventional natural gas plays on the Pennsylvania energy marketplace has resulted in Pennsylvania transitioning from being an importer of 75 percent of natural gas resources consumed in this state to a net exporter of natural gas within the last five years. In 2013, Pennsylvania produced over three trillion cubic feet of natural gas.

While Pennsylvania has traditionally been an electricity exporting state due to the strength of its coal and nuclear fleet, greater diversity in the market place due to an alternative energy portfolio standard, implementation of a widespread energy efficiency and conservation program, via Act 129 of 2008, as well as the increase in natural gas production and use have resulted in a variable and changing generation portfolio. In the midst of this change, Pennsylvania still operates as a significant electricity exporting state within the Mid-Atlantic region. Several neighboring states with large population centers, bounded by PJM, the regional transmission operator's territory, are significant net electricity importing states.

Energy efficiency also plays a significant role in Pennsylvania, with the adoption of Act 129 of 2008 which requires electricity distribution companies to implement energy efficiency and conservation plans aimed at reducing customer's energy use. According to the EIA,

[10] www.bls.gov/green/

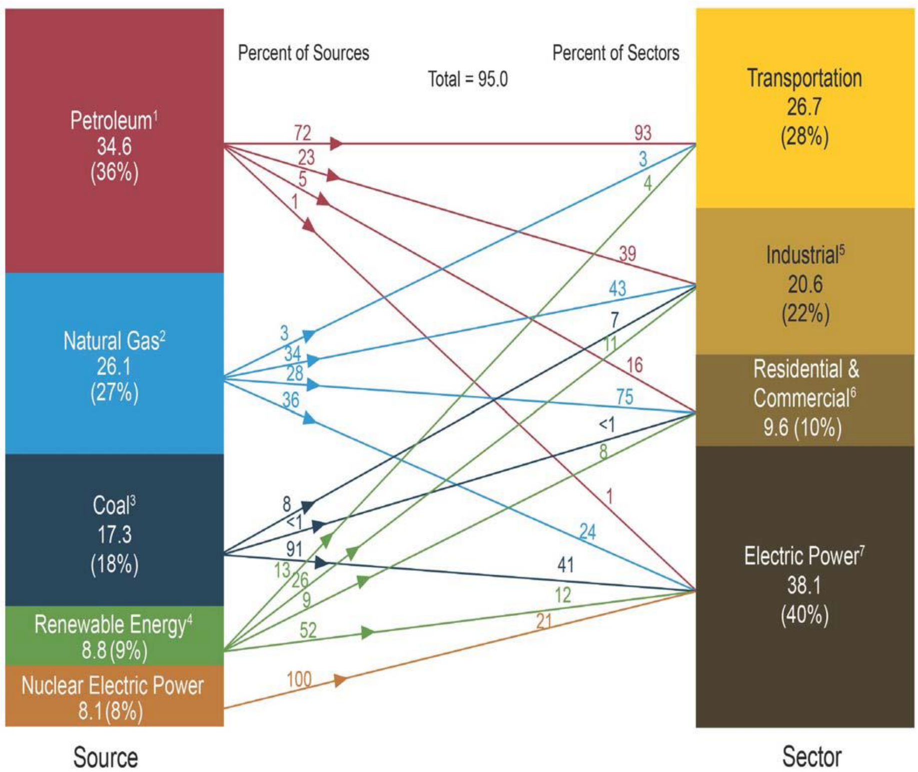
Pennsylvania ranks 31st in total energy consumed per capita. This ranking if likely influenced by Pennsylvania's old building stock, much of which was constructed before World War II.

4.A. Electricity Generation and Transmission

Generating Electricity with Less Carbon Intensity

According to the latest available State Energy Data System (2013 SEDS)[11] from the EIA, Pennsylvania, at nearly 227 million MWh, was the second largest generator of electricity in the United States. The majority of this electricity, roughly 39 percent (over 88 million MWh, fourth most in the U.S.) came from coal-burning power plants, 35 percent (79 million MWh, second most in the U.S.) from nuclear power, 22 percent (50 million MWh, sixth in the U.S.) from gas-fired power plants and about 4 percent (9 million MWh, 16th in the U.S.) from renewable sources. More than 65 million MWh (29 percent) of this energy was sold to users outside of the Commonwealth, making Pennsylvania the largest exporter of electricity in the U.S. Pennsylvania had the sixth highest consumption of electricity (over 160 million MWh) and the sixth highest population (almost 12.8 million people) and at 12.6 MWh/person was slightly below the national median in per capita electricity consumption. Overall, electricity production accounts for nearly 40 percent of all primary energy consumption in the United States.

U.S. Primary Energy Consumption by Source and Sector, 2012 (Quadrillion Btu)[12]



Fossil fuels, primarily coal and extracted gas, have traditionally been combusted in power plants to generate electricity. In addition to electricity, combustion of these resources also generates

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[11] http://www.eia.gov/state/seds/seds-data-fuel.cfm?sid=PA

[12] http://www.eia.gov/totalenergy/data/monthly/pdf/flow/primary_energy.pdf

pollutants, such as carbon dioxide and as oxides of sulfur and nitrogen, which contribute to acid rain and ground-level ozone pollution.

According to the EIA, electricity production in Pennsylvania resulted in emissions of over 108 million metric tons of carbon dioxide in 2013.[13] In addition to these air emissions, fossil fuel and nuclear generation consume large quantities of water, and can increase surface water temperatures in rivers, altering habitats for cold-water fish and other species. Electric utilities are also among the largest residual waste generators in the state. Replacing fossil fuels with non-emitting renewables like wind and solar displaces emissions and other environmental impacts from these sources.

Challenges and Opportunities

Pennsylvania is home to a diverse energy mix and a rich set of indigenous resources that are inextricably linked to our economy. According to the EIA, in 2012 Pennsylvania was the third largest producer of total energy in the United States at 4,720 trillion BTU. Broken down by energy source, Pennsylvania ranked

- 1st in the nation for electricity exports,
- 2nd in the nation for electric generation,
- 2nd in the nation for natural gas production,
- 4th in the nation for coal production,
- 2nd in the nation in nuclear generation,
- 12th in the nation for solar capacity,
- 16th in the nation in total wind capacity installed.

On August 3, 2015, the EPA announced the final rule for Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units (Clean Power Plan). The EPA's Clean Power Plan represents a significant opportunity for Pennsylvania to reduce the carbon intensity of electricity generation.

Pennsylvania has the opportunity to demonstrate the efficacy and the economics of clean energy development and prove that it cannot only be positive for the nation's energy grid, but positive for the nation's economy.

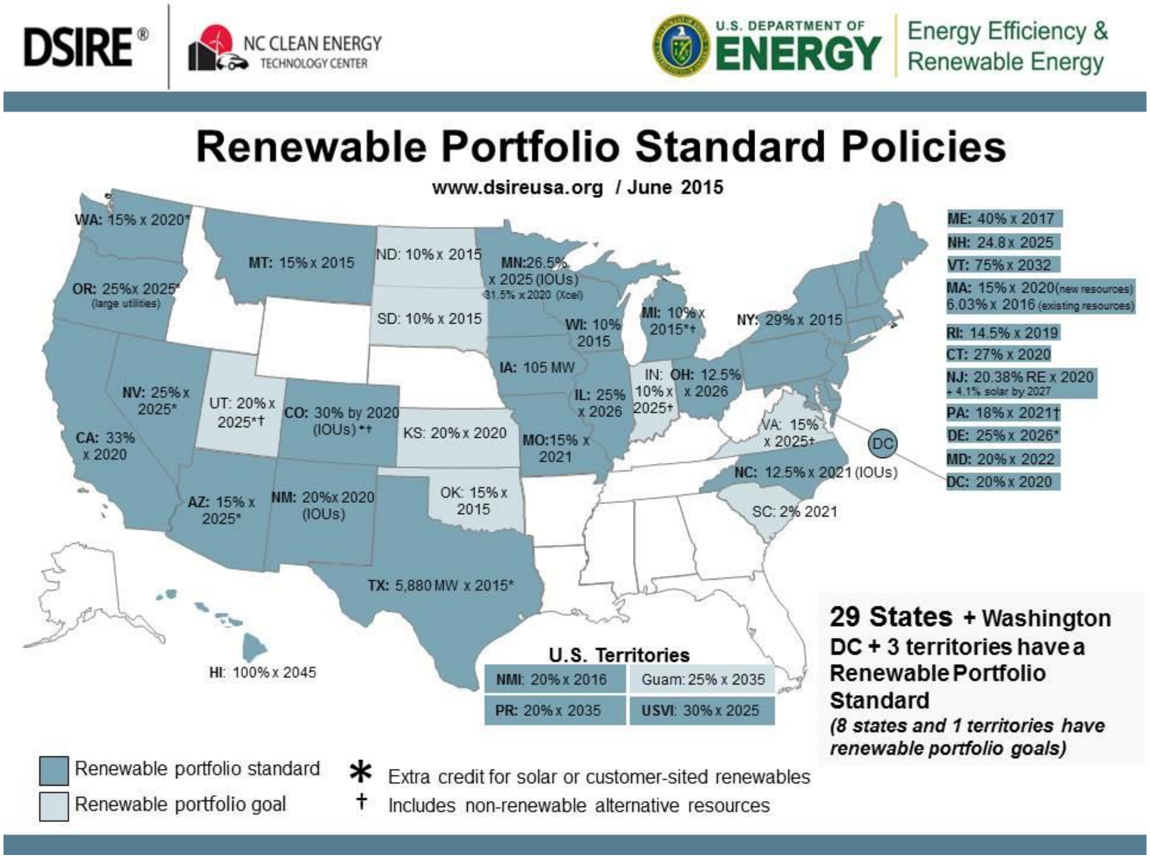
AEPS Tier 1 and Solar Requirements

Pennsylvania is one of 29 states that, along with 3 U.S. territories and the District of Columbia, have adopted some sort of renewable portfolio standard. These mandatory standards require utilities to sell a specified percentage or amount of renewable electricity. In addition, eight states and one territory have enacted less stringent voluntary renewable portfolio goals. Act 213 of 2004, the Pennsylvania Alternative Energy Portfolio Standard (AEPS) Act, requires that electric distribution companies and electric generation suppliers include a specific percentage of electricity from alternative resources in the generation that they sell to Pennsylvania retail customers.

[13] http://www.eia.gov/electricity/state/Pennsylvania/

While Act 213 does not mandate exactly which resources must be utilized and in what quantities, certain minimum thresholds must be met for the use of Tier I, Tier II, and solar photovoltaic resources. By 2021, 8 percent of Pennsylvania's electricity must be supplied by Tier 1 resources, including 0.5 percent of Tier 1 which must be supplied by solar. Tier I sources include solar photovoltaic and solar thermal energy, wind power, low-impact hydropower, geothermal energy, biologically derived methane gas, fuel cells, biomass energy (including generation located inside Pennsylvania from by-products of the pulping process and wood manufacturing process including bark, wood chips, sawdust and lignin in spent pulping liquors) and coal mine methane.[14]

Maryland, New Jersey, Delaware and New York each have Renewable Portfolio Standards (RPS) exceeding 20 percent, far surpassing Pennsylvania's AEPS. Based on a June 2015 detailed summary map[15] (see below) of all the states, territories and DC with set percentage goals in their mandated RPS, Pennsylvania's 8 percent Tier 1 renewables requirement is the least ambitious. There have been bills introduced in the Pennsylvania Legislature that would increase the percentage of Tier 1 AEPS resources required from the current 8 percent to 15 percent of the electricity consumed in the state, and to increase the solar carve-out from 0.5 percent to 1.5 percent, both by 2023.



[14] http://www.puc.pa.gov/electric/pdf/AEPS/AEPS_Ann_Rpt_2013.pdf

[15] http://www.dsireusa.org/resources/detailed-summary-maps/

Reinvest in the PA Sunshine Program

The PA Sunshine Program was an established and successful program that provided rebates to homeowners and small businesses for the installation of solar photovoltaic (PV) and solar hot water heaters. The program ran from 2009 until funds were exhausted in late 2013. The program was successful in furthering Pennsylvania's use of alternative energy and in turn helped to stimulate Pennsylvania's economy. Nearly 7,000 residents and 1,054 small business owners contracted with local installers to complete their solar projects. These projects then allowed households and companies to reduce electric costs, freeing up funds for other items, employee salaries, or expansion of their business.

Pennsylvania ended 2013 with approximately 200 MW of solar installed. About 98 MW of the total was a direct result of the small residential and small commercial systems installed utilizing the PA Sunshine Program. This program's 98 MW of solar PV capacity generates an estimated 142 million kWh per year. This would be enough energy to power approximately 14,000 Pennsylvania homes. The sum of GHG emissions displaced is equivalent to approximately 84,000 tons of carbon dioxide. This is equivalent to the annual GHG emissions from nearly 16,000 passenger vehicles, or 8.5 million gallons of gasoline consumed, or 407 rail cars worth of coal burned. In addition to CO2 reduction, other pollutants are reduced as well. Approximately 525,400 pounds of sulfur oxides and 167,418 pounds of nitrogen oxides were displaced and or reduced.

Significantly, solar PV systems help with grid reliability because PV electricity generation is at its peak during the long days of summer, when demand for electricity is highest.

This program's 5.3 MW of solar PV capacity generates an estimated 7.4 million kWh per year. This would be enough energy to power approximately 740 Pennsylvania homes. Economically, the $9.2 million of State Energy Program (DOE sponsored) funding deployed from the program, resulted in nearly $30 million in renewable energy investment total. Each dollar invested led to over $2 in private investment.

In total, the $113 million deployed from the program, resulted in more than $564.6 million of private sector funding invested in renewable energy deployment. Due to changes in the market since the last PA Sunshine program, primarily from a reduction in solar panel prices and component costs, a re-investment in the program could likely result in a much greater deployment of solar PV and corresponding energy, economic and environmental benefits.

The National Renewable Energy Lab has estimated the technical potential for rooftop solar PV in Pennsylvania to be nearly 20 GW, or enough to generate approximately 22,215 GWh per year. Technical potential represents the achievable energy generation given system performance, topographic limitations, environmental, and land-use constraints. Bringing that potential to market depends on technology and competing fuel costs, policy, and regulations, among other factors.[16]

There is significant opportunity for the Commonwealth to encourage and incentivize the use of residential rooftop solar PV and solar hot water systems. Solar electric and solar hot water systems have the potential to cost-effectively reduce electricity (up to ~20-30 percent) and domestic hot water (up to ~85 percent) energy consumption, and associated emissions, on properties with proper solar access and orientation (unobstructed, flat or south-facing sloped roofs). Solar thermal hot water systems are already cost-effective and solar PV costs have fallen by more than 50% in the last couple of years.

The commonwealth can further encourage and incentivize the use of residential rooftop solar PV and hot water systems through any number of mechanisms. In addition to funding a rebate program like PA Sunshine, establishing a feed-in tariff system (refer to Section 4A), and providing financing options (see Section 4D), an exchange system could be created that puts motivated buyers together with PA-approved installers. The exchange would consist of a database of interested homeowners. The exchange would maintain a database of pre-approved solar installers. When the group reaches a critical mass of customers, it would issue a request for proposals (RFP) for approved solar contractors able to handle the work. The exchange could act as a selection committee and evaluate and pick the winning bid.

Installers participating in this program would pay a fee to participate in this program. This fee would cover administrative costs to manage the program. Contractors, through the exchange RFP process, would have a pool of centrally located customers who have a very high likelihood of following through with a contracted solar sale. The contractor is then able to buy materials and schedule labor with a number of projects at the same time and can buy equipment in bulk, thus reducing both material and labor costs.

Another legislative recommendation could be amending the AEPS to allow for virtual net metering under AEPS to facilitate the development of community solar systems. Community solar is a strong opportunity to allow individuals to purchase “shares” of a solar farm/facility and thus own any number of solar panels in a community solar project. The benefits community solar offers are the ability to tap more efficient sources of capital to further grow the solar market. Individual customers, who are interested in investing in solar but rent or otherwise do not have the ability to install panels, can invest in a community solar program and receive the benefits of virtual net metering. States already supporting community solar include California, Colorado, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, Vermont, Washington DC, Washington State, Hawaii and Maryland. New York, Illinois, Oregon, and Connecticut are looking into considering this option.

[16] Renewable Energy Potential, National Renewable Energy Laboratory, http://www.nrel.gov/gis/re_potential.html

Invest in Wind and Solar Storage Technologies

Several types of energy storage technologies exist and have been deployed on the grid, including pumped storage hydro, compressed air storage, batteries, flywheels, and thermal energy storage. Pumped storage makes up the bulk of this, but battery technologies, in particular, have begun to be deployed more widely.

Variable generation resources like wind and solar generally do not need storage to integrate into the grid until levels of penetration reach relatively high levels. The American Wind Energy Association states that wind energy can provide 20 percent or more of our electricity without any need for energy storage.[17] If penetration increases much higher than this level, however, problems can include the need for curtailment or having insufficient electricity when needed. Including storage on the grid or within a renewable energy project alleviates these issues and allows the project to be more profitable by being able to take better advantage of peak power prices as well as participate in additional energy markets. Renewable energy generation with energy storage can help stabilize the grid and be able to help support critical infrastructure.

Energy storage can reduce GHG emissions by allowing better penetration of emissions-free resources, and offsetting emissions from older, dirtier plants for meeting peak demand. Energy storage can be more widely deployed in Pennsylvania if funding is provided for demonstration and deployment projects. This can be done by creating a stand-alone financing and/or grant program or by prioritizing projects that deploy other alternative energies in existing grant programs if they include energy storage.

Create a Feed-in Tariff for Carbon-free Renewables

A feed-in tariff is an energy supply policy promoting rapid deployment of renewable energy resources. It offers a performance-based guarantee of payments to renewable energy developers for the electricity they produce. Payments can be composed of electricity alone or of electricity bundled with renewable energy credits or certificates. These payments are generally awarded as long-term contracts set over a period of 15-20 years. Under a feed-in tariff, eligible renewable electricity generators, including homeowners, business owners, farmers and private investors, are paid a cost-based price for the renewable electricity they supply to the grid. This enables diverse technologies (e.g. wind, solar, biogas, etc.) to be developed and provides investors a reasonable and predictable return.

Feed-in-tariff policies have been successfully enacted in over 50 countries around the world, most notably throughout Europe. Currently there are six U.S. states (CA, HI, ME, OR, VT, and WA) that mandate feed-in tariff or similar programs.[18] Thirteen other states (AL, FL, GA, KY, IN, MI, MS, NC, NY, TN, TX, VA, WI) have utilities with voluntary feed-in tariffs. There is growing interest in these programs in the United States, especially as evidence mounts about their effectiveness as a framework for promoting renewable energy development and job creation.

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[17] http://www.awea.org/Issues/Content.aspx?ItemNumber=5452
[18] http://www.eia.gov/electricity/policies/provider_programs.cfm

In 2008, a detailed analysis by the European Commission concluded that "well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity."[19] This conclusion was supported by other analyses, including ones by the International Energy Agency,[20, 21] the European Federation for Renewable Energy,[22] as well as Deutsche Bank.[23]

By properly setting and differentiating payment levels, feed-in tariff policies can simultaneously increase the development of different technology types over a wide geographic area. They can also contribute to local job creation and increased clean energy development in a variety of sectors. Feed-in tariff policies can be implemented to support any renewable technology including those most viable in PA: wind, PV, solar thermal, biogas, biomass, fuel cells, combined heat and power (CHP) and energy storage.

By design, feed-in tariff programs allow for both quantitative goal-setting for emissions reductions and measurable results through metered alternative energy production. Comprehensive programs can include both percentage (e.g. 10 percent solar, 20 percent wind, 30 percent hydro…) and production (20,000 GWh solar, 40,000 GWh wind, 60,000 GWh hydro) goals, tiered (based upon quantity produced) and timed (based upon a schedule) monetary incentives, and any number of controls and mechanisms to achieve the desired effect and impacts. Therefore, the number of possible scenarios and impacts using feed-in tariffs are practically infinite.

[19] European Commission (COM), 2008. Commission Staff Working Document, Brussels, 57, 23 January 2008, http://ec.europa.eu/energy/climate_actions/doc/2008_res_working_document_en.pdf
[20] International Energy Agency (IEA) (2008). Deploying Renewables: Principles for Effective Policies, ISBN 978-92-64-04220-9
[21] de Jager, D., Rathmann, M. (2008). Policy Instrument Design to Reduce Financing Costs in Renewable Energy Technology Projects. Work performed by ECOFYS, Ultrecht, The Netherlands. Paris, France: International Energy Agency – Renewable Energy Technology Deployment, http://www.iea-retd.org/files/RETD_PID0810_Main.pdf
[22] European Renewable Energy Federation (EREF 2007). Prices for Renewable Energies in Europe for 2006/2007: Feed in tariffs versus Quota Systems – a comparison. Doerte Fouquet, editor, Brussels, Belgium, http://www.eref-europe.org/library/price-report/
[23] http://www.dbcca.com/dbcca/EN/_media/Global_Climate_Change_Policy_Tracker_Exec_Summary.pdf

4.B. Natural Gas Production, Transmission, and Distribution

Reducing Methane Leakage

Methane (CH4) has been identified by the EPA as the second most prevalent GHG emitted in the United States from human activities, accounting for 10 percent of domestic GHG emissions.[24] According to EPA, methane is estimated to have a global warming potential of 28-36 over 100 years.[25] This figure reflects the fact that methane emitted today will persist in the atmosphere for about a decade on average. For comparison, carbon dioxide (CO2), the primary GHG emitted through human activities persists in the atmosphere for approximately one hundred years. However, methane also absorbs much more energy than CO2. The net effect of the shorter lifetime and higher energy absorption is reflected in the global warming potential.

As noted in President Obama's March 2014 report, *Strategy to Reduce Methane Emissions*, key sources of methane include landfills, coal mines, agriculture, and oil and gas operations.[26] Pennsylvania is an economic leader in each of these industries and is committed to maximizing methane emission reductions from these sectors. As a leading state in gas and coal production, Pennsylvania is uniquely positioned to be a national leader in addressing climate change while supporting Governor Wolf's commitment to ensuring responsible development, creating new jobs, and protecting public health and our environment.

Challenges and Opportunities

In January 2015, the Obama Administration and EPA announced the goal to reduce methane emissions from the oil and gas sector by 40-45 percent of 2012 levels by 2025.[27] EPA is currently working with oil and gas companies to reduce methane emissions through their Natural Gas STAR Methane Challenge Program. This program builds on the Natural Gas STAR Program, which was first implemented in 1993 and designed to be a voluntary effort for operators to reduce methane emissions. In the first 20 years of the program, operators were able to reduce methane emissions by over 400 MMTCO2e. The Methane Challenge focuses on company-wide initiatives, instead of individual facilities, to recognize the companies that are leading in methane reduction techniques. This effort involves the entire chain of natural gas operations, including the gathering, processing, transmission, storage, and distribution aspects of use.

The Pennsylvania General Assembly has provided DEP with broad powers and duties to control air pollution through the Pennsylvania Air Pollution Control Act. Through the use of current statutes, regulations and permitting requirements, Pennsylvania has already demonstrated that technology and best practices to deliver substantial reductions in methane emissions exist, and can be accomplished cost-effectively.

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[24] *U.S. Greenhouse Gas Inventory Report: 1990-2013*, http://www.epa.gov/climatechange/GHGemissions/gases.html
[25] *Understanding Global Warming Potential*, http://epa.gov/climatechange/GHGemissions/gwps.html
[26] *The White House Climate Action Plan: Strategy to Reduce Methane Emissions*, March 2014, https://www.whitehouse.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf
[27] https://www.whitehouse.gov/the-press-office/2015/01/14/fact-sheet-administration-takes-steps-forward-climate-action-plan-anno-1

DEP is committed to working with all stakeholders to continue to identify and enhance existing technology and best-practice-based approaches and develop new approaches to further reduce methane emissions through both regulatory programs and voluntary incentive-based programs. In addition to EPA's Natural Gas STAR Methane Challenge, the ONE Future Coalition is comprised of natural gas companies that are "focused on demonstrating an innovative, performance-based approach to the management of methane emissions directed toward a concrete goal: to achieve an average rate of methane emissions across the entire natural gas value chain that is 1 percent or less of total natural gas gross production."[28] DEP is exploring the potential for these types of performance-based approaches, when fully developed, to serve as alternative compliance pathways.

Improve Natural Gas Transmission System Infrastructure and Invest in Leak Detection

Natural gas supplies nearly a quarter of all of the energy used in the United States. To deliver this energy, a network of pipelines interconnects across the country. With increased use of unconventional shale gas resources, miles of pipelines are growing quickly. Leaks from natural gas infrastructure are a major source of methane emitted into the atmosphere. Act 11 of 2012 allows for the recovery of costs by utilities to repair, improve, or replace distribution lines. However, repairs for many systems are far into the future and more investment is necessary to replace leaking infrastructure. Not only is methane emission into the atmosphere a climate concern, but methane is a highly flammable substance and infrastructure leaks can quickly become safety hazards.

Pennsylvania does not currently mandate through any of its existing authorities methane monitoring, leak detection, or measures to control or prevent fugitive emissions from gathering, transmission or distribution pipelines. Working through the Pennsylvania Pipeline Infrastructure Task Force effort, the Commonwealth will establish best practices for methane monitoring, leak detection and repair aimed at controlling or preventing fugitive emissions from gathering, transmission, or distribution pipelines.

DEP will also expand its efforts to identify and control fugitive emissions through a comprehensive inventory of potential emission sources beyond the traditional permitting programs. This includes evaluating additional methane control technologies as well as voluntary, incentive-based efforts, such as the EPA Natural Gas STAR Methane Challenge and the work of ONE Future, that provide greater flexibility in achieving performance-based standards.

The Environmental Defense Fund and Google Earth have piloted a project that measures natural gas leakage through sensors on Google Street View cars. These sensors identify areas where natural gas leakage is prevalent from distribution lines. This information is then forwarded to distribution companies to help prioritize lines for repair. A mobile monitoring program like this could be expanded in Pennsylvania by distribution companies. The Pennsylvania Public Utility Commission (PUC) could further improve requirements for the frequency of the leak inspections, prioritization of repairs, upgrading lines, and providing information to the public.

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[28] ONE Future: *Our goal: 99 percent efficiency*, http://www.onefuture.us/our-goal/

Control Methane Emissions at the Well Site

Initial regulation of oil and gas wells in Pennsylvania occurred pursuant to the passage of the Pennsylvania Oil and Gas Act in 1984. This Act and its implementing regulations require that operators obtain permits to drill and operate oil and gas wells in the Commonwealth. This includes conventional and unconventional natural gas wells.

Although these wells have permits and the locations are known, prior to August 2013, they were not required to be equipped with the best available technology for methane control. No periodic leak detection is required, nor is repair of any leaks. Without that data, it is not possible currently to quantify the extent of any fugitive methane emissions from this large group of sources. Natural gas compressor stations that predate August 2013 were permitted under a general permit that included best available technology at the time of permitting.

DEP regulates new sources of emissions of methane from oil and gas extraction activities through its Air Quality Permitting Program and the implementation of federal regulations found at 40 CFR Part 60, Subpart OOOO (relating to the Standards of Performance for Crude Oil and Natural Gas Production, Transmission and Distribution). The regulations are adopted and incorporated by reference in their entirety at 25 *Pa. Code*, Chapter 122. On August 18, 2015, EPA proposed amendments to the new source performance standards for the oil and gas sector to reduce VOC and methane emissions. Upon issuance of the final rule for this sector, the requirements will automatically take effect in Pennsylvania.

EPA has also developed Control Technique Guidelines for the Oil and Natural Gas Sector to reduce VOC emissions in ozone non-attainment areas including the Ozone Transport Region. These guidelines are planned to be finalized in the summer of 2016. DEP intends to expeditiously pursue the adoption of the guidelines as Reasonably Available Control Technology for each VOC source category in the oil and gas sector covered by EPA's guidelines.

DEP has established a comprehensive methane emissions reduction program for the oil and gas industry, regulating air contaminants including VOCs and methane emissions from sources located at well pad and mid-stream operations. This program is implemented using general permit terms and conditions and conditional permit exemption criteria authorized under the Pennsylvania Air Pollution Control Act and implementing regulations in 25 *Pa. Code* Chapter 127. This program will be further evaluated and strengthened as appropriate after considering advancement in air pollution control technologies and their technical and economic feasibilities.

Air quality permitting is one of DEP's key tools in preventing and reducing air pollution. Since February 2013, Pennsylvania's regulation of methane emissions from compressor stations has been achieved through the revised General Plan Approval and General Operating Permit for Natural Gas Compression and/or Processing Facilities (known as GP-5). This general permit for non-major sources establishes best available technology for controlling emissions, and contains terms and conditions requiring periodic inspection, a leak detection and repair (LDAR) program, and reporting obligations for affected owners and operators. Any concentration greater than

2.5 percent methane measured using a gas leak detector and a VOC concentration of greater than 500 parts per million (ppm) is considered a leak.

The GP-5 is the first general permit in the nation to require LDAR programs for mid-stream gathering and compression facilities. Pennsylvania's current LDAR program under GP-5 requires operators to conduct leak detection and repair monthly, using audible, visual and odor detection methods. In addition, on a quarterly basis, operators must use leak detection monitoring devices, such as a forward-looking infrared camera, to detect methane leaks. All methane leaks at compressor stations or processing facilities must be repaired, completely eliminating the leak in 15 days or less. These permit requirements will be further evaluated and strengthened as appropriately after considering advancement in air pollution control technologies and their technical and economic feasibilities.

The proposed actions will apply to new facilities; once the old GP-5 expires, all existing compressor stations will be required to be re-permitted under the new GP-5. These existing sources will then be required to conduct quarterly LDAR, resulting in additional methane emission reductions. GP-5 requirements will further control emissions from storage tanks and operations will be prohibited from venting hydrocarbon emissions from any access point or pressure relief device during normal operations.

Since August 2013, Pennsylvania's regulation of emissions from new sources of methane from unconventional natural gas wells has been through the implementation of conditional permit exemption criteria (Category No. 38) set forth in DEP's "Air Quality Permit Exemptions" (Document No. 275-2101-003). These conditional permit exemption criteria were issued by DEP for conventional wells, unconventional wells, wellheads and all other associated equipment. Sources at these natural gas well sites are exempt from permitting requirements if the owner or operator meets all applicable requirements established in the Category No. 38 exemption criteria. The owner or operator must also comply with all applicable federal requirements.

Through these conditional exemption criteria, the entire well pad/facility is subject to an LDAR program to address methane emissions from well pad operations. On well pads, leak detection and repair must be conducted within 60 days after a well is put into production, and annually thereafter, and include the entire well pad, not just the natural gas liquids tanks and piping as required by the EPA for the oil and gas sector. Any detected leaks on well pads in Pennsylvania are currently required to be repaired within 15 days. This criterion is more stringent than federal requirements; however, it will be further strengthened. Failure to comply with any criteria associated with the operation of a well pad may result in the requirement for that operator to cease operations. DEP received approximately 722 compliance demonstrations for wells and has also issued 38 Notices of Violation since implementing the permit in 2013. DEP is currently evaluating the adequacy of the compliance demonstrations.

Plug Abandoned Wells

Oil and gas wells drilled before passage of the Pennsylvania Oil and Gas Act in 1984 were not required to obtain permits. Thus, the number and locations of these wells are unknown, but it is estimated that there may be as many as 350,000 pre-regulatory wells (including abandoned wells) in the Commonwealth.

Prior to the 1984 Act and its implementing regulations, plugging requirements were not sufficient to ensure long-term closure of the well. The fugitive methane emissions from pre-regulatory, orphaned (abandoned prior to April 1985) and abandoned wells in Pennsylvania could be significant.

A recent study published by the National Academy of Sciences[29] suggests that GHG emission inventories could well be missing methane emission sources, specifically due to considerable releases from abandoned oil and gas wells in northwestern Pennsylvania. The study further suggests that these sources could comprise as much as 4 to 7 percent of current total anthropogenic methane emissions in the Commonwealth.

There are approximately 61,000 plugged gas wells in Pennsylvania. Leaking plugged wells may also represent a significant source of continuing methane emissions.

The National Energy Technology Laboratory has been using helicopter fly-over technology to help DEP locate abandoned wells, found from a magnetic survey. However, once identified, there is limited funding available to plug the discovered wells. A program modeled after the Underground Storage Tank Indemnification Fund could help to ensure that there is funding to plug abandoned wells. Other ideas involve increasing the surcharge fees on well permits. Act 13’s Impact Fee also provides for funding to Commonwealth Financing Authority (CFA) for well plugging, but the program is minimally used to plug wells. DEP cannot apply for CFA grant money to plug wells. An outside entity could apply for CFA grant money to plug wells, but that non-governmental organization has yet to be identified.

Much more work is needed to fully characterize the extent of the cumulative effects of the hundreds of thousands of abandoned, orphaned and closed oil and gas wells in Pennsylvania.

Steps Pennsylvania can take to address emissions from natural gas production, transmissions, and distribution include:

1. Verify methane emission data reported to DEP by operators.
2. Investigate the potential for methane emissions from plugged and abandoned wells, including wells plugged by DEP.
3. Pursue and implement remote-sensing technologies to identify fugitive and non-fugitive emission sources throughout the present and historical areas of operating, abandoned and plugged oil and gas wells.
4. 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.

Coal Mine Methane Recovery

Methane gas is an energy source that is found in various geologic formations in Pennsylvania, including coal formations. When coal is mined and processed for use, substantial amounts of

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[29] Proceedings of the National Academy of Sciences of the Unite States of America, vol. 111 no. 51, Mary Kang, 18173–18177, doi: 10.1073/pnas.1408315111

methane gas are released. Coal bed methane is methane contained within coal formations and may be extracted by gas exploration methods or released as part of mining operations.

Pennsylvania currently has 36 bituminous and 11 anthracite underground coal mine operations. These include four idle bituminous sites and two idle anthracite sites. The mines are ventilated for the safety of the miners through fan and return shafts and methane boreholes. The methane vented from active operations is monitored by the federal Mine Safety and Health Administration (MSHA) through quarterly Methane Liberation Samples (for mines liberating over 36.5 million cubic feet of methane a year). Some operations develop coal bed methane wells in advance of mining to capture the resource for safety and economic benefits. While fan and return shafts remain relatively consistent, the methane boreholes are dynamic in that they are installed and reclaimed as mining progresses.

DEP and CCAC developed Work Plan 1: Coal Mine Methane Recovery which encourages owners/operators of current long wall mines and of any new gassy underground coal mines that are mined by any method to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. The work plan specifically focuses on coal mine methane, the methane within the coal that can be vented or recovered prior to mining the coal, during mining, and immediately after mining as some gas escapes to the surface through post-mining vents or boreholes.

The 10 percent target is technically achievable with a combination of pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical/horizontal degas holes, capturing methane by horizontal drilling within active underground mines, and/or possibly capturing methane from post-mining areas of underground mines, where for a brief period of time gas is still making its way to the surface through existing boreholes. DEP annual coal production numbers and MSHA gas liberation numbers will be reassessed annually, as well as new technological developments, with changes made to trend forecasts on future coal production and revisions to estimates of methane gas released per ton of coal mined.

By 2030, adoption of the CCAC Coal Mine Methane Recovery work plan would result in .748 million tons of CO_2 reduced annually in Pennsylvania and cost $17.98 per ton of CO_2e reduced. The cumulative results from 2015 through 2030 show the potential for 12.643 $MMTCO_2e$ reduced, while costing $12.42 per ton of CO_2e reduced.

Work Plan 1: Coal Mine Methane Recovery					
2030 Annual			**2030 Cumulative**		
Reductions ($MMTCO_2e$)	**Cost ($ Million)**	**Cost-Effectiveness ($/$tCO_2e$)**	**Reductions ($MMTCO_2e$)**	**Total NPV ($ Million)**	**Cost-Effectiveness ($/$tCO_2e$)**
.748	13.45	17.98	12.643	156.98	12.42

4.C. Energy Consumption Reductions

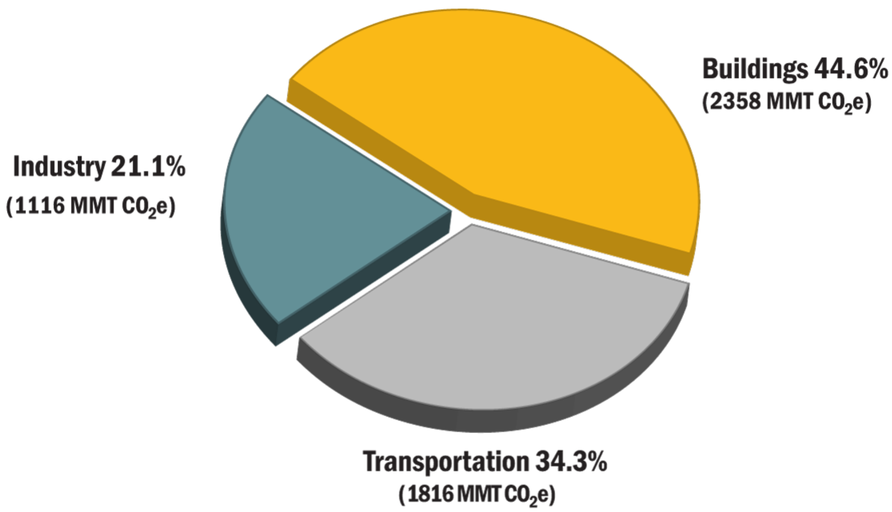
Being Smart Energy Users

Two of the most effective and expedient means of reducing the environmental impacts from energy use are conservation and increasing energy efficiency. These measures also limit resource depletion and can reduce the costs associated with energy consumption. Conservation measures are behavioral changes and activities, such as turning off electrical devices (lights, televisions, HVAC, etc.) when not in use, sealing drafts around your house and adding additional insulation. Increasing efficiency standards are technological changes that allow for the same or improved output from a device or piece of equipment while using less overall energy. Examples of advancements in energy efficiency include the transition from incandescent to compact fluorescent to LED lighting, and updated efficiency standards for HVAC systems and appliances. Conservation and efficiency measures not only reduce GHG emissions, but also can save consumers money.

Conservation can cost little to nothing, can be done relatively easily and can significantly reduce energy consumption. Replacing a 50 cent, highly inefficient 100W incandescent light bulb with a $2.50 higher efficiency 12W LED bulb costs more up front, but over the long term is actually less expensive. When considering the longer lifetime of LEDs and reduced energy consumption, a consumer would save over $230 and help avoid 1.5 tons of $CO2_e$ emissions from just changing one light bulb.

While the effectiveness and potential impact of efficiency and conservation strategies applies to virtually all resources and every sector, 14 of the 16 measures in this section address buildings, the largest sector of energy consumption in the U.S. In 2013, the building sector was responsible for over 70 percent of all electricity consumption and nearly half (44.6 percent) of all U.S. CO2 emissions in 2010. By comparison, transportation accounted for 34.3 percent of our national CO2 emissions and industry 21.1 percent.[30]

[30] http://architecture2030.org/buildings_problem_why/



U.S. CO_2 Emissions by Sector

Source: ©2013 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2012).

Challenges and Opportunities

The American Council for an Energy-Efficient Economy (ACEEE) is a nonprofit, 501(c)(3) organization that acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors. ACEEE produces an annual State Energy Efficiency Scorecard.[31] In 2014 Pennsylvania ranked 20th, scoring 20.5 points out of a possible 50.

[31] http://aceee.org/state-policy/scorecard

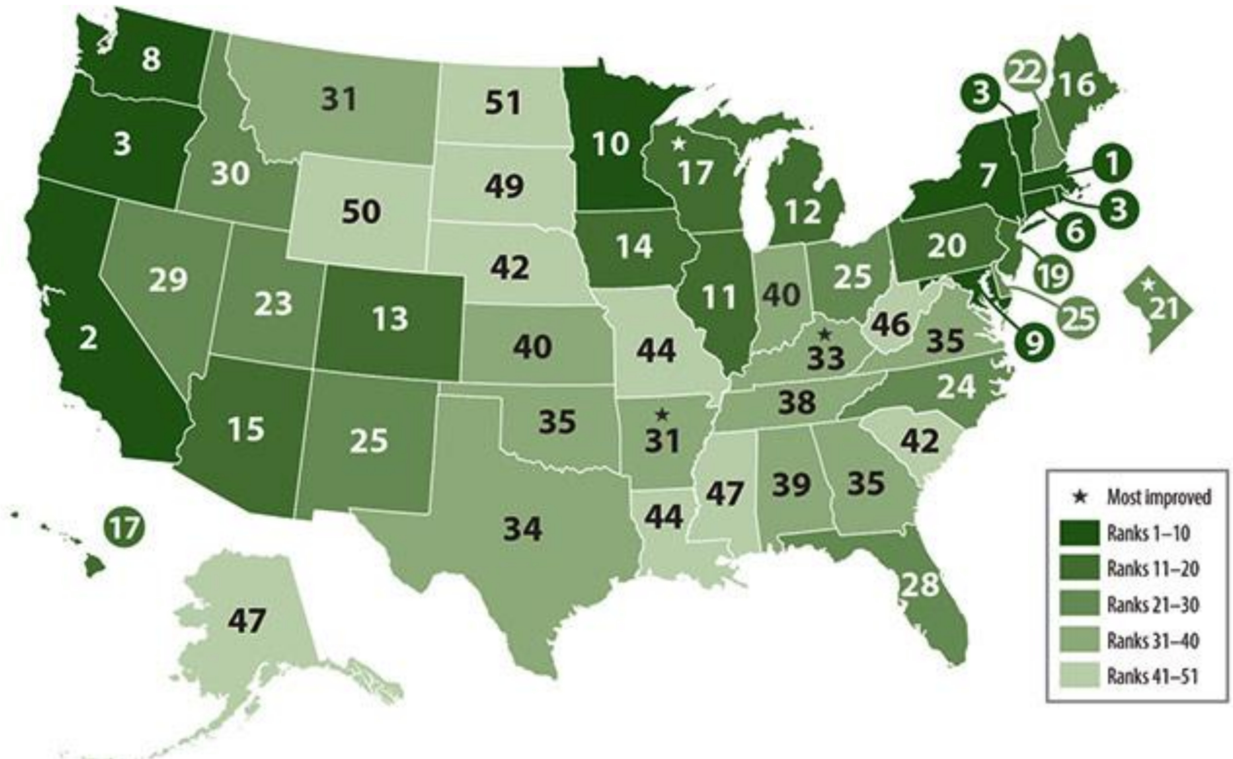


Figure 1. ACEEE 2014 State Energy Efficiency Scorecard Map

In 2014 the top-rated state, Massachusetts, scored over twice as many points (42/50), taking on a national leadership role and setting the bar for energy efficiency for other states to emulate. What follows are suggestions and recommendations for Pennsylvania to reduce energy consumption and move towards becoming a leader in energy efficiency and conservation.

According to the Natural Resources Defense Council, over 50 percent of the energy use in commercial office buildings comes from tenant spaces. In April 2015, the Federal Energy Efficiency Improvement Act of 2015 was signed into law. The most notable portion of the bill directs EPA and Department of Energy to create a tenant-focused version of EPA's highly-successful Energy Star program. The new initiative, which the bill gives EPA the option of calling Tenant Star, is being hailed as the next great tool for driving energy savings in commercial buildings. Tenant Star could help secure investments in high-performing buildings by providing owners with a federally-funded engagement platform to present to prospective tenants. The program's savings potential for energy and costs, as well as GHG reductions is staggering. Considering that there are roughly 6 billion square feet of existing leased office space in the U.S., and the estimated cost for lights as well as plug and process loads is $1.10 per square foot, 15 percent savings in tenant spaces would be worth almost $1 billion in avoided energy costs.[32]

[32] http://www.greenbiz.com/article/energy-star-tenant-star-next-frontier-building-efficiency

Support Act 129 Phases IV and V

Pennsylvania requires all electric distribution companies (EDCs) with over 100,000 customers (representing ~93 percent of electricity sales) to have an Energy Efficiency Resource Standard (EERS). On October 15, 2008, HB 2200 was signed into law as Act 129 of 2008, with an effective date of Nov. 14, 2008. The Act expanded the Pennsylvania PUC's oversight responsibilities and imposed new requirements on EDCs, with the overall goal of reducing energy consumption and demand[33].

Act 129 established a long-term, binding energy savings program for these largest EDCs. According to ACEEE, twenty-four states are currently implementing EERS policies requiring electricity savings (see map below). Of these states, 15 also have EERS policies in places for natural gas. Two states include EERS as part of their renewable energy standards. EERs policies in Indiana and Ohio were recently rolled back or suspended due to political aversion to mandatory clean energy policies. In these states, many utilities continue to run programs, with no clear policy in place to guide savings.

Figure 2. States with electric EERS policies in place (as of April 2015).

One unique aspect of Act 129 (Act) is that each applicable EDC is responsible to develop, manage and implement their own energy conservation and efficiency plan. These plans are developed with broad stakeholder input and must be approved by the PUC prior to implementation. This means that rather than having uniform offerings, messaging, and consolidated offerings across the entire state, each EDC and service territory has a separate program.

[33] http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information.aspx

In addition to mandated consumption reductions, the Act limits program spending to 2 percent of the EDC's 2006 annual revenue, and broadly established the approval, evaluation and reporting requirements. The initial phase (Phase I) of the Act required reductions in total energy consumption from retail customers of 1 percent by May 31, 2011, and 3 percent by May 31, 2013. The Act further required that by November of 2013 and every 5 years thereafter, the PUC must evaluate the costs and benefits of this program and establish new program goals.

According to the PUC's Statewide Evaluator (SWE), both of the Phase I targets, 1 percent reduction by 2011 and 3 percent by 2013 were exceeded, resulting in 5,403,370 MWh/year of total energy savings, resulting in an approximate 3,782,359 ton reduction in CO2 emissions while program spending was nearly $175,000,000 under budget.[34]

Phase II of the Act started upon the conclusion of Phase 1 (June 1, 2013) and spans 3 years through May 31, 2016, with an anticipated reduction of 3,313,246 MWh/year of energy savings and 2,319,272 tons of CO2 reductions. As of the latest SWE report (March 2016[35]), the EDCs have collectively achieved 93 percent of their compliance targets and should have no problem staying within their 2 percent of 2006 annual revenue spending budgets.

As of May 2015 Phase III[36] of the implementation of the Act had been approved and will run for 5 years from June 1, 2016 through May 31, 2021. This third phase calls for an additional 0.75 percent annual reduction in electricity consumption, equivalent to approximately 6,629,460 MWh/year while keeping the same 2 percent spending cap. These MWh reductions are estimated to result in an additional 4.6 million tons of CO2 reductions.

DEP and the CCAC developed a work plan (Work Plan 2: Act 129 Phases IV and V) that identifies potential carbon emission reductions and other benefits associated with future megawatt-hour electricity consumption savings associated with the continuation of Act 129. Suggested minimum reduction targets and associated benefits of this work plan are:

- Phase IV: An average reduction in electricity consumption of 0.75 percent per year for the five-year period from June 1, 2021, through May 31, 2026. Based on projected growth rates for the respective EDCs, this will result in savings of 6,227,960 MWh or an approximate average of 1,245,592 MWh per year. Program savings potential estimates are based on maintaining the 2 percent funding level caps, equivalent to a net present value (NPV) in EDC expenditures of roughly $1.3 billion over the planned five years of a potential Phase IV. This analysis results in $2.2 billion of consumer benefits through energy savings.
- Phase V: An average reduction in electricity consumption of 0.75 percent per year for the five-year period from June 1, 2026, through May 31, 2031. Based on projected growth rates for the respective EDCs, this will result in savings of 6,502,316 MWh or an approximate average of 1,300,463 MWh per year. Program savings potential estimates are based on maintaining the 2 percent funding level caps or an NPV in EDC

[34] http://www.puc.pa.gov/pcdocs/1274547.pdf
[35] http://www.puc.pa.gov/Electric/pdf/Act129/SWE_PY6-Semi_Annual_Report.pdf
[36] http://www.puc.pa.gov/pcdocs/1367313.doc

expenditures of roughly $1.6 billion. This analysis shows $2.6 billion of consumer benefits from energy savings.

Suggestions and recommendations for Act 129 program improvement include: 1.) Creating a centralized organization for the management of energy efficiency programs and dollars, 2.) Expanding Act 129 to include natural gas (see below), 3.) Expanding Act 129 to include municipality-operated utilities, rural electric cooperatives, and smaller electric utilities, 4.) Recognizing societal benefits in cost-benefit calculations, 5.) Eliminating the 15-year measure life limit for cost-effectiveness determinations and 6.) removing the 2 percent spending cap.

Below is the breakdown of expected GHG emissions reductions and cost-effectiveness of the work plan. In 2030, if the PUC were to implement Phases IV and V of Act 129 programs, GHG emissions would be reduced by 6 million tons of CO2e in Pennsylvania at a cost-savings of $163.8 per ton of CO2 reduced. The cumulative results from 2021 through 2030 show the potential for an 18.1 MMTCO2e reduction, at a cost-savings of $218.6 per ton of CO2e reduced.

Work Plan 2: Act 129 Phase IV					
Annual Results (2025)			**Cumulative Results (2021-2025)**		
GHG Reductions (MMTCO2e)	**Net Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Net Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
3.0	-223	-74.6	9.0	-891	-99.6

Work Plan 2: Act 129 Phase V					
Annual Results (2030)			**Cumulative Results (2026-2030)**		
GHG Reductions (MMTCO2e)	**Net Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Net Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
3.0	-271	-89.2	9.1	-1,083	-119

Demand Side Management of Natural Gas

Demand-side management of natural gas is energy efficiency for natural gas users. While some natural gas companies may provide demand-side management programs to their customers voluntarily, no legislative mandate exists like Act 129 (described above) for them.

As Pennsylvania is harnessing an abundant source of natural gas, lower costs of natural gas supply to end users for heating and cooking are becoming more attractive. Demand side management of natural gas is a significant opportunity to help homeowners, commercial, and industrial users reduce their total energy consumption. While natural gas is a cleaner burning source of fuel, there are environmental implications and as such, demand-side management of natural gas is important. Creating a program for natural gas similar to the Act 129 program for electricity could help to reduce potential methane leakage emissions and CO2 emissions from combustion by reducing the amount of gas used by consumers.

The EIA indicates that 51 percent of home heating in Pennsylvania is supplied with natural gas.[37] This is a large energy use market in Pennsylvania that is not benefitting from robust energy efficiency programs. The roadmap includes the following recommendations:

- The Pennsylvania PUC should develop a natural gas efficiency and conservation potential study to determine cost-effective energy efficiency and conservation goals and cost recovery strategies for each natural gas distribution company (NGDC) service territory. The benefits of merging, or combined, gas and electricity programs should be evaluated.
- Create an energy efficiency program that requires all NGDCs to achieve cost-effective demand side management usage reductions by developing comprehensive energy efficiency and conservation programs for all customer classes regardless of income. It should include cost-recovery for reasonable and prudent implementation costs as well as incentives for NGDCs exceeding their targets and financial penalties for failure to meet their targets.[38]
- If the suggestions in the roadmap are followed, and the Pennsylvania PUC study concludes such approaches are cost-effective, DEP recommends that amendments to Act 129 include provisions for administration and implementation of combined electric and natural gas energy efficiency programs.

According to ACEEE, the top-performing states in terms of overall energy efficiency program results, as ranked in ACCEE's annual State Scorecard, tend to have the most robust laws, regulations and policy structures supporting combined natural gas and electric programs. These states include California, Connecticut, Illinois, Maine, Massachusetts, Rhode Island and Vermont. A carefully structured, unified internal operation is a key feature of combined

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[37] U.S. Energy Information Administration, "Pennsylvania State Profile and Energy Estimates" http://www.eia.gov/state/?sid=PA (May 21, 2015)
[38] Penn Future, "Clean Energy Wins, A Policy Roadmap for Pennsylvania", http://cleanenergywins.org/wp-content/uploads/2014/03/CleanEnergyWins_PolicyRoadmap.pdf (March 2014)

programs at dual-fuel utilities. Key to the success of the program integration is communication and cooperation aimed at uniformity, simplicity and program alignment by design.[39]

Energy Codes

A building code is a minimum set of standards for design, construction, alteration and maintenance of structures. They specify the minimum requirements to adequately safeguard the health, safety and welfare of building occupants.[40] The requirements can be in the form of regulations, ordinances or legislation adopted by a government legislative authority. A national building code or standard requirement does not exist, leaving state or local levels of government responsible for adopting building codes, including energy codes.

The International Construction Code and the International Energy Conservation Code (IECC) provides a national residential energy code model, updated triennially. The American Society of Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE) Standard 90.1 is the commercial model energy code. The most current versions are IECC 2015 and ASHRAE 90.1-2013.

According to the U.S. DOE, building energy codes are an important energy, cost and emission reductions policy that helps new and renovated buildings benefit from cost-effective energy efficiency measures such as high performance insulation, windows, lighting and heating, cooling and refrigeration equipment. Adoption of up-to-date building energy codes ultimately provides the single most cost-effective and expeditious means of achieving reductions in energy-related GHG emissions in the building sector.

Commercial and residential buildings account for approximately 41 percent of all energy consumption and 72 percent of electricity usage in the United States. Building energy codes and standards set minimum requirements for energy-efficient design and construction for new and renovated buildings, assuring reductions in energy use and GHG emissions over the life of buildings. An impact analysis provided to DEP by the Building Codes Assistance Project shows that if homes and commercial buildings built in 2017 met the 2012 IECC and ASHRAE 90.1-2010 codes, by 2040 the projected energy demand of Pennsylvania's building's sector would decrease by 6.1 percent and cumulative CO2 emissions would be reduced by an estimated 34.6 million metric tons.[41] Additionally, improving Pennsylvania's building stock would avoid costly retrofits and reduce future needs for energy assistance.

Pennsylvania established a statewide building code through Act 45 of 2005. The Pennsylvania Uniform Construction Code (UCC) adopts the International Construction Code (ICC) family of codes, including the International Building Code (IBC), International Residential Code (IRC), International Plumbing Code (IPC), International Mechanical Code (IMC) and IECC. Although the original legislation called for automatic adoption of the latest triennial codes within a year of

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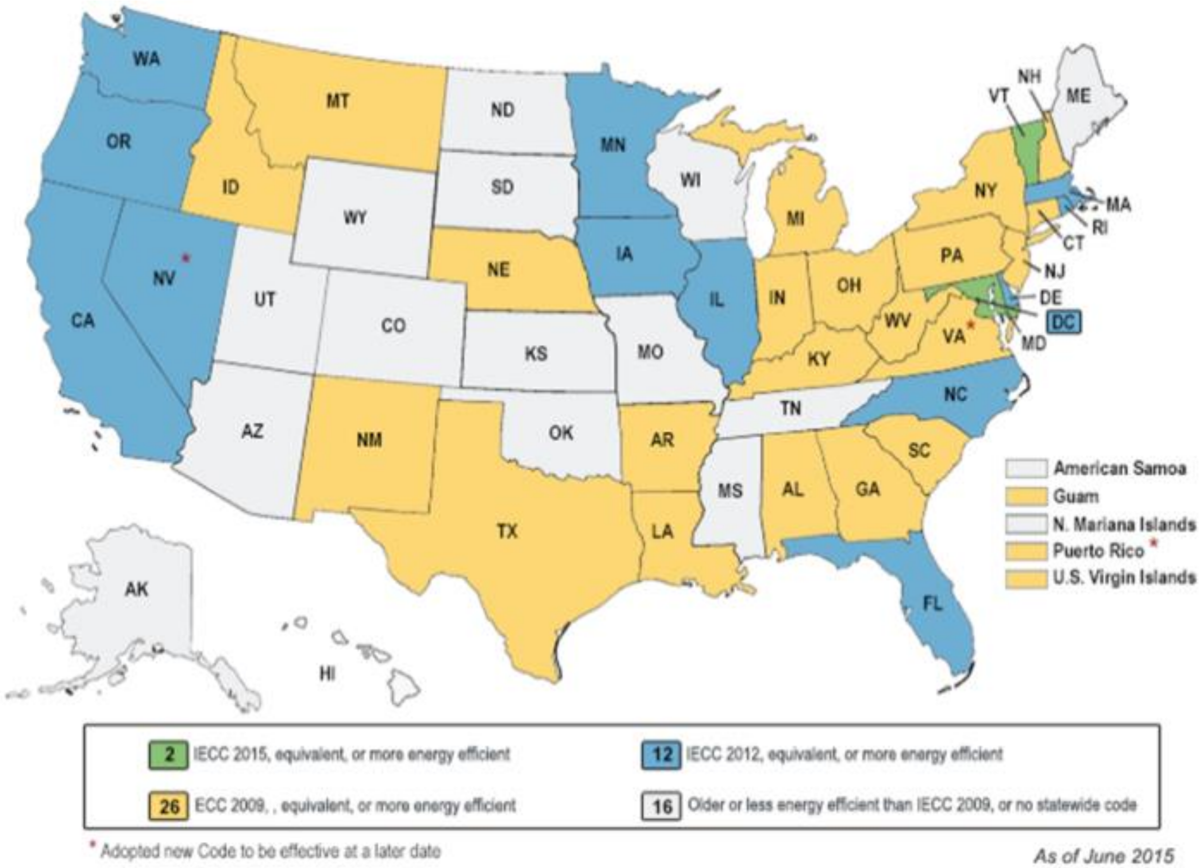
[39] American Council for an Energy-Efficient Economy, "Successful Practices in Combined Gas and Electric Utility Energy Efficiency Programs", http://aceee.org/research-report/u1406 (August 2014)
[40] Federal Emergency Management Agency, http://www.fema.gov/building-codes
[41] U.S. Department of Energy, "Energy Savings and Emission Reductions from Building Energy Codes" https://www.energycodes.gov/achieving-energy-savings-and-emission-reductions-building-energy-codes-primer-state-planning (April 30, 2015)

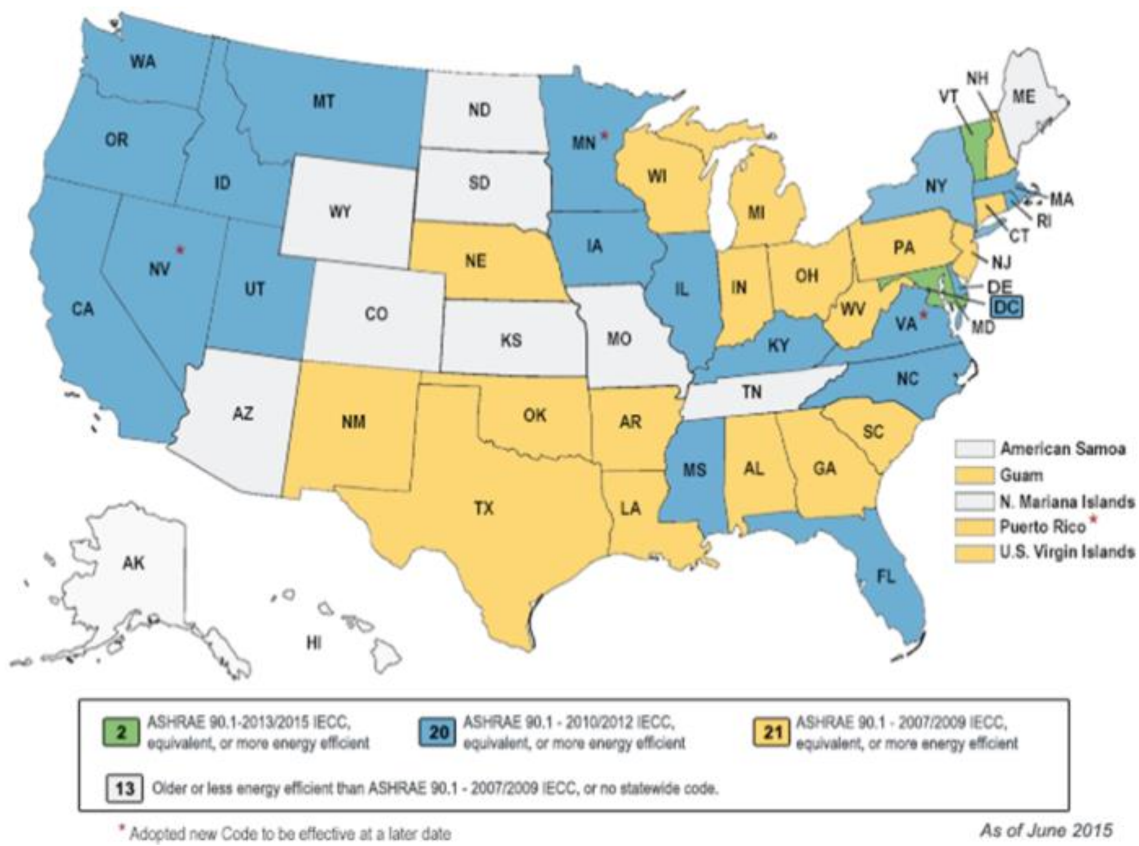
their publication, subsequent amendments resulted in Pennsylvania choosing not to adopt the 2012 ICC, and, therefore, the 2009 ICC and IECC are the state building code in the Commonwealth until at least 2015.

The UCC Review and Advisory Council was established by Act 106 of 2008. The council is charged with making recommendations to the governor, General Assembly and Department of Labor and Industry regarding proposed changes to Act 45, and the Pennsylvania Construction Code Act. The RAC is also responsible for reviewing the latest triennial code revisions issued by the International Code Council contained in the International Codes enforceable under the Pennsylvania UCC. The council is required to submit a report to the secretary of Labor and Industry within 12 months following publication of the latest triennial codes, specifying each code revision that is to be adopted as part of the UCC. No new code adoptions, not even an energy code, have occurred in Pennsylvania since the UCC Review and Advisory Council was established in 2008.

DEP and CCAC developed a work plan (Work Plan 3: Adopt Current Building Energy Codes) which explains that by consistently adopting the latest version of the ICC (or at least the IECC), Pennsylvania would be assured of maintaining a minimal incremental means of continuous building performance improvement, moving towards the goals set out in this work plan and playing a national leadership role in GHG emissions reductions.

Sixteen states have newer, higher efficiency residential buildings codes and 22 states have newer, higher efficiency commercial buildings requirements. The following U.S. Department of Energy maps indicate the status of current IECC (top) and ASHRAE Standard 90.1 (bottom) code adoption by state:


American Samoa
Guam
N. Mariana Islands
Puerto Rico *
U.S. Virgin Islands
2 IECC 2015, equivalent, or more energy efficient
12 IECC 2012, equivalent, or more energy efficient
26 ECC 2009, , equivalent, or more energy efficient
16 Older or less energy efficient than IECC 2009, or no statewide code
* Adopted new Code to be effective at a later date
As of June 2015


American Samoa
Guam
N. Mariana Islands
Puerto Rico *
U.S. Virgin Islands
2 ASHRAE 90.1-2013/2015 IECC, equivalent, or more energy efficient
20 ASHRAE 90.1 - 2010/2012 IECC, equivalent, or more energy efficient
21 ASHRAE 90.1 - 2007/2009 IECC, equivalent, or more energy efficient
13 Older or less energy efficient than ASHRAE 90.1 - 2007/2009 IECC, or no statewide code.
* Adopted new Code to be effective at a later date
As of June 2015

Maryland and Illinois are examples of states that have laws requiring their respective building codes to incorporate the latest applicable IECC within 12 months of the publication of the new code editions. Local jurisdictions must begin implementing the state code within 6 months of its adoption by state. Massachusetts is required by state legislation to review and update its code after each update to the IECC within one year of its publication. The work plan identified that states who adopt IECC 2015/ASHRAE 90.1-2013 codes will experience approximately a 20 percent increase in energy efficiency over that attained by adopting IECC 2009/ASHRAE 90.1-2009 codes.

In addition to the work plan recommendations, there are voluntary approaches to code adoption and compliance. DEP has been using U.S. Department of Energy State Energy Program funds to subcontract with the Pennsylvania State Association of Township Supervisors to offer residential and commercial energy code trainings for code officials and contractors for the last several years. More recently, Performance Systems Development was contracted to provide a benchmarking pilot on energy code compliance in the commercial sector.

Also, DEP signed contracts with Calliope Communications and the Building Codes Assistance Project to facilitate and support the Pennsylvania Energy Code Collaborative to meet and gather participant input for a report on future energy code adoption and voluntary compliance recommendations. The annual report included the following general recommendations:

- **Create a best-in-class energy code training website.**
  The Best-in-Class website foundation may be found at www.paconstructioncodesacademy.com. Trainings for code professionals are listed on the website. Participants in the Pennsylvania Energy Code Collaborative agreed to provide links from their sites and continue to expand the website.

- **Increase education outreach to consumer-facing audiences and policymakers.**
  Sample outreach materials have been developed for builders, real estate agents and home owners and are included in the report. The Pennsylvania Energy Code Collaborative recommends reaching out to design professionals (architects and engineers) by surveying their needs and providing support by working through the American Institute of Architecture and Pennsylvania Society of Professional Engineers. A peer-to-peer program for code officials should be institutionalized. A consumer survey of attitudes and awareness should be conducted and appropriate media should be developed. Lastly, the PECC could host a special tour of unfinished homes or buildings for policy makers such as legislators, local government leaders and political leaders.

- **Pilot code compliance approaches.**
  Performance Systems Development is currently funded by the U.S. DOE to pilot code compliance approaches that includes conducting focus groups with code officials, circuit riders to visit code offices and providing tools to code officials.

- **Formalize and continue the Pennsylvania Energy Code Collaborative.**
  The Northeast Energy Efficiency Partnership agreed to facilitate future meetings. DEP will continue to explore these ideas and other states' best practices.

In 2030, adoption of the Energy Codes Work Plan would result in 3.75 million tons of CO2e reduced annually in Pennsylvania and result in a cost savings. The cumulative results from 2026 through 2030 show the potential for 32.2 MMTCO2e reduced, while providing over $2.7 million in savings, for a cost-effective savings of $85 per ton of CO2e reduced.

Work Plan 3: Adopt Current Energy Codes					
Annual Results (2030)			**Cumulative Results (2026-2030)**		
GHG Reductions (MMTCO2e)	**Net Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Net Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
3.75	-838	-223	32.2	-2.745	-85

Behavior-Based Energy Efficiency (BEE)

Typically, energy efficiency programs rely on financial incentives to motivate people to purchase energy efficient products. BEE strategies rely on other motivations that influence people's energy consumption, such as competition between neighbors or residents on floors of a building. These non-financial influences can be powerful motivators that encourage people to reduce energy consumption. Over the past few years, programs run by various utilities and partnerships between non-profits and for-profits have successfully reduced energy usage through low-cost marketing and competitions. BEE involves educating energy users on ways to make choices that reduce their energy consumption, either by employing no-cost, low-cost, or investment actions such as:

a. No-cost: Actions such as unplugging appliances that are not in use and washing clothing in cold water.
b. Low-cost: Actions such as changing air filters, adding storm windows, and insulating outlets and light switches.
c. Investment: Actions such as choosing energy efficient water heaters, improving insulation, and installing a home power monitor.

BEE saves energy and thus reduces GHG emissions.

Behavioral efficiency strategies are a cost-effective way to reduce energy consumption. Academic research in behavioral science, economics and psychology can also help improve the performance of traditional efficiency programs. For instance, a recent study for ComEd estimates that "even if energy efficient residential lighting technology is in place, there is still approximately 11 percent waste due to occupant behavior."

Large scale BEE programs are a relatively new strategy for acquiring savings. Thus, the U.S. DOE and EPA are currently facilitating the State and Local Energy Efficiency Action Network, which is working on several initiatives to assist state and local entities, utilities and other program administrators in capturing energy savings through behavior-based strategies.[42]

Utilities across the country, such as Pacific Gas & Electric Company and ComEd, provide customers BEE programs via web, mobile, and mail communications to ensure they are engaged in reducing energy consumption. BEE consists of messaging that produces simple, actionable messages that are relevant to utility customers and motivates them to save energy and, in many cases, comparisons between homes. When customers see their energy usage compared to their neighbors or similar homes they often take actions that become permanent changes. These reports also provide energy efficiency tips that motivate customers with methods to reduce consumption. According to Advanced Energy Economy, "dozens of independent evaluations have found BEE programs consistently produce energy savings of 1.5% to 3.5% per household."

Advanced Energy Economy also indicated, "The cost-effectiveness of BEE makes it an attractive compliance strategy. Utilities that need new capacity must either increase supply or reduce demand. In a recent study, researchers at MIT and Harvard found behavioral energy efficiency costs an electric utility $0.025 per kilowatt hour saved, far less than the cost of a new power plant. . . . if deployed to all households in the U.S. for which it is cost-effective, [BEE] could save almost 19 million MWh of energy per year, leading to avoided emissions of 10.2 million metric tons of CO_2e."[43]

Another sector that has observed significant reductions in energy consumption via BEE is K-12 schools. A great example from Pennsylvania is the North Penn School District in Montgomery County. In 2013 and again in 2014, the district earned the prestigious Energy Star Partner of the Year award from EPA for their significant achievements in reducing energy usage and GHG emissions. All of these savings were the result of behavioral changes of the building occupants, not from major capital expenditures/upgrades. Their specific achievements included:

- Attaining a 30 percent reduction in overall energy use;
- Earning and maintaining the ENERGY STAR label for all 20 of the district's buildings;
- Engaging more than 3,000 students in their energy management program via awareness campaigns, prepared websites, performed energy audits, and interpreted data;
- Avoiding $3.2 million in cost over four years.

Pennsylvania can encourage energy efficiency through behavior via the following initiatives:

1. Continue and expand public outreach programs such as the DEP@Home display.
2. Encourage all electric distribution companies to follow best practices in BEE.
3. Continue offering energy education workshops and other educational outreach to schools.
4. Create and promote programs such as the Campus Conservation Nationals for various targeted sectors.
5. Continue bringing energy efficiency resources to schools by participating in the Pennsylvania Green and Healthy Schools Partnership.
6. Promote Tenant Star in Pennsylvania when opportunities arise.

[42] https://www4.eere.energy.gov/seeaction/topic-category/behavior-based-energy-efficiency
[43] Advanced Energy Technologies for Greenhouse Gas Reductions. Advanced Energy Economy. 2014.

Low-Income Energy Efficiency Program

Low-income energy efficiency programming can provide financially vulnerable households with energy and cost savings measures. Low-income programming as described in this report applies to residential households as well as small commercial master-metered multifamily buildings. Collaboration among state agencies is critical for comprehensive low-income programming. This reduces redundancy in programming and removes competing elements of programs. Programs that complement one another will best serve the low-income population and have a higher success rate in reducing energy consumption in that sector.

Multi-agency collaboration is important to implement weatherization programs which, for residential households, are an effective tool to assist low-income families in reducing their energy costs and consumption. Energy conservation and weatherization services are offered by the Department of Community and Economic Development (DCED), under its Weatherization Assistance Program (WAP) in compliance with DOE and Title XXVI requirements. Coordination between WAP and existing PUC low-income programs, such as the gas and electric utilities Low-Income Usage Reduction Program (LIURP) and the Act 129 low-income programs will help ensure that energy efficiency measures are both cost-effective for the entire residential rate base and for participating EDCs.

DCED is exploring and developing partnerships with utility companies and other entities that will generate non-federal resources for weatherization. Weatherization Policy Advisory Council Coordination Committee meetings were held throughout 2014 and 2015 to discuss prioritization of clients, the possible creation of a centralized database and the feasibility of adopting standard work specifications for WAP work that is coordinated with low-income programs such as LIURP.

Further, the Department of Human Services administers the Low-Income Home Energy Assistance Program (LIHEAP), a federally-funded program that enables Pennsylvania to help low-income households meet their home-heating needs. LIHEAP crisis funding includes money for emergency heating system repair or replacement, and a portion of that funding also provides energy conservation and weatherization measures to address long-range solutions for low-income households to address home-heating issues.[44] The department coordinates with other energy-related programs and agencies to develop its LIHEAP state plan, including DCED, the Department of Aging, and the LIHEAP Advisory Committee whose members include the PUC and the Office of Consumer Advocate, among others. Continuation of this work and other collaborative endeavors will allow for the low-income population to participate in the overall energy consumption reduction effort.

Another way to reach the low-income population is to incentivize affordable housing multifamily, master-metered facilities to install whole house energy efficiency measures that could generate both energy and cost savings. Many of Pennsylvania's low-income residents live in master-metered, multifamily buildings. The PUC recently released its Act 129 Phase III implementation plan which creates a Multifamily Housing Working Group. While Act 129 did

[44] LIHEAP Proposed State Plan for FY 2016:
http://www.dhs.state.pa.us/cs/groups/webcontent/documents/document/c_190443.pdf

not mandate any multifamily programs (either individually-metered or master-metered) or savings targets, the PUC is convening the working group to bring stakeholders together to discuss and design viable programs and/or a pilot program that may (or could) be implemented in Phase III of Act 129. Part of the discussion will focus on how to bridge the current issue of assigning costs to the correct rate class (commercial or residential), depending on how the multifamily unit is metered.

Some have suggested that, for Act 129 energy efficiency and conservation plan purposes, multifamily should be a subset of small commercial, so that different criteria could apply. However, Act 129 regulations require that savings be attributed to the same sector that paid for the measure. Savings can be counted toward the low-income carve-out for the funding sector (i.e. small commercial) if they are qualified low-income savings and if they meet the Act 129 definition of low-income, that is, 150 percent of the Federal Poverty Income Guidelines(FPIG). For example, if 60 percent of the residents in a multifamily building meet the low-income qualifications, then 60 percent of the savings from that building can count toward the low-income carve-out.[45] Other conversations will include program design to include the tenant areas (i.e. living units) and common areas (i.e. hallway lighting, laundry facilities). Expanding the dialogue concerning how to include affordable multifamily housing units can incentivize the installation of energy efficiency measures in additional facilities that may not have received attention in the past.

Finally, to include a broader base of low-income residents in low-income programming, the benefits of expanding qualifying low-income households to include households that are at 200 percent of the FPIG should be considered. Using 200 percent as a qualifier allows for the inclusion of working poor and elderly on fixed incomes that may not self-identify as low-income, and thus do not apply for beneficial energy efficiency programming that could save significant kilowatt hours as well as energy costs. Alternatively, different poverty qualifiers or measures apart from the FPIG could also be considered in developing low-income energy reduction programming.

Currently, most low-income programming applies to only those whose income is at or below 150 percent of the FPIG. The chart below lists the income limits for FY 2016 (based on the FPIG levels published in the Federal Register on January 22, 2015).

[45] Phase III Final Implementation Order - The Act 129 Phase III EE&C Program Final Implementation Order. From the Public Meeting of June 11, 2015. Docket No. M-2014-2424864.

Household Size	150 Percent of FPIG	200 Percent of FPIG
1	$ 17,655	$ 23,540
2	23,895	31,860
3	30,135	40,180
4	36,375	48,500
5	42,615	56,820
6	48,855	65,140
7	55,095	73,460
8	61,335	81,780
9	67,575	90,100
10	73,815	98,420
For each additional person add:		
	$ 6,240	$ 8,320

It is generally understood among researchers that the poverty measure used by the federal government is set too low and does not account for significant expenses in modern society. However, new methods for determining poverty level are under consideration for implementation including the Self Sufficiency Standard, developed in 1996.[46]

An article in the *Poverty & Public Policy Journal* titled "Determining Eligibility for Poverty-Based Assistance Programs: Comparing the Federally Established Poverty Level with the Self Sufficiency Standard for Pennsylvania" states the following:

> Alternatives to the current method of calculating poverty must be considered if the poverty level is to accurately reflect the need in contemporary society for assistance to afford basic services such as child care, transportation, and utility service. Recent studies recommending changes in how the poverty level is calculated recognize that updating or replacing the current methodology will result in dramatic shifts in who is considered to be in poverty and who is not.[47]

In part, those who administer and develop LIHEAP's weatherization component understand this philosophy. While the FPIG is still used, the weatherization component, as administered by DCED's WAP program, is expanded to include residents who are at 200 percent of the FPIG or less. Additionally, the PUC's LIURP regulations allow for up to 20 percent of the utilities' LIURP budget to be used for those who have special needs (including the elderly and those with a disabilities and medical issues) who are at 151 – 200 percent of the FPIG. WAP and LIURP are pursuing coordination efforts to better serve that segment of the low-income population. For other low-income programs, tiered programming could be implemented where a measure or program may be partially subsidized for those who are qualified at varying levels of poverty –

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[46] Mukhopadhyay, Åsa; Shingler, John M.; Alter, Theodore R.; and Findeis, Jill (2011) "Determining Eligibility for Poverty-Based Assistance Programs: Comparing the Federally Established Poverty Level with the Self Sufficiency Standard for Pennsylvania," *Poverty & Public Policy*: Vol. 3: Iss. 3, Article 7. Available at: http://www.psocommons.org/ppp/vol3/iss3/art7

[47] Id

determined by utilizing higher percentages of the FPIG or an alternative method of calculating poverty such as the self-sufficiency standard.

Geoexchange

A geoexchange ground source system, or ground source heat pump (GSHP) is an electrically powered heating and cooling system for interior spaces. This system utilizes the earth or a pond or lake for both a heat source and a heat sink. A geoexchange system consists of three main parts: pipes buried in the ground, a heat exchanger and ductwork to distribute heat into the structure. The series of pipes, called a loop, is buried in the ground, either vertically or horizontally, near or beneath the structure. The loop circulates a fluid (water, or a mixture of water and antifreeze) that absorbs heat from, or relinquishes heat to, the surrounding soil, depending on whether the building requires heating or cooling.

According to the EIA's most recent end use building consumption data, approximately 40 - 50 percent of the energy consumed is for space heating and water heating for the commercial and residential sectors.[48] GSHPs are a significant opportunity for GHG emission reductions and provide other benefits such as less maintenance, reduced heating fuel costs, and wide applicability. GSHPs are very efficient with a coefficient of performance (ratio of heating or cooling energy output to electrical energy input) of 3 to 6 on the coldest of winter nights, compared to 1.75 – 2.5 for air-source heat pumps on cool days. Capital costs of GSHP are higher than conventional HVAC systems primarily due to the additional cost of drilling / excavating and installing the external loops. However, when energy savings and other considerations are factored such as the working life of the system, rebates, tax credits and warranties, the cost differential is offset over time. Additionally, when installed during new construction or in applications such as campus locations or housing sub-divisions, GSHPs have the potential to be a more cost-effective technology.

DEP and the CCAC have developed a work plan (Work Plan 4: Geoexchange Systems) that details the potential for GSHP installations in the Pennsylvania commercial and residential building sectors and concomitant GHG reductions based upon a fairly conservative uptake of the technology. By 2030, this work plan would result in 3.65 million metric tons annual reduction in GHGs with $1,283 million in cost savings. Under this scenario, the cumulative emission reductions would exceed 35 million metric tons and $7,172 million in total cost savings, showing it to be one of the most cost-effective work plans developed.

The work plan includes using comprehensive life-cycle analysis, outreach and training, encouragement of financial incentives, and policies and legislation for deployment as means for overcoming market penetration barriers. Adoption of the Geoexchange Systems Work Plan would result in 3.65 million tons of CO2 reduced annually in Pennsylvania and a cost-savings by 2030. The cumulative results from 2015 through 2030 show the potential for a 35.1 MMTCO2e emissions reduction, while providing over $7 billion in savings, for a cost-effective savings of $204 per ton of CO2e emissions reduced.

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[48] U.S. Energy Information Administration, http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/pa.pdf, http://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/overview1.html

Work Plan 4: Geoexchange Systems					
Annual Results (2030)			**Cumulative Results (2015-2030)**		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
3.65	-$1,283	-$367	35.1	-$7,172	-$204.33

Oil Conservation and Fuel Switching

This initiative aims to replace or upgrade inefficient equipment that utilize fuel oil with cleaner burning, more energy-efficient natural gas models, thereby decreasing energy consumption and reducing emissions. By encouraging conservation and efficiency programs that include efficient furnace, boiler and hot water heater equipment and fuel switching to natural gas where available, additional GHG reductions can be achieved. The Pennsylvania PUC's Fuel Switching Workgroup recommendations include allowing EDCs to consider fuel switching for their low income customers. According to the EIA's most recent end use building consumption data, approximately 40 – 50 percent of the energy consumed is for space and water heating for the commercial and residential sectors.[16] Thus, an opportunity exists for GHG emission reductions through fuel switching from heating oil to higher efficiency natural gas-fired equipment.

According to the EIA, the average Pennsylvania home fueled by heating oil uses approximately 516 gallons per year, whereas the average home fueled by natural gas uses approximately 53,000 cubic feet per year. The mid-Atlantic region EIA data for 2015[49] predicts that the average delivered cost of natural gas to the residential sector was $11.55 per MMBtu. The average price of heating oil in the mid-Atlantic region for the same time period was $25.10 per MMBtu. At these prices the average family could save approximately $1,126 per year in heating fuel costs by switching to natural gas.

Work Plan 5: Heating Oil Conservation and Fuel Switching assumes a total of 4,500 homes converting each year from heating oil to natural gas for home heating. This is approximately 0.5 percent of the homes in the Commonwealth using fuel oil. The cost of switching from an oil furnace to natural gas furnace and the gas connection is estimated at $5,600. The work plan data analysis shows a payback of approximately five years when converting from an oil furnace to natural gas furnace and 2.62 tons of CO2e emissions reductions per year. The work plan includes implementation steps that encourage conservation measures such as air sealing and insulation, energy efficiency programs like Keystone HELP, strategies such as on-bill financing, and the expansion of natural gas programs that support fuel switching. The cost-effectiveness charts

[49] U.S. Energy Information Administration,
http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/pa.pdf ,
http://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/overview1.html

below show that heating oil conservation provides the most GHG reductions while being cost-effective, but fuel switching is more cost-effective with less GHG reduction potential.

Adoption of the Heating Oil Conservation and Fuel Switching Work Plan would result in 5.12 million tons of CO2e emissions reduced annually in Pennsylvania and a cost-savings by 2030. The cumulative results from 2015 through 2030 show the potential for a 43.49 MMTCO2e emissions reduced, while providing over $289 million in savings, for a cost-effective savings of $90.94 per ton of CO2e emissions reduced.

A legislative recommendation could be to continue programs like Keystone HELP. As discussed in Work Plan 5, there are various options that can be chosen to conserve energy and reduce GHG emissions related to the heating and cooling of homes in Pennsylvania. State funded programs can enable the homeowner to accomplish home improvements. The PUC could be encouraged to approve more programs such as UGI Utilities' Growth Extension Tariff program and Columbia Gas's New Area Service program to allow more home owners access to cleaner burning fuel for home systems to reduce their carbon footprint.

Work Plan 5: Heating Oil Conservation					
Annual Results (2030)			**Cumulative Results (2015-2030)**		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
4.93	-$14	-$2.83	41.9	-$151	-$3.62

Work Plan 5: Fuel Switching					
Annual Results (2030)			**Cumulative Results (2015-2030)**		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
0.19	-$57.58	-$306.88	1.59	-$138.54	-$87.32

Combined Heat and Power for Commercial and Industrial Users

Combined heat and power (CHP), also known as cogeneration, refers to the simultaneous production of electricity and thermal energy from a single fuel source. Simultaneous production is more efficient than producing electricity and thermal energy through two separate power systems and requires less fuel. This reduction in fuel use can produce a number of benefits, including energy cost savings, reduced GHG emissions, and reductions in other air emissions. Additionally, during energy emergencies, CHP is a valuable resource to infrastructure resiliency in providing critical facilities with uninterrupted power. CHP is generally most cost-effective in industrial or commercial settings with large thermal loads that are in operation 24 hours a day.[50] By using thermal energy that would otherwise be wasted in the power generation process, CHP systems can achieve total system efficiencies of approximately 60 to 80 percent (U.S. EPA, 2013b).[51] Work Plan 6: Combined Heat and Power focuses on industrial and commercial CHP.

On August 30, 2012, an Executive Order from the White House called for a national goal of deploying 40 GW of new, cost-effective industrial CHP in the United States by 2020. The order further outlines that no one-size-fits-all solution exists for our manufacturers, so it is imperative that we support CHP investments through a variety of approaches, including encouraging private sector investment by setting goals and highlighting the benefits of investment, improving coordination at the federal level, partnering with and supporting states, and identifying investment models beneficial to the multiple stakeholders involved.[52] According to the U.S. Department of Energy Mid-Atlantic CHP Technical Assistance Partnership, there has been small amount of CHP and distributed energy activity in the state to this point. A significant percentage of the electrical generation in Pennsylvania takes advantage of its waste heat, at 7.2 percent of total generating capacity. This is below the 8 percent national average in 2003. 3.8 percent of this capacity is in the industrial sector, 1.6 percent is in the commercial.[53]

The work plan focuses on increasing CHP capacity in the commercial and industrial sectors. 2012 data shows Pennsylvania with 124 CHP industrial and commercial sites with a total capacity of over 3,000 MW. Over 1,000 MW of these are coal-fired generating plants. The average capacity of commercial and industrial CHP units installed in Pennsylvania between 2002 and 2012 is approximately 1.9 MW and the median is approximately 400 kW. An average of approximately 6.0 MW of industrial and commercial CHP has been installed annually in Pennsylvania between 2002 and 2012. Calculations listed in this work plan are based on installing 15 MW of industrial and commercial CHP annually between 2015 and 2030, displacing a total of 8.16 MMTCO2e emissions.

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[50] State and Local Energy Efficiency Action Network, http://www4.eere.energy.gov/seeaction/topic-category/combined-heat-and-power

[51] Environmental Protection Agency, "Local Government Climate and Energy Strategies, Combined Heat and Power, A Guide to Developing and Implementing Greenhouse Gas Reductions, http://epa.gov/statelocalclimate/documents/pdf/CHPguide508.pdf (2014)

[52] The White House, President Barak Obama, https://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency

[53] U.S. Department of Energy, Mid-Atlantic CHP Technical Assistance Partnership, http://www.midatlanticchptap.org/states_pa.html

The key to implementing CHP systems is to provide adequate incentives for the development of infrastructure to capture and utilize the waste heat. Incentives could come in many forms, such as 1.) Recruiting suitable end users, such as industries, hospitals, government offices, or school campuses to a centralized location to utilize the waste heat,2.) Providing financial incentives such as tax credits, grants, and low or zero interest loans, 3.) Providing preferred zoning and zoning-related tax deferment, and 4.) Consideration of providing emissions offset credits for avoided emissions. A federal tax incentive allows for a 10 percent investment tax credit for CHP property up to 15 MW. Facilities may be eligible for state grants or loans through the Pennsylvania Alternative and Clean Energy Program or incentives from EDCs as part of their Act 129 program offerings. CHP systems, including those fueled by natural gas, are already an eligible Tier II resource under Pennsylvania's AEPS.

DEP recommends the legislature develop adequate incentive programs related to CHP technology. As discussed in Work Plan 6, the development of incentives programs to fund the infrastructure to capture and utilize waste heat is necessary in recruiting suitable end users of this technology. The Commonwealth should promote the use of cogeneration/CHP technology through the use of permit-by-rule, standardized utility power grid interconnection rules and direct financial incentives.

Adoption of the Combined Heat and Power Work Plan would result in 0.19 million tons of CO2e emissions reduced annually in Pennsylvania by 2030 and result in a cost-savings. The cumulative results from 2015 through 2030 show the potential for 1.59 MMTCO2e emissions reduced, while providing over $138 million in savings, for a cost-effective savings of $87.32 per ton of CO2e emissions reduced.

Work Plan 6: Combined Heat and Power					
Annual Results (2030)			**Cumulative Results (2015-2030)**		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
0.19	-$57.58	-$306.88	1.59	-$138.54	-$87.32

High Performance Buildings

The building sector is the nation's largest energy user, so a rapid transformation of the built environment is a central part of the solution to the climate and energy crises and should be a priority. Based upon the goals of *The 2030 Challenge*,[54] this initiative would establish buildings with higher performance and therefore lower energy consumption and operating costs. These

[54] http://architecture2030.org/2030_challenges/2030-challenge/

high performance building goals include targets for new and existing buildings in the residential, commercial, institutional and government sectors.

Work Plan 7: High-Performance Buildings takes a fairly aggressive stance, calling for an immediate (2015) 60 percent reduction (relative to a 2005 building) in fossil fuel energy consumption for all new buildings and 20 percent of existing buildings. By 2030, these consumption reductions would be increased to 80 percent in new buildings and 50 percent of existing stock.

Table 1. New Buildings Goals and Standards

		2015	2030
New Commercial	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	Average site EUI2005	Average site EUI2005
	Fraction of buildings that meet standard	100% of new	100% of new
New Residential	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	HERS 30	HERS 20
	Fraction of buildings that meet standard	100% of new	100% of new

Table 2. Existing Buildings Goals and Standards

		2015	2030
Existing Commercial	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	Average site EUI2005	Average site EUI2005
	Fraction of buildings that meet standard	20% of existing	50% of existing
Existing Residential	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	HERS 30	HERS 20
	Fraction of buildings that meet standard	20% of existing	50% of existing

Notes: Energy reductions refer to on-site energy consumption.

The 2030 Challenge takes an even more aggressive approach, calling for 70 percent immediate carbon reductions, 80 percent by 2020, 90 percent by 2025 and carbon-neutrality by 2030 (using no fossil fuel GHG-emitting energy to operate). Massachusetts, New Jersey and California have all adopted some form of The 2030 Challenge[55] while Minnesota, New Mexico, Ohio, Oregon,

[55] http://architecture2030.org/2030_challenges/adopters/adopters_govt_state/

Washington and Vermont have bills, plans or executive orders integrating targets based upon the 2030 Challenge.

Implementation can be accomplished by any number or combination of methods, including legislation, voluntary adoption of stretch codes, green strings, innovative financing, and incentives. Three of these methods could be implemented on the local level during the construction permits and inspections process for new construction or major renovations, a statewide mandate such as California's Act 24 Building Energy Efficiency Standards,[56] the adoption of the International green Construction Code (IgCC)[57] , ICC 700[58], or similar, or expedited permit reviews. Commonwealth agencies could provide expedited plan reviews and approvals during design, new construction and major renovations as appropriate and the Commonwealth could also require that publicly-funded buildings and construction projects meet higher performance standards (green strings). Innovative financing could be implemented through energy savings performance contracting – for which Pennsylvania already has the Guaranteed Energy Savings Act in place – and energy mortgages from various lending institutions. Finally, utilities and building labeling could help to further add incentives for high performance buildings.

The legislature should adopt the IgCC. As discussed in Work Plan 7 the recommendation to adopt the IgCC for municipalities to meet goals and commercial building standards of The 2030 Challenge is paramount. In addition, requiring IgCC compliance for all publicly-funded commercial building projects in Pennsylvania and improve administration and enforcement of both the existing UCC and the IgCC with a statewide emphasis on training to obtain the ultimate goal of zero-carbon buildings throughout the Commonwealth.

Real estate transfer provides the biggest opportunity for implementation of high performance buildings because this is when both residential and commercial buildings are most likely to undergo renovations and when financing is underway. See both the Change of Ownership Use Disclosure and Benchmarking sections of the work plan for additional details of two elements that are key for existing buildings to be transformed to high performance buildings.

Adoption of the High Performance Buildings Work Plan would result in a 8.5-million-ton reduction in Pennsylvania's annual CO2e emissions by 2030 and be highly cost-effective. The cumulative results from 2015 through 2030 show the potential for 97.9 MMTCO2e reduced, while providing over $8.7 billion in savings, for a cost-effective savings of $89.8 per ton of CO2e emissions reduced.

[56] http://www.energy.ca.gov/title24/
[57] http://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/igcc/
[58] http://www.homeinnovation.com/green

Work Plan 7: High Performance Buildings					
Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
8.50	-2,252	-265	97.9	-8,791	-89.8

Re-Light Pennsylvania

According to the EIA, lighting in residential and commercial sectors accounts for about 11 percent of U.S. annual electric consumption [59] That same proportion of energy use for lighting in Pennsylvania translates to approximately 16 billion kWh, and it represents one of the most visible and attainable opportunities for energy efficiency improvement in the Commonwealth.

Work Plan 8: Re-Light Pennsylvania addresses re-lighting. Re-Light Pennsylvania is an initiative designed to accelerate the replacement of older, less efficient lighting systems with higher efficiency systems using leading edge technologies, such as solid state lighting (LED), and advanced control strategies. It targets both interior and exterior lighting in the residential and commercial sectors, including buildings, parking facilities, and outdoor lighting systems. This recommendation also recognizes the potential impact to historic properties, only including re-lighting as a part of renovation projects requiring building code compliance.

Specifically, this initiative proposes to establish performance goals for lighting energy use in buildings, lamp efficacy, the use of occupancy sensors and other controls, and lighting power density (LPD) in outdoor lighting systems. Other proposed goals include: setting minimum requirements for natural daylighting in new construction of commercial buildings, improving energy efficiency of exit signs, and limiting light pollution from outdoor lighting systems.

In addition to performance goals, Re-Light Pennsylvania includes recommendations for the establishment of a state-wide education campaign focusing on low-cost and no-cost lighting efficiency improvements, and it identifies potential incentive strategies involving PUC, the EDCs, and other relevant state agencies.

The establishment of a statewide Re-Light Pennsylvania education campaign could engage relevant stakeholders, such as designers, installers, building owners, municipal officials, and residents for the purpose of increasing the awareness of new lighting technologies, performance goals, financial benefits, and incentives. Educational activities could include a variety of approaches ranging from publications to technical presentations at relevant events/conferences to technical workshops held specifically for targeted sectors. An example of a targeted sector

[59] http://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3

approach is currently underway in regions of Pennsylvania where the EDCs offer LED street lights to replace sodium and mercury vapor street lights. In particular, a program has been developed by DEP to educate municipal officials whose communities lease street lights from Penelec, Penn Power, and West Penn Power. These EDCs were recently approved for rate schedules allowing them to offer LED street lights for the first time. DEP will hold a series of workshops to educate municipal officials on LED technology and the substantial energy and economic savings available to them by adopting the new technology.

Re-Light Pennsylvania also seeks to increase incentives that can accelerate the adoption of more efficient lighting technology and strategies. By engaging the PUC, EDCs, and other relevant government agencies, the Commonwealth can promote the development of financial incentives and financing approaches to help reduce the financial hurdles that could otherwise delay wide-scale deployment of the improved technology. Continuation or expansion of rate-based programs that target lighting upgrades, such as Act 129, can be explored among PUC and EDCs. On-bill or other creative financing pilot projects can be developed in conjunction with utilities, DCED, and the Pennsylvania Energy Development Authority. State agencies, authorities, and commissions that provide related assistance programs, such as DEP, DCED, the Department of General Services (DGS), PennDOT, the Turnpike Commission, and the Commonwealth Financing Authority can promote energy efficient lighting technology in existing or new programs.

While increasing the energy efficiency of our lighting, this initiative would also improve the quality of light delivered and thus the safety and comfort of our citizens. Additionally, by re-lamping, re-fixturing, and upgrading lighting and control systems, Pennsylvania would be actively investing in manufacturing, sales, green collar jobs, and high-performance building infrastructure.

The Pennsylvania Legislature should develop incentives related to lighting. As discussed in Work Plan 8, the PUC should be encouraged to promote more programs such as Act 129 program to re-lamp, relight and control lighting using new technology. Electric companies should also be encouraged to develop pilot programs to expand lighting efficiency in their service areas. Other state government agencies, such as PennDOT and the Turnpike Commission, should continue to advocate public and municipal lighting using energy efficient technologies.

Adoption of the Re-Light Pennsylvania Work Plan would result in 8.6 million tons of CO2e emissions reduced annually in Pennsylvania by 2030 and result in a cost-savings. The cumulative results from 2015 through 2030 show the potential for 71.2 MMTCO2e emissions reduced, while providing over $5.1 billion in savings. This results in a cost-effective savings of $71.6 for every ton of CO2e emissions reduced.

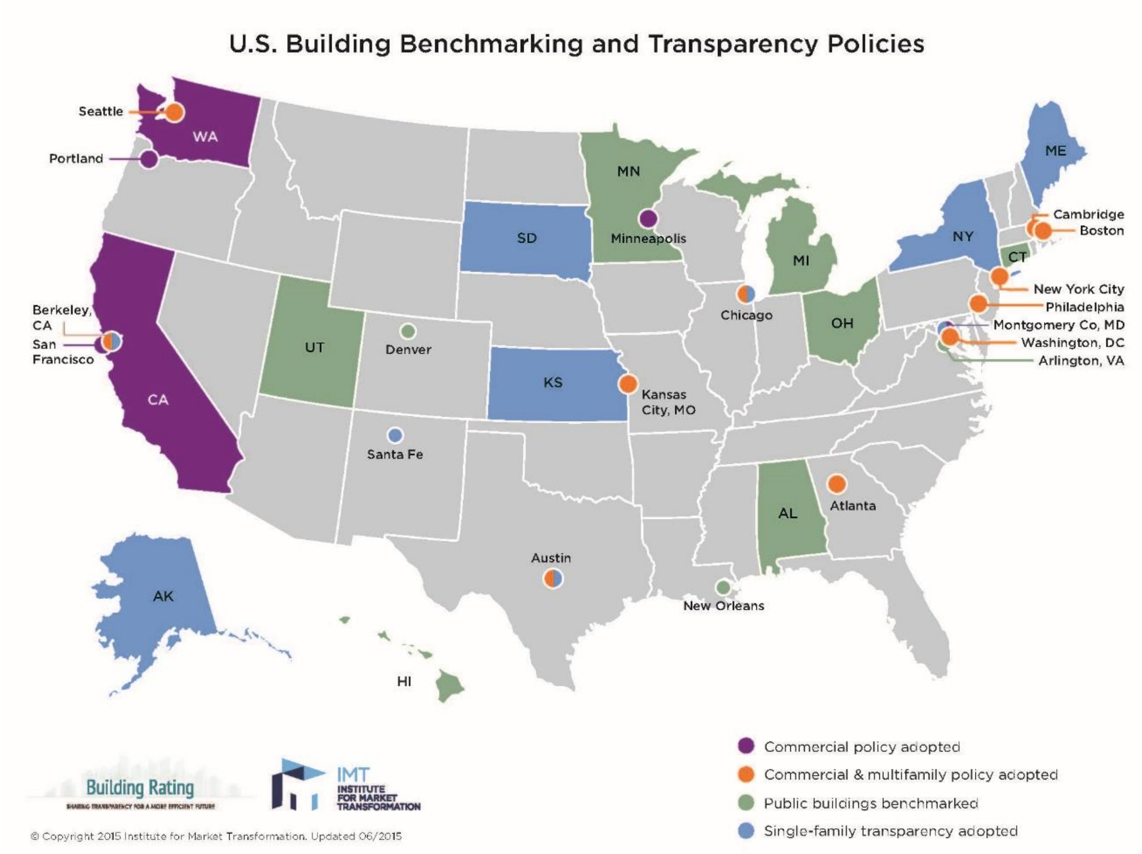
Work Plan 8: Re-Light Pennsylvania					
Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	Costs (Million $)	Cost-Effectiveness ($/tCO2e)	GHG Reductions (MMTCO2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO2e)
8.6	-843.0	-98	71.2	-5,101	-71.6

Change of Ownership Energy Use Disclosure

Energy use disclosures are a basic form of performance labeling which provides a potential buyer or lessee with data on a residential or commercial building's energy consumption – basically providing an energy label for homes and businesses. Virtually every other consumer product, from potato chips and cookies to appliances and automobiles, includes some form of performance label. Yet the two consumer items which practically every citizen invests the majority of their time, money and effort into – their house and their place of business or school – has no label whatsoever. There is currently no way for a potential purchaser or renter to identify how much energy, water or other resources are required to operate, live or work in a particular building. Nor is there any means of differentiating between a high energy using building and an ultra-efficient building.

Energy use disclosure would provide the necessary level of transparency to assist potential commercial and residential property buyers and renters in making informed decisions regarding anticipated energy, environmental and financial costs associated with the selection of a given property. A building's current performance level can be measured (providing a benchmark of operational performance) and/or modeled (providing an "asset rating" of predictive performance). In addition, the associated labels can vary in detail and appearance – ranging from simple alphabetic (A, B, C, etc.) or numeric scales (1-10, 1-100) to comprehensive sustainability indices which may consider dozens of building performance aspects. Scores of labeling systems have been prototyped, analyzed, and adopted across the globe. According to the Institute for Market Transformation, "fourteen cities, two states, and one county (see map below) have adopted energy benchmarking and transparency laws. While all of them require building owners to track their properties' energy use, the laws vary regarding the size and type of buildings they affect; whether the energy use data must be disclosed publicly, or just to potential tenants or buyers; and other factors.[60]

[60] http://www.imt.org/policy/building-energy-performance-policy



In addition to considering which energy performance indicators the label should include and the means of visually displaying this data, proper timing in order to receive and review the information is critical. The best, most impactful opportunity to use both predictive and historic building performance data is prior to a change of ownership (i.e. before the purchase). This is when a potential buyer has the greatest chance to consider the impacts on their budget, analyze the cost-effectiveness of making improvements and potentially roll those costs into their financing package.

While there are a multitude of available tools, rating systems and options for monitoring, analyzing and improving building energy performance, the intent of this recommendation is to keep it simple, making it easy for Pennsylvania to adopt and implement. This would allow one to compare "apples to apples" in building energy performance. A more thoughtful and informative target would be to require EnergyIQ and Home Energy Saver scores. This would provide consumers not only current performance levels, but also a list of recommendations to improve performance.

Results are dependent on how widespread the program is (i.e. commercial-only, residential-only or both; statewide or only selected metropolitan/urban areas; all buildings or size limitations; etc.) and on consumer reaction to this new level of information.

Manufacturing Energy Technical Assistance

According to the EPA, in 2013 approximately 21 percent of CO2 emissions from fossil fuels were from the industrial sector, making it the third largest contributor to U.S. GHG emissions.[61] There is a diverse portfolio of options for mitigating GHG emissions from the industrial sector, including energy efficiency, fuel switching, combined heat and power, renewable energy sources, and the more efficient use of and recycling of materials.

Before any industry can implement these measures, some type of assessment needs to be performed to ensure cost-effectiveness. As such, the Department of Energy, EPA and DEP recognize the need for funding and support for energy assessments for the small to mid-sized manufacturing sector. The Department of Energy has been funding the Industrial Assessment Centers since 1981. The EPA has been funding the assessments for several years and more recently, the DEP has been utilizing Department of Energy State Energy Program funds for assessments.

Work Plan 9: Manufacturing Energy Technical Assistance considers the possible reductions in GHG emissions in the industrial sector via increased efficiency and increased coordination between DEP, Pennsylvania Technical Assistance Program (PennTAP) industrial assessment centers at various universities and DOE. PennTAP and DOE's Industrial Assessment Centers (IAC) currently provide energy assessments for small to medium-sized manufacturing facilities in Pennsylvania. These services include technical assistance and follow-up to the manufacturing companies to facilitate implementation of the energy conservation measures. In order to implement the work plan, additional funding would be necessary.

DEP currently provides discretionary funding to PennTAP to administer technical assistance via energy efficiency assessments for manufacturers within the Commonwealth. A second program, for a more limited group of manufacturers based on size and location, is the IAC program, which is funded directly by the Department of Energy. Between these two programs, there are currently approximately 30 energy assessments completed each year in Pennsylvania. This initiative would require the legislature to dedicate sufficient state funding to perform an average of 125 energy assessments per year at qualifying Pennsylvania manufacturers. The assessments would be completed by PennTAP and other similar assessment centers. The cost of implementing the measures identified in the assessment would remain the sole responsibility of the manufacturing company.

Historical figures from the two programs demonstrate that there continues to be a demand for the energy assessments from this sector. According to the work plan, 18,666 manufacturing companies in Pennsylvania may qualify for either of these programs. The work plan proposes 125 assessments per year until 2030 with a total of 7.07 MMTCO2e emissions reduced as a result of implementing measures recommended during the assessments. These services, in addition to financial incentives from Act 129 energy efficiency and conservation programs, will provide for significant greenhouse gas mitigation opportunities.

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[61] U.S. Environmental Protection Agency, "Source of Greenhouse Gas Emissions", http://www.epa.gov/climatechange/GHGemissions/sources/industry.html (2013)

Adoption of the Manufacturing Energy Technical Assistance work plan would result in .82 million tons of CO2e emissions reduced annually in Pennsylvania and significant cost-savings, mostly for the energy users, by 2030. The cumulative results from 2015 through 2030 show the potential for a 7.07 MMTCO2e emissions reduction, while providing over $587 million in savings. This work plan shows a cost-effective savings of over $83 per ton of CO2e emissions reduced.

Work Plan 9: Manufacturing Energy Technical Assistance					
Annual Results (2030)			**Cumulative Results (2015-2030)**		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
.82	-144.59	-176.8	7.07	-587	-83.05

Net-Zero Energy Buildings

Net-zero energy buildings are typically defined as buildings which produce as much energy from on-site renewable energy sources as they use over the course of a typical year. Key to cost-effectively achieving this level of performance is to first design or retrofit the building to be extremely energy-efficient (see previous section and work plan on High Performance Buildings). This provides the dual benefit of reducing the required size and cost of the renewable energy system.

The next key to understanding the economics of net-zero energy building construction is integration and the interactivity of both the energy and cost savings that can occur with a properly designed building. For example, better windows might cost more, but they will reduce the amount of heat loss and gain through the windows, which improves the performance of the building envelope and reduces the size of the heating and cooling equipment – saving money. These premium windows also have the ability to increase the amount of natural daylight, reducing the amount of artificial lighting and again reducing the amount of cooling needed and saving money. If the walls are painted in a light color and have a light shelf (a means of reflecting natural daylight further into the room), even less lighting (and energy) is needed. Similar integrated design features exist for practically every aspect of a high performance building. Once all of these performance and integration features (which will vary for each and every building) are installed, the net result could be an overall cost savings, cost neutral – or if an owner decides to incorporate every leading-edge "green" product and feature, a hefty premium.

All of these design aspects figure into the overall size of any renewable energy system – as does building location determine renewable energy source. For example, a solar PV system will not produce any energy if the entire site is shaded – likewise a wind turbine cannot generate any energy if shielded by trees or other buildings. A pilot for net-zero energy buildings has been adopted by the federal Department of General Services, while California continues advancing toward a 2020 goal of all new buildings meeting net-zero performance.[62] Adopting a net-zero energy building policy requiring all new state office buildings or buildings undergoing major renovations to achieve net-zero energy by 2030 would result in 100 percent reductions in participating buildings' energy consumption and emissions.

62 http://www.energy.ca.gov/releases/2015_releases/2015-06-10_building_standards_nr.html

Energy: What You Can Do

1. Consumers should be aware of energy usage throughout the day. Unplugging appliances not in use, such as a toaster or a coffee pot, is an easy way to save energy. Washing clothing in cold water is also an energy saving measure.
2. Consider switching out old incandescent light bulbs with higher efficiency LED bulbs. Even with a slightly higher up front cost, a consumer could save over $230 over the lifetime of just one bulb.
3. Change air filters regularly to ensure your heating and cooling system are operating as efficiently as possible.
4. Add storm windows to your home to eliminate drafts and block the wind.
5. Switch basic outlet covers and light switches to insulated covers to prevent heat from escaping.
6. Replace old appliances with the highest efficiency appliances, including those that operate on natural gas.
7. Improve the insulation in your home to prevent heat from escaping and lower your heating bill.
8. Install a home power monitor to track your energy usage and a programmable thermostat.
9. Encourage your school district to participate in the PA Green and Healthy Schools Partnership.
10. Consider installation of a geoexchange system for heating and cooling options for your home.
11. If you currently use oil for home heating, evaluate the feasibility of switching to natural gas.

4.D. Energy Efficiency Financing

Provide Meaningful Assistance and Incentives to Reduce Energy Consumption

Upfront costs can be a major barrier to implementing energy efficiency projects in homes and businesses. An important goal of efficiency policies and programs is to help minimize these up-front project costs, encouraging owners to invest in energy efficiency improvements and significant retrofits. Several financing strategies are available to pursue this goal. Examples include on-bill financing, property tax financing (also known as Property Assessed Clean Energy, bond financing), energy service performance contracting, and energy efficiency mortgages. The non-quantifiable Work Plan 10: Energy Efficiency Financing discusses all of these options.

Energy Efficient Mortgages

An energy efficient mortgage (EEM) is a mortgage that credits a home's energy efficiency in the mortgage itself. EEMs give borrowers the opportunity to finance cost-effective, energy-saving measures as part of a single mortgage and stretch debt-to-income qualifying ratios on loans thereby allowing borrowers to qualify for a larger loan amount and a better, more energy-efficient home. EEMs are typically used to purchase a new home that is already energy efficient such as an ENERGY STAR certified home. The term *EEM* is commonly used to refer to all types of energy mortgages, including energy improvement mortgages (EIMs), which are used to finance existing homes along with energy efficiency improvements made to them.

EIMs allow borrowers to include the cost of energy-efficiency improvements to an existing home into the mortgage without increasing the down payment. EIMs allow the borrower to use the money saved in utility bills to finance energy improvements. The Federal Housing Administration (FHA) and Veterans Administration (VA) both have EEM programs that recognize the monthly utility cost savings when homebuyers make energy-efficient improvements. Borrowers may use the EEM program to finance the cost of energy efficient improvements into their new mortgages, without the need to qualify for additional financing, because cost-effective energy improvements result in lower utility bills, making more funds available for their mortgage payments.

The benefits of energy efficient homes include lower utility costs, increased home comfort and higher resale values. EEMs are designed to help make the option of living in an energy efficient home more affordable. All FHA approved lenders can offer EEMs. Although EEMs are widely available, their existence or benefits haven't been widely promoted. For that reason, many real estate professionals are not familiar with them.

The Alaska Housing Finance Corporation includes a second mortgage program for energy conservation. Borrowers may obtain financing to make energy improvements on owner-occupied properties. Borrowers select from the list of energy upgrades included with the energy audit of their home performed by a certified energy rater.[63]

Pennsylvania's encouragement of homebuyers to use the FHA and VA programs or undertaking an effort to challenge private lenders to offer EEMs would result in more energy efficiency measures being deployed in homes at the time of purchase when most major upgrades are made. Outreach to lenders and the real estate industry should include information on utility cost savings and the increase in mortgage and asset value.

On-Bill Financing or On-Bill Repayment

On-bill programs such as on-bill financing (OBF) and on-bill repayment (OBR) programs have the potential to incentivize the increased installation of energy efficiency measures by allowing for easier access to funding and repayment of said measures. The PUC's On-Bill Financing Working Group Report, released in October 2013, expands upon the concepts of OBF and OBR programs:

> On-bill financing (OBF) and on-bill repayment (OBR) provide convenient mechanisms for utility customers to implement energy-efficiency improvements to their properties with no up-front costs, leveraging the existing utility billing system to manage the repayment of a loan obtained to cover the costs of the improvements. The term on-bill *financing* typically refers to a program where the utility is serving as the lender. Often the utility capitalizes on its program by establishing a revolving loan fund, using system-benefit charges or episodic government funds that become available (*e.g.*, funds from the American Recovery and Reinvestment Act of 2009 etc.). On-bill *repayment* typically refers to a program where the utility serves mainly as an intermediary between the customer and another institution that provides market-based lending.
>
> Based on documented experience in other states, on-bill programs may be effective in expanding the reach of existing energy efficiency programs, especially to specific niche or targeted groups of customers, such as multifamily housing or municipal entities that must work within a fixed budget. However, financing alone does not drive deeper energy savings – it is merely one critical component of a well-designed program.

For utility customers using an on-bill program, energy cost savings resulting from an energy-efficiency improvement can be used to offset a monthly repayment amount. This would render the loan cash-flow neutral to the customer, or "bill neutral," reducing the likelihood of default. Once the loan is repaid, it is assumed that the customer will continue to benefit from the savings and lower utility bills.

Potential concerns with implementing an on-bill program include (but are not limited to) gaps in tenancy (for residential renters), creditworthiness, actual savings being less than projected

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[63] Alaska Housing Finance Corporation, www.ahfc.us/buy/loan-programs/second-mortgage-programs/#sthash.mH2y7vE5.dpuf

savings, partial payments, and termination of service for non-payment. All such circumstances must be addressed to effectively deploy on-bill programming.

In order to implement on-bill financing/repayment programming, a program will need to be tested in Pennsylvania to determine feasibility and the expected rate of participation/market acceptance. Pennsylvania could facilitate this process by requiring utility companies, either through statutory or regulatory amendment, to devise and offer pilot OBF/OBR programs. A proposed on-bill pilot program should be designed to identify the market segments and/or the energy efficiency programs that could most benefit from on-bill financing/repayment programs. Any proposed pilot program would need to be designed in such a way that a determination could easily be made as to cost-effectiveness of a full scale program. Any savings obtained through the pilot program should exceed what would have been obtained absent the program, and the pilot program should provide benefits in excess of the associated administrative costs.

Implementation of a full-scale OBF/OBR would not be without obstacles. Utilities may require assistance in order to upgrade billing systems to support this type of programming. However, in Pennsylvania, this may be less of an issue than in other states, as gas and electric utility companies already have the capability to add an item to a customer's bill if that customer has shopped for a different energy supplier. OBR could be modeled after this existing pass-through billing feature. Additionally, many utility companies are more receptive to OBR programs that allow a third party to handle the money lending/banking aspect of the program, and to administer the program.

Based on documented experience in other states, on-bill programs may be effective in expanding the reach of existing energy efficiency programs, especially to specific niche or targeted groups of customers, such as multifamily housing or municipal entities that must work within a fixed budget. On-bill programs are attractive as they are designed to remain bill neutral while reducing energy consumption. Municipalities and multifamily housing facilities typically do not have the up-front capital needed for such efficiency improvements, and are limited in the ability to finance projects with traditional loans. An on-bill program could allow entities to upgrade their facilities and reduce energy consumption without increasing their spending, or significantly impacting cash flows.

Keystone HELP

The Keystone Home Energy Loan Program (HELP) was a public/private partnership to provide lower cost financing to homeowners for ENERGY STAR single measure improvements such as heating, cooling, insulation, geothermal as well as whole house energy improvements under Home Performance with ENERGY STAR guidelines. Loans for energy efficiency home improvements save homeowners money, help the economy, create jobs, and reduce greenhouse gas emissions. The DEP had contributed funding to the program, administered by AFC First and the Pennsylvania Treasury Department, including $12 million of DOE funding from the American Recovery and Reinvestment Act (ARRA), in order to help lower interest rates.

The DEP-supported Keystone HELP funding has been fully expended as of May 2, 2014. The program provided over 13,000 consumer loans valued at over $115 million to Pennsylvania homeowners, resulting in annual energy savings of 31 million kWh of electricity; a 180 million kBTU in heating fuel consumption; and reduced 39 million pounds of CO2e emissions through installed residential energy conservation and efficiency measures since inception. The program has been instrumental in the creation of Warehouse for Energy Efficiency Loans, (WHEEL), which was a key piece in the development of a national secondary market for energy efficiency loans.

Part of the innovation of Keystone HELP was offering tiered incentives, aligned with tiered contractor training and infrastructure and increased levels of equipment efficiencies and home performance. The lowest interest rate reductions were tied to single measure improvements meeting minimum performance standards installed by contractors with minimum training in the benefits of energy efficiency improvements. In order to offer higher incentives (lower interest rates), a contractor had to attend specialized training in energy conservation and efficiency and the consumer had to install higher efficiency equipment. The highest level of incentives (down to 0 percent financing) were reserved for consumers who completed a whole house energy efficiency improvement project performed by specialized contractors specifically trained to complete this type of work.

These unique program requirements helped create and improve the residential energy contractor network in PA; moved consumers toward more significant improvements, provided greater energy savings, resulted in higher emissions reductions, increased financial savings, and provided high levels of both consumer and contractor education. Keystone HELP won the Alliance to Save Energy's 2013 Andromeda Star of Energy Efficiency award, was used as the model for several other state programs and as a basis for improvements to the national Home Performance with ENERGY STAR program. This program also offered an opportunity for interaction with utility rebate programs and offers to further enhance consumer benefit.

In January 2103 the Pennsylvania Treasury Department completed its first secondary market sale of almost 4,700 Keystone HELP loans. The sale, one of the first of its kind in the country, was an important milestone in making low-cost capital readily available to finance greater residential energy conservation improvements by homeowners across the country. Via this sale, Keystone HELP was instrumental in the creation of Warehouse for Energy Efficiency Loans, which is a potential key piece in the development of a national secondary market for energy efficiency loans.

WHEEL is a financing mechanism designed to make bundled packages of energy efficiency loans more attractive to purchasers on the secondary market by limiting the potential for losses due to loan defaults. Loan defaults are fairly low, a rate of less than 5 percent, due to the fact that improvements save homeowners money. WHEEL also applies further insurance against losses from defaults by having a backer provide a loan loss reserve, or guarantee of available funds, to cover a potential range of defaults. WHEEL launched in April 2014 with programs in Pennsylvania and Kentucky, and is expected to complete its first capital markets 2015, and launch new programs in Florida, Indiana, New York and Virginia.

Pennsylvania could add additional funding to Keystone HELP/WHEEL in order to continue the program. The estimated cost to continue the program such that it would be ultimately self-sustaining is $3 million over 7 years, plus approximately $1 million annually to support interest rate buy downs. This would enable up to $15 million in loans annually. Emissions and energy consumption reductions similar to the previous program could reasonably be expected if the same program structure were used and the same ratio of least to highest energy savings projects were chosen and financed. Assuming these similar results from the previous Keystone HELP loans, this would save homeowners 4 million kWh of electricity; create a 23 million kBTUs in heating fuel consumption; and reduced 5 million pounds of CO_2e emissions per year.

Property Assessed Clean Energy

As described in the attached Energy Efficiency Financing work plan, Property Assessed Clean Energy (PACE) is a capitalization and payment mechanism to finance energy efficiency, renewable energy, and water conservation upgrades to buildings. PACE can be used to finance energy efficiency upgrades for residential, commercial, industrial, non-profit, agricultural and multi-family sectors. PACE helps overcome some of the traditional barriers, such as up-front out-of-pocket payment, that has been a hindrance to implementing energy efficiency projects. PACE pays for 100 percent of a project's costs up-front, with no out-of-pocket expenses, and is repaid for up to 20 years with an assessment added to the property's tax bill.[64] Projects reduce electricity costs, reduce emissions and depending up on the project completed, will add value to the property. Governments across the United States are introducing and passing PACE legislation due to the economic development and job growth potential as well as the energy saving, cost savings to consumers and resultant environmental benefits associated with less power use.

PACE is based on the concept of special municipal tax districts. PACE districts are established at the local government level to issue loans to residential and commercial property owners who would like to implement energy efficiency retrofit projects or install small renewable energy systems. With PACE, the loan payments take the form of an assessment added to (but separate from) the property tax on the home or building. The financing and repayment stays with the building upon sale. PACE may enable larger energy efficiency retrofits with longer payback periods to be implemented due to property owners not being obligated to maintain ownership for the full payback period. The energy efficiency or clean energy measure stays with the building, continues to save the building owner and as such the beneficiary, the next owner, then continues to payback the obligation until complete.

Twenty-nine states have passed PACE-enabling legislation. Nationally, over 327 commercial PACE projects have been initiated. The Connecticut Commercial Property Assessed Clean Energy Program has allocated $65 million in capital for over 60 projects, with the average energy efficiency projects achieving 20-40 percent energy savings and solar projects delivering 50- 90 percent energy cost savings.

Pennsylvania could develop statewide PACE enabling legislation and then conduct outreach to work with interested local governments and lenders to help them establish local PACE programs to help create jobs, save energy and benefit their constituency and communities. All PACE program are voluntary, but legislation would allow for their potential development and existence across the state.

[64] http://www.pacenation.us/about-pace/

Qualified Energy Conservation Bonds

As described in the Energy Efficiency Financing Work Plan, Qualified Energy Conservation Bonds (QECBs) were authorized by Congress in the 2008 Energy Improvement and Extension Act. QECBs can be used:

- To reduce energy consumption in publicly owned buildings by at least 20 percent.
- To implement green community programs (including the use of grants, loans, or other repayment mechanisms to implement such programs).
- For rural development (including the production of renewable energy).
- For certain renewable energy facilities (such as wind, solar, and biomass).
- For certain mass commuting projects.

Pennsylvania had $129,144,000 in QECBs, as of December 31, 2014. $111,672,620 of the bond allocations were given directly to local governments, only about 33 percent ($41,835,000) have been issued. Pennsylvania state government has allocated nearly all of its $17.5 million allocation, accounting for over 40 percent of all allocations issued in Pennsylvania.

QECBs are fairly long-term financing options. The maximum amount of time the bonds can be outstanding (“maturity”) is set by the government periodically and has historically ranged from 12.5 to 26 years. The interest on QECBs is taxable, but the federal government offers a direct cash subsidy to the bond issuer to subsidize the interest costs. QECBs can be an extremely low-cost financing option for many issuers. The QECB subsidy (70 percent of the qualified tax credit bond rate) is generally correlated with U.S. Department of Treasury yields and has historically ranged from 2.86 to 3.9 percent. This corresponds to net financing costs for issuers of around 0.338 to 1.5 percent.

States, state agencies, finance authorities, territories, municipalities, municipal utilities, municipal agencies, counties, school districts and institutions of higher education can be issuers of QECBS. Issuances often take several months to structure, market, price, and close. Once QECBs are issued, proceeds must be spent (or used to redeem bonds) within three years of issuance. The U.S. Department of Treasury can in theory extend the spending period if it finds reasonable cause to do so. Issuers must also have a binding commitment with a third party to spend at least 10 percent of the proceeds within six months of issuance. Issuers can use up to 2 percent of the bond proceeds to finance the costs of issuance. QECBs are subject to sequestration by the federal government.

Use of QECB allocations has been slow to develop, as some state and local governments are unwilling to take on additional debt. Other jurisdictions have statutory debt volume caps, which may decrease their motivation to spend their volume cap on QECBs versus other types of bonds. In these instances, QECBs and energy efficiency projects may not rank high enough on the jurisdiction’s overall set of priorities for bond issuances. Only 2 percent of QECB issuance proceeds may be used for issuance costs. While issuance costs are mainly fixed regardless of size this means small allocations to various jurisdictions often results in high transaction costs per dollar of bonds issued.

At least 22 state energy offices have been charged with implementing QECBs. In other states, bonding authorities, development authorities, or other agencies have been authorized to run the QECB programs. Some states have explored different approaches to both encourage the use of QECBs allocated to municipalities including implementing processes by which large local governments may return their sub-allocations to the states for use. A letter of intent could be sent to the authorized party or agency of each large local government asking whether the government is going to use its QECB allocation. If the answer is no, the QECB funds could be allocated back to the state for use. Alternatively, a large local government could affirmatively waive its sub-allocation by passing a resolution or motion of the county or city council.

The New York State Energy Research and Development Authority (NYSERDA) issued $24.3 million of QECBs for a residential energy efficiency loan program. The bond proceeds were used to replenish the $42.5 million revolving loan fund to promote energy efficiency and the installation of clean technologies to reduce energy costs and greenhouse gas emissions as well as support sustainable community development and create opportunities for green jobs.

The Commonwealth of Virginia created a Green Community Program, the VirginiaSAVES (Sustainable and Verifiable Energy Savings) loan program to finance costs for energy efficiency, renewable energy generation and alternative fuel projects by local government, institutional, commercial and industrial entities. VirginiaSAVES is funded through $20 million in federally-allocated QECBs. The QECBs were allocated to Virginia in 2010 by DOE and re-authorized for use by Governor McAuliffe in 2014 under Executive Order 36.

Pennsylvania could explore either working with local governments to help them get projects funded or directly allocating unused funds on eligible projects. A state acquisition of $70 million of unused QECBs could be used to start a $700 Million Green Bank, leveraging 10:1, or $70 million in QECB funding could be used to support energy retrofits at state or municipally owned buildings across the state, reducing by greater than 20 percent energy use, environmental impact, energy bills and tax dollars needed for operation of state and municipally owned building.

Energy Efficiency Financing: What You Can Do

1. Research and use special energy efficiency financing options whenever purchasing a home or completing energy efficiency renovations.

2. Check with your lending institution regarding an energy efficiency mortgage or energy improvement mortgage.

3. Ask your bank about WHEEL as an additional financing option.

4. Encourage your local utility to allow on-bill financing or on-bill repayment to finance energy efficient upgrades to your home.

Chapter 5: Land Use

Prioritize Safe, Walkable Communities to Deter Driving

Smart growth principles seek to create more sustainable communities through compact and strategic development while saving green space. Mixed-use development minimizes vehicle use, by allowing people to work, shop, and live within the same area. It also enables commercial and industrial facilities to locate close to efficient freight transportation. Segregated land use promotes a spreading out of the population and industry and the "hollowing out" of urban fabric. City neighborhoods are in decline while there is unsustainable suburban development, increasing the need for automobile travel and hence greenhouse gas emissions.

Current sprawl development necessitates the use of private autos and the absence of defined communities often does not support other forms of transportation. Building towns, as independent rural communities or neighborhoods in an urban setting encourages people to remain local and use other forms of transportation.

Challenges and Opportunities

Redevelopment of existing sites and neighborhood redevelopment offer local agencies the ability to influence how their communities will grow. Building on existing programs, local officials need to understand the impacts of their decisions and help guide growth to a more sustainable pattern. By providing support to local communities for more smart growth planning, state agencies can ensure that development is responsible and possibly even reduce GHG emissions. However, the decentralized nature of development planning limits the influence that state agencies can have on local decisions. By using smart growth principles to evaluate projects for funding, state agencies can have more influence in local development, thereby increasing the sense of community for residents and also reducing GHGs.

Smart growth reduces the need to develop greenspace and protects and expands wooded areas that provide for much needed carbon sequestration. By preserving these areas from development, natural settings enhance their communities and can even provide an opportunity for tourism.

Brownfield Redevelopment

Pennsylvania's award-winning Land Recycling Program aims to reduce land consumption and encourages the transformation of abandoned, idle properties into economic opportunities. Since its inception in 1995, the program has resulted in 5,665 site cleanups, with another 1,301 sites in progress, and $535 million in grants have been awarded to facilitate cleanups through DCED, DEP and PENNVEST programs. The Pennsylvania Land Recycling Program has become a national model. Roughly 100,000 jobs have been created or retained because of the business opportunities that have been recognized and realized in Pennsylvania's abandoned, idle properties.

The Land Recycling Program hinges on uniform cleanup standards to assure that the site is protective of current and future uses, liability relief, standardized reviews and time limits, and financial assistance for people who did not cause or contribute to site contamination. DEP recently created the Brownfield Development Guide, which draws on 20 years of experience in cleaning up sites. It provides information on the services and resources available for redeveloping brownfield properties and is geared towards industry, state and local agencies, economic agencies, local officials, communities, property owners, developers, and other stakeholders. DEP helps to build public-private partnerships in this program, which have shown to be beneficial for the timely completion of successful projects.

Brownfield redevelopment is a sustainable practice because existing infrastructure if often reused. Buildings, water, and sewer services are already in place, so the need for manufactured materials is reduced. The use of brownfields for housing and new industrial or commercial uses decreases greenfield development, preventing a loss of carbon-sequestering vegetation and trees.

Pennsylvania's Statewide Comprehensive Outdoor Recreation Plan 2014-2019 recommends that the Commonwealth restore and repurpose brownfields, abandoned mine lands and other damaged lands for recreation and conservation purposes through at least five pilot projects. The plan notes that brownfield sites are a way to preserve history and reuse structures in new ways, such as restaurants, gathering places, comfort facilities and education centers. They can also be used for more recreational purposes, such as ATV trails, bicycle trails, and fishing and riverfront access.[65]

DEP and the Department of Conservation and Natural Resources should collaborate to identify and evaluate brownfield sites across the Commonwealth to repurpose into community recreation areas.

[65] Pennsylvania's Statewide Comprehensive Outdoor Recreation Plan 2014-2019 (DCNR 2014)

Chapter 6: Transportation

The transportation sector contributes 27 percent of the total U.S. GHG emissions. This is due to the scale of the activities encompassed and the intensity and inefficiency with which liquid fuels are consumed. According to the U.S. Department of Transportation (DOT), "transportation is the largest end-use sector emitting CO2" and 97 percent of the emissions from the sector come from direct combustion of liquid fuels.[66]

According to the EPA, there are four primary ways to reduce the climate impact of the transportation sector:

1. Increase fuel efficiency and improve technology and design
2. Reduce demand for travel or share travel modes among public
3. Switch to cleaner, less greenhouse gas intensive fuels
4. Improve operating practices and educate drivers[67]

The impacts of the transportation sector on the climate in Pennsylvania are looked at through these lenses to examine both the gains achieved so far as well as identify room for improvement. It's easier for the Commonwealth to impact certain areas, such as investment in transit services, while other areas, such as switching to alternative fuel vehicles, require a personal choice that the Commonwealth can only encourage through incentives.

Challenges and Opportunities

Smart transportation is defined as partnering to build sustainable communities for future generations by linking transportation investments and land-use planning to decision making. It reduces vehicle travel and GHG emissions by accommodating growth without taxing the current infrastructure. By focusing on enhancements to the local communities' transportation needs, continuity can be achieved, which can encourage local trips and support transportation modes other than vehicles. Smart transportation planning can encourage smart growth and reduce the need for vehicle miles traveled and GHG emissions.

Fuel efficiency is improving steadily across the country as older less efficient vehicles are replaced by newer, more fuel efficient ones. One major factor driving this transition is the increase in the national Corporate Average Fuel Efficiency standards in 2011. The historic agreement among 13 automakers and the Obama Administration requires that the average fuel efficiency of cars and light trucks must be 54.5 mpg by 2025.[68] As gas prices began a sustained

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[66] U.S. DOT, Transportation and Climate Change Clearinghouse, Transportation's Role in Climate Change, http://climate.dot.gov/about/transportations-role/overview.html retrieved on 8/21/15

[67] U.S. EPA, Sources of Greenhouse Gas Emissions, http://www.epa.gov/climatechange/GHGemissions/sources/transportation.html updated on 5/7/15, retrieved on 8/24/15

[68] National Highway Traffic Safety Administration, "President Obama Announces Historic 54.5 mpg Fuel Efficiency Standard", June 2011. http://www.nhtsa.gov/About+NHTSA/Press+Releases/2011/President+Obama+Announces+Historic+54.5+mpg+Fuel+Efficiency+Standard

march upward starting in the early 2000s, a trend to market cars as being fuel efficient has gained momentum and is currently still a norm.

Vehicle Emission Standards: Policy is an important factor in trends in the transportation sector. Current federal regulations promulgated jointly by EPA and the National Highway Traffic Safety Administration require improved fuel economy and reduced emissions for light-duty vehicles through model year 2025, and heavy-duty vehicles through model years 2014-2018 (Phase 1) and 2021-2027 (Phase 2).[69] From 2015 to 2030, Pennsylvania's total consumption of energy by transportation is expected to decrease at a rate of 0.52 percent per year. The Pennsylvania Clean Vehicles (PCV) Program, beginning in model year 2008, requires new vehicles to be certified for emissions by the California Air Resources Board (CARB) in order to be sold, leased, registered or titled in Pennsylvania. When the PCV Program was adopted, it only included certification for criteria pollutants. However, when the EPA granted CARB's request for a waiver of federal preemption to implement GHG standards for motor vehicles those standards were incorporated by reference into the PCV Program. When CARB adopted revisions to its low emission vehicle standards (LEV III) on March 22, 2012, covering model years 2017-2025 for criteria pollutants, evaporative emissions, and greenhouse gas emissions, the provisions affecting the LEV program were incorporated by reference into the PCV Program.

Idling Reduction: Act 124 of 2008 enacted restrictions on diesel idling in Pennsylvania. Under this law, diesel vehicles with a gross weight of 10,001 pounds or more that are engaged in commerce may not idle their engines for more than five minutes in any 60-minute period unless a specific exception applies. Exceptions include motor homes, farm equipment and certain cases where health or safety is an issue. The act also requires owners of parking lots with 15 or more spaces for qualifying vehicles to post and maintain a sign informing drivers of the law. Decreasing the amount of idle time has reduced GHGs from diesel emissions.

Grant Programs: Pennsylvania has made significant strides with respect to alternative fuel usage in the transportation sector. There are several programs that contribute to reducing emissions from the transportation sector either through vehicle replacement, switching to alternative fuels, reducing idling, or other fuel efficiency improvements. One such opportunity is a grant and rebate program, administered by DEP, to promote the use of alternative fuels in Pennsylvania under the Alternative Fuels Incentive Act (Act of Nov. 29, 2004, P.L. 1376, No. 178). This program was originally created in 1992 and administered by the Pennsylvania Energy Office through Chapter 72 of the Vehicle Code. The Alternative Fuels Incentive Grant (AFIG) Program was expanded in 2004 and 2008 and includes Alternative Fuel Vehicle (AFV) rebates among its offerings.

The AFIG and its associated AFV rebate programs have helped to decrease Pennsylvania's dependence on imported oil and improve air quality by reducing vehicle emissions of carbon monoxide and particulate matter (the pollutants that contribute to the formation of ground-level ozone), as well as carbon dioxide (a principle greenhouse gas).

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[69] U.S. EPA Regulations & Standards: Heavy-Duty, http://www3.epa.gov/otaq/climate/regs-heavy-duty.htm, updated on September 09, 2015, retrieved on 10/7/15.

The AFIG Program has fostered economic development in Pennsylvania by encouraging the transfer and commercialization of innovative energy technologies and the use of the state's indigenous resources. The fuels promoted by the program include ethanol, biodiesel, compressed natural gas (CNG), liquefied natural gas (LNG), hydrogen, hythane (a combination of compressed natural gas and hydrogen), liquefied petroleum or propane gas (LPG), electricity and synfuels derived from feedstocks such as coal and biomass.

The grants and rebates issued through the AFIG Program support DEP's objectives of reducing emissions from mobile sources to improve air quality and stimulating the use of domestically produced fuels. DEP has encouraged the development of partnerships among Pennsylvania businesses; alternative fuel providers; and key local, state and federal government agencies to accomplish the objectives of the Alternative Fuels Incentive Act. The AFIG Program also offers compliance incentives to fleet operators impacted by the federal energy policy acts of 1992 and 2005.

The AFIG Program is funded by an annual allocation from the General Fund equal to 0.25 mills of the utilities' gross receipts tax, which has ranged between $5 and $6 million dollars annually. The Alternative Fuels Incentive Act provides incentive grants that pay a percentage of each applicant's eligible project costs. The remaining project costs are paid by the grantee from other sources.

Another alternative fuel incentive program came from Chapter 27 of Act 13 of 2012, which provided $20 million over three years, out of impact fees paid by natural gas operators, for the purchase or retrofits of large fleet vehicles 14,000 pounds or less to operate on CNG or liquefied natural gas LNG. Round 1, Round 2 and Round 3 collectively have deployed 289 vehicles out of the 1,111 planned vehicle deployments. Once the fully deployed, the CNG- and LNG-powered vehicles are expected to displace 12.2 million gallons of diesel fuel. Deployment of new natural gas fueling infrastructure has also been realized by Act 13. Act 13 funding will provide for the incremental cost of over 40 natural gas refueling stations in Pennsylvania at the end of the three-year program.

The Pennsylvania State Clean Diesel Grant Program provides funding for diesel emission reduction projects for medium- and heavy-duty diesel vehicles (Classes 5-8) and equipment, including exhaust controls, engine upgrades or repowers, cleaner fuel use, alternative fuel conversions, vehicle/equipment replacement, idle reduction projects, and the use of Smartway® verified technologies. The program is open to businesses, nonprofits, school districts, municipal governments and authorities, and other state agencies. While the program is focused on reducing criteria pollutants, most project types will also reduce GHG emissions.

As Pennsylvania continues to experience repeated and significantly expensive impacts of climate change, it has shifted its posture to prepare for the eventuality of extreme weather and temperatures which are associated with increased carbon emissions. This presents one of the greatest challenges to both the transportation industry and to the government, PennDOT in particular; the challenge is to create a resilient system which anticipates extreme weather events and is designed with mechanisms and operating procedures to be quick to bounce back with a minimal cost to the taxpayer. In this vein, PennDOT has commissioned a study to examine vital infrastructure around the state to take inventory of the impacts these increasingly serious flooding events can be expected to cause. After analyzing these assets, it is recommended to continue looking at extreme weather other than flooding, such as freeze/thaw cycles, extreme heat, and drought.

Reducing Travel Demand

Statewide land use and transportation policies that follow more sustainable “smart growth” principles that generate fewer private auto trips, promote the use of transit and non-motorized modes, and protect open spaces could minimize the generation of associated GHGs. Smart growth seeks to create more compact communities throughout the state, featuring walkable communities of concentrated development and a mixture of land uses that generate less vehicle traffic while being more supportive of auto trip-reduction measures, such as transit, non-motorized modes and transportation demand management programs including car sharing, carpooling, mitigating congestion, improved traveler information, and other programs. Smart growth also sites commercial and industrial facilities with ready access to an efficient, multimodal freight transportation system.

Transit and Rail: In Pennsylvania, there are 37 urban and rural fixed transit agencies and 26 agencies that only provide community/demand response transportation. Many of the fixed route agencies also provide community/demand response transportation. For intercity rail, Amtrak operates 120 trains daily, which carry 6.3 million passengers annually, along numerous lines. Additionally, Amtrak operates several long distance (multi-state) trains that travel through Pennsylvania. Pennsylvania also has several regional rail operators in the Philadelphia and Pittsburgh areas. Rail based transportation is at a critical juncture all over the United States. Without long-term federal funding reauthorization, states and municipalities will not be able make any long-term plans, including the expansion of existing passenger rail and public transit services. PennDOT has some jurisdiction over both commercial and passenger rail, but the majority of the responsibility falls under the purview of the PUC. The biggest opportunity for increased commuter participation exists in passenger rail. In Pennsylvania, the Amtrak Keystone East line extends from Harrisburg to Philadelphia, and includes stations in Harrisburg, Middletown, Elizabethtown, Mount Joy, Lancaster, Parkesburg, Coatesville, Downingtown, Exton, Paoli, Ardmore, 30th Street Philadelphia, North Philadelphia, and Corwells Heights. From 2011 to 2012, the average growth in annual ridership for each station was 6 percent and this is estimated to grow by 1 percent to 1.5 percent each year. To accommodate this growing trend, PennDOT will evaluate stations and consider a number of capacity upgrades and/or increased service levels based on continuing increased demand. At this time there are no plans to expand the existing passenger rail system in the Commonwealth, but given the proper funding mechanism, this should be re-examined as demand changes and demographics shift towards cities and inner-suburbs.

Local or intra-city transit ridership growth potential is most likely in the larger urbanized areas with the highest population densities. These areas can provide the most efficient, cost-effective high-quality transit services that attract riders, including fixed-guideway modes, such as bus rapid transit (BRT), priority corridors, rail, etc. Transit services in the Philadelphia and Pittsburgh areas, for example, currently comprise more than 90 percent of total Pennsylvania transit ridership. Similarly, key intercity markets exist and may continue to emerge, as travelers continue to seek lower cost, higher quality, and more dependable travel modes. An example is the Keystone Corridor (commuter rail between Harrisburg and New York City via Philadelphia), but may include other intercity pairs inadequately or not served by rail or air modes.

Investing in growth recognizes that public transportation is first and foremost a public service, and that the sustainability of transit systems and services is dependent on demonstrating sound management practices and prudent use of public funding to attract and retain riders. Investment is necessary to better serve the state's present citizens and provide attractive service to populations in future residential areas, employment areas and other activity centers. This investment, made wisely, will significantly increase transit ridership and the proportion of total trips served by transit, *at a minimum* reducing the projected growth of vehicle-related GHG emissions, reducing highway vehicle-related GHG emissions from current projections, and working to reduce vehicle-related carbon emissions.

All transportation investments must be appropriate to the existing and planned environment to ensure implementation of smart transportation approaches. There are other more cost-effective approaches that can be implemented, such as:

- *Workplace incentives for public transit use*: To encourage public transit use by employees at workplaces with access to public transit systems, the state and local governments could work with businesses to provide incentives for their employees to use public transit for their work commute. Such programs should also include state workers, and incentives could include free/discounted bus or train tickets, transit ticket purchase with pre-tax dollars or vouchers for discounts at businesses in the area.
- *Workplace incentives for carpooling*: State and local governments could work with businesses to provide incentives for their employees to carpool for their work commute. Such incentives could include free/discounted parking, matching up riders or vouchers for discounts at businesses in the area.
- *Telecommuting in the private sector*: By working from home, workers can avoid vehicle trips and the resulting GHG emissions. Actions to encourage more telecommuting in the private sector include business tax incentives for employers to provide telecommuting as an option to their employees (could include local wage tax adjustments), and funding for regional telecommuting centers (which provide an office-like environment for workers in a given area closer to home and away from their employer's office).
- *Telecommuting in the public sector*: To help set the example and establish some of the regional telecommuting centers, the state should offer telecommuting as an option for employees wherever appropriate, and set clear targets and timelines for the number of employees using the telecommuting option.

<u>Shared Ride Programming:</u> The Commonwealth currently operates a shared ride program through PennDOT for citizens age 65 or older which provides reduced-fare transportation services, sometimes in suburban or even rural areas where transportation options are limited to using a single occupancy vehicle. By providing this service the Commonwealth helps to reduce carbon emissions by reducing the number of cars which would otherwise be needed to transport these citizens.

PennDOT recently expanded its FindMyRide service to include Adams, Cumberland, Cambria, Dauphin, Franklin and Lebanon counties. The software allows consumers of shared ride and para-transit transportation to coordinate their trips with local transit agencies throughout the Commonwealth. The program makes these services easier and faster to obtain for PennDOT customers. Ultimately the goal is to provide FindMyRide services throughout the Commonwealth to allow for the maximum amount of GHG reduction while providing robust and widespread mobility services for customers. While there is no timetable for achieving this goal, as new transit services are added, PennDOT will continue to look for opportunities to expand this service.

Bicycle and Pedestrian Facilities and Programs: Bicycles are an increasingly popular form of alternative transportation for commuters. Not only are they a mode of zero emission transportation, they are a great form of exercise. Bicycles also reduce the need for parking space and eliminate fuel costs. Improved pedestrian facilities may reduce local vehicle trips as well. PennDOT maintains information for bicycle/pedestrian information on the following website, including a statewide bicycle and pedestrian plan: http://www.penndot.gov/ProjectAndPrograms/ProjectRequirementsResources/Bike_and_Pedestrian/Pages/default.aspx. Additionally, many counties in Pennsylvania also have a bicycle/pedestrian plan available.

Complete Streets Policy: Complete Streets are streets for everyone. They are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. Complete Streets policies should result in the creation of a complete transportation network for all modes of travel. A network policy approach helps to balance the needs of all users. Instead of trying to make each street perfect for every traveler, communities can create an interwoven array of streets that emphasize different modes and provide quality accessibility for everyone. A strong Complete Streets policy will integrate Complete Streets planning into all types of projects, including new construction, reconstruction, rehabilitation, repair, and maintenance. Getting more productivity out of the existing road and public transportation systems is vital to reducing congestion and emissions.

PennDOT should encourage municipalities to make their communities available to alternative forms of transportation, including bikes and bike lanes. PennDOT hired a bike/pedestrian coordinator who will be responsible for improving bike and pedestrian programming across the Commonwealth. PennDOT is working with other state government partners, including DEP and the Department of Conservation and Natural Resources, to improve bike and pedestrian trails and facilities throughout Pennsylvania.

There are federal grant funding sources, mostly through the DOT, that fund the development of bicycle and pedestrian facilities as part of an area’s transportation plan.

Alternative Fuels and Fuel Switching

Many types of alternative fuels are available and in use in the Commonwealth. With the influx of natural gas supply in Pennsylvania, a low-cost, cleaner burning fuel is easily accessible with the proper infrastructure. The challenge of using natural gas as a transportation fuel is reducing the methane leakage in the supply chain from production to end-use. If natural gas can displace some gasoline and diesel emissions, GHGs from this sector could be reduced. Another challenge of using natural gas is consumer accessibility to refueling infrastructure. There are currently 58 natural gas refueling stations operational in Pennsylvania, with 37 being publicly accessible. There are also technologies being developed that would allow consumers to refuel their natural gas vehicles in their own home, if they have access to CNG. However, as previously mentioned, many Pennsylvania residents do not have access to natural gas distribution lines.

Another alternative fuel option is electrification. Electric propulsion technologies are present across all types of vehicles and mobile sources, from passenger cars to locomotive engines. Full electric and hybrid electric vehicles (HEV) present an opportunity for Pennsylvania residents and especially for transit fleets that traditionally run on diesel. Several of Pennsylvania's transit organizations use diesel-hybrid buses. Studies indicate the HEV buses experience a 37 percent improvement in fuel economy compared to a standard diesel bus. In addition, a U.S. Department of Energy study has demonstrated that NOx emissions from diesel-hybrid buses were 30 to 40 percent lower than conventional diesel units.[70] Diesel-hybrid buses also exhibited the lowest carbon monoxide emissions of any bus tested, including CNG powered units.

The urban transit systems make up 95 percent of the total transit vehicles in Pennsylvania and a transition of their fleet to lower carbon or zero emissions vehicles would statistically have the largest impact on GHG emissions from this sector. Many transit agencies have expressed interest in converting from diesel to CNG to streamline operations and to capitalize on the Commonwealth's natural gas resources. In order to optimize the economic and environmental benefits of CNG, as well as reduce operating costs for the Commonwealth's transit agencies, PennDOT is advancing a public-private partnership project to bundle the deployment of CNG fueling stations and vehicles to a number of municipal transit services to use natural gas, a cleaner fuel than diesel. There is a significant body of evidence supporting the benefits of converting transportation fleets to CNG. These benefits include lower and more stable fuel costs; diversification of the Commonwealth's transportation fuel portfolio; and lower emissions, including carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter.

In order to convert to CNG, transit agencies must make an investment in both the vehicles and fueling infrastructure. PennDOT should continue to work with transit agencies to determine their current fleet size, annual diesel fuel consumption, and the expected rate of replacing existing diesel buses with CNG buses. PennDOT estimates that over the next 20 years, CNG conversion could save the transit agencies approximately $158 million in fuel costs combined across the Commonwealth.

There exists a number of innovative incentives for encouraging the purchase of alternative fuel vehicles in addition to the existing programs, mentioned above. Some methods for incentivizing alternative fuel vehicles used in other states are:

- allowing single occupancy access to high-occupancy vehicle lanes for placarded vehicles,
- free or reduced rate access to high-occupancy toll lane access,
- rebates for installation of home charging units (or commercial fueling stations),

[70] Department of Energy *Early Results from the National Renewable Energy Laboratory Transit Bus Evaluations,* May 2005

- reduced prices for electricity used to charge an electric vehicle, and
- reduced sales taxes or registration fees.

Further study of Pennsylvania-specific incentives is needed.

Much of the Southeastern Pennsylvania Transportation Authority's (SEPTA) fleet is already made up of diesel-electric hybrid vehicles. SEPTA's replacement plan projects that 88.7 percent of the fleet will be diesel-electric hybrid vehicles by 2020. The Port Authority of Allegheny County's (PAAC) fleet is made up of a small number of diesel-electric hybrid vehicles. PAAC's replacement plan currently projects the use of clean diesel buses rather than diesel-electric hybrids. PAAC is currently working on a CNG feasibility study that may impact future vehicle replacement decisions. Other Pennsylvania transit systems also have incorporated and plan to continue incorporating alternative fuel transit buses within their system. Specifically, Centre Area Transit Authority's total fleet has been converting to CNG. Some transit authorities, such as River Valley Transit of Williamsport, are progressing with plans to install CNG fueling infrastructure and transition their bus fleet to operate on this alternative, domestically-produced fuel, while some others are in the process of evaluating the costs of such a transition.

In addition to natural gas (CNG/LNG) and electrification, other alternative fuel options include propane, hydrogen, renewable diesel, alcohols such as ethanol, methanol, and butanol, and vegetable and waste-derived oils.

Improved Operations and Driver Education

Another option to decrease GHG emissions from transportation is to improve vehicle operation through driver education and fuel efficiency improvements. Numerous resources are available online and in print describing activities drivers can take to reduce the environmental impact of their driving, commonly referred to as eco-driving. Drivers can operate vehicles more efficiently by reducing aggressive driving (speeding, rapid acceleration and braking), avoiding hauling cargo on the roof, removing excess weight from the vehicle, avoiding excessive idling, and using cruise control.

Two ways to improve vehicle operations are maintenance and fuel efficiency standards. Get regular tune-ups, follow the manufacturer's maintenance schedule and use the recommended grade of motor oil. A well-maintained car is more fuel-efficient, produces fewer greenhouse gas emissions, is more reliable, and is safer. Additionally, you should check your tire pressure regularly. Under-inflation increases tire wear, reduces your fuel economy, and leads to higher greenhouse gas and other air pollutant emissions. If you don't know the correct tire pressure for your vehicle, you can find it listed on the door to your vehicle's glove compartment, or on the driver's-side door pillar. The second way to improve operations is for manufacturers to improve vehicle fuel economy. As noted above, EPA and NHTSA recently passed regulations that require increases in fuel economy through MY2025.

Opportunities in Freight Movement

Semi-Truck Freight Transportation

Work Plan 11: Semi-Truck Freight Transportation sets a target for installing trailer fairings (or side skirts) on 50 percent of the Commonwealth's registered tractor trailer fleet by 2030. The technology option, considered in the semi-truck analysis, is based on EPA's SmartWay Transport Partnership.[71]

About 61 percent of the freight moved in the U.S. is carried by truck transport. In the U.S. more than 36 billion gallons of diesel fuel are used by truck transport annually.[72] In Pennsylvania alone approximately 851 million gallons of diesel fuel were estimated to have been used by semi-trucks hauling freight in 2015.

In a program to reduce GHG emissions and improve fuel efficiency of tractor trailers and other heavy duty vehicles, the EPA and the National Highway Traffic Safety Administration have developed the Heavy Duty National Program (HDNP). This program will be adopted in two phases, with phase 1 affecting heavy duty vehicles model years 2014 through 2018 and phase 2 affecting model years 2018 through 2025. The program is designed to increase the fuel efficiency standard of newly manufactured heavy duty engines and vehicles.

The initiative brought forth in this work plan is a voluntary program designed to encourage owner-operators and fleets to reduce air pollution and GHG emissions through lower fuel consumption on tractor trailers not subject to the HDNP by retrofitting vehicles with add-on aerodynamic technologies. The option explored here entails deployment of available fuel use reduction technology. By identifying and promoting fuel-saving retrofit technologies, the program enables the owners and operators of truck fleets to better understand how to reduce fuel consumption via the most economical means available. In many cases, fuel-saving retrofits can result in net cost savings over the long run.

Adding side fairings (e.g., skirts) to trailers reduces aerodynamic drag and improves fuel economy by 3 to 7 percent.[73] For the purpose of this analysis, a fuel savings of 4.5 percent is used. Side skirts have the largest rate of adoption among aerodynamic technologies for trailers, around 40 percent of new box trailers are sold with side skirts and roughly 50 percent of the side skirt market is for retrofitting existing trailer.

While the cost associated with installing trailer fairings ($1,100) is modest compared to the cost of a tractor-trailer, any up-front cost may be prohibitive for some truck owners. Low interest revolving loan programs are good financial assistance options. With a payback period of roughly 0.6 year, the money loaned from the initial fund can be quickly returned and used for new loans. The estimated GHG emission reductions from installing trailer fairings are based on diesel fuel

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[71] U.S. EPA, 2009b. U.S. Environmental Protection Agency, SmartWay Transport Partnership, "Technologies, Policies, and Strategies: Upgrade Kits," at http://www.epa.gov/smartway/transport/what-smartway/upgrade-kits-tech.htm, accessed 28 May 2009.
[72] U.S. Energy Information Administration, Annual Energy Outlook 2014 Early Release, December 16, 2013.
[73] ICCT, 2014 International Council on Clean Transportation "Costs and Adoption of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector" February 2014.

savings. At highway speeds, aerodynamic drag accounts for the majority of truck energy losses.[74] Reducing drag improves fuel efficiency. Since a majority of long-haul tractor trucks on the road already contain aerodynamic features, such as air deflectors mounted on the top of the cab, drag-reduction options should focus on trailer aerodynamics.[75] The addition of side fairings to a trailer can reduce fuel consumption by 4.5 percent.[76].

Increased Truck Stop Electrification

Diesel vehicles are a significant source of emissions that contribute to the production of ground-level ozone, a pollutant responsible for respiratory ailments. In 2008, the legislature passed the Diesel-Powered Motor Vehicle Idling Act (Act 124) and it became effective in February 2009. Act 124 restricts unnecessary idling of the main propulsion engine in heavy-duty diesel-powered motor vehicles by imposing idling time limits and signage requirements. Owners and operators of any diesel-powered motor vehicle with a gross weight of 10,001 pounds or more, as well as owners and operators of locations where subject vehicles load, unload, or park, cannot cause or allow the engine of the vehicle to idle for more than five minutes in any continuous 60-minute period, with some exemptions and exceptions.

One option to comply with Act 124 is to use electrified truck parking. Truck stop electrification (TSE) is the process of creating dedicated parking spaces which use a gantry or a pedestal with a dedicated hose which couples with the truck window fittings to deliver heating, ventilation, and air conditioning (HVAC), auxiliary power outlets, and even an internet connection to vehicle operators, instead of using energy from the vehicle's main engine. Truck stop electrification gives commercial trucks the opportunity to turn off their diesel engines and avoid idling. The Alternative Fuels Data Center of DOE lists electrified truck stops. There are currently six locations in Pennsylvania, as shown on the map below. Encouraging the building of TSE for truck stop owners through a grant program or by other means is a potential solution for reducing the intensity of the GHG emissions created from the trucking industry. Truck stops are also major sources of air pollution in the Commonwealth. The Commonwealth has already funded several TSE projects through various grant programs.

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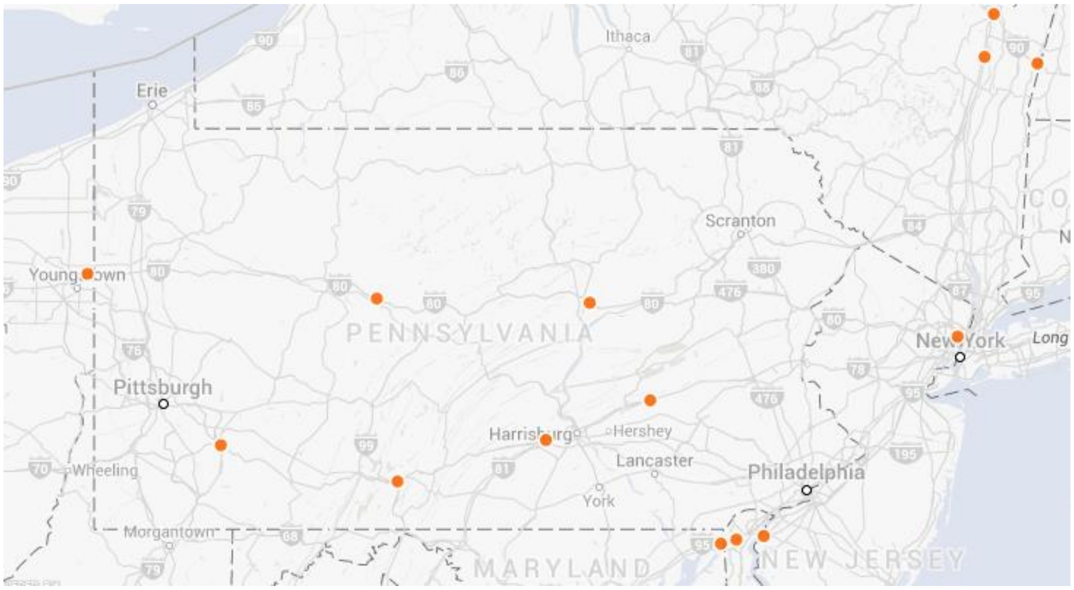
[74] U.S. EPA, 2004b. U.S. Environmental Protection Agency, SmartWay Transport Partnership, "A Glance at Clean Freight Strategies: Improved Aerodynamics," EPA420-F-04-012, February 2004, at http://www.epa.gov/smartway/transport/documents/carrier-strategy-docs/aerodynamics.pdf, accessed 28 May 2009.
[75] Bynum, 2009. Personal communication, Jonathan Dorn, E.H. Pechan & Associates, with Cheryl Bynum, U.S. Environmental Protection Agency, SmartWay Transport Partnership, 28 May 2009.
[76] U.S. EPA, 2009b. U.S. Environmental Protection Agency, SmartWay Transport Partnership, "Technologies, Policies, and Strategies: Upgrade Kits," at http://www.epa.gov/smartway/transport/what-smartway/upgrade-kits-tech.htm, accessed 28 May 2009.



http://www.afdc.energy.gov/truckstop/

Encouraging Adoption of Auxiliary Power Units

Auxiliary power units (APUs) are generators mounted on-board commercial trucks. APUs are usually powered by diesel, although propane and electricity are also used. APUs are much smaller than a main diesel engine and are much more efficient and economical to operate for the purposes of producing on-board HVAC, electric power and engine block warming when the main engine is turned off. APUs can reduce pollution from main diesel engines, extend engine life and be a very economical solution for businesses. Studies are recommended to examine the impact of more APU usage in the Commonwealth as well as methods for encouraging their adoption by the industry. Funding for APUs is available through the Small Business Advantage Grant Program and the Pennsylvania State Clean Diesel Grant Program.

Establish Emissions Standards for Transport Refrigeration Units

Transport refrigeration units (TRUs) are often used in the transport of perishable goods and produce or for climate controlled cargo. These units are mounted on trucks and use a dedicated fuel source separate from the main engine. Typically, smaller horsepower generators powered by diesel are used. Trucks with TRUs tend to congregate in similar areas for unpacking, loading, and transfers. TRUs are specifically exempt from the idling law mentioned previously for diesel vehicles. Performance standards and compliance schedules were released by the CARB in 2004 for compliance starting in 2009. As a result, newer ultra-low emissions TRUs have been developed to comply and provide a standard which could be adopted here in the Commonwealth. The costs and benefits of requiring a lower emissions TRU should be studied and implemented if found to not be overly burdensome on industry.

Transportation: What You Can Do

1. Prioritize fuel efficiency when choosing a vehicle to purchase.

2. Maintain your vehicle to achieve optimum fuel efficiency. Proper tire inflation, keeping clean filters, and having regularly scheduled maintenance can help to lower emissions.

3. Drive fewer miles. Eliminate unnecessary trips, share rides, or opt for other modes of transportation.

Chapter 7: Forests

Protecting Pennsylvania's Greatest Carbon Sequestration Asset

Forests play an important role in mitigating the impacts of climate change. Healthy, productive forests store and sequester carbon; sustainable timber harvesting can not only improve the health of the forests and encourage the growth of young, vigorous trees, but the resulting "durable wood products" continue to store carbon for long periods of time.

Forests also help to combat the effects of climate change by providing key ecosystem services, such as ameliorating rising stream temperatures, reducing runoff during heavy rain events, and taking up excess nutrients to keep water clean. Additionally, they play a key role in providing habitat and pathways for species whose ranges are shifting to the north or to higher elevations in response to climate change.

Challenges and Opportunities

Pennsylvania's 2.2-million-acre state forest system is an important reservoir for sequestering carbon from the atmosphere. Through the process of plant respiration or photosynthesis, atmospheric carbon dioxide is taken in by trees and other plants, stored as carbon, and oxygen is released back to the atmosphere. In 2015, state forests sequestered 4.7 million tons of carbon, while storing (above ground) 143 million tons. Forest soils are also important reservoirs for storing below-ground carbon, although total volumes have not been estimated to date. The Department of Conservation and Natural Resources (DCNR)'s third-party certified sustainable forest management practices protect the state forest system from threats and mortality, promote productivity, ensure adequate regeneration of the future forest, and limit forest conversion – all of which contribute to carbon sequestration and storage to help mitigate the impacts of climate change. Pennsylvania's 11.5 million acres of privately owned forestland also provide carbon sequestration, although rates vary depending on how well these forests are managed.

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.

Urban and Community Forestry

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.

DEP, DCNR and the CCAC have developed Work Plan 12: Urban and Community Forestry to show how communities can have a positive impact on climate change through strategic tree planting. As the only practical mechanism for both sequestering and storing carbon, trees are an invaluable tool for addressing climate change. Trees store carbon long-term within their structures; this carbon, which equates to approximately 50 percent of a tree's dry weight, remains in place until they are burned or begin to decay. According to a study by Nowak et al. (2010), the City of Scranton's urban trees remove an estimated 3,000 tons of carbon annually from the atmosphere and have stored about 93,000 tons. Other pollutants that trees filter from the atmosphere include ground-level ozone, carbon monoxide, nitrogen dioxide, sulphur dioxide, and particulate matter.

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.

Philadelphia Street (www.thesanguineroot.com)

Situating trees around parking lots gives shade to vehicles, which slows the speed at which the gasoline volatizes, or changes from liquid to vapor. Trees also reduce the runoff and flooding that occur after a storm, by soaking up water through their roots, which allows more water to infiltrate the ground and take its place. Reducing runoff is not only beneficial for the health of streams and rivers, it lowers the amount of stormwater that goes through wastewater infrastructure. Because many areas have aging stormwater systems, this is an important way to reduce costs and prevent flooding.

The i-Tree suite of tools from the USDA Forest Service and partnering organizations has enabled planners, funders, and everyday citizens to quantify the benefits, costs, and management requirements of urban tree planting. With the free, online software, users can access peer-reviewed urban and community forestry analysis, including assessments of forest health concerns, such as diversity of species, proximity to infrastructure, and impacts of forest pests. In addition, many benefits of trees, such as energy conservation, carbon sequestration and storage, and air quality improvement, can be calculated in terms of dollars, which provides support for the economic advantages of increasing urban canopy cover.

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 426,000 TreeVitalize trees have been planted in urban and suburban areas throughout the Commonwealth. This has provided a reduction in 1.5 billion gallons of stormwater and a savings of $11.8 million; a reduction of 38,400 pounds of nitrogen; sequestration of 217 million pounds of carbon; and a 38 million kWh decrease in electricity consumption and $5.3 million in savings, among other things (DCNR Bureau of Forestry, 2015).

Major obstacles to urban tree planting efforts persist, including lack of knowledge about the cost savings associated with increasing urban forest cover, few stable funding sources, and concerns about maintenance. These can be addressed through a more comprehensive outreach and education program. Home and business owners should be made aware of the numerous benefits of planting trees on their properties, and educators should focus on the little-known monetary savings as a universally appealing topic. Improved coordination with both potential funding partners and homeowners will enable urban and community forestry initiatives to expand and thrive throughout the state, ensuring that more trees are at work sequestering and storing carbon, lowering energy usage, and reducing flooding.

TreeVitalize and other tree-planting programs will also need to adapt to changing climate conditions, promoting trees that can survive better and provide the highest level of integrated benefits. Different tree species sequester carbon at different rates (Nowak et al, 2010), and some trees are better suited to urban and suburban environments than others, so foresters and urban planners will need to modify tree ordinances, species recommendations and best management practices to promote survivability over time as conditions change.

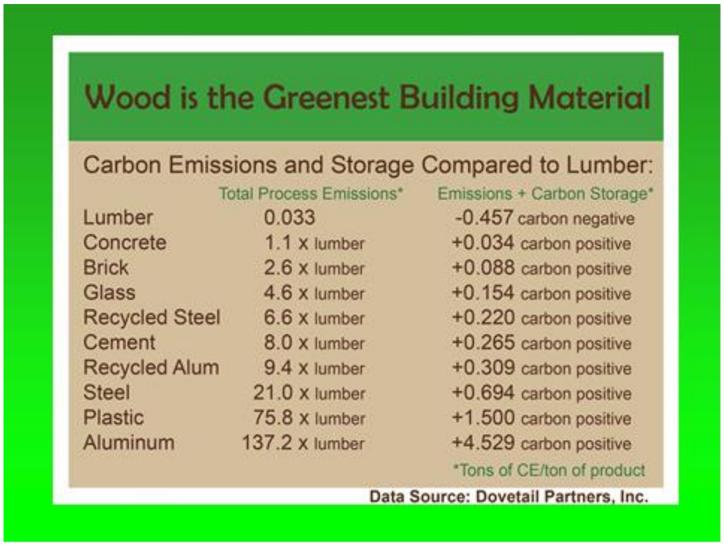
Adoption of the Urban and Community Forestry work plan would result in .915 million tons of CO2e emissions reduced annually in Pennsylvania and a cost-savings of $182.7 million by 2030. The cumulative results from 2015 through 2030 show the potential for 7.32 MMTCO2e emissions to be reduced, while saving over $431 million, for a cost-effective savings of $58.99 per ton of CO2e emissions reduced.

Work Plan 12: Urban and Community Forestry					
2030 Annual			**2015-2030 Cumulative**		
Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/tCO2e)**	**Reductions (MMTCO2e)**	**Total NPV ($MM)**	**Cost-Effectiveness ($/tCO2e)**
.915	-182.7	- 199.8	7.32	-431.60	-58.99

Durable Wood Products

Once wood is turned into furniture, building materials, or other finished products, it continues to store carbon and prevent the release of carbon into the atmosphere. Life cycle analyses of wood harvest, production, transportation and other costs that require energy inputs increasingly show that durable wood production is not only carbon neutral, but can be carbon negative. A 2012 study by PE International, an internationally recognized leader in life cycle analysis in Germany, showed that 19 U.S. hardwood species, from ash to willow, store on average twice the amount of carbon than is expended on felling, sawmill production, kiln drying and transportation of one-inch hardwood lumber from the United States to Japan, one of the most distant markets for U.S. hardwood lumber. When assessed for domestic distribution, the 2:1 carbon storage to carbon release ratio rises even higher.

Locally grown Pennsylvania trees are in demand throughout the world. Pennsylvania is the leading U.S. state for lumber exports, and its cherry and oak lumber still command competitive prices. As a building material, wood outcompetes concrete, brick, glass, recycled steel, cement, recycled aluminum, steel, plastic and aluminum in terms of total process emissions.[77]



Wood is the Greenest Building Material

Carbon Emissions and Storage Compared to Lumber:

	Total Process Emissions*	Emissions + Carbon Storage*
Lumber	0.033	-0.457 carbon negative
Concrete	1.1 x lumber	+0.034 carbon positive
Brick	2.6 x lumber	+0.088 carbon positive
Glass	4.6 x lumber	+0.154 carbon positive
Recycled Steel	6.6 x lumber	+0.220 carbon positive
Cement	8.0 x lumber	+0.265 carbon positive
Recycled Alum	9.4 x lumber	+0.309 carbon positive
Steel	21.0 x lumber	+0.694 carbon positive
Plastic	75.8 x lumber	+1.500 carbon positive
Aluminum	137.2 x lumber	+4.529 carbon positive

*Tons of CE/ton of product

Data Source: Dovetail Partners, Inc.

Despite the fact that wood is a sustainable building material, it has not received preferential treatment as a carbon neutral or carbon negative building material from sustainable building certification programs, such as LEED. Efforts are underway to provide additional information and research to ensure that durable wood products are recognized by architects, planners, and builders as essential green building components.

The Pennsylvania Hardwoods Development Council and others are leading the effort to promote wood as the greenest building material available, particularly when it is grown under sustainable management regimes and logged and manufactured locally to reduce transportation-related emissions. The council and other industry representatives believe that the timber industry has a

[77] See reports by Dovetail Partners for more information, including, "Building with Wood: Proactive Climate Protection."

widespread, but unjustified, reputation of promoting an environmentally destructive practice; this is likely in part due to the perception that equates timber harvesting with the ongoing deforestation of tropical forests. In reality, sustainable forestry practices provide multiple environmental benefits – including carbon storage and sequestration – while being periodically timbered on a sustainable rotation basis, such as that used by DCNR's Forest Stewardship Council-certified forest management regime.

Without any forest management or harvesting, forests that succeed into old-growth do provide diverse habitat and other benefits but begin to slow in terms of their carbon sequestration rate. Younger forests sequester carbon at a faster rate, and without harvest, regeneration must rely on natural processes like wind-throw, fire, and disease to create the forest openings to allow new growth.

While Pennsylvania has lost much of its original wood-based manufacturing base, it has more standing timber resource now than it did in 1955. In 1955, still recovering from the clear-cut of the state at the turn of the 20th century, Pennsylvania had 22.8 million board feet of standing timber. In 2014, it had grown to 114.3 million feet.

Wood supply is not necessarily the limiting factor for durable wood production in Pennsylvania, but the loss of manufacturing – from furniture to finishing to cabinetry – is a concern. Efforts and incentives to bring back more wood-based manufacturing to Pennsylvania – and with it Pennsylvania jobs – will also serve to reduce carbon emissions from transportation costs and promote greater production of durable wood products and markets.

Forest Land Conservation

Conserving healthy, working forests in Pennsylvania has many carbon benefits. Trees store carbon as wood but are also constantly growing and absorbing carbon dioxide from the atmosphere. Sustainably-harvested trees contribute to the pool of durable wood products that continue to store carbon for many decades or centuries.

Pennsylvania is currently holding steady with 60 percent of its land base in forest cover; however, the Commonwealth still loses approximately 40,000 acres each year to development. The steady-state in forest acreage is also not a steady-state in economic or ecological terms; most forest gains come from afforestation of abandoned fields or mined lands, while forest losses are often mixed or more mature forest stands. It is vital to maintain and improve the health and viability of the existing forest through sustainable practices and protection from invasive diseases, insects, plants, and other threats. When forests are converted to other uses, they are no longer able to sequester and store carbon. As DCNR's Statewide Forest Resource Assessment notes, "While economic growth is critical to improving our quality of life, unplanned and poorly planned development negatively impacts natural systems and causes permanent forest loss" (2010).

The wood products industry has long been an integral part of Pennsylvania's economy, thanks to the Commonwealth's large expanses of high-quality forests. For some, the idea of timber harvesting calls to mind the clear-cutting mentality of the late 19th and early 20th centuries, however, timber harvesting goals and methods have progressed far since that era. Now, harvesting is based on scientific research and the development of best management practices through the study of silviculture, a practice used to change the forest condition to meet or support certain needs, such as forest regeneration and sustaining habitat for species of special concern.

A constant threat to sustaining forests is fragmentation, which is the process by which continuous forest is converted to non-forest or becomes separated into smaller, more isolated patches. This process can be cause by natural phenomena, such as forest fires and flooding, or through man-made changes in the landscape, including land clearing, construction, and development projects. Permanent conversion of forest land to a non-forest use has significant disruptive impacts on plant and wildlife populations. Interior, or core, forest areas shrink, and forest edge grows, which increases the susceptibility of the ecosystem to invasive species.

Of the nearly 17 million forested acres in Pennsylvania, approximately 11.5 million are owned by about 738,000 private forest landowners, and the majority of tracts are under 10 acres in size. Land ownership has become increasingly fractured, as older generations split their parcels between multiple heirs. As the number of landowners grows and plot sizes shrink, it becomes increasingly difficult to successfully promote proper stewardship across the landscape and makes it unlikely that forested areas will stay forests.

DCNR's enabling legislation indicates that part of the agency's responsibilities are "to promote and develop forestry and knowledge of forestry throughout this Commonwealth [and] to advise and assist landowners in the planting of forest and shade trees, to obtain and publish information respecting forest lands and forestry in this Commonwealth." This has guided the Bureau of Forestry to develop a plan for community and private forest conservation. DCNR service foresters advise private forest landowners on forest management techniques and practices, and the agency's consulting foresters are contacted when landowners wish to harvest their timber.

Although Pennsylvania has supported the successful Agricultural Conservation Easement Purchase Program since 1988, the Commonwealth does not have a forest conservation easement program. The creation of such a program would enable greater assurance that forests will remain forests in perpetuity, without pressure for development. In line with this idea, DCNR continues to acquire land and give open space preservation grants to local communities. Since 1995, the agency has acquired approximately 140,000 acres of land, significantly expanding the Commonwealth's state parks and forests systems. The Bureau of Forestry has developed a set of strategic priorities for land acquisitions, including: interior holdings or deeply indented tracts that will simplify boundaries and thus make land management more efficient; properties that strategically link existing state forest lands or other public/conserved lands; lands that contain species of special concern or unique habitats or plant communities; and lands that are threatened by development pressure or that will buffer existing state forest land from nearby development.

Loyalsock State Forest (Annie Macky)

DCNR recognizes that there will never be enough resources to simply buy up forests in peril of development, so other measures – including outreach to private forestland owners, easement programs, forest stewardship planning, and other private partners are all necessary to stem forest loss and fragmentation. Permanently protecting and sustainably managing forests is a failsafe way to ensure that they continue sequestering and storing carbon for the long term. It confers greater protection for plant and wildlife habitat and adds to the base of land that can sustainably support a vibrant wood products industry. Conserving forest land through public land acquisitions, forest easements, landowner legacy planning, and other methods is an essential component of alleviating the effects of climate change.

Forest-related Initiatives

During 2015, DCNR began working on two specific initiatives that will further forest-related climate mitigation efforts: the Green Ribbon Task Force on Forest Products, Conservation and Jobs and the formation of a state-level riparian forest buffer program.

The Green Ribbon Task Force was formed in conjunction with the departments of Agriculture and Community and Economic Development to address barriers to job growth in Pennsylvania's forest products industry and to support long-term, sustainable conservation of forests. The team, made up of representatives from industry, nonprofits, academic institutions, government agencies, and other stakeholders, is charged with identifying specific issues faced by the conservation and wood products worlds and, through a collaborative process, developing recommendations to address these issues. Some specific areas of conversation include: private forest landowner engagement, education, and programming; the growing market for forest-based carbon offsets; aligning workforce training opportunities to meet the needs of a modernizing industry; and educating children and the public at-large on the many benefits that forests and sustainable forest management bring to communities.

In an effort to help Pennsylvania meet its EPA-mandated goal of 95,000 additional acres of riparian forest buffers in the Chesapeake Bay watershed by 2025, DCNR and DEP have convened a group of nonprofits, agencies, and academics to discuss current best practices, barriers to success, and innovative ideas to increase future buffer implementation. DCNR is also forming a new state-level program to complement existing programs by appealing to landowners who would require a greater level of flexibility than is currently offered.

Through these efforts, the agency will gather recommendations from experts on the best ways to plant more trees, quantify their benefits, and properly manage them for the future.

Forests: What You Can Do

1. Evaluate your property and determine if additional trees can be planted on site. In addition to sequestering carbon, trees provide energy savings through shade in the summer and wind shielding in the winter.

2. Consider wood as a viable building material for homes, furniture, or other finished products.

3. Maintain the trees and forest resources you have in a sustainable manner. Monitor them for pests and other threats.

Chapter 8: Agriculture

Reduce Energy Use from the Agriculture Sector

Agricultural activities are one of the most important and necessary contributions to society and have the potential to act as both producer and reducer of GHG emissions. Like our forests and forest soils, crops and agricultural soils also sequester carbon. The majority of farming activities, however, result in releasing more GHG emissions than they can store. Transportation, energy usage, feed, pesticides and herbicides, fuel, and emissions released by livestock all contribute to increasing CO2 emissions to our atmosphere. GHG emissions from farms can be summarized into the categories of energy consumption activities and livestock emissions. In addition to simply reducing these farming-related GHG emissions, farms can also help reduce GHG emissions by utilizing their resources to produce energy. This section makes recommendations to help reduce GHG emissions in the areas with the highest carbon footprints, as well as highlights opportunities for alternative energy production on farms.

Globally, the agriculture sector releases significant amounts of GHGs into the atmosphere. Statistics vary, but in 2004, agriculture accounted for roughly 14 percent of all global GHG emissions.[78] According to a 2014 report from the United Nations, global emissions solely from livestock now account for 14 percent of all human-activity-caused GHGs in our atmosphere.[79] Nationally, the EPA estimates domestic agriculture emissions at nine percent of total U.S. GHG contributions. Within Pennsylvania, emissions from agriculture are estimated to be approximately 3 percent of the state's total emissions.[80] Pennsylvania is home to 58,800 farm operations operating 7,720,000 acres of farmland.[81]

Challenges and Opportunities

Fossil fuel combustion, whether it be for electricity generation, transportation, heating use or other needs, results in the release of GHG emissions to the atmosphere. Agriculture can work to reduce its contribution to GHG emissions by managing farm energy usage and by increasing energy efficiency. Farms consume energy both directly and indirectly. Direct energy usage is from the use of fossil fuels and electricity consumption. Fuel is needed for the vehicles and machinery used in planting, tilling, harvesting, and transportation. Electricity is used to run pumps, heaters, fans, for drying crops, and various livestock applications. Comparatively, indirect energy usage occurs when farmers utilize products that have energy-intensive production, mainly fertilizers and pesticides, with fertilizer being the most energy-intensive input on a farm.[82] Overall, direct energy use accounts for 63 percent of a farm's energy consumption, with indirect usage accounting for the remaining 37 percent.[83]

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[78] http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms2.html
[79] http://www.fao.org/news/story/en/item/197623/icode/
[80] 2009 Climate Change Action Plan, 9-1
[81] http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA
[82] "Agriculture's Supply and Demand for Energy and Energy Products," USDA, Pages 9-10.
[83] "Agriculture's Supply and Demand for Energy and Energy Products," USDA, Pages 9-10.

Generally, without other incentives, increases in energy efficiency on a farm are driven by higher energy costs, or a general desire to reduce energy bills. In order to encourage energy efficiency upgrades on farms for environmental reasons and concerns, there will likely have to be greater outreach and support from government agencies and other potential financial supporters of agriculture projects.

Prioritize Energy Efficient Upgrades on Farms

The first step in understanding where to target energy efficiency upgrades is by assessing a farm's current energy usage by having an energy audit performed by an expert. Audits can represent a large up-front cost to the farmer—Penn State Extension estimates that most audits cost upwards of $1,500 for farmers[84]—but there are resources available to reimburse or lower the costs of the audit. The USDA's Environmental Quality Incentives Program provides technical information and financial assistance for on-farm energy audits through their Agricultural Energy Management Plans.[85] PPL Electric Utilities employs an Agricultural Rebates Program, which is currently so popular that there's a wait list. PPL will provide eligible farms with a free energy assessment of on-farm usage and highlight potential savings areas. In addition, PPL offers incentives on some energy savings projects.[86] Finally, Penn State Extension often has ongoing projects and other resources available to farms to assist with energy needs and energy audits.[87]

After an audit is conducted by a professional, farmers will receive specific suggestions for how to increase efficiency, or decrease energy usage, on their farm. Often, these recommendations can decrease a farmer's energy bills by 10-30 percent. However, these potential savings can require expensive equipment upgrades, so energy auditors will show how the savings will pay for the equipment upgrades over time, which aids farmers in their decision-making process. As there are for the audits, there are also funding and cost-share resources available to assist farmers in making energy-saving upgrades to farms. Through USDA's Rural Energy for America Program, farmers can receive loan financing or grant funding to make energy efficiency improvements.[88] Farmers can also apply for project financing and assistance options through the DEP, such as Growing Greener and Pennsylvania Energy Development Authority grants, loans and loan guarantees.[89] There are also third parties, banks, and others that may be able to assist in project funding.

In spite of these cost barriers, focusing on the highest energy usage areas for reductions and improvements will allow farms to see the biggest energy bill savings, while improving their carbon footprint. Simple, universal efficiency fixes are also available and include ensuring the overall maintenance and cleanliness of equipment, especially pumps and motors, replacing older

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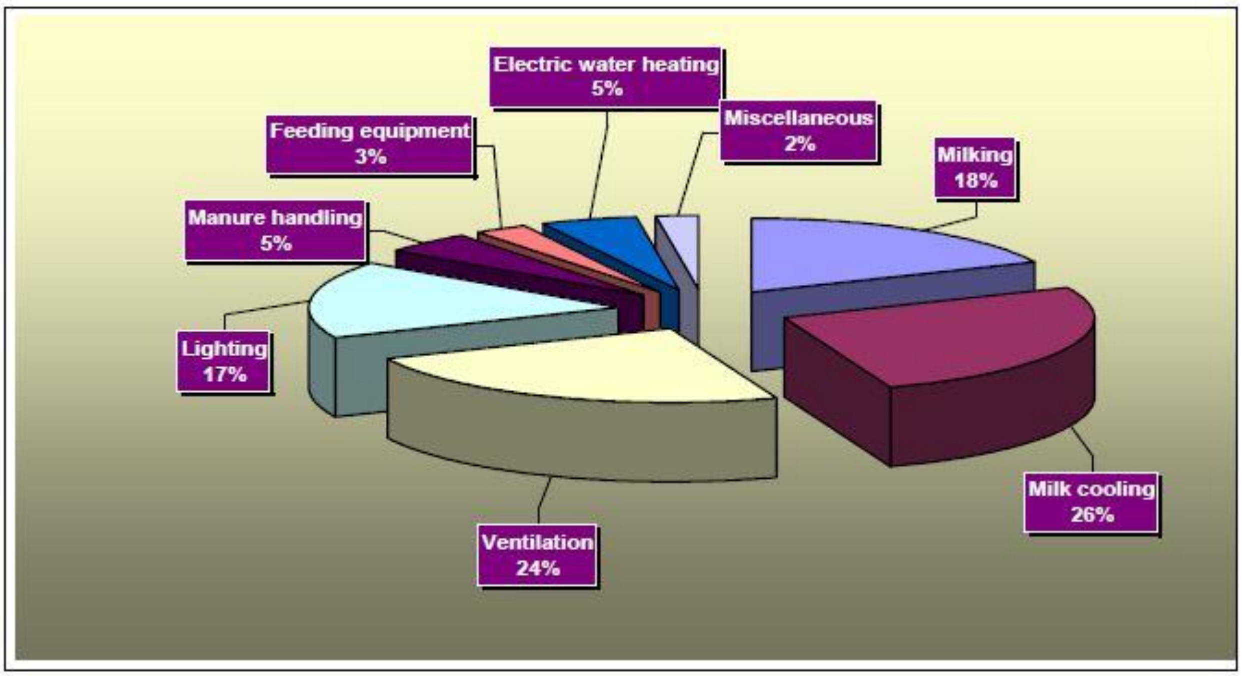
[84] http://extension.psu.edu/plants/tree-fruit/news/2011/energy-efficiency-help-from-the-pennsylvania-farm-energy-audits-program
[85] http://www.nrcs.usda.gov/wps/portal/nrcs/main/wa/energy/
[86] https://www.pplelectric.com/save-energy-and-money/all-rebates-and-discounts/business-and-nonprofit/agriculture-program.aspx
[87] http://extension.psu.edu/
[88] http://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency
[89] http://www.portal.state.pa.us/portal/server.pt/community/grants_loans_tax_credits/10395

lighting with higher efficiency fluorescent and LED options, and utilizing renewable inputs for energy generation.

Dairy Farming

Dairy farming is one of the most prevalent types of farming in Pennsylvania. According to the Center for Dairy Excellence, Pennsylvania has 7,370 dairy farms with an average herd size of 72 cows.[90] Pennsylvania is home to over 530,000 milk-producing cows, compared to 150,000 beef cattle.[91] In addition, Pennsylvania was the only state in the nation that increased in number of dairy farms in 2014,[92] and compared to dairy farming in most of the world, Pennsylvania has high overall yield of milk and meat production, which translates to a more efficient process.[93] Even with this level of efficiency, though, opportunities to reduce energy usage exist due to dairy production's necessary reliance upon electric equipment for milking cows.

Figure 8.1: Breakdown of Direct Energy Usage on Dairy Farms



Source: NATC, Ithaca, NY

Milking, milk cooling, and ventilation account for 68 percent of all energy usage on the typical dairy farm. Penn State Extension suggests dairy farms focus on the following ten areas for the biggest energy savings:

- Variable speed pump for milking vacuum pump
- Pre-cooler to cool milk

[90] http://centerfordairyexcellence.org/pennsylvania-dairy-industry-overview/
[91] http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=PENNSYLVANIA
[92] http://centerfordairyexcellence.org/pennsylvania-dairy-industry-overview/
[93] http://news.psu.edu/story/306497/2014/03/04/earth-and-environment/penn-state-led-project-aimed-reducing-greenhouse-gases

- Recover heat from milk cooler compressors
- Tune-up vacuum system
- Replace ventilation fans w/ high efficiency models
- Upgrade lighting
- Clean the fans
- Replace motors with properly sized, high efficiency motors
- Use variable speed drive for milk pump
- Switch to energy efficient feed storage/delivery system[94]

Several of these suggestions apply to all farms: ventilation and lighting upgrades, fan cleaning, and regular tune-ups for farm equipment will all result in energy cost-savings and reduced carbon emissions from the agricultural sector. The milking-specific suggestions focus on pumps, motors, and refrigeration. Variable speed drives for pumps can result in up to 60 percent energy usage reduction, which can translate into thousands of dollars saved each year. Variable speed drives help pumps run only at the speeds necessary to provide the proper milk output, otherwise the pump will run at maximum speed all the time. Farmers must verify that they are purchasing the correct pump for these variable drives to operate, but most farms who install these pumps will see benefits.

Pre-cooling utilizes cold water, usually from a well, to remove heat from the milk before it enters the refrigeration unit. This pre-cooling reduces the strain on the refrigeration system, reducing the amount of energy the system requires to operate. It may also be possible to recover heat from the milk coolers to divert the heat to a water heater, reducing the energy used by the water heater. Installing horizontal, bunker silos may be a more energy efficient feed system, although some farmers experience feed spoilage and waste, offsetting the cost savings provided by the reduced energy usage.[95]

Crop Farming

For crop farming, farmers can focus on some of the suggestions above, like equipment maintenance, as well as irrigation, reducing tilling activities (discussed below), and changes in grain-drying in order to reduce energy usage. It is estimated that 25 percent of electrical energy used for irrigation pumping is due to waste from poor pump and motor efficiency. Properly sizing, maintaining, and adjusting irrigation systems can reduce energy usage by up to 40 percent. Making mechanical improvements and running the systems when irrigation will be most effective (i.e. timing watering when more water will be absorbed by the soil and plants) help to ensure energy efficiency of the irrigation system.

Grain-drying has been noted to sometimes use more energy than was used to produce the crops themselves.[96] Energy usage can potentially be reduced either through harvest practices or the efficiency of the supplementary drying process (e.g. additional to any natural drying). Selecting

[94] http://extension.psu.edu/publications/h-87/at_download/file
[95] http://extension.psu.edu/publications/h-87/at_download/file
[96] https://www.extension.org/sites/default/files/Field%20Crop%20Production%20-%20Fact%20Sheet%20-%20Grain%20Drying.pdf

hybrid seeds with better standability and faster drydown in fall can be a first step towards reducing energy consumption. Other field practices may also help to increase the efficiency of supplemental drying by reducing particulate matter, such as increasing cut height, which also saves the energy needed to run the combine, and keeping threshing fan speeds high. With supplemental drying, it is important to avoid over-drying and to use the ideal temperature for the seed type and equipment; higher temperatures are typically more energy efficient than lower temperatures. Dryeration systems can also reduce energy usage by up to then percent by allowing grain, after it has been heated and moisture is lost, to sit in a cooling bin and allow the residual heat to continue to remove moisture from the seeds.[97] Aging infrastructure presents an opportunity to support farm upgrades through funding, grants, and loans from government sources.

Continue to Encourage No-Till and Crop Rotation Farming

The soil on farms can act as a carbon sink, meaning it can retain high levels of carbon, preventing its release into the atmosphere as CO2. The best way to keep carbon in the soil is by keeping the earth undisturbed. No-till farming, along with crop rotation, can be the most effective ways to keep CO2 sequestered in the soil. Plants capture carbon from the atmosphere as CO2 during photosynthesis, and some is released back into the atmosphere through respiration, but much of the carbon is deposited into the soil via the root systems. Beyond merely sequestering carbon in soil, no-till methods combined with crop rotation can benefit the farmer by increasing crop yields and reducing the loss of invaluable top soil.

PA's No-Till Alliance reports that 68 percent of Pennsylvania farms currently employ no-till practices.[98] Tilling fields to grow crops has traditionally been done for many reasons. Tilling loosens and aerates top soil layers, mixes previous crop residues into the soil, destroys weds, and dries the soil (sometimes beneficial), all of which generally facilitate seed planting. However, this churning of the soil, when performed by machines, is fuel-intensive.[99] Additionally, there are downsides to tilling: it facilitates erosion and loss of the nutrient-rich top soil, decreases water infiltration, increases fertilizer and pesticides run-off, and reduces the presence of beneficial organisms and organic matter in the soil. All of these negatives result in increased fertilizer, pesticide, and water application, leading to further fuel and electricity uses. Top soil loss is especially costly, as its formation can take hundreds of years, and is the most nutrient-rich soil available to crops; nutrients that end up being replaced by excessive fertilizer application.[100] Soil loss also threatens our ability to grow crops in the future:

> "There are two key issues. One is the loss of soil productivity. Under a business as usual scenario, degraded soil will mean that we will produce 30% less food over the next 20-50 years. This is against a background of projected demand requiring us to grow 50% more food, as the population grows and wealthier

[97] https://www.extension.org/sites/default/files/Field%20Crop%20Production%20-%20Fact%20Sheet%20-%20Grain%20Drying.pdf
[98] http://www.panotill.org/publication_files/pa-farmers-no-till-and-best-management-practices.pdf
[99] http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/crop-rotations-and-conservation-tillage
[100] http://www.ce.cmu.edu/~gdrg/readings/2007/02/20/Pimental_EnvironmentalEnergeticAndEconomicComparisonsOfOrganicAndConventionalFarmingSystems.pdf

> people in countries like China and India eat more meat, which takes more land to produce weight-for-weight than, say, rice."[101]

By eliminating tillage, farmers can slow top soil costs, which reduce future food production's carbon footprint. However, some of the challenges farmers will face in switching to no-till practices are: physical labor increases, having to purchase new equipment to help plant and manage the soil, dealing with leftover, deep root systems, and it can result in lower yields.[102] Although, when a no-till strategy is employed in conjunction with well-planned crop rotations, some of these negatives are alleviated.

Crop rotation is the practice of planting different crops on a certain field every year or couple of years. Benefits include: disease, insect, and weed control; improved soil properties; spreading out the workload of planting; reduced fertilizer input; and, most important to the farmer, increased yields.[103] Growing the same plant-type in a field, year after year, depletes the same nutrients continuously, but leaves behind other nutrients that may be utilized by different crops. Studies performed by Penn State have shown that certain crop rotations can increase corn yields five to twenty percent per acre over continuous corn on the same field.[104] However, market demand and economics may prevent a farmer from employing crop rotations.

All of the benefits of crop rotation and no-till can be further enhanced when utilized together by reducing fuel, fertilizer, pesticide, and water usage, while increasing yields. This requires specific planning, but benefits both the farmer and the environment. As mentioned above, tilling the soil depletes it of nutrients, but the goal of crop rotation is to utilize remaining nutrients of previous crops. This is the main reason why no-till and crop rotation are more effective together: nutrient utilization and fertilizer/pesticide use reduction. In addition, crop rotation planning can include cover crops for the winter that have root systems favorable to the planned spring and summer crops, reducing labor when dealing with old roots during planting. Crop rotation benefits can be seen even under conventional tilling practices, so for farms considering these methods, crop rotation may be the best practice for farms to adopt, initially, and then conservation or no-till practices can be added in the future in the future.

Encourage the Construction of Manure Digesters

As mentioned in the first part of this chapter, global emissions solely from livestock now account for 14 percent of all human-activity-caused GHGs in our atmosphere.[105] "Emissions from enteric fermentation were the greatest contributor to agricultural emissions (40%), followed by manure left on pasture (16%), synthetic fertilizers (13%), rice cultivation (10%), manure management (7%)."[106] Enteric fermentation results from the process by which most animals digest

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[101] http://world.time.com/2012/12/14/what-if-the-worlds-soil-runs-out/
[102] http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/crop-rotations-and-conservation-tillage
[103] http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/crop-rotations-and-conservation-tillage
[104] http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/crop-rotations-and-conservation-tillage
[105] http://www.fao.org/news/story/en/item/197623/icode/
[106] http://www.fao.org/docrep/019/i3671e/i3671e.pdf (Page 22)

carbohydrates. Digestion turns food inputs into products usable by the animal and microbes assist digestion with fermentation. In ruminant animals, such as cows, this fermentation process results in high levels of methane byproducts.[107] There are research efforts to review food options and supplements to help reduce methane production during this fermentation, but much of this research is still in its infancy.[108]

Manure is the other contribution to GHG emissions from livestock operations. Animals must consume a lot of energy to grow, but not all of the energy and nutrients consumed are used by the animal. Some of it is excreted and will breakdown into gasses and nutrients (utilized as fertilizer). All decomposition of organic matter occurs via the actions of aerobic and anaerobic organisms. For manure, controlled anaerobic digestion will convert animal waste into biogas and low-odor solids. These solids can usually be applied to fields as low-odor fertilizer, while biogas can be captured and used as energy. Biogas is generally comprised of 60-70 percent methane, 30-40 percent CO2, and trace amounts of other gases.[109]

Anaerobic digestion is a biological treatment process that breaks down manure, thereby producing biogas which can be converted to heat or electrical energy, improving the storage and handling characteristics of manure, and possibly reducing manure odor. The associated work plan recommendation analyzes the potential for increasing anaerobic digester deployment at medium to large-sized dairy and swine farms.

Anaerobic digesters utilizing animal manure on farms represent two opportunities for decreasing climate change: (1) Reducing the amount of methane released into the atmosphere from traditional manure management practices and (2) generating energy for on-farm use, replacing varying amounts of fossil fuels.[110] Other benefits of manure digestion are odor reduction, which local communities appreciate, and the sale some of the "cleaned" manure for animal bedding.

Currently, Pennsylvania houses 29 manure digesters, mostly on dairy farms because dairy cows produce higher methane emissions. These digesters work by controlling the way in which manure biodegrades. Methane-forming bacteria feed on the liquid organic compounds and release methane gas, which is then captured and either utilized on the farm or sold to a utility company.[111] Some farmers have been able to save over $60,000 per year by using the biogas produced in their manure digester.[112] Additionally, these digesters produce "biologically derived methane gas," which is defined as a Tier I resource under the Alternative Energy Portfolio Standards Act.

However, manure digesters are very costly and require a certain amount of space on the farm. To better understand these cost and space considerations, Penn State Extension provides various resources and has developed a checklist to help farmers determine whether anaerobic digestion is

[107] http://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s04.pdf
[108] http://extension.psu.edu/animals/dairy/nutrition/nutrition-and-feeding/diet-formulation-and-evaluation/carbon-methane-emissions-and-the-dairy-cow
[109] "Managing Manure with Biogas Recovery Systems," EPA, The AgSTAR Program.
[110] "Managing Manure with Biogas Recovery Systems," Page 7.
[111] http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/projects/g-77
[112] http://www.popularmechanics.com/science/environment/a3889/4285577/

a good option for their farm.[113] Additionally, the EPA AgSTAR program provides funding resources and guidance to farmers interested in installing anaerobic digestion equipment. The AgSTAR program is the best place to start when considering manure digesters. Among their many tools, AgSTAR provides financing modelling and resources to help determine project feasibility. Rural Energy for America Program funding is also available for manure digester project, with grants up to $500,000 and loans are also available.[114]

The legislature should consider establishing or expanding state-funded programs related to digesters. As discussed in Work Plan 13, measures should be taken to incentivize farms to install digesters. Existing funding programs through the Commonwealth Financing Authority and Pennsylvania Energy Development Authority should be continued and expanded.

Work Plan 13: Manure Digesters - Dairy					
2030 Annual			**2030 Cumulative**		
Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/MTCO2e)**	**Reductions (MMTCO2e)**	**Total NPV (2014 $MM)**	**Cost-Effectiveness ($/MTCO2e)**
.2543	-5.994	-23.57	2.0347	.384	.19

Work Plan 13: Manure Digesters - Swine					
2030 Annual			**2030 Cumulative**		
Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/MTCO2e)**	**Reductions (MMTCO2e)**	**Total NPV (2014 $MM)**	**Cost-Effectiveness ($/MTCO2e)**
.0379	-.025	-.651	.3146	8.363	26.58

Encourage the Growth of Bioenergy Crops

Farmers can further create their own energy, and contribute to GHG emissions reductions, by growing certain crops that can be used to generate electricity. This type of fuel is known as "biomass," a term that includes plant materials and animal wastes and is considered a sustainable and renewable source of energy. An example of biomass most people are familiar with is burning wood in a fire. However, some biomass burns more cleanly than others, releasing far less carbon into the atmosphere than others; the best candidates for biomass are explained below. Biomass can be converted into liquid fuels, such as ethanol or biodiesel, or burned along with fossil fuels in power plants in as process called "co-firing" to reduce overall emissions. This section focuses on biomass co-firing.

[113] http://extension.psu.edu/natural-resources/energy/waste-to-energy/resources/biogas/projects/g-77
[114] http://www.usda.gov/wps/portal/usda/usdamediafb?contentid=2015/02/0034.xml&printable=true

Coal co-firing is the most common use of biomass in co-firing, and coal can be efficiently co-fired with biomass around an 80:20 ratio (coal to biomass). Some research is looking to increase the biomass component to 30 percent of the co-firing, but 20 percent biomass remains standard.[115] Modifications to the power plants to accommodate biomass are generally minimal, with changes mostly addressing the processing, handling, and storage of biomass. Co-firing can occur by either blending the biomass and coal before injecting the fuel to be burned, or each component can be injected separately. The decision on which approach to choose rests on modification requirements or the abilities of the power plants.[116]

Sources of biomass can include forestry activities, agricultural crop residues, wood construction residues or storm debris, and even some residual waste. "Energy-dedicated crops"—crops grown for the specific purpose of being used as an energy source—present an opportunity for farmers to make money while reducing other's GHG emissions.

Switchgrass is the most promising biofuel in terms of GHG emissions in co-firing. It grows rapidly, is native to Pennsylvania, and is relatively hardy and resilient. Switchgrass also protects soil, water, and air quality as it grows.[117] Willows are another fast growing and sustainable option for biomass energy.[118] These types of crops, as opposed to timber and food crops, are expected to provide more sustainable options and less impact on food supplies. In Pennsylvania, Act 95 of 2012 (relating to mining) requires the DEP to encourage and promote the use of switchgrass, camelina, canola and other bioenergy crops for the revegetation of lands affected by surface mining activities. The land used for this purpose will be considered cropland for post-mining land use purposes.

Agriculture: What You Can Do

Food waste represents energy waste and creates avoidable climate impacts. The most commonly seen estimate is that around 40 percent of all food is wasted. Almost half of everything farmers work to create ends up in the garbage, which then goes to a landfill and will decompose and release methane. The best action all Pennsylvanians can take to prevent climate change is to reduce the amount of food waste we produce.

115 http://www.eesi.org/files/cofiring_factsheet_030409.pdf
116 http://www.eesi.org/files/cofiring_factsheet_030409.pdf
117 http://www.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production#.VhbCZZdIngo
118 http://www.nrdc.org/energy/renewables/biomass.asp

Chapter 9: Waste Management

Reduce Fugitive Emissions from Waste Disposal and Processing Facilities

Currently, Pennsylvania is home to 43 municipal waste landfills, 3 construction and demolition waste landfills, 6 resource recovery facilities (waste-to-energy combustion), 95 material recovery facilities, approximately 260 composting facilities, and 14 permitted digesters for manure and food waste. In addition, DEP authorizes the processing or beneficial use of certain waste materials to a number of facilities through its general permitting program, and many small operations are permitted by rule.

Challenges and Opportunities

Most of the organic materials that are placed in landfills ultimately decay and become a source of methane emissions. In addition, landfills operate as a sink for certain organic and man-made materials. The EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, published in February 2014, ranks landfills as the third largest source of human-related methane emissions in the United States, accounting for approximately 18 percent of methane emissions in 2012. As documented in Chapter 3, Pennsylvania's landfills had a net negative GHG emission rate in 2012. In fact, the White House's recent *Climate Action Plan, Strategy to Reduce Methane Emissions* cited a Pennsylvania landfill as the national case study on how to reduce GHG emissions from landfills. Landfills produce "biologically derived methane gas", which is defined as a Tier I resource under the Alternative Energy Portfolio Standards Act, when used to produce electricity.

Pennsylvania can further reduce methane emissions from waste disposal activities by preventing illegal dumping and open burning of waste; encouraging and eliminating barriers to recycling, employing best management practices to reduce fugitive emissions from landfills; removing barriers to encourage expanded use of collected landfill gas as alternative energy sources; co-locating industrial facilities with waste-to-energy facilities; and continuing to explore alternate technologies for the management of organic wastes.

Pennsylvania's municipal waste and air quality regulations require landfills to implement fugitive air contaminant control measures and otherwise prevent and control air pollution in accordance with the Air Pollution Control Act. To comply with these regulations, all active landfills have gas management systems. These systems are designed, using radius-of-influence engineering calculations to collect 100 percent of the landfill gas that is generated under normal operating conditions and typically collect 75 to 99 percent of the total amount of landfill gas that is generated over the lifetime of the landfill. The collected landfill gas is either beneficially used or destroyed using an enclosed flare.

The DEP Bureau of Air Quality issued the *Best Available Technology and Other Permitting Criteria for Municipal Solid Waste Landfills* policy to ensure that Pennsylvania's landfills minimize all emissions. The requirements are considerably more stringent than current federal requirements, as they require Pennsylvania landfills to collect and control methane from smaller landfills, and they require all landfills to collect gas sooner after waste deposition, than federal law.

Landfills report methane emissions annually to the DEP's Bureau of Waste Management on the Landfill Gas Collection and Beneficial Use Data portion of the Annual Landfill Report, Form 2520-FM-BWM0167. The reported emissions are based on the minimum overall collection efficiency of the landfill gas management system allowed under the landfill's permit and the combustion efficiency of beneficial energy use projects and flares. Landfills also report GHG emissions, including methane emissions, to the EPA using the methods and procedures set forth in 40 CFR Part 98. These emission estimates, like those reported to the Bureau of Waste Management, are calculated values rather than a measured amount.

Dispose of Waste Properly

In 2011, the Keep Pennsylvania Beautiful program identified nearly 5,800 illegal dump sites in Pennsylvania, accounting for more than 17,000 tons of illegally dumped trash. In addition, in many communities, open burning of waste by citizens is allowed. Eliminating illegal dumping will reduce GHG emissions, which occur when the waste in these sites breaks down without any gas collection or control. Similarly, banning the open burning of municipal waste by residents will significantly reduce GHG emissions, because open burning generates significantly more GHG emissions than disposal through permitted landfills or waste-to-energy facilities.

Encourage and Expand Access to Recycling

Recycling offers significant GHG emissions reductions and is preferable to disposal. When products are recycled, energy is conserved from manufacturing products using recycled feedstock rather than virgin raw materials. Aluminum, steel, cardboard, and paper provide the maximum GHG emissions reductions. In particular, by recycling paper and cardboard, carbon-sequestering trees are also saved.

Act 101 of 1988, the Municipal Waste Planning Recycling and Waste Reduction Act, provides the foundation for recycling and has resulted in comprehensive environmental and economic benefits for Pennsylvania. However, access to recycling infrastructure in rural areas remains a significant issue across the state. Requiring recycling programs for smaller populations and densities would capture more recycled materials. Similarly, requiring consumers to recycle where it is available would divert waste from disposal.

Employ Best Management Practices to Reduce Fugitive Emissions from Landfills

Under Pennsylvania's current municipal waste management program, several best management practices can and are typically implemented in active landfills to reduce the fugitive methane emissions. Pennsylvania can encourage landfill design and operation to reduce the acreage of uncapped cells containing waste that has been in place for greater than one year to decrease the amount of methane escaping from the surface of the uncapped landfill; the DEP best available technology policy generally requires gas collection from areas with waste in place more than one year. Gas collection wells are also typically installed in active uncapped cells pursuant to the policy and as set forth in air permits issued to landfills by the DEP Bureau of Air Quality.

On August 14, 2015, EPA proposed "Standards of Performance for Municipal Solid Waste Landfills" (40 CFR Part 60, Subpart XXX) and the proposed Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart Cf)." These federal proposals are designed to update standards to reduce methane emissions from new and modified (proposed Subpart XXX) and existing (proposed Subpart Cf) municipal solid waste landfills.

All of EPA's New Source Performance Standards (NSPS) and emissions guidelines promulgated under Section 111 of the Clean Air Act (such as proposed Subparts XXX and Cf) are automatically adopted and incorporated by reference in their entirety in the *Pennsylvania Code.* Consequently, EPA's final standards and guidelines will take effect in Pennsylvania on the same effective date for the federal rules. Pending the issuance of new or amended plan approvals and operating permits, if necessary, owners and operators of affected sources would be obligated to comply with the requirements to reduce methane emissions from new, modified, and existing municipal solid waste facilities in the Commonwealth. EPA's final emission guidelines will obligate DEP to develop a state plan to implement and enforce the guidelines or seek delegation of the federal plan following promulgation by EPA.

As currently drafted, it is unlikely that any landfills in Pennsylvania will require permit amendments to implement the "best system of emission reduction" for controlling, minimizing and eliminating landfill gas emissions including methane emissions from municipal solid waste landfills as they already are required to meet more stringent requirements under the DEP best available technology policy than are set forth in the proposed Subparts XXX and Cf. Permits issued by DEP may require enhanced routine inspection and maintenance programs to identify potential problems before leaks occur, although most DEP regions have been including such programs in permits issued or renewed since the issuance of the DEP best available technology policy. Leak detection and repair programs with an increased monitoring frequency will ensure timely repair of leaks to reduce fugitive emissions.

Upon issuance of the EPA final emission guidelines, Pennsylvania will initiate the development of a state plan to implement the guidelines, including methane emission control and reduction measures for municipal solid waste landfills.

Encourage the Use of Collected Landfill Gas as an Alternative Energy Source

Through the Landfill Methane Outreach Program , EPA encourages the reduction of methane emissions through voluntary programs – partnering with industry, state and local leaders, many of whom are putting the methane to use powering their communities. To this end, DEP could expand outreach efforts to broaden participation in this effective voluntary program. According to EPA, 645 landfill gas-to-energy projects were operational across the country (including 42 operational projects in Pennsylvania) as of March 4, 2015. EPA has also identified eight landfills in the Commonwealth as candidates for this voluntary program. Pennsylvania is currently ranked third in the country in the beneficial use of landfill gas.

Pennsylvania has the existing regulatory authority for the collection of landfill gas under the Solid Waste Management Act, the Clean Air Act, the Air Pollution Control Act, and their implementing regulations. In 2013, based on annual reports filed with DEP's Bureau of Waste Management (BWM), these landfills collected 58,789 million standard cubic feet per year (MMscfy) of landfill gas (590,569 tons of methane). Sixty-three percent of the collected landfill gas was beneficially used through 26 gas-to-electricity projects, which used 28,056 MMscfy of landfill gas to power 275.5 MW of electric-generating capacity. Additionally, 15 direct-use or high BTU projects used 9,139 MMscfy of landfill gas. The remaining 37 percent of the collected landfill gas was burned in a flare. Pennsylvania can continue to encourage the utilization of collected landfill gas to generate energy and provide an alternative source to natural gas by supporting permitting processes for the beneficial use of landfill gas, implementing programs and upcoming initiatives established by EPA and prioritizing projects with enhanced renewable energy technologies. The Public Utility Commission recently approved regulations that will limit net metering from facilities, such as landfills, such that these facilities do not size their systems to more than 200 percent of their own needs, without being considered a utility. This new regulation does not prevent landfills from sizing their electricity generation systems larger but it does limit the additional economic incentive that otherwise would have been provided via net metering, towards the development of landfill gas-to-energy (LFGTE) 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.

Continue to Explore Alternate Technologies for the Management of Organic Wastes

Anaerobic digestion is most commonly used for manure management, but it's a technology that is being expanded to the waste sector. The potential exists to manage larger amounts of waste more efficiently and with greater output by encouraging the siting of regional digesters utilizing thermophilic anaerobic digestion. Some manure would still be used as feedstock, but the remaining material could be organic-containing wastes such as food waste, yard waste, sewage sludge, or the organic fraction of municipal solid waste. This form of waste management has the ancillary benefits of diverting more material from the landfill, reducing nutrient run off, and providing high quality organic matter as a by-product that can be used as a soil amendment. Pennsylvania could incentivize use of this technology through streamlined permitting processes, grants/loans, and facilitating purchasing agreements with utilities for electricity and direct heat provided by digesters. The Department created Waste Management General Permit WMGM042 for using food waste in anaerobic digesters.

Waste-to-energy technology plays an important role in managing solid waste, and has multiple benefits including energy production, preservation of landfill capacity, and reduction of methane emissions. Currently, there are six resource recovery facilities in Pennsylvania that annually incinerate approximately 3.2 million tons of municipal solid waste, which generates approximately 270.6 MW of electricity.

Waste: What You Can Do

1. Be a mindful consumer.
    a. Buy only what you need; approximately 40 percent of all food ends up in the waste stream and look for items with minimum packaging.
    b. Buy for durability; Look for things which will last a lifetime.
    c. Buy used; reusing is a far higher purpose than recycling or disposal.
    d. Buy items made from recycled goods; Goods made from recycled materials generally require less energy to make and help fund recycling operations

2. Recycle as many products as possible.

3. If disposal of waste is necessary, do it properly. Don't dump it illegally and don't burn it at home. Ban the Burn Barrel!

Chapter 10: Macroeconomic Analysis

The DEP engaged the Center for Climate Strategies (CCS), the non-profit which supported Pennsylvania's prior climate action planning process, to complete analyses of the likely impacts of 12 work plans on the broader Pennsylvania economy. CCS worked with DEP staff to review the existing analyses (which are the basis for the estimates of each policy's GHG reduction effectiveness and cost-effectiveness) in order to develop a basis for macroeconomic analysis. This executive summary describes the process and summarizes the results. Individual discussions providing more detail about the modeling and results are included separately within this report as part of the description of each work plan.

The CCS has led climate action planning and analytical efforts similar to this effort for over ten years, guiding over 20 states and over a dozen foreign jurisdictions through planning and analytical efforts. CCS has recently carried out very similar dedicated macroeconomic analyses for collections of policies in Washington, Oregon, Minnesota and Southern California, and has completed macroeconomic analyses in the majority of its climate action planning efforts.

Role of Macroeconomic Analysis

Climate policy analysis often includes an assessment of the direct financial losses and gains likely to be associated with a given policy. Policymakers and decision-makers frequently seek to understand how regulated parties will be affected by any combination of cost increases or decreases, additional or lowered compliance costs, subsidies or taxes, and many other potential financial changes that policies can bring about. Cost-benefit analysis practices seek to expand the understanding of policy impacts beyond these direct impacts by including assessments of some indirect or distributed benefits as well. Social costs of carbon and value assessments of the health benefits of reducing emissions of a certain pollutant are examples of indirect or non-monetary impacts often included in such assessments.

Macroeconomic analysis is distinct in that it seeks specifically to understand how the direct financial and economic impacts of a policy drive responsive changes throughout the rest of the economy, and how those direct and responsive changes all contribute to a single overall change to an area's total employment, consumption, production and earnings levels. These are most commonly expressed as the number of jobs supported by a region's economy, and the estimate of a region's gross domestic product (GDP).

Though there are many dynamics through which different actors in the economy interact, one important way in which changes move quickly between sectors is through *intermediate demands:* the demands that producers of goods and services make on one another in order to deliver their own goods and services to market. Increasing or reducing needs for a good or service will, in turn, increase or reduce the need for all the inputs required for its production. Those inputs can come from all around the economy. Each of these inputs will have its own demand for inputs as well, and those inputs will, in course, have inputs of their own. By following these linkages (almost always in the form of specialized software packages), macroeconomic models are capable of quantifying projections of how a change in one sector will affect every other sector.

A second important way that changes translate through the economy (and one that factors heavily in some of the work plans) is *changes in consumer spending*. Consumers spend on a very wide range of products and services, ranging from basic needs such as food, clothing, shelter, and transportation to a comprehensive range of investment and consumption choices. If a policy influences the level of money available to households to be allocated without restriction, that policy will immediately drive changes in demand in an impressive array of sectors around the economy.

A third important way that changes translate through the economy (and one that factors heavily in some of the work plans) is *changes in consumer spending*. Consumers spend on a very wide range of products and services, ranging from basic needs such as food, clothing, shelter, and transportation to a comprehensive range of investment and consumption choices. If a policy influences the level of money available to households to be allocated without restriction, that policy will immediately drive changes in demand in an impressive array of sectors around the economy.

Summary of Methodology

The first step in this process was a full review of each policy's descriptive documentation and spreadsheet analyses which informed the emissions-reduction and cost-effectiveness impacts. It is from these documents that CCS developed (a) the quantified estimates of expenses, savings, and cost and price changes, and (b) understandings of which actors are expected to be on the supply and demand side of each changed financial flow or cost/price change.

The second step was the development of a full list of macroeconomic modeling inputs, which represent not only the spending, savings and cost/price changes, but also the necessary responsive changes to keep financial flows balanced. For example, if a given policy calls for consumers to spend $10 on equipment and save $20 on energy, there is a net gain of $10 to consumers (which they will spend or otherwise put to use), a net gain of $10 to sellers of the equipment (which they will also put to use), and a $20 loss to the energy supplier (which will require some adjustment for the supplier to absorb). Not only the original spending changes driven by the policy but also these responsive actions must be identified and quantified.

The third step was to utilize the REMI Policy Insight Plus macroeconomic modeling software, which is a dynamic economic forecasting model specific to the Pennsylvania economy and capable of modeling changes to 160 distinct and interconnected productive sectors. This software is the current leader in future scenario economic modeling power, and CCS analysts have significant experience utilizing this tool for GHG policy analysis. It is from this modeling effort that all results presented in this report were developed.

Throughout this effort, CCS bound the macroeconomic modeling work to a requirement to be consistent with the pre-existing analysis, assumptions and design of work plans. This is a significant principle, and is necessary to ensure that the macroeconomic analysis represents the work plan rather than some other policy with different parameters. Crucially, all assumptions about effectiveness and scale of these policies were retained from the cost-effectiveness analyses. The only independent decisions about design made as part of the macroeconomic analysis had to do specifically with modeling economic impacts. As such, the policy outcomes and projected policy effectiveness were defined before the macroeconomic analyses, and these analyses represent projections of the economic impacts when those outcomes occur. CCS did not, as part of this process, independently assess or verify the likely effectiveness of the emissions-reduction or cost-effectiveness analysis.

It is also worthwhile to keep in mind that while models predict values in extreme detail, the reporting here represents a decision to round results to a level of precision more appropriate to the circumstances. Projections of economic impacts 15 years in the future are automatically of low precision because many underlying assumptions (such as energy prices, technological advancement, and worker productivity) are highly unpredictable – as is the overall size of the economy so far in the future. As such, results were rounded significantly, and results close to zero are described as neutral, meaning that no clear impact of any significance can be reasonably inferred from such a result. The most valuable information to be taken from these results is an understanding of the direction and the intensity of the pressure each policy can be expected to put on levels of overall economic activity.

Summary of Results

The tables below summarize the three most common indicators of total economic impact from a policy: jobs created or lost, gross domestic product increases or reductions, and gains or losses in personal incomes.

There is a general theme to these results. A great many of the work plans seek to create emissions reductions through investments in efficiency-producing equipment and capital. Everything from boilers, insulation, heavy-truck aerodynamics, shade trees, advanced lighting and equipment, geothermal systems and CHP systems are used to reduce the need for fossil fuel consumption while retaining the same level of activity as before. This approach actually tends to produce a distinctive pattern of results, characterized by the following:

- *Improvements in indicators of individual and household welfare*. Total employment often rises as mandatory spending on energy falls, as a consequence of spending being redirected to more labor-intensive efforts. Disposable income categories also often rise. These changes even sometimes drive projections of greater in-migration as the lowered costs of living and higher employment draw residents.
- *A reduction in total economic activity*. Efficiency policies that dramatically reduce energy use do end up reducing the total amount of goods & services produced and consumed. So while employment rises, GDP and output levels often fall as a consequence of so much less demand for (and production of) energy. Also, while total income may well rise with employment, it may well fall instead. This is because a shift of the economy away from energy may displace higher-paying jobs than it creates, offsetting the net gain in total jobs.
- *Early pain and longer-term benefits for businesses*. The initial costs to business of investment do drive up costs, which typically hurts the capacity for competitive expansion or growth. However, as the capital is eventually paid off and the benefits of

lower costs from the efficiency measure begin to accumulate, the impacts shift from negative to positive as operating costs decrease below the no-policy scenario.

High-Performance Buildings: An Example of Efficiency Policy Impacts

CCAC Work Plan 7: High-Performance Buildings is the second largest driver of economic changes of all the work plans, and its impacts are two to four times larger than those of any other single policy, except for Act 129. It drives employment impacts of several thousand new jobs above business as usual and GDP/income impacts in the hundreds of millions – or even billions – of dollars.

This policy is also exemplary of the efficiency-policy pattern described above, in that it drives both employment and incomes upward while driving GDP dramatically downward. The fall in GDP is driven by a dramatic reduction in spending on utilities. (Because GDP is calculated by measuring the dollars spent in the economy, a scenario in which the economy spends far less on electricity will have at least one strong downward influence on GDP.) The rise in employment reflects (a) employment increases due to the large amount of money spent in construction and equipment manufacturing to improve buildings, as well as due to the structural advantage to the economy of lower costs of production caused by the greater efficiency over time, and (b) employment losses in the utilities sectors, which are facing significantly lower demands under this policy scenario and are not likely to maintain the workforces they had when producing much less output.

To see how these competing influences individually impact the economy, it may be useful to pull this analysis apart. The High Performance Buildings Work Plan includes three major drivers of economic change:

1. Spending on new equipment and installation to make buildings more energy-efficient;
2. Significant energy use reductions, as a result of the greater efficiency of buildings; and
3. Responsive spending and investment changes – the money saved on electricity is now available for spending or investing by businesses and consumers, while the money spent on equipment must be found by reducing spending and investment.

The isolated impact of the reductions in energy use, when modeled alone, is to produce a forecasted drop in GDP of approximately $2.8 billion and an employment drop of nearly 11,000 positions statewide by 2030.

By contrast, the isolated impact of what happens when all the money saved is redirected to other spending drives a gain of nearly $1.6 billion in GDP by 2030, and a gain of over 17,000 jobs. What is remarkable is that the GDP impact is not enough to replace what was lost by cutting energy use, but the employment impacts were far more than enough to replace the lost positions.

There is a third component: the spending on new equipment. Businesses and homes have to absorb costs, and cut other spending, to buy a combination of construction and equipment. The analysis of these expenditures (along with the increases in business operating costs and reductions in consumer spending they require) produce a forecast of a small gain in GDP - maybe a quarter of a billion increase – and a growth in employment of approximately 2,500 new positions.

One key observation from these results is that other spending is more jobs-intensive than energy spending. Prices also fall, so buying power (after inflation and taxes) rises even more than incomes. But GDP (which is a simple measure of how many dollars move around the economy) does not rise. Despite that, there are more total jobs, people earn more money, and their dollars go farther.

The nature of a state's energy economy also influences these results. A state that has much of the supply chain for its own energy (coal mining, specifically) within its borders is going to see less demand not only for the final product (electricity) but also intermediate steps to that product (such as mining and activities that support it). As a result, total economic impact of lowering energy use will be more negative than in a state like Minnesota, where the mined coal is 100 percent imported. More generally, it is valuable to understand the impact of changing imports rather than changing domestic production. Exports are additive to GDP, and imports are negative. By displacing an import with domestic production, GDP can be made to grow even if no new money is spent. If you displace a heavily domestic industry, however, it's hard for GDP to rebound. Shifting to imports reduces GDP, even if total dollars spent do not change.

It's useful to consider that the energy sector is expected to be less and less dependent on labor even without any of these policies. Electricity is forecast to be about half as labor-intensive by 2030 as it is today. So while it will continue to spend, and earn, a lot of money, it will be less a driver of jobs and incomes with each passing year. This is part of why the non-GDP variables improve so much - the other sectors that gain are more labor-intensive already, and the gap widens as time goes on.

A great many efficiency policies have this profile of results: Everything gets better except GDP. This discussion is offered as a way to gauge the varying interpretations such an outcome can produce. Some points of view will find any policy with the potential to reduce GDP to be unappealing by virtue of being threatening to a benchmark metric. Other points of view dispute that total volume of dollars is the best measure of economic welfare and prosperity. The two might read different meaning in these results, and so an understanding of how key inputs produce key outcomes is valuable.

Act 129: The Largest Single Driver of Economic Benefits

CCAC Work Plan 2: Act 129 Phases IV and V also would achieve distinctive results by funding a set of subsidies and incentives through a surcharge on utility bills. The surcharge functions like a price increase on electricity. While price increases tend to exert downward pressure on total economic activity, the Act 129 policy returns the full volume of surcharges back into the economy in ways that overwhelm that downward influence with larger positive impacts. The initiative directs the majority of the funds to direct employment by utilities of a steadily increasing number (in the thousands) of administrators, marketers, designers, developers, auditors and evaluators within the state. The remainder of the funds are delivered back to the consuming public as lower prices on appliances and energy-efficient equipment. The net impact of these three influences – higher prices felt on utility bills, lower prices felt on efficient appliances, and expanded total employment by utilities as a result of the program – is significantly positive.

This is more directly a consequence of the direct employment initiative than it is of the efficiency impacts. The direct employment is far larger in scale (in terms of total dollars) than the electricity savings. Also, the GDP growth is fundamentally a consequence of the direct hiring, rather than the efficiency gains – in fact, as we see with other policies, efficiency achievements often impose downward pressures on total GDP, as people spend fewer dollars in order to get the same lighting, heating, cooling, refrigeration or other services they buy energy to obtain.

This policy differs from the High Performance Buildings Work Plan in that it doesn't drive a decline in GDP, even though it is a policy focused on efficiency. The reason has to do with the scale of its drivers of economic change. In terms of economic impacts, the Act 129 Work Plan is most powerfully characterized by the surcharge placed on utility bills and the direct hiring of staff carried out by electric distribution companies (EDCs), with the majority of the funds collected through that surcharge. The other direct changes it creates – the incentives paid around efficient equipment and appliances and the total energy savings produced from the efficiency – are actually much smaller in scale. So while there is an efficiency component reducing demand for energy, which has a downward influence on GDP, the presence of far larger increases in general consumer spending as EDCs employ thousands of new people is strong enough as a positive driver to overwhelm that efficiency impact – and the price impact imposed by the surcharge as well.

The comparison of how the High Performance Buildings Work Plan and the Act 129 Work Plan produce their impacts is a valuable insight into how efficiency policies more broadly can be understood to influence the economy.

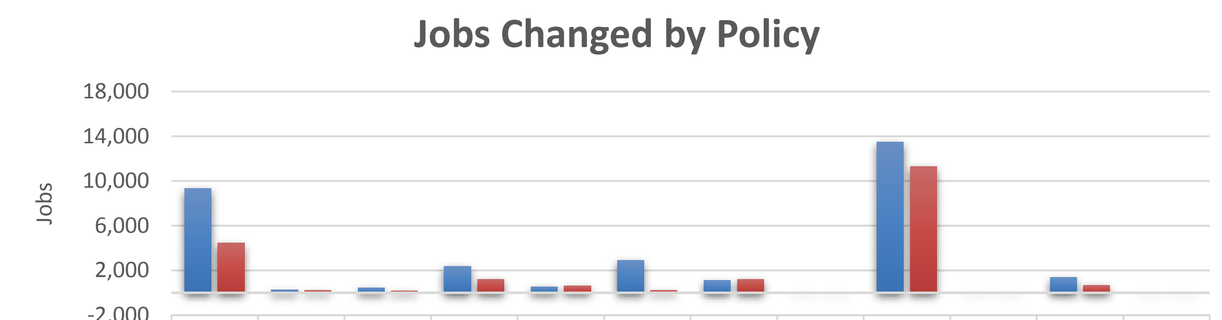
Impacts of the Twelve Work Plans on the Pennsylvania Economy

Below are several tables showing the forecast impacts of the 12 work plans on the Pennsylvania economy from 2016 to 2030. The tables focus on total employment (both full-time and part-time), total GDP, and total incomes. Incomes are further examined by showing a value called "real disposable income" (RDI), which measures income after inflation and taxation changes are taken into account.

In the tables, the work plans are referred to as follows:

- HPB: High Performance Buildings
- UCF: Urban & Community Forestry
- CHP: Combined Heat & Power
- GEO: Geo-Exchange Systems
- HOFW: Heating Oil and Fuel Switching
- REL: Re-Light PA
- BC: Building Codes
- MD: Manure Digesters
- A129: Act 129, Phases IV and V
- CMM: Coalbed Methane
- FT: Freight Trucks Efficiency
- Meta: Manufacturing Energy Technical Assistance

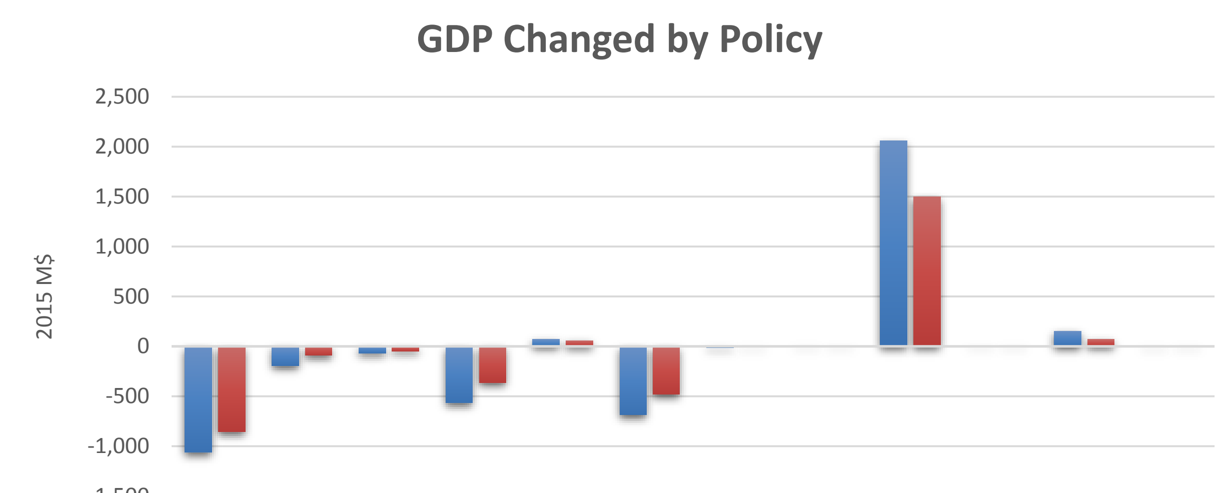
Table 1: Employment Changes



	HPB	UCF	CHP	GEO	HOFW	REL	BC	MD	A129	CMM	FT	Meta
2030 Jobs	9358.58	267.37	452.04	2372.66	531.86	2902.77	1093.11	49.28	13495	62.34	1350.86	-33.03
Avg. Jobs	4442.68	218.27	197.64	1219.39	619.79	219.17	1213.79	20.93	11305.0	87.48	674.48	-24.55

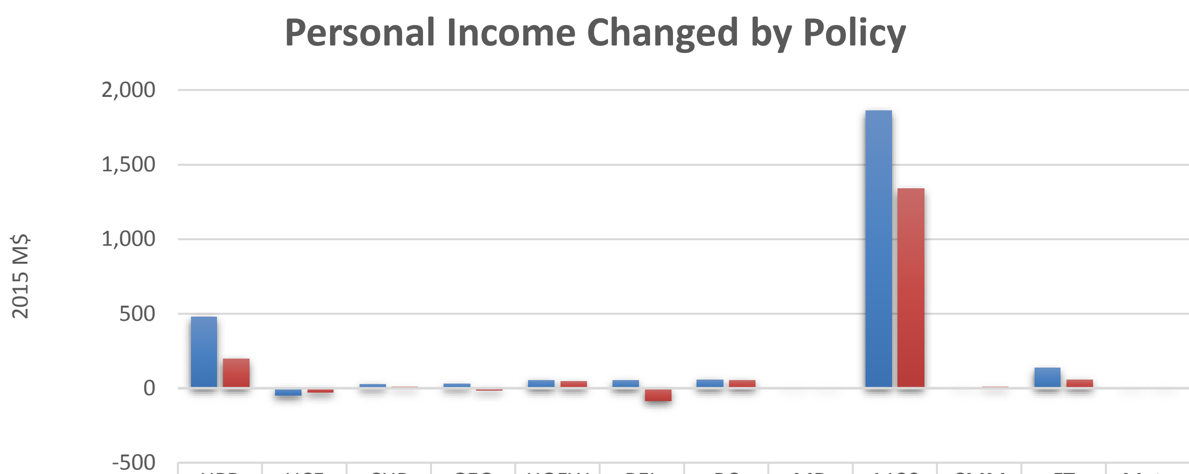
*Averages for the Act 129 policy are calculated in the period of the year 2021-2030 in all tables in this summary.

Table 2: GDP Changes



	HPB	UCF	CHP	GEO	HOFW	REL	BC	MD	A129	CMM	FT	Meta
2030 GDP	-1060.4	-193.41	-67.57	-563.69	70.26	-686.25	-16.37	6.18	2056	0.93	151.81	-11.10
Avg. GDP	-856.96	-92.00	-48.22	-362.11	55.83	-480.67	-9.75	2.68	1500.20	4.08	68.42	-8.16

Table 3: Personal Income Changes

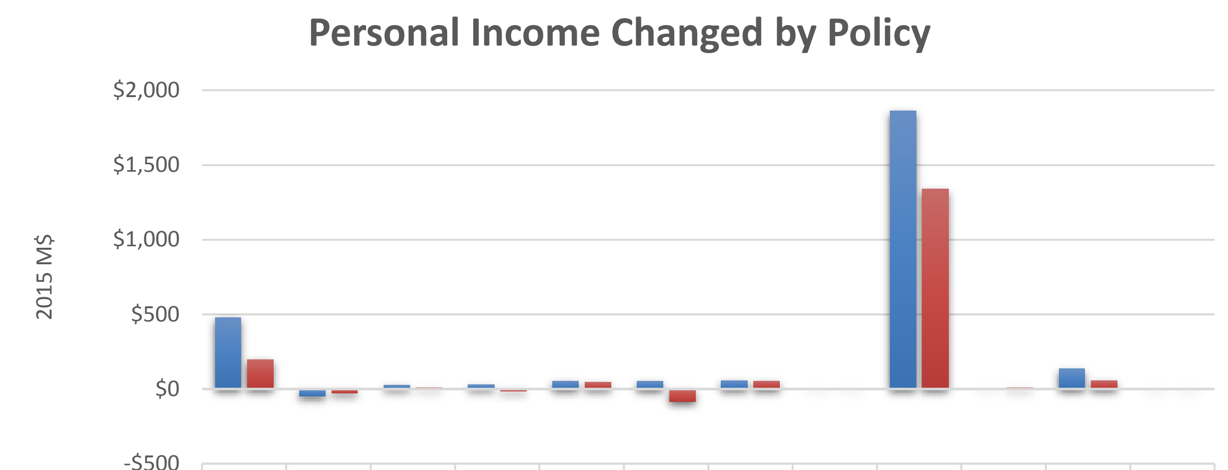


	HPB	UCF	CHP	GEO	HOFW	REL	BC	MD	A129	CMM	FT	Meta
2030 Income	477.92	-46.60	25.00	28.32	52.78	50.92	58.39	4.81	1863	6.65	134.15	-1.63
Avg. Income	196.23	-28.57	7.67	-15.00	45.26	-84.96	53.15	1.84	1337.20	7.66	58.53	-0.58

Income Changes: Comparing All Income to Disposable Income

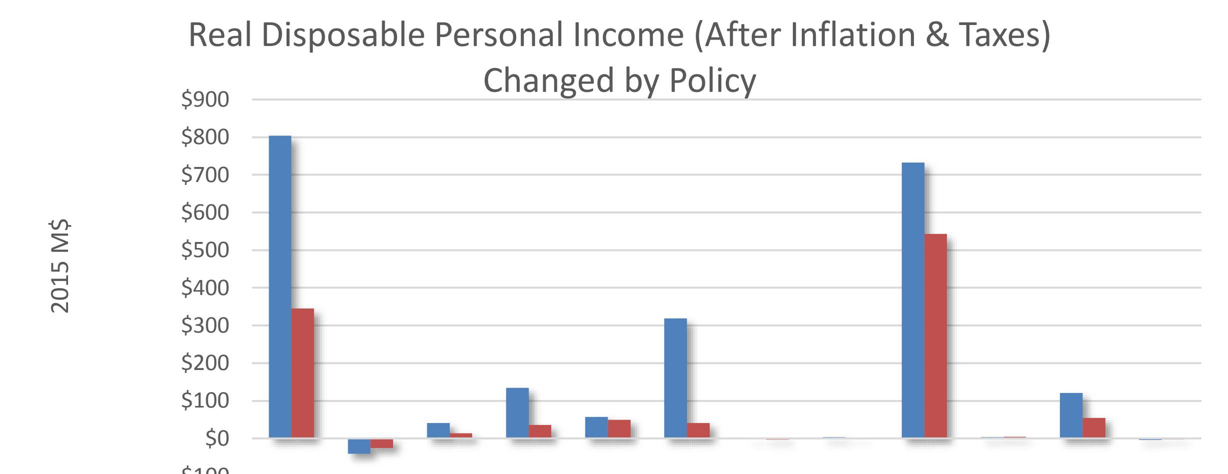
When measuring income, it is important to remember that this value encompasses not just salaries, wages and benefits, but also a wide range of income from other sources as well. When considering equity issues and questions (either implicit or explicit) about how policies treat the middle class or whether they create opportunities for upward mobility, it is informative also to consider levels of RDI. This variable measures the change specifically to after-tax income, and it is adjusted for changes in prices as well. As such, it captures changes in spending power of consumers more clearly than total income. The two charts below display this difference:

Table 3 (Repeated): Personal Income Changes



	HPB	UCF	CHP	GEO	HOFW	REL	BC	MD	A129	CMM	FT	Meta
2030 Income	477.92	-46.60	25.00	28.32	52.78	50.92	58.39	4.81	1863	6.65	134.15	-1.63
Avg. Income	196.23	-28.57	7.67	-15.00	45.26	-84.96	53.15	1.84	1337.20	7.66	58.53	-0.58

Table 4: Real Disposable Personal Income Changes



	HPB	UCF	CHP	GEO	HOFW	REL	BC	MD	A129	CMM	FT	Meta
2030	804.29	-40.58	40.78	134.69	57.04	318.53	0.44	3.38	733	3.61	120.96	-3.88
2016-2030 Average	344.86	-24.95	14.25	35.92	49.32	41.41	-3.20	0.37	543.40	4.39	54.52	-2.60

Some work plans show much better results for RDI, suggesting that lower bills and lower prices are making consumers better off even when they are not necessarily earning more total dollars (or may even be earning less):

- The High Performance Buildings Work Plan produces hundreds of millions more in RDI than in total income.
- The Geoexchange Installation Work Plan leads to negative total income but positive RDI.
- The Re-Light Pennsylvania Work Plan results in a negative income shift in most years, but RDI is more strongly positive.

Other work plans have strong shifts in the opposite direction. RDI shows that the amount of money in consumers' wallets falls even more severely than their total income does, suggesting that they feel the impacts of prices or higher bills and are changing their spending accordingly:

- The Act 129 Work Plan leads to significant RDI gains but they're still smaller than total-income gains, because the surcharge on electricity reduces consumers' buying power.
- The Adopt Current Building Codes Work Plan raises total incomes but not RDI, suggesting that the spending required to implement the codes and/or the associated higher production costs of business roughly displace the extra earning.

Conclusion
Based on the costs and savings developed by DEP, macroeconomic analysis shows that nearly all 12 work plans have real potential to generate not only GHG emission reductions but also significant economic improvements:

Total employment: 11 work plans show positive impacts, and the total impact would be on the order of 30,000 jobs by 2030.
Total income: 10 work plans show positive impacts by 2030, and 8 show average positive impacts throughout the 2016-2030 period, with a likely total gain on the order of $2.5 billion in the final year.
RDI: About 80 percent of the size of the total-income effect.

Because many of the work plans target (and are assumed to achieve) significant energy-use reductions, they do less well on total GDP: only 5 of the 12 plans show positive impacts, and the total is likely to be lower than business as usual by approximately $250 million by 2030. Again, however, GDP is measured as total amounts of spending, and efficiency policies by their very nature seek to reduce the amount of spending on energy. So this downward result is somewhat characteristic of such policies. It would not be as characteristic a result of other common greenhouse-gas reduction policies, such as conversion of energy generation to cleaner sources in the electricity and transportation sectors or requiring the adoption of advanced materials or equipment in the building and agriculture sectors.

A single modeling effort, representing the implementation of all 12 work plans, produced a forecast wherein Pennsylvania enjoys approximately 30,000 more jobs and $2.5 billion in income more than if none of the policies were implemented. GDP is forecast in this case to fall by approximately a quarter of a billion dollars by 2030. A separate modeling effort, representing the implementation of the work plans from Chapter 4C together, produced a very similar forecast, indicating the major drivers of the overall impact are “4C” work plans. The non-”4C” work plans, when run as a group, corroborate this interpretation – their combined effect is below $100 million in any indicator, though the forecast projects a jobs gain of between 1,500 and 2,000 new positions from those policies by themselves.

Importantly, this analysis shows that climate change policies, like initiatives in any other area of public policy, will vary dramatically in their impact on economic activity, as well as on equity concerns. Further, policies can be designed and redesigned to achieve their climate goals while also tending to concerns about overall economic health of a region. Both observations help to erode the assumption that climate policy is at odds with economic development – indeed, efficiencies such as those sought by most of these work plans are projected by this analysis to drive increases in jobs and incomes more often than not.

Chapter 11: Climate Change Mitigation Needs

Developing Game-Changing Technologies

Some researchers believe that our planet is already beyond the tipping point to preserve conditions under which civilization developed and to which life on earth has adapted. Researchers also conclude that the most optimistic projections for renewable energy and sustainable industry, agriculture and land-use based on existing technologies will result in irreversible changes for centuries to come. That is why new technologies that can be economically competitive with existing technology in a time frame on the order of ten years are needed to

1. reduce GHG emissions,
2. cope with a changing environment, and
3. remove GHG from the atmosphere.

Scientists and engineers are tasked with researching and developing this technology with private non-government, and government entities that can bring this game-changing technology to fruition quickly. However, the restrained pace at which traditional research occurs and the lack of focus of government research programs does not facilitate the challenges offered by climate change. Researchers and developers not beholden to the carbon economy are necessary to address the growing problems of climate change. The focus to be economically competitive will be necessary for timely deployment of the game changers.

Potential Future Technologies

Recently patented technologies that may be game changers for climate change have recently appeared on the forefront: 1) integral fast reactors, 2) nuclear fusion, 3) advanced biofuels and 4) biochar.

Integral Fast Reactor: The integral fast reactor (IFR) is a revolutionary Generation IV reactor design concept developed at the Argonne National Laboratory in 1984-1994. Although not a new concept, the emerging IFR technology is a type of nuclear reactor that uses the dangerous bi-products of other nuclear power stations as a fuel, releasing the stored energy not utilized at the first power station and rendering the waste considerably easier to dispose of. In addition it is impossible for an IFR to go into meltdown.

The reactor is a fast reactor. The chain reaction is maintained by fast neutrons with high energy, which produces its own fuel. The IFR reactor and associated fuel cycle is a closed system. Electrical power is generated, new fissile fuel is produced to replace the fuel burned, its fuel is processed for recycling by pyroprocessing – a new development – and waste is put in its final form for disposal. This is accomplished on one self-sufficient site.

A United States company, Hitachi GE Energy, has recently been granted a patent for an IFR Generation IV reactor process and is looking to put it into widespread use. In July 2012 Hitachi

GE Energy submitted a feasibility report to the UK Government Nuclear Decommissioning Authority showing that their PRISM (IFR) could provide a cost-effective way of quickly dealing with the UK's plutonium stockpile. Also in 2012 a *Guardian* article pointed out that an IFR such as Hitachi GE's PRISM could dispose of the waste problem, reduce the threat of radiation and nuclear proliferation and at the same time generate vast amounts of low-carbon energy. In addition IFR technology has been deployed and generating electricity in Russia (BN-600 fast reactor) for over 30 years. Russia is currently beginning to build the BN-800 reactor for use in Russia and China, and India's first commercial IFR is about to be finished.

IFR technology, if developed and deployed to its full extent, could be a source of carbon-free energy that holds the potential to provide base load power to the planet for thousands of years hence, it could be deployed along the existing transmission grid and even be housed in retrofitted coal fired power stations.

Nuclear Fusion: Fusion is the process that heats the sun and all other stars, whereby atomic nuclei collide and release energy. Fusion scientists and engineers are developing the technology to use this process in tomorrow's power stations. To get energy from fusion, gas from a combination of types of hydrogen (deuterium and tritium) is heated to very high temperatures in the neighborhood of 100 million degrees Celsius through a process known as magnetic confinement. The hot gas produced is known as plasma and is controlled by strong magnets. The most promising device for this is the *Tokamak*, the Russian word for ring-shaped magnetic chamber.

The world is in need of a new, cleaner way to supply our increasing demand for energy amid the concerns over climate change. In the future, power stations using fusion technology would have a number of advantages such as:

- No carbon emissions: The only byproduct is helium, an inert gas.
- Abundant fuel: Deuterium can be extracted from water, and tritium is produced from lithium, which is found in the earth's crust.
- Energy efficiency: One kilogram of fusion fuel provides the same energy as 10 million kg of fossil fuel (CCFE, *Introduction to Fusion*, 2012).
- No long-lived radioactive waste: Only plant components are radioactive and they can be recycled or disposed of within 100 years.
- Safety: Because of the small amount of fuel used, a large-scale nuclear accident is not possible.
- Reliable power: Fusion plants could provide a base-load supply of large amounts of electricity at costs that are similar to other energy sources.

Fusion energy, if it ever works, could greatly decrease our reliance on fossil fuels and reduce the emissions that contribute to climate change.

In the United States, Tri-Alpha Energy has had a patent granted for a fusion process called field reversed configuration. This technology is arguably the universal remedy for the world's energy needs. Unlike nuclear fission, fusion power would be inherently safe, produce little harmful waste materials and produce large amounts of energy from sea water. Tri-Alpha believes it can have a prototype for commercial deployment by 2020.

Advance Biofuels: Second-generation biofuels, also known as advanced biofuels, are fuels that can be produced from various types of biomass. Unlike first-generation biofuels which are made from the sugars and oils of arable crops through existing technology, second-generation biofuels can be made from lignocellulosic biomass (plant dry matter), agricultural residues and waste.

The goal of second-generation biofuel is to extend the amount of biofuel that can be produced sustainably by using biomass consisting of the residual non-food parts of current crops, as well as other crops that are not used for food purposes and also industry waste. In addition advanced biofuels can help reduce CO2 emissions by up to 90 percent and are the most efficient way to reduce carbon in transport. Advanced biofuels produced as little as 10 percent of the GHG emissions of renewable diesel. In addition to road transport, high-quality advanced biofuels can be used as aviation fuel, compatible with existing jet engines. Neste Oil's renewable aviation fuel was used for 1,187 Lufthansa flights, providing a 1,471-ton reduction in CO2 emissions.[119] Advanced biofuels can be used in other industries, such as in the plastics and chemicals industries, to replace fossil raw materials.

Advanced biofuel technology continues to make strides into the future. LanzaTech, a New Zealand company, recently patented a method of obtaining biofuels from industrial waste gases that contain carbon monoxide. Its process involves biological conversion of carbon to products through *gas fermentation.* Using microbes that grow on gases (rather than sugars, as in traditional fermentation), carbon-rich waste gases and residues are transformed into useful liquid commodities, used in everyday applications, providing a novel approach to carbon capture and reuse. Their method reduces carbon emissions and does not use farmland grown crops to produce the fuel. Widespread implementation of this technology would not only reduces carbon emissions but would not be detrimental to global food supplies.

Biochar: Fossil fuels are carbon positive; they contribute more CO2 and other GHGs to the air and thus intensify global warming. Ordinary biomass fuels are considered carbon neutral; the carbon captured in the biomass by photosynthesis would have eventually returned to the atmosphere through natural processes like decomposition. Sustainable biochar systems can be carbon negative by transforming the carbon in biomass into stable carbon structures in biochar which can remain sequestered in soils for centuries. This results in a net reduction of CO2 in the atmosphere. One of the most critical characteristics of biochar as a climate change mitigation technology is its long-term persistence in soil. Quantification of the persistent carbon component of biochar can facilitate the participation of biochar projects in carbon markets, providing an additional revenue stream to projects delivering GHG emissions reductions through soil carbon sequestration.

According to one prominent study, sustainable biochar implementation could offset a maximum of 12 percent of anthropogenic GHG emissions on an annual basis. Over 100 years, this amounts to a total of roughly 130 petagrams (106 metric tons) of CO2-equivalents.[120] The study assessed

[119] Neste Oil, *Biofuels 2050, Our Energy Future Today, 2015*
[120] Woolf, Sustainable biochar to mitigate global climate change, 2010

the maximum sustainable technical potential utilizing globally available biomass from agriculture and forestry.

Carbon in biochar can persist in soils over long time scales. Beyond the carbon sequestered in the biochar itself, biochar incorporated in soils also offers numerous other potential climate benefits:

- **Soil fertility**: Biochar improves the fertility of soil, thereby stimulating plant growth, which then consumes more CO2.
- **Reduced fertilizer inputs**: Biochar can reduce the need for chemical fertilizers, resulting in reduced emissions of greenhouse gases from fertilizer manufacture.
- **Reduced N_2O and CH_4 emissions**: Biochar can reduce emissions of nitrous oxide (N_2O) and methane (CH_4)—two potent greenhouse gases—from agricultural soils.
- **Enhanced soil microbial life**: Biochar can increase soil microbial life, resulting in more carbon storage in soil.
- **Reduced emissions from feed stocks**: Converting agricultural and forestry waste into biochar can avoid CO2 and CH_4 emissions otherwise generated by the natural decomposition or burning of the waste.
- **Energy generation**: The heat energy—and also the bio-oils and synthesis gases—generated during biochar production can be used to displace carbon positive energy from fossil fuels.

CarbonScape, a New Zealand company, has developed a means to convert waste biomass into valuable finished products in a cheaper and more efficient fashion than traditional methods. The use of microwave-induced plasma technology is used to convert waste biomass into metallurgical char, a type of green coke. The green carbon products are cost competitive compared to fossil fuel derived carbons particularly because of the valuable chemical byproducts and energy which can be recycled during the conversion process. CarbonScape green coke products and by-products are renewable, sustainable, inherently stable and chemically superior to coking coal derivatives. The use of one metric ton of CarbonScape's high-grade green coke (85 percent elemental carbon) offsets the equivalent of 3.10 metric tons of carbon dioxide emissions. The result significantly reduces the amount of fossil carbon released into the atmosphere from the steel making process. Applied globally in the steel industry the green coke could address 3.7 percent of GHGs.

Carbon Capture and Sequestration

Taking into consideration this nation's and the world's dependence on fossil fuels, it is essential to have in place a technology and a strategy to reduce GHG emissions from large industrial facilities that burn these fuels, even though their complete phase-out through energy efficiency improvements and a transition to renewable fuel sources might be technically and theoretically possible. Using all available tools is a wise and necessary hedging strategy in the face of the steep emission cuts that are needed. Projections differ as to the exact portion of reductions that will be delivered by different technologies, but from a strategic point of view, carbon capture and sequestration (CCS) provides a much needed answer for fossil fuel use.

Carbon capture refers to the separation and capture of CO_2 from emissions point sources or the atmosphere and the recovery of a concentrated stream of that CO2 that can be feasibly stored, sequestered or converted in such a way as to mitigate its impact as a GHG. This means stripping the carbon out of the fuel either before or after it is burnt, and burying it in the hope that it will stay where it's put. For all practical purposes, it entails the capture of CO2 from stationary sources, such as fossil fuel-fired power plants and industrial facilities. Research efforts are focused on systems for capturing CO2 from coal-fired power plants because they are the largest stationary sources of CO2. Although current research and development emphasizes CO2 capture in coal-fired power plants, the carbon capture technologies to be developed could apply to natural gas-fired power plants and industrial CO2 sources as well. With sufficient political commitment, this technology could be widely deployed before 2030. While it cannot provide the whole answer, CCS can and must be one of the means we use to make low-carbon electricity.

Petroleum, coal, and natural gas rank first, second, and third in global energy production, and are expected to remain so for years to come. Current consumption of fossil fuels continues to increase, driving growth in CO2 emissions. Even when it is assumed that current policy and government commitments around the globe to tackle climate change are all implemented, it is expected that fossil fuels will still account for 75 percent of the world's energy demand by 2035.[121] Many scientists believe that the only technology available to mitigate GHG emissions from large-scale fossil fuel usage is CCS. The Energy Technology Perspective BLUE scenario (part of the International Energy Agency report "Energy Technology Perspectives 2008"), which assessed strategies for reducing GHG emissions by one-half in 2050, concluded that CCS will need to contribute one-fifth of the necessary emissions reductions to achieve stabilization in the most cost-effective manner. CCS is therefore an essential part of the portfolio of technologies that is needed to achieve deep global emission reductions.

Right now in spite of all the advancing technology there simply is no alternative to using these fuels to meet our basic needs, whether it be for generating electricity, for manufacturing processes, for meeting our residential and commercial needs, or for transportation. If we are to reduce GHG emissions significantly, it will be important to successfully develop and deploy CCS technologies. Even if we continued to produce most of our electricity from burning fossil fuels, we could, in theory, reduce carbon emissions by 80 or 85 percent with CCS technology.[122] CCS is an emerging technology that is essential to the achievement of most long range GHG reduction goals.

CCS is the most promising technique to dramatically reduce CO2 emissions from coal-fired power plants. Because the potential to reduce U.S. carbon emissions is much greater in the existing fleet of power plants than in new ones, climate policy should ensure that CCS research and deployment efforts focus attention on retrofits of existing plants with carbon capture in addition to developing and deploying new integrated gasification combined-cycle power plants. CO2 CCS could be the critical enabling technology that provides for continued coal use even as we reduce our CO2 emissions. If cost-effective, reliable, and highly efficient new coal plant designs with CO2 capture are available to the industry, coal could maintain a large role in the generation mix and help constrain possible increases in electricity and natural gas prices.

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[121] Global CCS Institute, *The Global Status of CCS, 2014*)
[122] George Monbiot: *How to Stop the Planet from Burnin*, 2009

CCS offers a technological option for reducing the CO2 emissions produced from coal-based generation. At present, retrofitting existing coal fired generating units with CCS or building new plants with CCS technology involves significant cost in addition to reduced power output due to the additional energy required to operate the CCS equipment.

Geologic sequestration of CO2 has been proven effective by nature, as evidenced by the numerous natural underground CO2 reservoirs in Colorado, Utah, and other western states. CO2 is also found in natural gas reservoirs, where it has resided for millions of years. Thus, evidence suggests that depleting or depleted oil and gas reservoirs and similar ‘capped’ sandstone formations containing saltwater that cannot be made potable are capable of storing CO2 for millennia or longer.

Recent work by the Electric Power Research Institute illustrates the necessity and the urgency to develop CCS technologies as part of the solution to satisfying our energy needs in an environmentally responsible manner. As public concern increases over the environmental impacts of coal-based generation, new technologies and practices to improve plant efficiency and reduce emissions of air pollutants and greenhouse gases are of interest.

CCS technology has recently been deployed at the utility scale. However, the resolution of several political and technical issues is needed, such as establishing clear CO2 emission rules. In October 2014 the world’s first large-scale CCS project in the power sector came on line at the Boundary Dam power station in Saskatchewan, Canada. Additional large-scale projects at the Kemper County Energy Facility in Mississippi and at the Petra Nova Carbon Capture Project in WA Parrish Texas are under constructed and are planned to come into operation in 2016. The Kemper County Energy Facility is a 582 MW pulverized coal fired generating station. The pre-combustion CCS project is designed to capture 3.5 million tons of CO2 annually. The Petra Nova Carbon Capture Project at the Washington Parish Electric Generating Station in Texas is a 240 MW existing coal fired generating station. The post-combustion CCS project is designed to capture 1.6 million tons of CO2 annually. Capture CO2 from this project will be used to enhance production at mature oil fields in the Gulf Coast region.

Large-scale CSS projects in the power and steel/iron industries such as Boundary Dam and those expected to commence operation within the next two years are important for expanding the portfolio of CSS into sectors where capturing CO2 is more challenging. The Global CCS Institute has identified 13 operational large-scale CCS projects worldwide. Nine operate within the United States. In total there are 55 large scale CCS projects operating or in various stages of planning and development around the globe. The total potential CO2 capture from these large-scale CCS projects is approximately 106 Metric tons per annum.[123] Many international studies continue to show that CCS technology is an essential mitigation strategy for meeting global climate change targets. We need to realize the potential of carbon sequestration and incentivize the development and deployment of projects across a wide range of industries and regions to provide the basis for future next generation projects. But, in order for this to occur a few things must happen now:

[123] Global CCS Institute, *The Global Status of CCS*, 2014

- Financial and policy support structures must be provided to enable the potential planned CCS projects to transition to actual operating CCS projects by 2020.
- Robust, sustainable emission reduction policies that encourage CCS are urgently needed for long-term development and investment predictability.
- A need exists for policies and funded programs which encourage the exploration and assessment of significant CO2 storage capacity so that broader deployment is not delayed by uncertainty over available storage.
- A considerable effort must be devoted to CCS technology knowledge sharing.

Maria van der Hoeven, former executive director of the International Energy Agency, notes,

> “After many years of research, development and valuable, but limited practical experience, we need now to shift to a higher gear in developing CCS into a true energy option, to be deployed in large scale. It is not enough to only see CCS in long term energy scenarios as a solution that happens some time in a distant future. Instead, we must get to its true development right here and now.”[124]

In conclusion, the ideal solution to global climate change is to stop making waste CO2 by phasing out fossil fuels and getting our energy from other no carbon power sources. Given the world’s and this nation’s dependence on fossil fuels, it is essential to have in place technologies and strategies to reduce GHG emissions from large industrial facilities that utilize fossil fuels, even though their complete phase-out through energy efficiency improvements and a transition to renewable fuel sources might be technically and theoretically possible. Using all available tools is a wise and necessary hedging strategy in the face of the steep emission cuts that are needed. Projections differ as to the exact portion of reductions that will be delivered by different technologies, but from a strategic point of view, the above mentioned technologies can provide a much needed answer for GHG mitigation.

Carbon as a Commodity

There are currently several existing uses for CO2. These include uses in the oil and gas industry, food and beverage industry, pharmaceutical industry, agriculture, metal industries, pulp and paper processing, and others. There are also several emerging uses for CO2 that are at various stages of development and may possibly be viable by 2030. These include uses in enhanced coal bed methane recovery, chemical synthesis, industrial use as a working fluid, concrete, metal carbonates, Bauxite residue treatment, and others.

Several barriers will need to be overcome to create a sustainable market for captured CO2. Pennsylvania coal- and gas-fired power plants generated approximately 100 million metric tons of CO2 in 2012, far greater than the current collective demand of CO2 in all of the categories listed above. There is also no current infrastructure for transporting captured CO2 long distances by pipeline in Pennsylvania, thus creating additional hurdles. There are currently over 4,000 miles of CO2 pipeline in the United States, most of which is west of the Mississippi River. A study prepared for the Interstate Natural Gas Association of America Foundation found that,

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[124] *Maria van der Hoeven, IEA, Technology Roadmap: Carbon Capture and Storage, 2013.*

depending upon the quantity of CO2 that must be stored and the degree to which enhanced oil recovery (EOR) will be involved, the length of pipeline needed to transport CO2 will be in the range of 12,000–66,000 miles by 2030.[125] The development of the markets and transportation infrastructure for CO2 will depend greatly on regulations for CO2 emissions.

One established market for CO2 is EOR, which involves flooding oil reservoirs with injected CO2 to displace oil contained within. EOR can result in an increase of recovery between 7 and 23 percent.[126] EOR is a proven technology, first applied in Texas during the 1970s. CO2 injection per oil displacement rates vary, depending on reservoir characteristics (size, temperature, pressure) which would need to be examined on a site by site basis. Pennsylvania produced approximately 18,000 barrels of oil per day in 2014. At this production rate,[127] approximately two million tons of CO2 could be used in Pennsylvania annually for EOR.

A second established market for captured CO2 is in Urea production. Urea is commonly used as the nitrogen constituent in fertilizer. Urea is produced by combining ammonia and carbon dioxide to form ammonium carbamate, which then undergoes dehydration to form urea. Urea production plants are typically located near ammonia production facilities, in order to have access to the necessary ammonia. The United States produced over nine million metric tons of ammonium in 2012 and approximately 75 percent of the ammonia produced went to producing fertilizers, including urea.[128] Urea production is different from EOR in that once urea is exposed to water, it will release carbon dioxide back into the atmosphere, so it is not a long-term storage solution for carbon dioxide.

Enhanced geothermal systems are an emerging market in which supercritical CO2 is used as a heat exchange fluid to recover geothermal heat from heat-producing granites two miles below the earth's surface.[129] A demonstration project was successfully completed in January 2015 at the Cranfield location in Mississippi. Approximately 4,000 metric tons of CO2 has been sequestered at the site while creating enough heat energy to operate a 1 MW generator.[130] Simulations have revealed the design could potentially sequester as much as 15 million tons of CO2 per year, roughly equivalent to the emissions of three average sized coal-fired plants annually.[131]

Another emerging market for captured CO2 is its use as a feedstock in polymer processing which can be used to create polypropylene carbonate (PPC) and polyethylene carbonate (PEC) that could contain up to 50 percent CO2.[132] In 2011, Bayer Material Science opened a pilot project in Germany to develop polyurethanes from waste CO2 from power generation, which had a CO2 scrubbing system for separating the carbon dioxide from the flue gas.[133] The plant, when

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[125] ICF International; *Developing a Pipeline Infrastructure for CO_2 Capture and Storage: Issues and Challenges.* 2009
[126] Global CCS Institute; *Accelerating the Uptake of CCS: Industrial use of Captured Carbon Dioxide.* March, 2011
[127] United States Chamber of Commerce, Institute for 21st Century Energy; *CO_2 Enhanced Oil Recovery.* 2012
[128] USGS; *Nitrogen (Fixed)-Ammonia.* 2013
[129] Global CCS Institute; *Accelerating the Uptake of CCS: Industrial use of Captured Carbon Dioxide.* March, 2011
[130] United States Department of Energy, Geothermal Technologies Office; *Cranfield CO_2 Geothermal Field Demonstration.* May 11, 2015
[131] United States Department of Energy, Energy Efficiency & Renewable Energy; *2013 Annual Report.* 2014
[132] Global CCS Institute; *Accelerating the Uptake of CCS: Industrial use of Captured Carbon Dioxide.* March, 2011
[133] Chemicals Technology Market & Customer Insight; *Plastics Pilot Plant, Germany*. 2015

expanded to industrial scale, should use several thousand metric tons of carbon dioxide in the process.[134] The plastics formed from the polymers will act as a sink for carbon dioxide sequestration. This process will also lessen the need for the petroleum products that are currently being used as feedstock for the polymer production process.

Mineral carbonation is another method of sequestering carbon dioxide into a usable, solid material. In mineral carbonation CO2 gas is chemically reacted with a metal oxide or metal silicate bearing mineral to form a metal carbonate.[135] Olivines and serpentine oxide are the two most abundant metal silicates that could be used in this process.[136] One drawback is the need to physically mine the minerals to be used in this process. Underground injection of carbon dioxide into underground deposits of these minerals is a storage option, although no viable product would be available. The rate of uptake of the CO2 would also be much slower if done in situ as compared a controlled reaction.[137] An estimated cost of $15 per ton of sequestered CO2 was given for the process using the serpentine mineral.[138]

An established use for captured carbon dioxide is in the food and beverage industry. Liquid or solid carbon dioxide is used for quick freezing, surface freezing, chilling and refrigeration in the transport of foods. In cryogenic tunnel and spiral freezers, high pressure liquid CO2 is injected through nozzles that convert it to a mixture of CO2 gas and dry ice “snow” that covers the surface of the food product. Carbon dioxide gas is used to carbonate soft drinks, beers and wine and to prevent fungal and bacterial growth. Liquid carbon dioxide is a good solvent for many organic compounds. Liquid carbon dioxide is also used to de-caffeinate coffee. CO2 can be used an inert “blanket”, as a product-dispensing propellant and an extraction agent or used to displace air during the canning process. Supercritical CO2 extraction coupled with a fractional separation technique is used by producers of flavors and fragrances to separate and purify volatile flavor and fragrances concentrates. Cold sterilization can be carried out with a mixture of 90 percent carbon dioxide and 10 percent ethylene oxide, the carbon dioxide has a stabilizing effect on the ethylene oxide and reduces the risk of explosion. There are two post-combustion capture from pulverized coal-fired electric power plants in the United States that have the captured carbon dioxide used in the food and beverage industry. The plants are located in Maryland and Oklahoma, together capturing nearly 200,000 tons of carbon dioxide.[139]

A final market for captured carbon dioxide that has demonstrated technology is in enhanced coal bed methane recovery. Conventional coal bed methane extraction is achieved by dewatering and reducing the pressure in the coal bed, releasing methane from the porous coal. As the affinity of coal for CO2 is approximately twice as great as it is for methane, the methane stored in un-mineable coal will be released to be captured when exposed to carbon dioxide.[140] A 2007 Congressional Budget Office paper estimated the storage capacity of un-mineable coal seams in

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[134] Vink, David; *CO2 aids Baye's sustainability efforts.* European Plastics News, October 16, 2013
[135] Mazzotti, Marco; *Mineral carbonation and industrial uses of carbon dioxide.* 2005
[136] Mazzotti, Marco; *Mineral carbonation and industrial uses of carbon dioxide.* 2005
[137] Global CCS Institute; *Accelerating the Uptake of CCS: Industrial use of Captured Carbon Dioxide.* March, 2011
[138] Yeboah, Frank, T.M. Yegulalp, H. Singh; *Cost Assessment of CO2 Sequestration by Mineral Carbonation.* May, 2006
[139] United States Department of Energy, National Energy Technology Laboratory; *CO2 Capture Usage*. 2012
[140] Ripepe, Nino Samuel; *Carbon Dioxide Storage in Coal Seams with Enhanced Coalbed Methane Recovery: Geologic Evaluation, Capacity Assessment and Field Validation of the Central Appalachian Basin.* Aug. 3, 2009

the United States to be approximately 156 billion metric tons.[141] According to the Union of Concerned Scientists, CO2 emissions from the consumption of energy in the United States during 2011 was almost 5.5 billion metric tons.[142] At that emission rate, nearly 25 years' worth of CO2 from the consumption of energy could be stored in un-mineable coal seams. From April 1995 to August 2001, an enhanced coal bed methane recovery pilot project took place at the Allison Unit in New Mexico.[143] Approximately 1.6 billion cubic feet of methane was recovered while approximately 4.7 billion cubic feet of carbon dioxide was sequestered within the coal bed.[144]

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[141] Tawil, Natalie - Congressional Budget Office; *The Potential for Carbon Sequestration in the United States.* Sept. 2007

[142] Union of Concerned Scientists; *Each Country's Share of CO2Emissions*. 2011

[143] Reeves, Scott, Oudinot, Anne; *The Allison Unit CO_2-ECBM Pilot – A Reservoir and Economic Analysis.* 2005

[144] Kuuskraa, Vello; *Economics of CO_2 Injection and Storage in Deep Coal Seams.* March, 2002

Chapter 12: Legislative Recommendations

Based on the research and analysis conducted by DEP and macroeconomic analysis completed by The Center for Climate Strategies, the following are DEP's recommendations for legislative action:

1. **Explore increasing the Alternative Energy Portfolio Standard:** As discussed on page 37, increasing the percentage of Tier 1 AEPS required in Pennsylvania should be explored, including the solar carve out.

2. **Reinvest in rooftop solar:** As discussed on page 39, funding should be provided for PA Sunshine solar rebates, and net metering under AEPS should be expanded to address community solar systems.

3. **Improve the Act 129 program:** As discussed on page 52, and in Work Plan 2, the Act 129 program should be expanded to include municipal co-ops and smaller electric utilities, eliminate the 15-year measure life limit for cost-effectiveness determinations, and remove the 2 percent spending cap.

4. **Create a demand side management of natural gas program:** As discussed on page 55, a program similar to Act 129 should be created to require all natural gas distribution companies to achieve cost-effective demand side management usage reductions by developing comprehensive energy efficiency and conservation programs for all customer classes regardless of income. It should include cost-recovery for reasonable and prudent implementation costs as well as incentives for exceeding their targets and financial penalties for failure to meet their targets.

5. **Adopt the latest energy codes:** As discussed on page 56 and in Work Plan 3, by adopting the latest version of the ICC (or at least the IECC), Pennsylvania would be assured of maintaining a minimal incremental means of continuous building performance improvement, moving towards the goals set out in this work plan and playing a national leadership role in GHG reductions.

6. **Require change-of-ownership energy use disclosure:** As discussed on page 74, energy use disclosures provide a potential buyer or lessee with data on a residential or commercial building's energy consumption when the property is placed for sale. Requiring them to be included in all property listings would allow buyers to make the most informed decisions.

7. **Continue to invest in programs such as Keystone HELP:** As discussed on page 82 and in Work Plan 5, there are various options that conserve energy and reduce GHG emissions related to the heating and cooling in homes in Pennsylvania. State-funded programs can encourage homeowners to invest in energy-saving home improvements. Incentive programs such as these can also be used to promote and encourage the use of combined heat and power (CHP), as discussed on page 68 and in Work Plan 6.

8. **Adopt the International Green Code Consortium:** As discussed on page 70 and in Work Plan 7 adopting the IgCC for municipalities to meet goals and commercial building standards of the 2030 Challenge is paramount. In addition require IgCC compliance for all publicly-funded commercial building projects in Pennsylvania and improve administration and enforcement of both the existing UCC and the IgCC with a statewide emphasis on training to obtain the ultimate goal of zero-carbon buildings throughout the Commonwealth.

9. **Provide additional resources for manufacturing energy technical assistance:** As discussed on page 76 and in Work Plan 9, DEP currently provides discretionary funding to PennTAP to administer technical assistance via energy efficiency assessments for manufacturers within the Commonwealth. A second program, for a more limited group of manufacturers based on size and location, is the IAC program, which is funded directly by the federal Department of Energy. Between these two programs, approximately 30 energy assessments are completed each year in Pennsylvania. The legislature should dedicate sufficient state funding to perform an average of 125 energy assessments per year at qualifying Pennsylvania manufacturers.

10. **Create a Pennsylvania PACE program:** As discussed on page 80 and in Work Plan 10, PACE is a capitalization and payment mechanism to finance energy efficiency, renewable energy, and water conservation upgrades to buildings. PACE can be used to finance energy efficiency upgrades for residential, commercial, industrial, non-profit, agricultural and multi-family sectors. All PACE program are voluntary programs, but legislation is necessary to allow for their potential development and existence across the state

11. **Expand funding for TreeVitalize:** As discussed on page 103 and in Work Plan 12, the only practical mechanism for both sequestering and storing carbon, trees are an invaluable tool for addressing climate change. Trees sequester carbon by absorbing carbon dioxide from the atmosphere and combining it with sunlight during photosynthesis. Since its inception in 2004, more than 426,000 TreeVitalize trees have been planted in urban and suburban areas throughout the Commonwealth. This has provided a reduction in 1.5 billion gallons of stormwater and a savings of $11.8 million; a reduction of 38,400 pounds of nitrogen; sequestration of 217 million pounds of carbon; and a 38 million kWh decrease in electricity consumption and $5.3 million in savings, among other things. Additional funding to the TreeVitalize Program would ensure these successes continue well into the future.

12. **Provide for funding opportunities that incentivize the construction of manure digesters:** As discussed on page 114, the legislature should consider establishing or expanding state-funded programs related to digesters. As discussed in Work Plan 13, measures should be taken to incentivize farms to install digesters. Existing funding programs through the Commonwealth Financing Authority and Pennsylvania Energy Development Authority should be continued and expanded.

Appendix A: Climate Change Advisory Committee

The Climate Change Advisory Committee (CCAC) is composed of 18 members (and two vacancies) of diverse backgrounds and expertise. Over a series of meetings, the CCAC members and DEP selected a group of work plans based on three criteria: GHG emission reduction benefits, cost-effectiveness and the ability of the work plan to be implemented. Through 14 meetings over two years, these members and their alternates have worked with DEP to develop and refine all of the work plans referenced in this Action Plan. The work plans contain specific actions for achieving GHG reductions, including implementation steps and recommendations. In each of the 12 quantifiable work plans, DEP and CCAC have calculated expected GHG reductions as well as costs or savings associated with implementation of the work plan.

The full texts of the 13 work plans endorsed by the CCAC are included in Appendix B. While many of the work plans were unanimously endorsed, some were not endorsed by all of the members. A voting record is included in this Appendix.

Accompanying each of the 12 quantifiable work plans is a macroeconomic analysis completed by the Center for Climate Strategies. This macro-level analysis provides detailed information regarding economic impacts of any policy that might be implemented in Pennsylvania. These Pennsylvania-specific economic impacts include changes in economic output, changes in demand, changes in employment, and changes in compensation.

Work Plan Title	**Potential Reductions through 2030 (MMTCO2e)**	**Cost-Effectiveness through 2030 ($/MMTCO2e)**
1. Coal Mine Methane Recovery	12.6	12.42
2. Act 129 of 2008 Phase IV & V	18.1	-218.6
3. Adopt Current Building Energy Codes	32.2	-85
4. Geoexchange **Systems (**Heat Pumps)	35.1	-204
5. Heating Oil Conservation and Fuel Switching	43.49	-90.92
6. Combined Heat and Power (CHP)	8.2	-27.5
7. High Performance Buildings	97.9	-89.8
8. Re-Light PA	71.2	-71.6
9. Manufacturing Energy Technical Assistance	7.1	-83.1
10. Energy Efficiency Financing in Pennsylvania	Not Quantified	Not Quantified
11. Semi-Truck Freight Transportation	2.1	-309
12. Urban & Community Forestry	7.3	102
13. Manure Digesters	2.4	26.6
Total	**337.69**	**-1038.5**

Members

Ex Officio Members:

Cindy Dunn, Pennsylvania Department of Conservation and Natural Resources, Secretary
Designee: Sara Nicholas, Director of the Office of Policy and Planning

Gladys M. Brown, Pennsylvania Public Utility Commission, Chairman
Designee: Joseph M. Sherrick, Supervisor of Policy and Planning Division of Technical Utility Services

Dennis Davin, Pennsylvania Department of Community and Economic Development, Secretary
Designee: Paul Opiyo, Executive Policy Specialist

Senate of Pennsylvania Appointees:

Gary Merritt, Northern Star Generation Services Company, LLC, Management Executive

Mark Hammond, Land Air Water Legal Solutions, LLC, Managing Partner (CCAC VICE CHAIR)

Michael Winek, Babst, Calland, Clements, & Zomnir, P.C., Chairman of the Environmental Health and Safety Services Group
Alternate: Meredith Graham, Babst, Calland, Clements, & Zomnir, P.C.

Christina Simeone, Kleinman Center for Energy Policy, Deputy Director
Alternate: Robert Altenburg, PennFuture Energy Center, Director

House of Representatives Appointees:

James Warner, Lancaster County Solid Waste Management Authority, CEO
Alternate: Brooks K. Norris, Lancaster County Solid Waste Management Authority, Senior Manager of Technical Services

George Ellis, ARIPPA, Executive Director

Steve E. Winberg, Global Laboratory Operations, Battelle, Program Manager

Terry Bossert, Range Resources – Appalachia, LLC, Vice President of Legislative and Regulatory Affairs

Representative Greg Vitali, Pennsylvania House of Representatives

Representative Ryan Bizzarro, Pennsylvania House of Representatives
Alternate: Amy Schmidt, Chief of Staff

Governor's Office Appointees:

Patrick Henderson, Private Citizen

Luke Brubaker, PA Milk Marketing Board, Chairman
Alternate: Grant Gulibon, PA Farm Bureau, Director of Regulatory Affairs

Robert Graff, Delaware Valley Regional Planning Commission, Manager of the Office of Energy and Climate Change Initiatives
Alternate: Shawn Megill Legendre, Delaware Valley Regional Planning Commission, Senior Research Analyst

J. Scott Roberts, SunStorm, Owner

Steven Krug, Krug Architects, Architect (CCAC CHAIR)

Climate Change Advisory Committee Voting Record

Work Plan Title	CCAC Recommended Yes	CCAC Recommended No	CCAC Recommended Abstain	Bizzarro	Bossert	Brubaker	Ellis	Gill/Sherrick	Graff	Henderson	Merritt	Nicholas	Opiyo	Roberts	Simeone	Vitali	Winberg	Warner/Norris	Winek/Graham	Hammond	Krug	Date
1. Coal Mine Methane Recovery	14	0	0	*	*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	*	*	Y	Y	Y	Y	Approved 6-9-15
2. Act 129 of 2008 Phase IV & V	9	6	0	*	N	Y	N	Y	Y	N	N	Y	Y	Y	Y	*	*	Y	N	N	Y	Approved 6-9-15
3. Adopt Current Building Energy Codes	12	0	0	*	*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	*	*	*	*	Y	Y	Approved 4-21-15
4. Geoexchange Systems (Ground Source Heat Pumps)	13	0	0		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	*	*	*	Y	Approved 1-6-15
5. Heating Oil Conservation and Fuel Switching	14	1	0	*	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	*	Y	*	Y	Y	Y	Approved 3-18-15
6. Combined Heat and Power (CHP)	13	0	0		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	*	*	*	Y	Approved 1-6-15
7. High Performance Buildings	12	0	0	*	*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	*	*	*	*	Y	Y	Approved 4-21-15
8. Re-Light PA	16	0	0		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Approved 2-6-15
9. Manufacturing Energy Technical Assistance	14	1	0	Y	Y	*	N	Y	Y	Y	Y	Y	Y	*	Y	*	Y	Y	Y	Y	Y	Approved 7-7-15
10. Energy Efficiency Financing in Pennsylvania	12	0	1	Y	Y	Y	*	Abs	Y	Y	Y	*	Y	Y	Y	*	*	Y	Y	Y	*	Approved 8-18-15
11. Semi-Truck Freight Transportation	11	0	0	*	*	Y	Y	Y	Y	Y	Y		Y	Y	Y	*	*	*	*	Y	Y	Approved 4-21-15
12. Urban & Community Forestry	15	1	0	*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	*	Y	Y	N	Y	Y	Approved 6-9-15
13. Manure Digesters	12	0	0		Y	Y	Y	Y	Y		Y	Y	Y	*	Y	Y	Y	*	*	*	Y	Approved 1-6-15
* Absent with no proxy																						

Appendix B: Work Plans

Work Plan 1: Coal Mine Methane Recovery

Goal:
Encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations

Initiative Background:
The release of methane gas to the atmosphere is a major component of GHG emissions. Methane gas is a fossil fuel and energy source, commonly known as natural gas, which occurs in various geologic formations in Pennsylvania, including coal formations. When coal is mined and processed for use, substantial amounts of methane gas are released. Coal bed methane is methane contained within coal formations and may be extracted by gas exploration methods or released as part of coal mining operations. This work plan deals with coal mine methane , the methane within the coal that can be vented or recovered prior to mining the coal, during mining, and immediately after mining as some gas escapes to the surface through post-mining vents or boreholes. Methane gas that remains sequestered within an abandoned underground coal mine does not contribute to GHG emissions, but could be and sometimes is recovered by subsequent gas exploration operations.

The federal Mine Safety and Health Administration (MSHA) definition of a gassy mine or tunnel, as specified in 30 CFR § 27.2 (g), is that a “a mine, tunnel, or other underground workings in which a flammable mixture has been ignited, or has been found with a permissible flame safety lamp, or has been determined by air analysis to contain 0.25 percent or more (by volume) of methane in any open workings when tested at a point not less than 12 inches from the roof, face, or rib.” MSHA records coal mine methane readings with concentrations of greater than 50 parts per million (ppm) methane. Readings below this threshold are considered non-detectable.

According to data reported to EPA from 2011-2013 approximately 90-93 percent of the methane gas released during the mining of coal in Pennsylvania occurs from mining in longwall underground mines. The five large longwall underground coal mines now operating in Pennsylvania extract approximately 50 percent of the 60 million tons of coal mined each year within Pennsylvania. These high amounts of longwall mine production and the fact that the longwall mines recover coal from greater depths than other mines make longwall mining the predominant current source of coal mine methane release and an important contributor to GHG emissions. In recent years several mines have begun to capture and utilize methane gas within longwall underground mines, resulting in a reduction of methane GHG emissions.

Longwall Mines:
Production and emission data for active longwall mines in Pennsylvania during 2011-2014 were analyzed to determine an average emission factor of methane due to longwall mining. See Table 1.

TABLE 1:

	Production (Million tons of coal)*					Emissions (MMTCO2e)**			
Mine	2011	2012	2013	2014		2011	2012	2013	2014
CONSOL Bailey Mine	10.8	10.1	11.3	12.3		2.08	1.83	2.99	2.16
CONSOL Enlow Fork Mine	10.2	9.5	10.1	10.6		2.08	1.74	1.76	1.85
Harvey Mine***	N/A	N/A	N/A	3.2		N/A	N/A	N/A	0.77
Alpha Cumberland	6.2	6.4	5.6	7.4		1.85	2.15	2.11	2.04
Alpha Emerald #1	3.7	4.4	3.6	4.0		0.96	0.93	1.11	0.84
Total	30.9	30.4	30.6	37.5		6.996	6.669	7.984	7.684

*Production data taken from:
http://www.portal.state.pa.us/portal/server.pt/community/bituminous_coal_mining_activities/20871
**Emissions data taken from http://www.epa/gov/GHGreporting/
***Harvey Mine began operation in 2014.

Based on the data provided in Table 1, an emission factor of .228 MMTCO2e / ton of coal was used in calculating projected emissions for longwall mines through 2030. The emission factor is equivalent to 475 cubic feet of methane per ton of coal.

Non-Longwall Underground Mines:
Production and emission data for other active underground bituminous mines in Pennsylvania during 2011-2013, where data were available, were analyzed to determine an average emission factor of methane due to underground mining. See Table 2.

TABLE 2: Production and Emission Data for Other Active Underground Bituminous Mines in Pennsylvania

	Production (million tons coal)*				Emissions (MTCO2e)**		
Mine	2011	2012	2013		2011	2012	2013
4 West Mine	1.2251	1.4959	1.6113		62,458	61,193	NA
Cherry Tree Mine	0.8840	0.6165	0.5872		52,547	31,169	19,355
Clementine Mine	0.2346	0.4040	0.4439		45,494	39,054	14,437
Gillhouser Run Deep Mine	1.2300	0.2101	0.2557		NA	NA	23,280
Logansport Mine	0.8776	0.7229	0.3299		96,610	89,073	79,185
Lowry Mine	0.3522	0.3211	0.2395		47,807	43,693	54,573
Parkwood Mine	0.0000	0.0538	0.2535		NA	NA	18,100
Starford Mine	0.0934	0.0726	0.0345		13,980	68,417	53,678

	Production (million tons coal)*				Emissions (MTCO2e)**		
Toms Run Mine	0.2847	0.3298	0.4572		53,246	59,584	88,744
Tracy Lynne Mine	0.2916	0.2793	0.3594		81,878	58,958	52,014
TOTAL	5.4732	4.5062	4.5720		454,020	451,141	403,366

NA: Not available
* Production data taken from
http://www.portal.state.pa.us/portal/server.pt/community/bituminous_coal_mining_activities/20871
** Emission data taken from http://www.epa.gov/GHGreporting/

Based on the data provided in Table 2, an emission factor of 0.09 MMTCO2e per ton of coal was used in calculating projected missions for underground bituminous non-longwall mines through 2030. The emission factor is equivalent to 189 cubic feet of methane per ton of coal.

This Coal Mine Methane Recovery Work Plan would encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations.

Quantification Approach and Assumptions:
Estimates of methane emissions, expressed in thousand cubic feet (Mcf), are converted to carbon dioxide equivalents (CO2e) by multiplying the quantity of methane times its global warming potential of 25. One million cubic feet of methane is equal to 479 metric tons of CO2 equivalent.

The following inputs were used in the analysis of coal mine methane GHG reductions and costs. Three cost & performance sensitivities were conducted (the summary table only reports the central estimate).

PA specific data inputs were used for the following parameters:

- Coal mining emissions for longwall mining (cubic feet of methane per ton of coal mined),
- Methane capture target from longwall mines,
- Coal mining emissions for underground bituminous non-longwall mining (cubic feet of methane per ton of coal mined)
- Methane capture target from underground bituminous non-longwall mines.

National data inputs were used for the following parameters:

- Natural gas value assumed to start at $2.50/MMBtu and increase by 3 percent a year.
- Methane emission factors for all surface mining and anthracite mining from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
- 2030 coal production is based on the EIA Annual Energy Outlook 2015 (Table A-15) forecast for Appalachia production declining by 11 percent. Note: This decline does not take into consideration additional coal reductions that may occur if the Clean Power Plan is implemented.

TABLE 3. Summary of Estimated Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2013 Levels, no Additional Methane Capture

	Methane Emission Factor (ft^3/ton)	Coal (tons)	Methane (Million Cubic Feet)	MMTCO2e
Anthracite Underground Mines	138.3*	87,889	12.2	0.006
Anthracite Surface Mines	138.3*	4,590,820	635	0.304
Bituminous Surface Mines	138.3*	8,526,774	1,179	0.565
Room & Pillar Bituminous Underground Mines	189	16,018,737	3,028	1.450
Longwall Bituminous Underground Mines	475	30,594,284	14,523	6.961
Totals for Coal Mining in Pennsylvania		**59,818,504**	**19,377**	**9.28**

*Methane emission factors are from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

As illustrated in Table 3, in 2013 reported GHG emissions from all coal mining activity in Pennsylvania were 9.3 MMTCO2e. Future emissions are expected to drop commensurate with projected decreases in coal mining activity. Table 4 shows 2030 GHG emissions estimated at 8.3 MMTCO2e, a 14 percent reduction in GHG from the 2013 baseline. In Table 4, the 2030 GHG emissions assumes no methane capture is in place. In contrast, if the goal of 10 percent capture of this work plan is achieved in gassy, underground mines and there is a decrease in Pennsylvania coal production, the resultant emissions, as shown in Table 5 below, are estimated to be 7.51 MMTCO2e, a decrease of approximately 19 percent from the 2013 baseline.

TABLE 4: Summary of Estimated and Protected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2030 Levels with No Capture in Gassy Underground Mines

Mine Type	Methane Emission Factor (ft^3/ton)	Coal (tons)**	Methane (Million Cubic Feet)	MMTCO2e
Anthracite Underground Mines	183.3*	78,221	10.8	0.005
Anthracite Surface Mines	183.3*	4,085,830	565	0.271
Bituminous Surface Mines	183.3*	7,588,829	1050	0.503
Room & Pillar Bituminous Underground Mines	188	14,256,676	2,685	1.286

Mine Type	Methane Emission Factor (ft^3/ton)	Coal (tons)**	Methane (Million Cubic Feet)	MMTCO2e
Longwall Bituminous Underground Mines	475	27,228,913	12,925	6.191
Totals for Coal Mining in Pennsylvania		**53,238,469**	**17,263**	**8.26**

*Methane emission factors are from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
**Assumed an 11 percent reduction in Pennsylvania coal (tons mined) based on EIA Annual Energy Outlook 2015 (Table A-15).

TABLE 5. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2030 Levels with 10% Methane Capture in Gassy Underground Mines

Mine Type	Methane Emission Factor (ft^3/ton)	Coal (tons)**	Methane (Million Cubic Feet)	MMTCO2e
Anthracite Underground Mines	138.3*	78,221	10.8	0.005
Anthracite Surface Mines	138.3*	4,085,830	565	0.271
Bituminous Surface Mines	138.3	7,588,829	1050	0.503
Room & Pillar Bituminous Underground Mines	188	14,256,676**	2417	1.158
Longwall Bituminous Underground Mines	475	27,228,913**	11,633	5.572
Totals for Coal Mining in Pennsylvania		**41,485,589**	**14,050**	**7.51**

*Methane emission factors taken from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
**Assumed 10% reduction in methane emissions.

Implementation Steps:
This Coal Mine Methane Recovery Work Plan would encourage owners/operators of current longwall mines and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations but at current natural gas prices and challenges associated with securing rights-of-way for the gathering systems from surface landowners, the 10 percent goal will be difficult to achieve without some financial incentives

such as a production tax credit or investment tax credit. The 10 percent target is technically achievable with a combination of pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical/horizontal degas holes, capturing methane by horizontal drilling within active underground mines, and/or possibly capturing methane from post-mining areas of underground mines, where for a brief period of time gas is still making its way to the surface through existing boreholes. DEP annual coal production numbers and MSHA gas liberation numbers will be reassessed annually, as well as new technological developments, with changes made to trend forecasts on future coal production and revisions to estimates of methane gas released per ton of coal mined.

Economic Cost:
At present, there is no net financial benefit to coal mine owners/operators given current and forecasted natural gas prices versus the cost to drill a well and install the necessary gathering systems to collect the gas from the wells. Projections for future methane value were based on an estimated current value of $2.50 per MMBtu and assume a 3 percent annual increase. These prices ranged from $2.50 to $3.89 per MMBtu between 2015 and 2030. Capital costs are assumed to be about $1.4 million per well which includes the well, gathering, and processing. Each panel would need 2 wells, and a panel gets mined in a year. In most cases, the wells are no longer of use after the longwall mines through the seam so the useful life of a well is between 1-3 years, depending on how far in advance of the longwall the wells are drilled. Two of the mines have two panels operating per mine simultaneously, so a total of 14 wells will be needed each year for a total annual cost of $19.6 million. The calculated net present value of this initiative reflects a net cost of approximately $157 million. The cost-effectiveness is $12.42 per ton of CO2e reduced.

TABLE 6:

	2015	**2020**	**2030**
Room & Pillar Bituminous Underground Mines (tons of coal)	15,902,491	15,333,790	14,245,676
Longwall Bituminous Underground Mines (tons of coal)	30,372,264	29,286,100	27,228,912
Methane emission room and pillar (million ft^3)	2,995	2,888	2,685
Methane Emission Longwall (million ft^3)	14,417	13,902	12,925
Room and Pillar Methane Capture (million ft^3)	300	289	269
Longwall methane capture (million ft^3)	1,442	1,390	1,293
Total methane capture (million ft^3)	1,741	1,679	1,561
Projected value of methane per million Btu (assumes a 3% increase per year)	$2.50	$2.90	$3.89
Projected value of ft^3 methane (assumes a 3% increase per year)	$0.00253	$0.00293	$0.00394
Projected total value of captured methane ($ million)	$4.41	$4.92	$6.15
Estimated cost of capture equipment ($ million)	$19.60	$19.60	$19.60
Net cost (savings) of methane capture	$15.19	$14.68	$13.45
Emission reduction annual (MMTCO2e)	0.834	0.804	0.748
Cost-effectiveness ($/ton)	$18.22	$18.25	$17.98

	2030 Annual			2030 Cumulative		
	Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/tCO2e)**	**Reductions (MMTCO2e)**	**Total NPV ($MM)**	**Cost-Effectiveness ($/tCO2e)**
Coal Mine Methane	.748	$13.45	$17.98	12.643	$156.98	$12.42

Macroeconomic Analysis of Coal Mine Methane Recovery Work Plan:
The Coal Mine Methane Recovery Work Plan would encourage owners/operators of current longwall mines and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations.

Summary Table of Policy Impacts

CMM Macroeconomic Analysis				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+95	+70	+60	+90
GDP ($Millions)	+$5	+$2	+$1	+$5
Income ($Millions)	+$8	+$7	+$7	+$8

<u>Work Plan Costs and Savings Identified for Inclusion in Analysis</u>
Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the analysis and from discussion with the technical analysts who completed the analysis were as follows:

- Costs associated with drilling the wells.
- Costs associated with purchasing equipment for gathering and processing the methane.
- Savings associated with selling methane to consumers.

<u>Direct Economic Impacts Caused by Costs and Savings</u>
Once all spending, savings, costs and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with drilling the wells:
    - These are characterized as increases in demand to the construction sectors.
    - Those demands must be funded somehow, however. The burden of paying for the construction over time results in a higher overall production cost to the sectors

  carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.

- Costs associated with purchasing equipment for gathering and processing the methane:
  - These are characterized as increases in demand to the industrial machinery manufacturing.
  - Those demands must be funded somehow, however. The burden of paying for the construction over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Savings associated with selling methane to consumers:
  - These are characterized as increases in sales for companies recovering coal-bed methane.
  - These increases, however, replace some demand of the original natural gas market. Natural gas products that used to be produced and sold solely from natural gas industry are now also produced and sold by coal mining industry.

How this Work Plan Changes the Economy of Pennsylvania
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output grows in the first several years and the trend drops gradually to a decrease in total output through the year 2023. The output increases by around $21 million by 2015, and it decreases by about $3.5 million by 2030.
- The individual sectors that increase most are:
  - Construction, which contributes most the increase in the total output, stays at a relatively steady level at approximately $10 million through 2030.
  - Industrial machinery manufacturing grows by around $1.6 million by 2030.
  - No other sectors show a significant increase in the policy scenario.
- The sectors that have the worst results are:
  - Petroleum products manufacturing industry falls by about $6 million by 2030.
  - Natural gas utilities, coal mining, and oil and gas extraction also decrease over time, by approximately $3.7 million, $2.7 million, and $2.2 million, respectively, by 2030. However, coal mining industry shows an increase by 2017 but then declines.
  - No other sectors report obvious negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):

- Overall demand within Pennsylvania rises by $30 million in the first year of the policy scenario (2015), and the trend drops gradually to an increase of about $7.8 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time Or Part-Time):

- Total employment rises the largest amount in the first year, adding 162 jobs in Pennsylvania. After the first year, however, the trend decreases gradually to 62 additional positions by 2030.
- The sectors that have the highest employment changes are:
    - The construction sector grows in this policy scenario by around 100 jobs in the first year and drops to an increase of 61 jobs at the year of 2030, and is not surprisingly the largest area of growth.
    - No other sector grows significantly compared with the construction sector.
- The sectors with the lowest employment changes are:
    - Coal mining loses about 6 jobs by 2030.
    - No other sector shows obvious job losses in this policy scenario.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work rises by about $8.6 million by 2015 and drops to an increase of $4 million by 2030. This is approximately $70,000 per new position created.
- The average income per person in Pennsylvania does not show change.

Work Plan 2: Act 129 of 2008 Phases IV and V

Summary: This work plan identifies potential carbon dioxide emission reductions associated with future megawatt-hour (MWh) reductions of electricity consumption from continued participation in Act 129 energy conservation and energy efficiency programs and the associated implementation orders from the Pennsylvania PUC.

Background:
Phase I of Act 129 required electricity reductions from June 1, 2009, through May 31, 2013. Phase II began when Phase I ended and runs through May 31, 2016. The PUC's proposed Phase III will operate from June 1, 2016, through May 31 2021. Implementation of Phase I and Phase II have shown net customer benefits.

Pennsylvania has already demonstrated overall success at achieving cost-effective energy efficiency outcomes through energy efficiency and conservation measures implemented via its energy efficiency standard, Act 129 of 2008. The Statewide Evaluations report for Phase 1 achieved pursuant to Act 129 is summarized below in Table 1.

Table 1: Summary of Statewide Technical Reference Manual Verified Savings:

	CPITD Reported Gross Impact	CPITD TRM Verified Gross Impact	Savings Achieved as % of 2013 Targets
Total Energy Savings (MWh/yr)	5,567,257	5,403,370	123%
Top 100 hours Demand Reduction (MW)	1,405.12	1,349.92	113%
Total Demand Reduction	1,608.64	1,540.61	N/A
TRC Benefits ($1,000)	N/A	$4,192,389	N/A
TRC Costs ($1,000)	N/A	$1,755,384	N/A
TRC Costs-Benefits Ratio	N/A	2.4	N/A
CO2 Emissions Reduction (Tons)	3,535,208	3,431,140	N/A

TRC = total resource cost. CPITD- Cumulative Program Inception To-Date

Based upon the success of these energy conservation and efficiency programs, a continuation of the Act 129 program beyond the Phase III end date is recommended. Potential Phase IV (running from June 1, 2021, through May 31, 2026) and Phase V (running from June 1, 2026, through May 31, 2031) schedules are provided in this work plan analysis.

Note, however, that the imposition of Act 129 requirements covers the vast majority of Pennsylvania but does not include electricity consumption from EDCs with fewer than 100,000 customers, municipalities that are service providers and customers of rural electric cooperatives.

The potential electricity reduction targets and associated benefits for Act 129 Phases IV and V are:

Phase IV

- An average reduction in electricity consumption of 0.75 percent per year for the five-year period from June 1, 2021, through May 31, 2026. Based on projected growth rates of the respective EDCs, this will result in savings of 6,227,960 MWh or an approximate average of 1,245,592 MWh per year. Program savings potential estimates are based on maintaining the 2 percent funding level caps or an NPV in EDC expenditures of roughly $1.3 billion. This analysis results in a net $2.2 billion of consumer benefits through energy savings.

Phase V

- An average reduction in electricity consumption of 0.75 percent per year for the five-year period from June 1, 2026, through May 31, 2031. Based on projected growth rates of the respective EDCs, this will result in savings of 6,502,316 MWh or an approximate average of 1,300,463 MWh per year. Program savings potential estimates are based on maintaining the 2 percent funding level caps or a NPV in EDC expenditures of roughly $1.6 billion. This analysis shows net $2.6 billion of consumer benefits from energy savings.

<u>Costs and GHG Reductions:</u>

Tables 2 and 3 depict the anticipated last year annual and cumulative benefits of Act 129 through the two prescribed five-year periods of implementation for a fourth and fifth phase to extend through 2030.

Table 2. Work Plan Cost and GHG Results: Phase IV

Annual Results (2025)			Cumulative Results (2021-2025)		
GHG Reductions (MMTCO2e)	Net Costs (Million $)	Cost-Effectiveness ($/tCO2e)	GHG Reductions (MMTCO2e)	Net Costs (NPV, Million $)	Cost-Effectiveness ($/tCO2e)
3.0	(223)	(74.6)	9.0	(891)	(99.6)

Table 3. Work Plan Cost and GHG Results: Phase V

Annual Results (2030)			Cumulative Results (2026-2030)		
GHG Reductions (MMTCO2e)	Net Costs (Million $)	Cost-Effectiveness ($/tCO2e)	GHG Reductions (MMTCO2e)	Net Costs (NPV, Million $)	Cost-Effectiveness ($/tCO2e)
3.0	(271)	(89.2)	9.1	(1,083)	(119)

The net present value (NPV) of the cost savings resulting from implementation of Act 129 from 2013 through 2020 is estimated at approximately $2.0 billion. Some of this will be due to peak load reductions that result in lower wholesale energy and capacity charges, but not less energy used. Peak demand reductions are not quantified in this analysis, as discussed later in this document. There is an assumption that lower wholesale charges will be passed through to customers. Other savings will result through reducing energy consumption.

Quantification Approach and Assumptions:

- A 2014 report prepared by the PJM Resource Adequacy Planning Department (PJM) provides the energy supply data for the analysis of this work plan.[145]
- The Pennsylvania PUC has implementation responsibility for Act 129, determination of annual MWh reductions, peak load reductions and approval of each EDC's individual implementation.
- Efficiency investments installed under Act 129 are reasonably expected to have lifetimes as long as or longer than the 5-year periods of analysis (2021-2025 and 2026-2030).
- Efficient equipment is cost-effective to install, and it is assumed that it will be replaced in-kind at the end of its life. Act 129 does not specify how these reductions are to be achieved. Responses will be market-driven and will be identified in the implementation plans provided by the EDCs to the PUC. Actual savings will likely vary throughout the EDC territories, within the various rate classes and economic sectors and also based on socioeconomic factors for residential consumers.
- The efficiency percentage targets are applied to residential, commercial, and industrial loads but this assessment does not try to identify the specific percentage of load reductions that will be met by each EDC for each of the three sectors. Instead, this assessment applies a weighted average cost for energy efficiency measures, which is held constant throughout the period of analysis. This value is determined by the sector costs as identified in the Act 129 Statewide Evaluator (SWE) Energy Efficiency Potential for Pennsylvania - Final Report.[2]
- This work plan assumes that energy conservation and energy efficiency measures will continue to be cost-effective and that the existing Act 129 implementation structure, including budget caps, will remain in effect. The cost of energy efficiency measures includes program and participant costs as is typically used in a total resource cost (TRC) test. Based on SWE assessment of Phase I and Phase II flat average TRC benefit to cost ratio of 1.7 is used for this analysis.
- Projected GHG emissions in electricity assume a 0.5 percent annual reduction from the EIA's 2013 Pennsylvania value (1,112 pounds/MWh). One metric ton = 2,204.63 pounds.

Implementation Steps:

This work plan recommends a continuation of Act 129 activities beyond the currently proposed 2021 Phase III implementation plan. Based upon the SWE's Energy Efficiency Potential Study for Pennsylvania[146] there remains sufficient additional market potential for conservation and efficiency measures in electricity consumption to meet the Phase IV and Phase V targets in this work plan.

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[145] PJM Resource Adequacy Planning Department (2014). PJM Load Forecast Report. http://www.pjm.com/~/media/documents/reports/2014-load-forecast-report.ashx

[146] Act 129 Statewide Evaluator Energy Efficiency Potential for Pennsylvania - Final Report – Dated February 2015. Released via Secretarial Letter, at Docket No. M-2014-2424864, on February 27, 2015. http://www.puc.pa.gov/pcdocs/1345079.pdf

Act 129 requires the PUC to submit 5-year plans assessing the potential of further energy efficiency requirements deemed cost-effective according to a total resource cost test that also considers the annual EDC budgets for these reductions not to exceed two percent of annual revenues. The Act further stipulates that the PUC must continue this planning process every 5 years thereafter. It is recommended that Act 129 be continued through at least two additional 5-year implementation cycles (through 2030) or until such time that electricity conservation and efficiency measures are no longer cost-effective.

Potential Future Considerations
Other related items for potential future evaluation and/or consideration include: increasing the reach of the Act to include smaller electricity providers, increasing the budget cap, and creating a Commonwealth-wide systems benefit fund administered by a central authority (similar to New York State's NYSERDA).

Macroeconomic Analysis of the Act 129 of 2008 Phases IV and V Work Plan:
This work plan identifies potential carbon dioxide emission reductions associated with future reductions of electricity consumption from continued participation in Act 129 energy conservation and energy efficiency programs and the associated implementation orders from the Pennsylvania PUC.

Summary Table of Policy Impacts

Act 129 of 2008 Phases IV and V				
Economic Indicator	***2021***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+8,750	+11,200	+13,500	+10,500
GDP ($Millions)	+$980	+1,400	+$2,100	+$1,500
Income ($Millions)	+$820	+$1,300	+$1,900	+$1,300

<u>How this Work Plan Changes the Economy of Pennsylvania</u>
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output starts to grow when Phase IV comes into effect, beginning with an immediate increase of approximately $1.5 billion in 2021, and reaching nearly $3.2 billion by 2030.
- The individual sectors that increase most are:
    - The work done by the directly hired administrators, marketers, designers, developers, auditors and evaluators represent about two thirds of this growth in output.
    - Other sectors grow in size as a result of all the spending these hired people will do – retail trade grows nearly $170 million in the state, and construction, real

estate, credit services, building heating and air conditioning, and health care all show growth of at least tens of millions of dollars.

- The sectors that have the worst results are:
    - The only sector with significant reduction in output is the electricity sector, which experiences approximately $350 million less in annual activity (in 2015 dollars) by 2030 than it would have in the no-work-plan forecast. As a policy designed to spur the adoption of efficient appliances, this is an expected outcome.

Changes in Demand (Willingness to Buy Goods and Services):

- The direct labor expansion drives demand in sectors where these new employees are expected to spend the new money they earn (and would not earn in the absence of this policy), such as real estate, retail purchases, credit services and construction. A wide range of other sectors also see gains in demand, both directly from these employees, and indirectly as their spending in various sectors drives gains in demand by those sectors for labor and other intermediate demands (i.e. retail sector growth requires hires of its own, as well as more money spent on rent, wholesale goods and other needs).
- The only sector to show significant losses in demand is the electricity supply sector, where demand falls by approximately $400 million by 2030. Again, as electricity efficiency is a primary goal of this policy, reduced demand for electricity is its intended outcome.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):

- Total employment rises by 13,500 positions by 2030.
- This represents an increase of about 2.6 times the number of direct hires by the Act 129 program. That number of direct hires appears to be on the order of 5,000 positions by 2030 (the highest year).
- A lot of lower-paying sectors have high employment changes. These are retail trade (about 1,250 positions), construction (about 800 positions), food service and private household workers (about 500 each) and building maintenance (about 300 positions).
- Some higher-skilled and higher-paying sectors also grow, however. The direct hires themselves are in well-paid fields, and this policy drives growth in medical office employment (350 hires) and management and scientific/technical services (200 hires). The fields of accounting, education, securities, credit services and business support also add over 100 positions apiece.
- The sectors with the lowest employment changes are:
    - The electricity supply sector is projected by this analysis to employ about 250 fewer people under this policy than without this work plan. This is due to the lower total scale of its operations as a result of lower total demand for electricity.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work increases by about $2.0 billion by 2030.
- The overall income of jobs in Pennsylvania rises by $135 per worker by 2030.
- These per-person gains are spread broadly over dozens of sectors, with no sector showing losses in per-worker compensation.

Work Plan 3: Adopt Current Building Energy Codes

Summary:

By making conscientious efforts to reduce building energy use through energy codes, we help improve the economy and reduce the impact of buildings on the environment. Under this plan, the Commonwealth would consistently adopt the latest version of the International Construction Code (ICC) or at least the International Energy Conservation Code (IECC). By adopting the 2015 IECC (approximately 20 percent increase in energy efficiency compared to the 2009 IECC, the current code in the Commonwealth), Pennsylvania would be assured of maintaining a minimal incremental means of continuous building performance improvement. Building energy codes and standards are pivotal to a clean and sustainable energy future.

Background and Overview:

Building energy codes and standards are minimum energy efficiency requirements for the design and construction of new buildings and additions and renovations to existing buildings. Building energy codes are an integral part of building construction codes and regulations that govern all aspects of a building from structural integrity to electrical safety and fire protection.

The two most widely adopted forms of energy codes are the IECC and ANSI/ASHRAE/IEE Standard 90.1 (ASHRAE Standard 90.1). The IECC applies to all buildings, and the ASHRAE codes apply only to commercial buildings. When adopted, these codes must be satisfied as a condition for building approval and occupancy. When adoption of and compliance with these codes are achieved, buildings will use less energy, thus reducing energy demand and associated GHG emissions.

Potential Implementation Strategies:

Pennsylvania should, through the appropriate process, adopt the current building energy codes.

Building Energy Conservation Codes

Adoption of up-to-date building energy codes ultimately provides the single most cost-effective and expeditious means of achieving reductions in energy-related GHG emissions in the building sector. Commercial and residential buildings account for approximately 41 percent of all energy consumption and 72 percent of electricity usage in the United States. Building energy codes and standards set minimum requirements for energy-efficient design and construction for new and renovated buildings, assuring reductions in energy use and GHG emissions over the life of buildings.

Pennsylvania established a statewide building code through Act 45 of 2005. The Pennsylvania Uniform Construction Code (UCC) adopts the International Construction Code (ICC) family of codes, including the International Building Code (IBC), International Residential Code (IRC), International Plumbing Code (IPC), International Mechanical Code (IMC) and IECC. Although the original legislation called for automatic adoption of the latest triennial codes within a year of their publication, subsequent amendments resulted in Pennsylvania choosing not to adopt the

2012 ICC and, therefore, the 2009 ICC and IECC will be the state building code in the Commonwealth until at least 2015.

The UCC Review and Advisory Council was established by Act 106 of 2008. The council is charged with making recommendations to the governor, the General Assembly and the Department of Labor and Industry regarding proposed changes to Act 45, The Pennsylvania Construction Code Act, and reviewing the latest triennial code revisions (2015, 2018, 2021…) issued by the International Code Council contained in the International Codes enforceable under the Pennsylvania UCC. The council is required to submit a report to the secretary of Labor and Industry within 12 months following publication of the latest triennial codes specifying each code revision that is to be adopted as part of the UCC.

By consistently adopting the latest version of the ICC (or at least the IECC), Pennsylvania would be assured of maintaining a minimal incremental means of continuous building performance improvement, moving towards the goals set out in this work plan and playing a national leadership role in GHG reductions. Fourteen states (New York, Massachusetts, Rhode Island, Delaware, Maryland, Virginia, Kentucky, Mississippi, Illinois, Iowa, Utah, California, Oregon, Washington) and the District of Columbia) have already surpassed Pennsylvania by adopting the 2012 IECC and are on track to adopt the 2015 IECC.

Key Assumptions:

- Megawatt hour consumption estimates from the EIA AEO 2014;
- Projected cost of electricity and natural gas from the EIA AEO 2014;
- 20 percent reduction in electricity and natural gas use for buildings adopting new codes vs. projected use;
- 2.0 percent of buildings annually will be built to new code;
- Cost of adopting new code = $99 million (commercial) and $140 million (residential) based on payback period (residential = 3.4 years, commercial = 4.2 years) estimated using Department of Energy analysis to adopt 2012 EICC;
- Projected GHG emissions in electricity assume .5 percent annual reduction from 2013 Pennsylvania value (1,112 pounds/MWh).

Commercial	2015	2030
Projected Electricity Consumtion (MWh)	42,915,282	43,459,194
Projected Cost of Electricity ($/MMBtu)	$36.32	$40.16
Projected NG Consumption (Billion btu)	149,558	152,298
Projected Cost of NG ($/MMBtu)	$8.38	$11.65
Energy Savings by adopting new codes	18.00%	18.00%
% of buildings changing up to code	2.00%	2.00%
Projected GHG Emissions Electricity (lb CO2e/MWh)	1,101	1,021
Projected GHG Emissions NG (Lb CO2e/MMBtu)	117	117
Emission Savings in MMtCO2e	0.106	1.662
Cost of adopting the code in million $ (4.2 yr payback)	99.0	99.0
Energy Savings in Million $	23.66	403.23
Net Cost of adopting the code in million $	75.34	-304.23

Residential	2015	2030
Projected Electricity Consumtion (MWh)	51,632,590	51,085,560
Projected Cost of Electricity ($/MMBtu)	$50.26	$53.34
Projected NG Consumption (Billion btu)	225,235	209,685
Projected Cost of NG ($/MMBtu)	$11.55	$15.21
Energy Savings by adopting new code	18.00%	18.00%
% of buildings changing up to code	2.00%	2.00%
Projected GHG Emissions Electricity (lb CO2e/MWh)	1,101	1,021
Projected GHG Emissions NG (Lb CO2e/MMBtu)	117	117
Emission Savings in MMtCO2e	0.136	2.088
Cost of adopting the code in million $ (3.4 yr payback)	140.0	140.0
Energy Savings in Million $	$41.24	$673.67
Net Cost of adopting the code in million $	98.76	-533.67

	2030 Annual			2030 Cumulative		
	Reductions (MMTCO2e)	Cost ($MM)	Cost-Effectiveness ($/tCO2e)	Reductions (MMTCO2e)	Total NPV ($MM)	Cost-Effectiveness ($/tCO2e)
Energy Codes	3.75	-838	- 223	32.2	-2,745	-85

Potential Overlap

- High Performance Buildings Work Plan

Macroeconomic Analysis of Energy Codes Work Plan:

By making conscientious efforts to reduce building energy use through energy codes, we help improve the economy and reduce the impact of buildings on the environment. Under this plan, the Commonwealth would consistently adopt the latest version of the ICC or at least the IECC. By adopting the 2015 IECC (approximately 20 percent increase in energy efficiency compared to the 2009 IECC, the current code in the Commonwealth), Pennsylvania would be assured of maintaining a minimal incremental means of continuous building performance improvement. Building energy codes and standards are pivotal to a clean and sustainable energy future.

Summary Table of Work Plan Impacts

Adopt Current Building Energy Codes				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+1,250	+1,100	+1,090	+1,200
GDP ($Millions)	-$9	-$20	-$20	-$10
Income ($Millions)	+$50	+$50	+$60	+$50

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with adopting the latest version of building code. This additional spending applies to both the residential sector and to businesses. The costs stay at a steady level over the 2016-2030 period as the policy design document indicates.
- Savings associated with the reduction in use of natural gas and electricity as buildings become more efficient. The savings applied to both the residents and businesses.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with adopting the building code:
  - For residential sector improvements: increases in spending in household maintenance.
  - For businesses: increases in demand to the construction sector.
  - Those spending and sales must be funded somehow, however. For residents, the burden of paying for the household maintenance over time results in less spending on other consumer goods and services, ranging from basics like food, clothing, housing and transportation to all manner of other consumer demands.

    - For business, the burden of paying for construction over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product as before.
- Savings associated with the reduction in use of electricity and natural gas:
    - For residents: decrease in spend for electricity and natural gas.
    - For business: reductions in demand for electricity and natural gas.
    - For residents, these reductions, free up money for spending on a mix of consumer goods and services.
    - For business, these reductions represent a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

How this Work Plan Changes the Economy of Pennsylvania
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:
Changes in Output (Total Value of Goods or Services Produced):
- Total output increases in the first couple of years and drops gradually to a decrease through 2019. In the policy scenario, it grows by around $70 million by the first year (2015), and turns to decrease by around $16.6 million by 2030.
- The individual sectors that increase most are:
    - Construction, which contributes the most among other industries, grows at a relatively steady level by around $84 million by 2030.
    - The private households sector, the services to buildings and dwellings sector, and business support services sector also shows growth at a steady level, by around $19 million, $18 million, and $16 million respectively by 2030.
    - No other sectors grow significantly when compared with construction sector.
- The sectors that have the worst results are:
    - Electric utilities lose output steadily over time, decreasing nearly $46 million in annual output by 2030.
    - Retail trade shows a similar trend, falling nearly $14.6 million by 2030.
    - Natural gas utilities also decrease steadily over time, nearly $11 million by 2030.
    - No other sectors report significant negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):
- Overall demand within Pennsylvania rises by approximately $67 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):
- Total employment rises significantly in the first year, adding 1,851 jobs in Pennsylvania. After the first year, however, the trend of employment decreases to a fraction. It then increases steadily to around 1,100 additional positions by 2030.

- The sectors that have the highest employment changes are:
    - The private households sector grows in this policy scenario by around 1,000 jobs in the first year, and drops to around 850 new jobs annually for the following years.
    - The construction sector sees growth in the employment of approximately 500 jobs by 2030.
    - The services to buildings and dwellings sector and business support services sector also see growth of about 250 and 180 new jobs respectively by 2030.
    - Indirect benefits show up in sectors like truck transportation, personal and household goods, repair and maintenance, etc., which all show gains in the policy scenario, but not significantly when compared with private household sector.
- The sectors with the lowest employment changes are:
    - Retail trade sector and food service places sector both show a loss of jobs by approximately 100 by 2030.
    - Indirect impacts also show up in sectors like nursing and residential care facilities, educational services, accommodation, etc., but by losses of jobs less than 50 by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work rises by about $34 million by 2030. This is approximately $18,000 per new position created.
- The overall income of jobs in Pennsylvania drops by $6 by 2030, mostly due to construction and private household industry bringing in many relatively low-income jobs.

Work Plan 4: Geoexchange Systems (Ground Source Heat Pumps)

A geoexchange ground source system is an electrically powered heating and cooling system for interior spaces. This system utilizes the earth or a pond or lake for both a heat source and a heat sink. A geoexchange system consists of three main parts: pipes buried in the ground, a heat exchanger and ductwork to distribute heat into the structure. The series of pipes, called a loop, is buried in the ground, either vertically or horizontally, near or beneath the structure. The loop circulates a fluid (water, or a mixture of water and antifreeze) that absorbs heat from, or relinquishes heat to, the surrounding soil, depending on whether the building requires heating or cooling. Components of this system include a heat pump, a hydronic pump, a ground heat exchanger, and a distribution subsystem. Most geoexchange systems utilize air ducting for the distribution system and polyethylene piping in the earth for the heat exchanger.

How Geoexchange Works:

The ambient temperatures above ground change from day to day and season to season. However, depending on latitude, the temperature beneath the upper 6 meters (20 ft.) of the Earth's surface remains nearly constant between 10 and 16 °C (50 and 60 °F) if it is undisturbed by the presence of a heat pump. A ground source heat pump (GSHP) is a type of central heating and/or cooling system that transfers heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). Like a refrigerator or air conditioner, these systems use a heat pump to force the transfer of heat from the ground. Heat pumps can transfer heat from a cool space to a warm space, against the natural direction of flow, or they can enhance the natural flow of heat from a warm area to a cool one. This is much more energy-efficient because underground temperatures are more stable than air temperatures through the year. Seasonal variations drop off with depth and disappear below 7 meters (23 ft.) to 12 meters (39 ft.) due to thermal inertia. Geothermal pump systems reach fairly high coefficient of performance (CoP), 3 to 6, on the coldest of winter nights, compared to 1.75 - 2.5 for air-source heat pumps on cool days.[147] GSHPs are among the most energy efficient technologies for providing HVAC and water heating.

GSHP Cost and Deployment:

Initial installation costs for a GSHP are higher than for conventional HVAC systems, but the difference is usually returned in energy savings in 3 to 10 years, and even shorter lengths of time when federal, state and utility tax credits and incentives are applied. While equipment costs are competitive, installation costs vary significantly. The cost of the loop proves to be the most expensive component of the system. However, because the ground infrastructure is typically warrantied for 50 years, the assumption here is that the cost of installing a ground source heat pump is only slightly higher than the cost of conventional equipment. When the life cycle and replacement cost of conventional equipment are taken into consideration, compared to the warranted time frame the GSHP, the up-front added cost of the ground loop is offset over time. Cost is factored by including avoided boiler capital, operational, and maintenance costs.

[147] Colorado Renewable Energy Society (2011). Geothermal Energy

In other applications, such as at campus locations, institutions, industrial parks and housing sub-divisions, geoexchange can be more cost-effective because a single loop can be used to provide for multiple units, thereby lowering the installation cost of the loop. In the case of housing subdivisions a single loop can be used to accommodate multiple homes. In this way the cost of the loop can be split among the involved homeowners, thereby lowering the cost. When it comes to residential heating and cooling loads, the trend is toward smaller loads (due to improved building envelopes with reduced air leakage, thicker insulation, and better windows), rather than larger loads. A new home with a good thermal envelope doesn't need much heating or cooling.

Geoexchange heat pump systems are reasonably warrantied by manufacturers, and their working life is estimated at 25 years for inside components and 50+ years for the ground loop. As of 2010, approximately 1.5 million GSHP units have been installed in the United States, accounting for approximately 337,000 tons of heating and cooling capacity.[148] Pennsylvania has installed approximately 21,350 tons of geothermal heating/cooling capacity.[2]

Summary:
This work plan strategy capitalizes on the energy-effectiveness of GSHPs in Pennsylvania's climate, and the accompanying reductions in carbon emissions and in demand for peak generation and transmission. The environmental impact of geoexchange energy depends on how it is used or on how it is converted to useful energy. GSHPs have almost no negative impact on the environment. Geoexchange heat pumps can actually have a positive effect because they may reduce or avoid the use of other types of energy that may have greater negative impacts on the environment.

Pennsylvania is already ranked as one of the top-tier states for experienced and competitive installation of GSHPs in its urban centers. This strategy would build on that strength, expanding the network of trained drillers and installers throughout the state. This strategy advocates GSHP installations for individual buildings and in district systems.

Additional benefits of GSHPs include:

- They level seasonal electrical demand and lead to 42–48 percent reduced demand for new capacity.[149]
- They are widely applicable.
- Operating costs are economical due to high coefficient of performance (metered Department of Defense installations in Pennsylvania achieve mean coefficient of performance of 4.0 [4] and energy efficiency ratio of 20.83).[5]
- Water heating is integrated at low cost (waste heat can be scavenged whenever compressors are running).

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[148] Oak Ridge National Laboratory (U.S.), Tianjin University (China), Chongqing University (China) (2010), A Comparative Study of the Status of GSHP Application in the U.S. and China.
[149] Hughes, Patrick (2008). Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

- Part-load performance is excellent.
- Maintenance is simpler and less costly than conventional fossil fuel heating and cooling tower systems.
- Reduces the use of fossil fuels as heating fuel.
- Reduction in peak demand reduces the need for new power plants, and carbon emissions are reduced.

The calculations here are based on GSHP installations for individual buildings. District systems can offer economies of scale in the exterior infrastructure, but data on this are limited. Table 1 shows the estimated GHG reductions and cost-effectiveness projected for new installations in Pennsylvania.

Table 1. Estimated GHG Reductions and Cost-Effectiveness

Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
3.65	-$1283	-$367	35.1	-$7172	-$204.33

Table 1- Residential emissions reductions and costs are calculated using 20 percent of new and 2 percent of existing dwelling GSHP installations for heating and cooling by 2030 scenario. Commercial reductions and costs are calculated using 12.5 percent of existing and 40 percent of new commercial building GSHP installations for heating and cooling by 2030 scenario.

Key Assumptions:

Key Data and Assumptions	2015	2030	Units
First Year Results Accrue		**2015**	
Electricity			
Incremental Cost of a Geoexchange GSHP system			
Residential, household with/without central cooling		**$3,000**	$/housing unit

[4]The coefficient of performance (COP**)** of a heat pump is a ratio of heating or cooling provided to electrical energy consumed. Higher COPs equate to lower operating costs. COP is highly dependent on operating conditions, especially absolute temperature and relative temperature between sink and system.
[5]The Energy Efficiency Ratio (EER) of a particular cooling device is the ratio of *output* cooling energy (in BTU) to *input* electrical energy (in Wh) at a given operating point. EER is generally calculated using a 95 °F outside temp and an inside (actually return air) temp of 80 °F and 50% relative humidity.

Key Data and Assumptions	2015	2030	Units
Cost of Geothermal system[6]			
Commercial, existing buildings		**$14.4**	$/sq ft
Commercial, new buildings		**$12.5**	$/sq ft
Cost of NG+AC VAV system (base case system)[7]			
Commercial, existing buildings		**$14.4**	$/sq ft
Commercial, new buildings		**$12.5**	$/sq ft
Avoided Electricity Cost		**$134**	$/MWh
Avoided Natural Gas Cost		**$6.7**	$ / million Btu
Avoided Fuel Oil Cost	**$24.8**	**$29.7**	$ / million Btu
Emissions from additional Electricity Use		**0.85**	tCO2/MWh

Results Summary	2015	2030	Units
Incremental GHG Emission Savings	**0.87**	**3.65**	MMTCO2e
Net Present Value		**-$7,172**	$ million
Cumulative Emissions Reductions		**35.1**	MMTCO2e
Cost-Effectiveness		**-$204.33**	$/tCO2e
Cost 2030		**-$1283**	$ million
Cost-Effectiveness 2030		**-$367**	$/tCO2e

Other Data, Assumptions, Calculations	2015	2030/all	Units
Inputs to/Intermediate Results of Calculation of Electricity and Gas Savings			
Total Commercial Floorspace in Pennsylvania	5,336	6,139	million sq ft
Annual demolition of commercial floorspace		0.58%	
.			
Est. area of new commercial space per year in PA	85.2	89.8	million sq ft
Total Residential Housing Units in Pennsylvania	5,666,055	5,577,335	units
Implied persons per housing units in Pennsylvania (for reference only)	2.26	2.26	persons

[6]Hughes, Patrick (2008). Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf
[7]Meline Engineering (2009), Installed Costs (U.S. Estimated Range 2009)

Other Data, Assumptions, Calculations	2015	2030/all	Units
Annual demolition of residential floorspace		**1.43%**	
Estimated number of new residential units per year *Calculated based on estimates above.*	**88,286**	**90,020**	units
Average Electricity Consumption per Square Foot Commercial Space (2003)		**12.50**	kWh/sq. ft.
Average Natural Gas Consumption per Square Foot Commercial Space (2003)		**43.80**	thousand Btu / sq. ft.
Average Fuel Oil Consumption per Square Foot Commercial Space (2003)		**23.97**	thousand Btu / sq. ft.
Average Electricity Consumption per Housing Unit (2005)		**8.50**	MWh
Average Natural Gas Consumption per Housing Unit		**82**	million Btu / household
Average Fuel Oil Consumption per Housing Unit		**106**	million Btu / household
Coefficient of Performance (COP) - Residential and Commercial		**3.7**	
Energy savings due to ground source heat pumps			
Residential		**45%**	
Commercial[8]		**30%**	

<u>Implementation Steps</u>:

1. Encourage the Department of General Services to do comprehensive life-cycle cost analysis for new buildings and building upgrades and advocate/support use of life-cycle cost analysis for all new and retrofit projects in the public and private sectors.
2. Outreach Training. Educate designers/contractors/consumers about geothermal heat pump efficiency ratings, COP/EER, and highlight currently achievable efficiencies in

[8] Calculations and assumptions provided in this table can be found in the RCI Quantifications Work Book. Data was contributed by multiple sources including: *G. Mattern, P.E., Adjunct Professor & geothermal specialist, Carnegie Mellon Univ., Input from V. Loftness & N. Baird, CBECS Tables. RECS Table US14 EIA calculated estimate for AC assumes electricity.*

Pennsylvania climate. Provide information on current federal and state policies and programs that can provide grants and loans for geothermal installation. Establish a mechanism for verifying the competence of drillers and external loop/well installers, and require that only state-approved drillers/installers are used (Oregon has such a policy).

3. Establish or encourage policies that will give electric distribution companies (EDC) an incentive to install the external loop infrastructure and lease them on per-ton basis such as allowing aggregated savings from GSHPs to be a proxy for carbon trading credits. With this strategy, utilities will lose energy sales revenue, but will recoup some of it on loop leases and rate-based infrastructure. They'll also lose money on demand charges, but can earn credit under the Alternative Energy Portfolio Standard. Consumers get some efficiency benefits.
4. Encourage Congress to extend the Federal Energy Efficiency Tax Credits beyond 2016.
5. Establish state-funded programs that offer tax breaks to companies who install geothermal heating at new construction and renovated commercial buildings.
6. Encourage state agencies such as DEP and the Commonwealth Financing Authority to continue offering energy efficiency grants and loans.
7. Research the current geothermal resource availability and identify possible stakeholders. This will provide insight into the amount of geothermal opportunity in a particular area allowing for the design of policy that is feasible and will also address any strengths and weaknesses for geothermal deployment.
8. Provide incentives to land developers to install community loops and provide geoexchange heating and cooling options to potential home buyers in subdivisions.

Assumptions:

Related to implementation step 3 above and to the extent that it is allowed, EDCs can and/or should be eligible to receive Tier II AEPS credits from the energy savings associated with the operation of GSHPs. The same should also be true for compliance with Act 129.

Macroeconomic Analysis of Geoexchange Systems Work Plan:

This work plan strategy capitalizes on the energy-effectiveness of GSHPs in Pennsylvania's climate, and the accompanying reductions in carbon emissions and in demand for peak generation and transmission. The environmental impact of Geoexchange energy depends on how it is used or on how it is converted to useful energy. GSHPs have almost no negative impact on the environment. Geoexchange heat pumps can actually have a positive effect because they may reduce or avoid the use of other types of energy that may have greater negative impacts on the environment.

Pennsylvania is already ranked as one of the top-tier states for experienced and competitive installation of GSHPs in its urban centers. This strategy would build on that strength, expanding the network of trained drillers and installers throughout the state. This strategy advocates GSHP installations for individual buildings and in district systems.

Summary Table of Policy Impacts

Geoexchange Systems (Ground Source Heat Pumps)				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+720	+1,450	+2,375	+1,220
GDP ($Millions)	-$280	-$400	-$560	-$360
Income ($Millions)	-$30	-$20	+$30	-$20

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the analysis, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with the use of exterior heat exchangers. The design document of this policy states that the cost of installing ground source heat pumps is no greater than cost of conventional equipment because of the 50-year warranty of ground infrastructure. The policy thus assumes incremental cost of Geoexchange system reflects exterior heat exchangers. In order to receive benefit from Geoexchange system, both residents and businesses need to spend money on those exchangers.
- Savings associated with the reduction in use of electricity, natural gas, and fuel oil as Geoexchange system provides energy to users; the reduction in use of natural gas and electricity as buildings become more efficient. These savings actually grow each year, as a larger and larger share of all buildings are using the Geoexchange systems each year.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with the use of exterior heat exchangers:
    - For residents, these are increases in sales to the household appliance companies.
    - Those sales must be funded somehow, however. The burden of paying for the household appliances over time results in less spending on other consumer goods and services, ranging from basics like food, clothing, housing and transportation to all manner of other consumer demands.
- Savings associated with the use of exterior heat exchangers:
    - For businesses, this specific policy study shows the cost of heat exchangers is actually less than conventional equipment, and so on an annualized basis, the demand change in HVAC industry is actually a savings.
    - These are characterized as decreases in demand to the HVAC industry.
    - This reduction represents a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

- Savings associated with the reduction in use of electricity, natural gas, and fuel oil:
    - For residents, these are a decrease in spending in electricity, natural gas, and fuel oil.
    - For business, these are reductions in demand for electricity, natural gas, and fuel oil.
    - For residents, these reductions, however, free up money for spending on a mix of consumer goods and services.
    - For business, these reductions represent a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

How this Work Plan Changes the Economy of Pennsylvania
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output declines gradually by $635 million by 2030.
- The individual sectors that increase most are:
    - Indirect benefits show up in sectors like retail trade, real estate, and offices of health practitioners, which all show gains in the policy scenario by $50-$60 million by 2030.
    - Indirect benefits also show up in sectors like food services and drinking places, monetary authorities, wholesale trade, etc., which show gains in the policy scenario by $25-$40 million by 2030.
- The sectors that have the worst results are:
    - Electric utilities lose output steadily over time, falling by nearly $746 million in annual output by 2030.
    - Natural gas utilities also decrease steadily over time, by nearly $127 million by 2030.
    - Petroleum utilities, construction, and oil and gas extraction decrease by about $90 million, $85 million, and $60 million respectively by 2030.
    - The support activities for mining sector decreases by approximately $25 million by 2030.
    - Indirect impacts also show up in sectors like the computer system design and architectural, which show loss in output about $20 million and $17 million by 2030.

Changes in Demand (Willingness to Buy Goods and Services):

- Overall demand within Pennsylvania reduces by approximately $918 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-time or Part-time):

- Total employment rises gradually, adding 2,373 jobs in Pennsylvania by 2030.

- The sectors that have the highest employment changes are:
    - Food and beverage establishments, which add 551 jobs by 2030.
    - Retail trade sees growth in this policy scenario by around 450 jobs by 2030.
    - Positions in the offices of health practitioners sector increases by 345 jobs by 2030.
    - Indirect benefits show up in sectors like the individual and family services, educational services, nursing and residential care facilities, etc., which all show gains in the employment by around less than 200.
- The sectors with the lowest employment changes are:
    - Electricity supply and the construction sector both show a loss of jobs by approximately 500 positions by 2030.
    - Indirect impacts show up in sectors such as computer system design, oil and gas extraction, natural gas supply, support activities for mining, architectural, etc., which all show losses in the employment by over 60 but less than 100 by 2030.
    - No other significant job losses are shown in the policy scenario.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work drops by about $42 million by 2030.
- The average per-employee compensation in Pennsylvania drops by $28 by 2030.
- The pipeline transportation sector and the petroleum products sector see a reduction of average annual income per person by $96 and $68 per year by 2030 respectively. Many sectors impacted indirectly see some gain in average annual income between $5 to $10 by 2030, such as air transportation, offices of health practitioners, hospitals, etc.

Work Plan 5: Heating Oil Conservation and Fuel Switching

Summary:

Demand Side Management for Heating Oil

Demand side management (DSM) is the modification of consumer demand for energy through various methods such as financial incentives, education, conservation and fuel switching to name a few. The goal of DSM is to encourage the consumer to use less energy. This initiative aims to replace or upgrade inefficient household appliances that utilize fuel oil with more energy-efficient models, thereby decreasing energy consumption and reducing emissions.

DSM for Heating Oil

Residential sector: Achieve 37 percent reductions from reference case oil consumption in 2030.
Commercial sector: Achieve 26 percent reductions from reference case oil consumption in 2030.

Fuel Switching - Natural Gas

This initiative recognizes the potential for additional GHG reductions through fuel switching from heating oil to natural gas. Please note that the work plan is a simple analysis of combustion and does not include an analysis of methane leakage. This analysis evaluated only residential sector GHG savings. In the future, the commercial sector should be examined, as it may have the potential for cost-effective GHG savings.

Natural Gas

Fuel switching to natural gas can also yield reductions in GHG emissions. Fuel switching to natural gas has increased with the decrease in natural gas prices and is expected to continue. According to the EIA, the average Pennsylvania home fueled by heating oil uses approximately 516 gallons per year, whereas the average home fueled by natural gas uses approximately 53,000 cubic feet per year. The mid-Atlantic region EIA data for 2015 predicted that the average delivered cost of natural gas to the residential sector was $11.55 per MMBtu[1]. The average price of heating oil in the mid-Atlantic region for the same time period was $25.10 per MMBtu[1]. At these prices the average family could save approximately $1,126 per year in heating fuel costs by switching to natural gas. In addition, every household that switches from oil to natural gas could contribute a GHG emission reduction of 28 metric tons annually, not accounting for any future additional natural gas projections. UGI expects to increase their customer base by almost 10,000 new customers and Columbia Gas expects an increase of 3,500 new customers in 2015. However, large geographical areas of the Commonwealth still do not have access to natural gas, including urbanized areas of the southeast. Additionally, there are numerous neighborhoods where natural gas is only partially available.

With the onset of two pilot programs in 2014 by Pennsylvania natural gas distributions companies, UGI's GET Program and Columbia Gas's NAS Program, the addition of another 2,350 households switching to natural gas is possible. These new acquisitions are in addition to their normal annual new customers. This work plan assumes a total of 4,500 homes converting each year from fuel oil to natural gas for home heating (approximately .5 percent of the homes in the Commonwealth using fuel oil). The cost of conversion is assumed to be $5,600—the estimated cost of a furnace conversion and a gas connection to a home.

Fuel switching to natural gas should be encouraged by first ascertaining what may be the barriers to greater deployment and providing incentives to hasten the transition to this cleaner-burning, domestically produced fuel.

Implementation Steps for Conservation:

Encourage:

1. Air sealing and insulation (10–40 percent annual energy savings)
   - Seal air leaks in homes or businesses; duct sealing increases efficiency and reduces energy usage.
   - Adding insulation to buildings can slow heating and cooling in extreme temperatures.
   - By air sealing & insulation, consumers could probably save up to 25 percent of this.
   - Install multi-pane windows to provide extra layers of protection from heat entering or escaping, reducing energy consumption.
2. Furnace and boiler efficiency at >95
   - Nationwide and in Pennsylvania, more than 10 percent of homes use oil for heating.[3]
   - Continue programs like Keystone HELP to provide low interest loans to Pennsylvania residents who wish to upgrade their present heating system and building envelope.
3. Domestic hot water heaters
   - Encourage purchase of high efficiency water heaters.

Implementation Steps for Fuel Switching:

- Encourage the PUC to approve more programs such as UGI's Growth Extension Tariff (GET) program and Columbia Gas's New Area Service (NAS) program, which allows customers to pay a monthly surcharge, avoiding significant up-front costs, when connecting to a new natural gas main extension.
- Encourage other natural gas distribution companies to develop pilot programs to expand natural gas service areas.
- Encourage the use of on-bill financing and other creative financing options to assist with the payment of new and conversion gas appliance installations and hook-up fees.
- Recommend the PUC and DCED create map(s) showing the areas likely underserved by natural gas based on analysis of population density and number of natural gas customers.
- Heating water accounts for 14–25 percent of total household energy consumption. Solar water heaters can provide 85 percent of domestic hot water needs.
- Tankless water heaters heat the water as it runs through a coil in the appliance. These are more efficient than high efficiency heaters, given that they only use fuel to heat water when flowing (rather than heating the tank). They can save 45–60 percent over standard water heaters.
- For homes that use 41 gallons or less of hot water daily, demand water heaters can be 24-34 percent more energy efficient than conventional storage tank water heaters.
- Instantaneous hot water heaters can be 8–14 percent more energy efficient for homes that use a lot of hot water—around 86 gallons per day. Even greater energy savings of

27-50 percent can be achieved if a demand water heater is installed at each hot water outlet.

Key Data and Assumptions	2015	2030	Units
First Year Results Accrue	**2015**		
Savings Targets			
Heating Oil DSM			
Achievable cost-effective savings in heating oil use as a fraction of total oil demand:			
Residential		**37%**	
Commercial		**26%**	
Fraction of achievable savings reached under program		**100%**	
Year in which target fraction reached		**2030**	
Year in which programs fully "ramped in"		**2030**	
Fraction of full program savings by year	0%	100%	
Implied fractional new annual oil demand savings, residential	0.0%	4.6%	
Implied fractional new annual oil demand savings, commercial	0.0%	3.3%	
Residential		**$0.63**	$/gal
Commercial		**$0.98**	$/gal
Value from Pennsylvania: Energy Efficiency, Demand Response and On-Site Solar Potential. ACEEE 2009.			
Assumed average measure lifetime		**16**	years
Avoided Delivered Heating Oil Cost		**$29.97**	$/MMBtu
Avoided Delivered Heating Oil Cost		**$3.9**	$/gal
Avoided Heating Oil Emissions Rate		0.07	tCO2e / MMBtu

Additional Data and Analyses	2015	2030	Units
DSM Heating Oil Analyses			
Reduction in Oil Use (Cumulative)	4,465	98,095	Billion Btu
Reduction in Oil Use (Cumulative)	32	490	Million Gal
Reduction as % of overall projected sales in that year	2.14%	32.51%	
Incremental GHG Emission Savings, Heating Oil	**0.3**	**4.9**	MMTCO2e
GHG Emission Savings (2015-2030)		**41.9**	
Net Present Value (2015-2030) (DSM)		**-$137**	$million
Cost (2030) (DSM)		**-$14**	$million
Cost-effectiveness (2030) (DSM)		**-$3**	$/tCO2e
Cost-effectiveness (2015-2030) (DSM)		**-$3.27**	$/tCO2e
Total Fuel Consumption after DSM	204,490	141,333	Billion Btu
Total Heating Oil Consumption after DSM	1,397	966	Million Gal

Fuel Switching from Heating Oil to Natural Gas	2015		2030

Year	2015			2030	
Fuel	NG	Fuel Oil		NG	Fuel Oil
% of Homes (2013 data)	50.9%	17.6%			
PA Homes	4900000	4900000			
Homes using fuel	2,494,100	862,400			
Total BTU's consumed (2012 data)	2.06E+14	7.15E+13			
BTU's per household	8.26E+07	8.29E+07		8.26E+07	8.29E+07
BTU content of fuel	1,030	138,500		1,030	138,500
Total amount of fuel	199,991,262	516,194,946			
Units	MCF	gallon			
fuel per home	53,457	516		53,457	516
2015 cost per MMBtu (EIA est.)	11.554	25.101		15.208	29.266
2015 yearly cost per home	954	2,081		1,256	2,426
CO2 emission Rate	.12/scf	22.58/gallon		.12/scf	22.58/gallon
Emission per home (lb CO2e)	6,415	11,657		6,415	11,657
fuel savings ($) per home	1,126.61			1,170.10	
Emission savings (tons) per home	2.62			2.62	
# of homes switching	4500			4500	
Cost of switching per home	5600			5600	
Gross cost of switching ($ million)	25.20			25.2	
Fuel savings ($ million)	5.07			82.78	
Net Cost of switching ($ million)	20.13			-57.58	
GHG Reductions by switching (MMTCO2e)	0.01			0.19	
Cost effectiveness	1881.69			-306.88	

Potential GHG Reduction:

Table 1. Estimated GHG Reductions and Cost-effectiveness for Heating Oil Conservation

Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	Costs (Million $)	Cost-Effectiveness ($/tCO2e)	GHG Reductions (MMTCO2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO2e)
4.93	-$14	-$2.83	41.9	-$151	-$3.62

Table 2. Estimated GHG Reductions and Cost-effectiveness for Fuel Switching

Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMTCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
0.19	-$57.58	-$306.88	1.59	-$138.54	-$87.32

Potential Overlap:

- High Performance Buildings Work Plan

Summary Table of Policy Impacts

Heating Oil Conservation and Fuel Switching				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+680	+600	+530	+620
GDP ($Millions)	+$50	+$60	+$70	+$60
Income ($Millions)	+$40	+$50	+$50	+$50

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the analysis and from discussion with the technical analysts who completed the analysis were as follows:

- Costs associated with adapting buildings to meet the requirements of heat oil conservation. This additional spending applies to both the residential sector and to businesses.
- Costs associated with household appliances to switch from heat oil to natural gas
- Costs of using more natural gas.
- Savings associated with using less heat oil for both residential sector and business due to the heat oil conservation policy.
- Savings associated with using less heat oil due to fuel switching for residents.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with adopting buildings to meet the requirements of heat oil conservation:

  - For residential sector improvements, these are increases in sales to the household maintenance sector and the household appliances sector.
  - For businesses, these are increases in demand to the heat insulation companies and boiler improvement companies.
  - Those sales must be funded somehow, however. The burden of paying for house insulation materials to household maintenance and appliance companies over time result in less spending on other consumer goods and services, ranging from basics like food, clothing, housing and transportation to all manner of other consumer demands.
  - For business improvements, the burden of paying for the insulation and boiler improvement over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product as before.
- Costs associated with switching household appliances from heat oil to natural gas:
  - These are an increase in sales to household maintenance companies.
  - Those sales must be funded somehow, however. The burden of paying for household maintenance over time results in less spending on other consumer goods and services.
- Costs associated with using more natural gas due to the switch from heat oil:
  - These are an increase in spending on natural gas from utilities.
  - This spending must be funded somehow, however. The burden of paying for additional natural gas over time results in less spending on other consumer goods and services.
- Savings associated with using less heat oil due to the heat oil conservation policy:
  - For residents, these are a decrease in spending for fuel oil.
  - For business, these are reductions in demand for petroleum products.
  - For residents, these reductions, however, free up money for spending on a mix of consumer goods and services.
  - For business, the reduction represents a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.
- Savings associated with using less heat oil due to fuel switching for residents:
  - These are characterized as decrease in spending for fuel oil.
  - These reductions, however, free up money for spending on a mix of consumer goods and services.

How this Work Plan Changes the Economy of Pennsylvania
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:
Changes in Output (Total Value of Goods or Services Produced):

- Total output grows gradually to about $40 million through 2019 and keeps at a relatively steady level at about $45 million through 2030.
- The individual sectors that increase most are:

  - Natural gas supply would add approximately $46 million to Pennsylvania's economy by 2030.
  - Electricity supply and the construction sector both grow about $17 million by 2030.
  - Indirect benefits show up in real estate, offices of health practitioners and other sectors, but in very small amounts.
- The sectors that have the worst results are:
  - Petroleum and coal products manufacturing loses output over time, decreasing nearly $80 million in annual output by 2030.
  - Retail trade also shrinks gradually over time, nearly $50 million by 2030.
  - No other sectors report significant negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):
- Overall demand within Pennsylvania rises by nearly $62 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):
- Total employment keeps rising in the policy scenario by around 530 new positions by 2030.
- The sectors that have the highest employment changes are:
  - The private households sector grows in this policy scenario by more than 200 jobs by the first year, and keeps this level through 2030.
  - The construction sector and services to buildings and dwellings sector see growth by nearly 100 and 75 new employments, respectively, by 2030.
  - Indirect benefits show up in sectors like food and drink establishments, office of health practitioners, etc., which all show gains in the policy scenario, but not significantly when compared with private household sector.
- The sectors with the lowest employment changes are:
  - Only retail trade show significant losses of jobs. The number of employment declines by nearly 420 by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):
- Total compensation for work rises by about $38 million by 2030. This is approximately $72,000 per new position created.
- The average compensation per person in Pennsylvania does not show a significant change.
- No individual industry shows a significant change in annual income rate.

Work Plan 6: Combined Heat and Power (CHP)

Combined heat and power (CHP) describes an energy production system that produces not only electricity, but also useful thermal energy, typically in the form of steam.

CHP allows for a user of both thermal and electrical energy to integrate a production system that optimizes thermal energy to address electrical needs as well as thermal energy needs. CHP offers significant benefit to industry and our Commonwealth and the country through increased efficiency, improved environmental performance, reduced losses and improved reliability in electricity transmission, more effective use of natural resources, decreased costs and improved national competitiveness. As with all power generation, CHP deployment has unique cost, operational, and other characteristics, but it is a proven and effective available clean energy option that can help Pennsylvania enhance energy efficiency, reduce GHG emissions, promote economic growth, and maintain a robust energy infrastructure. CHP also offers the opportunity to improve and contribute to critical infrastructure resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in service. CHP is generally most cost-effective in industrial or commercial settings with large thermal heat loads that are in operation 24 hours a day. Currently there are CHP units located at food, paper, chemical, refinery, and metal industries along with solid waste, healthcare, colleges and other commercial settings across Pennsylvania.

Other Involved Agencies: Public Utility Commission

Possible New Measure(s):
2012 data shows Pennsylvania with 124 CHP industrial and commercial sites with a total capacity of over 3000 MW. Over 1,000 MW of these are coal-fired generating plants. The average capacity of commercial and industrial CHP units installed in Pennsylvania between 2002 and 2012 is approximately 1.9 MW and the median is approximately 400 kW. An average of approximately 6.0 MW of industrial and commercial CHP has been installed annually in Pennsylvania between 2002 and 2012. An August 30, 2012 Executive Order from the White House called for a national goal of deploying 40 GW of new, cost-effective industrial CHP in the United States by the end of 2020. Calculations listed in this work plan are based on installing 15 MW of industrial and commercial CHP annually between 2015 and 2030.

Potential Work Plan Costs and GHG Reductions:

Table 1 Work Plan Costs and GHG Results*

Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	Cost (Million $)	Cost-Effectiveness ($/MtCO2e)	GHG Reductions (MMTCO2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/MtCO2e)
.96	$-85.11	$-88.66	8.16	$-224.21	$-27.48

* *Projections based on additional 240 MW capacity industrial and commercial CHP.*

The composition of the costs presented in Table 1 use EPA capital, operation, and maintenance cost estimates for a reciprocating engine prime mover CHP system. The cost estimates do not account for avoided boiler capital, operational, and maintenance costs. The cost estimates assume the overall efficiency of the CHP system to be 75 percent and will be in operation 95 percent of the time. The cost estimates assumes a value of $.09 / kWh for excess electricity. The cost estimates assume the reciprocating engine to be operating on natural gas.

- As noted earlier, the sectors for deployment include commercial (includes institutions) and industrial.
- Electrical transmission and distribution losses are estimated at 9.67 percent.
- Estimates of future CHP costs are inherently uncertain because cost estimates are highly sensitive to natural gas prices, the cost of avoided power, and the assumption about the CO2 intensity of displaced electricity. Different electric generation technologies also have different associated costs and emissions.

State case studies and approximate savings associated with each:

- **Evergreen Community Power Plant:** 33 MW, using biomass fuel; ~53,500 metric tons of CO2e saved annually; CHP became operational in 2008.
- **Bucknell University:** 6 MW, using natural gas fuel, ~ $1.25 million saved annually; CHP became operational in 1998.
- **Geisinger Medical Center:** 5 MW, using natural gas fuel, ~ $1.5 million saved annually; ~ 14,500 metric tons of CO2e saved annually; CHP became operational in 2012.
- **Philadelphia Gas Works:** 200 kW, using natural gas fuel; ~ $130,000 saved annually; ~ 475 metric tons of CO2e saved annually; CHP became operational in 2011.
- **PSECU:** 800 kW, using natural gas fuel; ~ 1,360 metric tons of CO2e saved annually; CHP became operational in 2014.

Implementation Steps:

The key to implementing CHP systems is to provide adequate incentives for the development of infrastructure to capture and utilize the waste heat. Such incentives could come in many forms, such as recruiting suitable end users, such as industries, hospitals, government offices, or school campuses to a centralized location to utilize the waste heat, tax credits, grants, zoning, and offset credits for avoided emissions. A federal tax incentive allows for a 10 percent investment tax credit for CHP property up to 15 MW. Facilities may be eligible for state grants or loans through the Pennsylvania Alternative and Clean Energy Program or from other individual power supply companies. Additionally, Section 9.4.8 of the Governor's Marcellus Shale Advisory Commission report, issued on July 22, 2011, recommends that, "The Commonwealth should promote the use of cogeneration technology (Combined Heat & Power (CHP)) through the use of Permit-by-Rule, standardized utility power grid interconnection rules and direct financial incentives." As previously mentioned, CHP systems, including those fueled by natural gas, are already an eligible Tier II resource under Pennsylvania's AEPS. The AEPS also established a set of statewide interconnection standards.

A large group of locally financed small projects spread widely across the Commonwealth could capture the value of carbon benefits while limiting transportation costs of the feedstock. This model has been shown to allow displacement of current or projected fossil carbon release from a broad range of users.

The following are policies that can potentially increase the installed capacity of CHP in Pennsylvania:

- Design of standby rates utilities can charge CHP facilities.
- Review interconnection standards for CHP facilities with no electricity export.
- Create a fair market for excess power sales from CHP facilities to overcome barriers for smaller generators.
- Continued inclusion of CHP as an eligible power source for clean energy portfolio standards.
- Review use of CHP in creating critical infrastructure (power during natural disasters)
- Evaluate ability of utilities to participate in CHP operation, either in ownership or service packages for CHP facilities.
- The Environmental Permitting Process need to be modified to encourage CHP facilities.

The following are scenarios that can potentially be barriers to business owners incorporating CHP:

- A conversion within a company to CHP prompting additional environmental permitting and could trigger New Source Review, resulting in more stringent emission requirements, permitting time and additional costs to install additional pollution control equipment.
- A non-EGU could be reclassified as an EGU and be covered by EGU emission and Effluent Guidelines that could impact the non-EGUs operations.
- Since Pennsylvania is a deregulated state with open access provided to the PJM, PURPA does not require that the Utilities sign Power Purchase Agreements tied to the avoided costs. As such, the PUC will need to encourage these agreements with CHP.
- A lack of cost certainty related to Regional Transmission Organizations RTO or transmission access charges; if the CHP unit would be classified as an EGU and requires access, including upgrades to the interconnection and transmission.
- Restrictive FERC and NERC imposed oversight and reporting requirements for a CHP site, which would be reclassified as an EGU.

Macroeconomic Analysis of Combined Heat and Power Work Plan:

Combined Heat and Power

Summary:

Combined heat and power (CHP) describes an energy production system that produces not only electricity, but also useful thermal energy, typically in the form of steam.

CHP allows for a user of both thermal and electrical energy to integrate a production system that optimizes thermal energy to address electrical needs as well as thermal energy needs. CHP offers significant benefit to industry and our Commonwealth and the country through increased efficiency, improved environmental performance, reduced losses and improved reliability in electricity transmission, more effective use of natural resources, decreased costs and improved national competitiveness. As with all power generation, CHP deployment has unique cost, operational, and other characteristics, but it is a proven and effective available clean energy option that can help Pennsylvania enhance energy efficiency, reduce GHG emissions, promote economic growth, and maintain a robust energy infrastructure. CHP also offers the opportunity to improve and contribute to critical infrastructure resiliency, mitigating the impacts of an emergency by keeping critical facilities running without any interruption in service. CHP is generally most cost-effective in industrial or commercial settings with large thermal heat loads that are in operation 24 hours a day. Currently there are CHP units located at food, paper, chemical, refinery, and metal industries along with solid waste, healthcare, colleges and other commercial settings across Pennsylvania.

Summary Table of Policy Impacts

Combined Heat and Power				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+70	+230	+450	+200
GDP ($Millions)	-40	-60	-70	-50
Income ($Millions)	$0	+$7	+$25	+$8

<u>Policy costs and savings identified for inclusion in analysis</u>

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with construction activities and equipment for using CHP systems.
- Costs associated with the operation and maintenance of the systems.
- Costs associated with the increase need of natural gas for operating the CHP system.
- Savings associated with the reduction in use of electricity from utility as CHP system provides it on-site.
- Savings associated with the federal investment tax credit.

<u>Direct Economic Impacts Caused by Costs and Savings</u>

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with construction activities and equipment for using CHP systems, and operation and maintenance need for CHP systems:
    - These are increases in sales to the construction sector and to the heating, ventilating, and air conditioning (HVAC) sector.
    - Those sales must be funded somehow, however. The burden of paying for the construction and HVAC over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Costs associated with relative operation and maintenance needs from CHP systems:
    - These are sales to the commercial and industrial machinery and equipment repair and maintenance sector.
    - The burden of paying for operation and maintenance results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Costs associated with the increased need for natural gas:
    - These are characterized as increase in demand for natural gas.
    - The burden of paying for additional natural gas results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Savings associated with the reduction of electricity:
    - These are characterized as reductions in demand for electricity.
    - For business, these reductions represent lower electricity demand. This represents a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.
- Savings associated with the 10 percent federal investment tax credit:
    - The tax credit is effective before 2017. This is paid by the federal government, and has no impact on Pennsylvania's government spending.
    - However, this tax credit represents a lower production cost – money that no longer needs to be spent in order to produce the same amount of product.

How this Work Plan Changes the Economy of Pennsylvania
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output starts to decrease from the year 2016. Output hits a low point in 2022, when the reduction is approximately $42 million. The lost output shrinks to less than $4 million below a no-work-plan scenario by 2030.
- The individual sectors that increase most are:
    - Commercial and industrial machinery and equipment repair and maintenance grows gradually to $21 million larger by 2030.
    - The natural gas sector grows gradually and the increase reaches approximately $14 million by 2030.

  - Construction and HVAC grow approximately $9 million and $7 million, respectively, by 2030.
  - Indirect benefits show up in sectors like iron and steel, sugar and confectionery product manufacturing, etc., which all show gains in the year of 2030, but not significant when compared with commercial and industrial machinery repair industry.
- The sectors that have the worst results are:
  - Electric utilities lose output gradually over time, shrinking by nearly $145 million in annual output by 2030.
  - Basic chemical manufacturing and support activities for mining shrink slightly, but by less than $4 million and approximately $3 million, respectively, in 2030. These numbers are so small as to be effectively neutral in light of the low precision of such long-range forecasting.
  - No other sectors report significant negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):

- Overall demand within Pennsylvania increases by $38 million in the first year but starts turning to decrease from 2017 on and reduces by approximately $52 million by 2030.
- The individual sectors that increase most are:
  - Commercial and industrial machinery and equipment repair and maintenance, which increases gradually and reaches approximately $36 million by 2030.
  - The natural gas and HVAC sectors also grow gradually and the increases reach approximately $24 million and $18 million respectively by 2030.
  - Construction has a jump in the first years with nearly $17 million in annual demand, but then decreases to approximately $9 million through 2030.
  - Indirect benefits show up in sectors like real estate, wholesale trade, retail trade, etc., which all show gains in the year of 2030, but not these are not significant when compared with commercial and industrial machinery repair industry.
- The sectors that have the worst results are:
  - Electric utilities decrease gradually by nearly $180 million in annual demand by 2030.
  - Support activities for mining, computer system design and some other industries decrease, but by less than $6 by 2030.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):

- Total employment rises in the policy scenario, adding 452 jobs in Pennsylvania by 2030. The trend of increase of employment reduces a bit around 2019 but the trend continues to grow through 2030.
- The sectors that have the highest employment changes are:
  - The commercial and industrial machinery and equipment repair and maintenance sector grows in this policy scenario gradually by around 240 jobs by 2030.
  - Number of new jobs in construction increases by approximately 130 by the first year and the trend reduces to a fraction of that, between 35 and 50 through 2030.
  - Indirect benefits show up in sectors like nursing and the food and beverage industry, which all show gains in the first year of this work plan, but not

significantly when compared with the commercial and industrial machinery repair sector.

- The sectors with the lowest employment changes are:
    - Only electricity supply show significant losses of jobs compared to others. The numbers increase gradually and reach approximately 100 fewer positions by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation to for work rises by $7.2 million in 2016 and drops gradually to -$6.7 million by the year 2021. After that, the trend starts to rise again and the total compensation rises by about $8 million by 2030.
- Average compensation in Pennsylvania does not show any change. No individual sectors show changes in per-person income large enough to be reliably non-neutral.

Work Plan 7: High-Performance Buildings

Summary:

Building upon the goals of The 2030 Challenge, this initiative would establish a voluntarily higher performance building than required by baseline building energy codes, lowering energy and operating costs. These high performance building goals include new and existing buildings in the residential, commercial, institutional and government sectors.

Background and Overview:

Architecture 2030, a non-profit, non-partisan and independent organization, was established in response to the climate change crisis by architect Edward Mazria in 2002. Its mission is to rapidly transform the built environment from being the major contributor of GHG emissions to being a central part of the solution to the climate and energy crises. Architecture 2030 issued the 2030 Challenge, asking the global architecture and building community to adopt the following targets:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60 percent below the regional average/median for that building type.

These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power, and/or purchasing (20 percent maximum) renewable energy.

The main goals for this work plan were generally modified from the Architecture 2030 Challenge building goals. These goals are summarized in Tables 1 and 2. Following the tables are proposed implementation steps to meeting these goals. The GHG emission reductions for Pennsylvania through 2030 were estimated assuming that these goals are met. The key assumptions and results of that analysis are provided later in this work plan initiative.

Goals:

Table 1. New Buildings Goals and Standards

		2015	2030
New Commercial	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	Average site EUI2005	Average site EUI2005
	Fraction of buildings that meet standard	100% of new	100% of new
New Residential	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	HERS 30	HERS 20
	Fraction of buildings that meet standard	100% of new	100% of new

Table 2. Existing Buildings Goals and Standards

		2015	2030
Existing Commercial	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	Average site EUI2005	Average site EUI2005
	Fraction of buildings that meet standard	20% of existing	50% of existing
Existing Residential	Overall goal (relative to 2005 building)	60% fossil fuel energy reduction	80% fossil fuel energy reduction
	Performance standard	HERS 30	HERS 20
	Fraction of buildings that meet standard	20% of existing	50% of existing

Notes: Energy reductions refer to on-site energy consumption.

Potential Implementation Strategies:

Building Energy Conservation Codes

In addition to adopting current building energy codes (see Work Plan 3: Adopt Current Building Energy Codes) as a prerequisite to meeting the goals of this High-Performance Buildings initiative, the following implementation steps are presented for consideration:

High-Performance Commercial Buildings

- **Stretch Codes** - Recommend adopting the IBC 2015 and allowing use of the International Green Construction Code (IgCC) as a voluntary option for municipalities to meet the goals and commercial building performance standards cited above.
- Additional implementation steps could include:
    - Require IgCC compliance for all publicly-funded commercial building projects in Pennsylvania.
    - Provide incentives to encourage municipalities, school districts and others to voluntarily adopt and implement the IgCC.
    - Consider a phased-in approach to adopting the IgCC beginning with Energy Star standards, and expanding to cover high-performance standards for energy sources, water, stormwater, materials, etc. Ultimately the goal will be zero-carbon buildings throughout the Commonwealth – a goal that is aligned with the 2030 Challenge.
    - Improve administration and enforcement of both the existing UCC and the IgCC with a statewide emphasis on training.
- **Benchmarking** - Require benchmarking (such as EPA Energy Star Portfolio Manager) for all publicly-owned and leased commercial facilities and all commercial buildings in Pennsylvania over 50,000 square feet by 2020. Other implementation steps could revise public-sector facility manager job descriptions and train staff to incorporate benchmarking into their standard operating procedures.
- **Energy Savings Performance Contracting (ESPC)-** Re-establish a robust Guaranteed Energy Savings Act (GESA)/energy service company (ESCO) program to promote energy

savings performance contracting for buildings in the municipal, university, school district and institutional sectors Hire and train staff to run public-sector GESA/ESCO/ESPM programs. Leverage the efforts of the Pennsylvania Treasury's new program that aims to facilitate ESPC contracts.

- **Green Strings** – Require all Commonwealth-funded buildings, whether grants, loans, tax credits, tax incentives, etc., to have minimum performance expectation of energy/resource conservation results.
  - The intent of this initiative is to educate involved parties, inform the Commonwealth, and potentially reduce the GHG impacts of building projects. If projects with similar costs and benefits are proposed, give preference to the project with the lowest GHG life-cycle-cost impact.
  - Commonwealth agencies and commonwealth-funded construction projects should include in their decision-making processes appropriate and careful consideration of life-cycle-cost GHG emission effects from proposed actions, and their alternatives. This will be done to understand, minimize, and/or avoid potential adverse effects from GHG emissions as much as possible. Commonwealth agencies will integrate GHG emission impacts as early in their planning processes as possible.
- Leadership PA - Establish a minimum Energy Star rating goal of 75 for all Commonwealth-owned and leased buildings by 2020.

High-Performance Homes (Residential)

- **Stretch Codes** - Recommend adopting the National Green Building Standard (ICC 700) as a voluntary option for municipalities to meet the goals and commercial building performance standards cited above. Support educational and training sessions about ICC 700 provided by professional associations and providers.
  - Additional implementation steps could include:
    - Require ICC 700 compliance for all publicly-funded residential building projects in PA.
    - Provide incentives to encourage home-builders, developers and others to voluntarily adopt and implement ICC 700.
    - Improve administration and enforcement of both the existing UCC and ICC 700 with a statewide emphasis on training.
- Offer the Commonwealth's residential sector incentives for implementing whole-house energy performance improvements.

<u>Supporting Steps to Meet Targeted Goals:</u>

- **Energy Mortgages:** Consultation with Pennsylvania Department of Banking to investigate the legal and regulatory barriers to creating a Pennsylvania policy of requiring energy mortgages.
  - Energy audits coupled with energy mortgages could increase the number of families qualified for mortgages. Energy mortgages credit a home's efficiency rating into the loan by proportionately increasing the value of the home. To have a Pennsylvania policy of requiring lenders to provide energy mortgages, it is necessary to adopt a standardized home rating system, like the one adopted by the Residential Energy Services Network (RESNET). Home energy ratings provide a standard measurement of a home's energy

efficiency. Ratings can be used for both new and existing homes. An effective rating system will include all information necessary for a lender to judge the worthiness of a home to meet the criteria for an energy mortgage. In October 1998, the mortgage industry, RESNET and National Association of State Energy Officials adopted the Mortgage Industry National Home Energy Rating System Accreditation Standard. Fannie Mae and Freddie Mac adopted the national accreditation standard.

  - Basing a mortgage on the home efficiency rating allows the buyer to borrow more on the basis that monthly utility bills will be proportionally less. In cases where the home is in need of energy-efficient upgrades, an Energy Improvement Mortgage could help finance the upgrades in an existing home by allowing the owner to use a portion of the mortgage payment to pay for the cost of the upgrades.
  - If appropriate, based on the feasibility of the program, educate the real estate and mortgage industry on the benefits of recognizing a standardized home rating system and adjust the current mortgage profile to include value realized as a result of increased energy efficiency.
- **Reduce Administrative Costs -** Continue working with the U.S. Green Building Council and EPA to streamline work processes and minimize the costs associated with implementing LEED and Energy Star principles and performance requirements into building operational procedures.
- Implement a Pennsylvania Home Climate Champion Collaborative to provide vision, clarity, and access to human and physical resources to encourage substantial (greater than 70 percent) energy reductions, while maintaining or improving indoor air quality, resilience to storms and power outages, adaptability, comfort, and affordability between now and 2020. A percentage of these projects should achieve passive house goals of 90 percent energy consumption reductions, with 10 percent met through renewable energy sources.
- Building Energy Usage Disclosure
  - Require disclosure of energy usage at time of listing of residential and commercial buildings.
  - An overarching step is the performance of a rigorous precautionary principle analysis which identifies harms and mitigation actions for those harms concurrent with this implementation step.
  - Provides price signals to prospective buyers about the economic value or cost of efficient or inefficient building design and operation.

Key Assumptions:

- Megawatt hour consumption estimates are from the EIA AEO 2014.
- Projected cost of electricity and natural gas is from the EIA AEO 2014.
- 30 percent reduction in electricity and natural gas use is assumed for energy efficient buildings.
- 20 percent of buildings are energy efficient the first year, with an additional 2 percent each year until 2030.
- Cost of adopting new code = $199 million (commercial) and $278 million (residential) based on 33 percent additional payback period (residential = 4.5 years, commercial = 5.6 years), estimated using Department of Energy analysis to adopt 2012 EICC.

- Projected GHG emissions in electricity assume .5 percent annual reduction from 2013 Pennsylvania value (1,112 pounds/MWh).
- Costs include the added cost of administration, design and construction related to high performance buildings.

Commercial	2015	2030
Projected Electricity Consumtion (MWh)	42,915,282	43,459,194
Projected Cost of Electricity ($/MMBtu)	$36.32	$40.16
Projected NG Consumption (Billion btu)	149,558	152,298
Projected Cost of NG ($/MMBtu)	$8.38	$11.65
Energy Savings in energy efficient building	27.00%	27.00%
% of energy efficient buildings	20.00%	50.00%
Projected GHG Emissions Electricity (lb CO2e/MWh)	1,101	1,021
Projected GHG Emissions NG (Lb CO2e/MMBtu)	117	117
Emission Savings in MMtCO2e	1.586	3.808
Cost of adopting energy efficiency in million $ (5.6 year payback)	1990.0	199.0
Energy Savings in Million $	354.85	1043.51
Net Cost of adopting energy efficiency in million $	1635.15	-844.51

Residential	2015	2030
Projected Electricity Consumtion (MWh)	51,632,590	51,085,560
Projected Cost of Electricity ($/MMBtu)	$50.26	$53.34
Projected NG Consumption (Billion btu)	225,235	209,685
Projected Cost of NG ($/MMBtu)	$11.55	$15.21
Energy Savings in energy efficient building	27.00%	27.00%
% of energy efficient buildings	20.00%	50.00%
Projected GHG Emissions Electricity (lb CO2e/MWh)	1,101	1,021
Projected GHG Emissions NG (Lb CO2e/MMBtu)	117	117
Emission Savings in MMtCO2e	2.037	4.696
Cost of adopting energy efficiency in million $ (4.5 year payback)	2780.0	278.0
Energy Savings in Million $	$618.61	$1,685.70
Net Cost of adopting energy efficiency in million $	2161.39	-1407.70

	2030 Annual			**2030 Cumulative**		
	Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/tCO2e)**	**Reductions (MMTCO2e)**	**Total NPV ($MM)**	**Cost-Effectiveness ($/tCO2e)**
Energy Efficient Buildings	8.50	-2,252	- 265	97.9	-8,791	-89.8

Macroeconomic Analysis of High Performance Buildings Work Plan:

Building upon the goals of the 2030 Challenge, this initiative would establish a voluntarily higher performance building than required by baseline building energy codes, lowering energy and operating costs. These high performance building goals include new and existing buildings in the residential, commercial, institutional and government sectors.
All new buildings, developments, and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60 percent below the regional average for that building type.

Summary Table of Policy Impacts

High-Performance Building				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+1,350	+6,250	+9,350	+4,450
GDP ($Millions)	-$885	-$850	-$1,060	-$860
Income ($Millions)	-$9	+$23	+$48	+$20

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- *Costs associated with construction activities and equipment for adopting the requirement of high-performance building*s. This additional spending applies to both the residential sector and businesses. The work plan assumes 20 percent of buildings are adopting this policy in the first year (2015), and that 2 percent of the building stock would adopt these improvements each year thereafter. The additional spending starts at the highest level at the beginning, and stays at a lower level over the 2016-2030 period, as industries and residents implement this policy gradually to a similar number of additional buildings each year.
- *Savings associated with the reduction in use of natural gas and electricity as buildings become more efficient*. These savings actually grow each year, as a larger share of all buildings are in compliance with the high-performance building policy (and therefore using less energy) each year.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with construction activities and equipment for adopting the requirement of high-performance buildings:
  - For residential sector improvements, these are increases in sales to the construction and household appliance manufacturing industries.
  - For businesses, these are increases in sales to the construction and heating, ventilation, and air conditioning (HVAC) industries.
  - Those sales must be funded somehow, however. The burden of paying for the construction and equipment over time results in less spending on other consumer goods and services, ranging from basics like food, clothing, housing, and transportation to all manner of other consumer demands.
  - For business, the burden of paying for the construction and HVAC over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product as before.

- Savings associated with the reduction of electricity and natural gas:
  - For residents and businesses alike, these are a decrease in demand for electricity and natural gas.
  - For residents, these reductions free up money for spending on a mix of consumer goods and services.
  - For business, these reductions represent lower electricity and natural gas demand. This represents a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

<u>How this Work Plan Changes the Economy of Pennsylvania</u>
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output grows quickly at first, and hits the highest change in the first year at nearly $7 billion. It then falls below neutral to -$128 million and stays level through 2030. The Pennsylvania economy is producing more in the first year but producing less in the following years.
- The individual sectors that increase most are:
  - Construction; which contributes almost all the increase in the first year at nearly $4 billion, and stays at a relatively steady level at approximately $180 million from shortly after through 2030.
  - Household appliance manufacturing; which grows about $550 million in the first year, and keeps at a relative steady level at approximately $55 million through 2030.
- The individual sectors that decrease are:
  - Electric utilities lose output steadily over time, shrinking by nearly $1.9 billion in annual output by 2030.

- Natural gas utilities also shrink steadily over time, by nearly $400 million by 2030.
- Support activities for mining and pipeline transportation both shrink a little, but by less than $14 million and $1 million, respectively, in 2030.
- No other sectors report negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):

- Overall demand within Pennsylvania reduces by approximately $1.9 billion by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-time or Part-time):

- Total employment rises significantly in the first year, adding 50,916 jobs in Pennsylvania. After the first year, however, the trend of employment decreases to a fraction. It then increases steadily to more than 9,000 additional positions by 2030.
- The sectors that have the highest employment changes are:
    - The construction sector grows in this policy scenario by around 32,000 jobs in the first year, and drops to average annual new 1,100 jobs for the following years, and is not surprisingly the largest area of growth.
    - Retail trade sees growth in the employment of approximately 1,900 jobs by 2030.
    - Indirect benefits show up in sectors like food services and drinking places, office of health practitioners, wholesale trade, etc., which all show gains in the first year of this policy, but not significant when compared with construction sector.
- The sectors with the lowest employment changes are:
    - Only electricity supply, natural gas supply, and support activities for mining sector show significant losses of jobs. The numbers increase gradually and reach approximately 1,300, 250 and 180, respectively, by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work rises by about $151 million by 2030. This is approximately $17,000 per new position created.
- The overall income rate per person of jobs in Pennsylvania drops by $75 per year by 2030, mostly due to construction industry brings in many relatively low-income jobs.
- The pipeline transportation sector sees a reduction of average annual income by $218 per year by 2030. Managers of companies and enterprises see the highest gain in average annual income, at $22 per year by 2030.

Work Plan 8: Re-Light Pennsylvania

Summary:
The Re-Light Pennsylvania initiative is a critical building technology that accelerates replacement of less efficient outdoor and indoor lighting systems, including maximizing use of daylighting in indoor settings. It applies to residential and commercial buildings, and parking facilities. Actively investing in Pennsylvania manufacturing, sales, green collar jobs, and green building infrastructure by re-lamping, re-fixturing, and upgrading lighting systems, and control systems would also measurably improve the pastoral and remarkable qualities of the state, the quality of light delivered, and the health and safety of residents.

The recommendation recognizes the potential cost to older properties and only includes re-lighting as a part of renovation projects requiring building code compliance. Existing facilities that are not renovated are not included.

Implementation:

Propose establishment of the following goals in the Commonwealth:

Lighting Performance goals
- Lighting power of 0.9 watt/square foot connected load as maximum for all workplaces.
- New construction effective immediately; existing construction increase at 5 percent annually.

Lamp Performance (for all new lamp purchases, for all points of sale by 2020)
- 90 mean lumens/watt lamps.
- Mercury not to exceed 80 picograms per lumen-hour, 5 milligrams of mercury per lamp.
- Color rendering index of 85 minimum.
- 92 percent luminance maintenance (lamp depreciation) over rated life.

Controls and System Performance
- Occupancy sensors in single-occupancy rooms or short time-of-use rooms.
- Commissioning of installed lighting system, including controls.
- New construction effective immediately; existing construction increase at 5 percent annually.

Daylight (all non-residential buildings)
- Seated daylight access for 90 percent of occupants (new construction and historic buildings).
- Daylight-responsive controls for all fixtures within 15 feet of window
- New construction effective immediately; existing construction increase by 5 percent annually.

Exit Lighting

- Maximum 5 watts per fixture or “face.”
- New construction effective immediately; existing construction increase by 5 percent annually.

Site Lighting (all new construction by 2020; existing buildings by 2025)

- LPD 0.15 watt/sq. ft. max.
- No night sky pollution (0 percent above 90° cutoff).
- Zone-occupancy controls in large parking lots.
- New construction effective immediately; existing construction increase by 5 percent annually.

No- or Low-Cost Education Campaign

- Commonwealth publish news about new technology (LED and lighting controls) and payback examples via the internet to promote Pennsylvania businesses and jobs.
- Commonwealth speak at conferences about new technology (LED and lighting controls) and payback examples to promote Pennsylvania business and jobs.
- Wash reflectors and lenses to maximize light output.
- Install occupancy and daylight sensors.
- Promote the “Turn It Off” campaign.
- Delamp where light levels are not needed.
- Raise or tilt the blinds and use daylight.

Continue to encourage incentives:

- Encourage the PUC to promote more programs such as Act 129 program to re-lamp, relight and control lighting using new technology.
- Encourage electric companies to develop pilot programs to expand lighting efficiency in their service areas.
- Encourage the use of on-bill financing and other creative financing options to assist with the payment of new energy efficient lighting and conversion of old lighting to new efficient lighting technology.
- Encourage PennDOT and the Turnpike Commission to continue to advocate public and municipal lighting using energy efficient technology.

Key Assumptions:

- Cost of electricity (residential) = $133.9 / MWh
- Cost of electricity (commercial) = $97.4 / MWh
- Rate of emission reduction = .771 Mt CO_2e

SUMMARY TABLE
Potential GHG Reduction:
Table 1. Estimated GHG Reductions and Cost-effectiveness

Annual Results (2030)			Cumulative Results (2015-2030)		
GHG Reductions (MMTCO2e)	Costs (Million $)	Cost-Effectiveness ($/MtCO2e)	GHG Reductions (MMTCO2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/MtCO2e)
8.6	-843.0	-98.0	71.2	-5,101	-71.6

Assumptions and Calculations	2015	2020	2030	Units
Residential				
Fraction of Res. Elec. Cons. as Lighting	8.8%	8.8%	8.8%	
Residential elec. consumption as lighting	4,544	4,490	4,496	GWh
Power demand of existing lamps	60.0	60.0	60.0	W
Power demand of new lamps	9.0	9.0	9.0	W
Difference between old and new lamp	51.0	51.0	51.0	W
Daily hours of operation	6.0	6.0	6.0	h
Rate of uptake of high-efficiency lamps	5%	30%	80%	
Lifetime	10.0	10.0	10.0	yr
Energy Savings	193	1,145	3,057	GWh
Number of high-efficiency lamps in use	1,728,945	10,252,064	27,370,041	lamps
Number of lamps replaced annually	1,901,840	1,766,798	1,842,000	lamps
Cost Premium	$9.00	$9.00	$9.00	one-time
Gross annual cost	17.1	15.9	16.6	$ million
Emissions avoided	.15	.88	2.36	MMTCO2e
Net annual cost	-8.74	-137.42	-392.75	$ million

Commercial Lighting Performance Goals	2015	2020	2030	
Existing power density of lighting	2.0	2.0	2.0	W/ft^2
New power density of lighting	0.9	0.9	0.9	W/ft^2
Rate of uptake of high-efficiency lamps	5%	30%	80%	
Commercial Electricity Consumption	42,915	42,939	43,459	GWh
% of Comm. Elec. Consumption as Lighting	23.11%	23.11%	23.11%	
Energy savings - total	232	1,395	3,766	GWh
Cost premium (4-ft. 15 W T8)	$20.00	$20.00	$20.00	one-time
Lifetime	20	20	20	yr
Estimate number of lamps in PA	85,145,276	85,192,678	86,224,415	lamps
Number of lamps replaced annually	4,257,264	5,434,563	8,924,932	lamps
Gross cost of replacing lamps	85.1	108.7	178.5	$ million

Assumptions and Calculations	2015	2020	2030	Units
Emissions avoided	.18	1.08	2.90	MMTCO2e
Net Cost of replacing lamps	62.50	-27.23	-188.34	$ million

Daylighting	**2015**	**2020**	**2030**	
Reduction in lighting energy consumption	44%	44%	44%	
% of existing buildings that are historic	0.50%	0.50%	0.50%	
Applicable floor space	81.0	81.0	82.2	Million sq. ft.
Cost premium	$0.90	$0.90	$0.90	$/sq. ft.
Gross Cost	3.65	21.86	59.20	$ million
Energy savings	7.53	151.40	931.78	GWh
Emissions avoided	0.01	0.12	.72	MMTCO2e
Net cost	2.91	7.11	-31.56	$ million

Controls and System Performance	**2015**	**2020**	**2030**	
Reduction in lighting energy consumption	25%	25%	25%	
Rate of uptake in existing buildings	5%	30%	80%	
Commercial Electricity Consumption	42,915	42,939	43,459	GWh
% of Comm. Elec. consumption as lighting	23.1%	23.1%	23.1%	%
Energy Savings	124	744	2,009	GWh
Total Floor Space	5,336	5,604	6,139	Million sq. ft.
Cost Premium	$0.30	$0.30	$0.30	$/sq. ft.
Gross Cost	$80.04	$84.05	$92.08	$ million
Emissions avoided	0.10	0.57	1.55	MMTCO2e
Net cost	$67.97	$11.57	-$103.57	$ million

Site Lighting	**2015**	**2020**	**2030**	
Number of vehicles in Pennsylvania	9,637,112	9,697,888	9,824,445	
Ratio of parking spaces to vehicles	9 / 1	9 / 1	9 / 1	
Eligible parking lot area	25%	25%	25%	
Area of parking space	150	150	150	sq. ft.
Existing lighting intensity in parking lots	0.29	0.29	0.29	W/sq. ft.
Proposed lighting intensity in parking lots	0.15	0.15	0.15	W/sq. ft.
Annual hours in operation	2920	2920	2920	hrs/yr
Rate of Participation	5%	30%	80%	
Area of parking lot with efficient lighting	163	164	166	Million sq. ft.
Energy Savings	66	400	1,074	GWh
Cost premium	$0.05	$0.05	$0.05	$ / sq. ft.
Gross cost	$8.13	$8.18	$8.29	$ million
Emissions reduced	0.05	0.31	0.83	MMTCO2e

Assumptions and Calculations	2015	2020	2030	Units
Net cost	$1.66	-$30.79	-$96.32	$ million

Exit sign - 5 W / face	2015	2020	2030	
Average power of existing sign bulb	16	16	16	W
Average power of new bulb	5	5	5	W
Annual savings per sign	96.36	96.36	96.36	kW/lamp/year
Rate of uptake in existing buildings	5%	30%	80%	
Number of Signs	4,200,000	4,200,000	4,200,000	
Cost of unit retrofit	$5.00	$5.00	$5.00	One time
Total cost of retrofit	$1.05	$1.05	$1.05	$ Million
Energy savings	20.24	121.41	323.77	GWh
Emissions reduced	0.02	0.09	0.25	MMTCO2e
Net cost	-$0.92	-$10.78	-$30.49	$ million

Macroeconomic Analysis of Re-Light Pennsylvania

The Re-Light Pennsylvania initiative is a critical building technology that accelerates replacement of less efficient outdoor and indoor lighting systems, including maximizing use of daylighting in indoor settings. It applies to residential and commercial buildings, and parking facilities. Actively investing in Pennsylvania manufacturing, sales, green collar jobs, and green building infrastructure by re-lamping, re-fixturing, and upgrading lighting systems, and control systems would also measurably improve the pastoral and remarkable qualities of the state, the quality of light delivered, and the health and safety of residents.

The recommendation recognizes the potential cost to older properties and only includes re-lighting as a part of renovation projects requiring building code compliance. Existing facilities that are not renovated are not included.

Summary Table of Policy Impacts

Re-Light Pennsylvania				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	-1,090	+790	+2,900	+220
GDP ($Millions)	-$400	-$550	-$680	-$480
Income ($Millions)	-$150	-$80	+$50	-$80

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with replacing lamps for residents.
- Costs associated with purchasing relative equipment or service for implementing, improving, or adopting site lighting, control and system performance implementations, lamp fixture performance, exit sign equipment, and daylight equipment.
- Savings associated with the reduction in use of electricity. This saving applies to both residents and businesses. These savings actually grow each year, as a larger and larger share of all buildings are in compliance with the Re-Light Pennsylvania policy each year.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with replacing lamps for residents:
  - These are characterized as increases in spending on the household supplies.
  - This spending must be funded somehow, however. The burden of paying for the household supplies over time results in less spending on other consumer goods and services, ranging from basics like food, clothing, housing and transportation to all manner of other consumer demands.
- Costs associated with purchasing relative equipment or service to implement the policy for businesses:
  - These are characterized as increases in demand in the electrical equipment manufacturing industry.
  - Those demands must be funded somehow, however. The burden of paying for electrical equipment over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Savings associated with the reduction in use of electricity:
  - For residents, these are characterized as decrease in spending for electricity.
  - For businesses, these are characterized as reductions in demand for electricity.
  - For residents, these reductions, however, free up money for spending on a mix of consumer goods and services.
  - For business, these reductions represent a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

How this Work Plan Changes the Economy of Pennsylvania

In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output drops gradually in the policy scenario by approximately $550 million by 2030.

- The individual sectors that increase most are:
    - Retail trade grows by nearly $104 million by 2030.
    - A couple of sectors increase by a range between $20 million to around $40 million by 2030, including offices of health practitioners, real estate, electric lighting equipment manufacturing, etc.
- The sectors that have the worst results are:
    - Electric utilities lose output gradually over time, declining by nearly $1.01 billion in annual output by 2030.
    - The construction sector also falls over time, by nearly $50 million by the year of 2030.
    - No other sectors report significantly negative shifts in output

Changes in Demand (Willingness to Buy Goods and Services):
- Overall demand within Pennsylvania reduces by approximately $646 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (i.e. the number of individuals employed, either full-time or part-time):
- Total employment drops in the first several years and hits the lowest point at -1,576 by the year 2017. It then recovers and turns to an increase in Pennsylvania's economy by 2,902 by 2030.
- The sectors that have the highest employment changes are:
    - The retail trade sector grows in this policy scenario by around 830 jobs by 2030, though it shows a decrease in first couple of years.
    - The food services and drinking places sector is similar. Around 520 new position is added to this sector by 2030 after it recovers from job losses since the year 2020.
    - Indirect benefits show up in sectors like office of health practitioners, individual and family services, educational services, etc., which all show losses in the first couple of years and recover to gains in the last by a range of 100 to 240 new jobs.
- The sectors with the lowest employment changes are:
    - Electricity supply and the construction sector show significant losses of jobs. Electricity supply loses approximately 700 positions by 2030 while the construction loses nearly 300 by the same year.
    - Indirect impacts show up on other sectors such as the computer systems design, support activities for mining, etc., but not so significantly when compared with electric supply.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):
- Total compensation for work rises by about $53 million by 2030.
- The average compensation per person drops by $34 by 2030.
- The pipeline transportation sector sees a reduction of average annual income by $108 per year by 2030. The annual income rates of the petroleum production sector and electricity supply drop $76 and $60, respectively. A couple of sectors see increases in annual

income rate but not significantly, including the apparel manufacturing, funds trusts or other financial vehicles, newspaper, periodical, book and directory publishers, offices of health practitioners, etc.

Work Plan 9: Manufacturing Energy Technical Assistance

Summary:
This initiative looks to ensure that each year, 125 energy assessments are conducted at qualifying small and medium-sized manufacturing facilities in Pennsylvania. The energy assessment criteria will be primarily designed by the DEP Energy Office, and will also include assessments performed through the Pennsylvania Technical Assistance Program (PennTAP), the Department of Energy Industrial Assessment Centers (IAC) program, and/or other similar government-sponsored endeavors.

Background:
The DEP currently provides discretionary funding to PennTAP to administer technical assistance via energy efficiency assessments for manufacturers within the Commonwealth. A second program, for a more limited group of manufacturers based on size and location, is the IAC program, which is funded directly by the federal Department of Energy. Between these two programs, there are currently approximately 30 energy assessments completed each year in Pennsylvania.

This initiative would dedicate sufficient state funding to perform an average of 125 energy assessments per year at qualifying Pennsylvania manufacturers. The assessments will be completed by PennTAP and other similar assessment centers. The cost of implementing the measures identified in the assessment will remain the sole responsibility of the manufacturing company. These energy assessments will model the assessments completed by IAC. The energy assessments will be designed and monitored through DEP. These assessments will focus on both electricity and other forms of energy consumption. The criteria for determining a manufacturer's eligibility for the assessments will be completed by DEP.

PennTAP Energy Efficiency Assessments
The purpose of the **PennTAP Program** is to assist Pennsylvania companies improve their competitiveness by providing technical assistance and information to help resolve specific technical questions or needs. An outreach program of the Pennsylvania State University, PennTAP is a federal-state-university partnership for economic development. The program focuses on helping smaller manufacturers that normally do not have the in-house expertise or resources to resolve specific technology needs. PennTAP serves the entire state of Pennsylvania through a network of technical advisors, each of whom has specific areas of technical expertise and are located throughout the state. PennTAP offers several different services, and has been performing energy efficiency assessments for Pennsylvania small and medium-sized manufacturers for over 15 years.

Energy efficiency assessments are conducted at no cost to the manufacturer, and consist of a detailed examination of how the facility uses energy for targeted facility operations, followed up with a detailed report documenting specific energy efficiency related projects that provide a positive economic payback. If applicable, the report may document funding opportunities to the manufacturer to assist in implementation. After sufficient implementation steps have been completed by the manufacturer, PennTAP conducts follow-up activities to determine the environmental and economic benefits resulting from implementation of energy solutions. Engineering students are educated about energy efficiency opportunities by participating in on-site assessments.

Department of Energy's Industrial Assessment Centers

Independent of the PennTAP program, the Department of Energy's Advanced Manufacturing Office provides no-cost assessments to eligible small and medium sized manufacturers at its IACs. IACs at Lehigh University, University of Delaware, and West Virginia University are the three currently designated providers for assessments conducted in Pennsylvania.

The scope of the energy audits includes identifying opportunities to improve productivity, reduce waste, and save energy. The typical IAC assessment conducted in Pennsylvania identifies more than $120,000 in potential annual savings opportunities, with an average one-time implementation cost of approximately $150,000. The Department of Energy bears the entire cost of the assessment; manufacturers bear the entire cost of implementing any of the recommendations in the assessment. Although manufacturers are under no obligation to implement any of the recommendations made in the IAC assessment, the Department of Energy's experience is that a significant percentage of recommendations are implemented because they have positive economic paybacks. Manufacturers qualify for an IAC assessment if they meet these criteria:

- Located less than 150 miles of a participating IAC university,
- Gross annual sales below $100 million,
- Fewer than 500 employees at the plant site,
- Annual energy bills more than $100,000 and less than $2.5 million,
- No professional in-house staff to perform the assessment.

Table 1 below depicts the projected average annual energy savings, implementation costs, payback period, and CO2 reductions per company, as calculated from all of the recommendations included in the 47 IAC assessments completed in Pennsylvania since 2012. Source: DOE IAC database.

Table 1 - Identified Cost / Savings with 100% Implementation	
Avg. Cost of Implementation (not including assessment)	$152,519
Avg. annual Savings due to Elec.	$77,929
Avg. annual Savings due to NG	$34,892
Total avg. annual savings due to Elec. and NG	$112,821
Avg. Payback Period in years	1.352
Avg. CO2 Reduction due to Elec. (tons)	16,118
Avg. CO2 Reduction due to NG (tons)	316

Implementation Steps:

- DEP Energy Office staff will work with PennTAP and Department of Energy IAC staff to identify a prioritized list of opportunities and barriers achieving energy reductions and a strategy to overcome those barriers.
- Energy Office staff will work with PennTAP, community colleges and trade schools to educate and train students and staff to be able to perform resource assessments.
- PennTAP staff will coordinate with the Pennsylvania PUC and utilities to share and develop cost-effective energy use reduction programs for small, medium and large manufacturers.
- Energy Office staff will seek additional funding for assessments.
- Once additional funding is obtained, select and contract with additional technical assistance providers.
- PennTAP and Energy Office staff will conduct additional outreach to potentially eligible manufacturers.

Potential Overlap:

- Act 129 Phases IV and V Work Plan
- Energy Efficiency Financing Work Plan

Additional Information:

According to the Pennsylvania Manufacturing Register and industrial database profile, there are 18,666 manufacturing companies in Pennsylvania (two-digit NAICs codes 31 to 33). Some, but not all, of these facilities either would qualify for one of the existing programs—PennTAP or IAC—or would qualify for the expanded programs under the auspices of the DEP Energy Office. According to EPA (2012) data, combustion of fossil fuels in the industrial sector accounted for 41.3 MMTCO2e of GHG emissions in Pennsylvania.

The initiative is limited to manufacturing operations, and would therefore not include assessments at other large energy users, such as facilities in mining, quarrying, and oil and gas extraction (NAICs Code 21), utilities (22), wholesale or retail trade (42, 44-45), 48-49 transportation and warehousing (48-49), waste management facilities (56), or hospitals and other health care facilities (62).

Quantification Approach and Assumptions:

The additional costs associated with this work plan will be covered by a combination of public funds (assessment costs) and private funds (implementation costs). The average kilowatt hour savings from table 1 will be used for each manufacturer projected to have an assessment. The average cost of the assessment and the implementation costs are also taken from Table 1 and assume an annual 2.5 percent increase. Historical data from the IAC suggests an approximately 50 percent implementation rate three years after the assessment. The total annual costs, energy savings, and GHG reductions have been adjusted in Table 2 to account for the implementation rate.

- Projected cost of electricity and natural gas from the Energy Information Administration Annual Energy Outlook 2014

- Projected GHG emission in natural gas assumes an emission factor of 117 pounds/MMBtu.
- Projected GHG emissions in electricity assumes 0.5 percent annual reduction from 2013 Pennsylvania value (1,112 pounds/MWh)
- Companies will continue to have steady energy savings and GHG reductions annually for each year after implementing measures suggested in the assessment.
- Future assessment costs and results are assumed equal to past Department of Energy IAC costs and results.
- Assumes that 50 percent each identified energy project is implemented.
- Assumes that each energy project remains 100 percent effective from its implementation through 2030 (i.e. no plant closures, etc.)
- Assumes that energy projects identified for future participants will have the same energy savings, costs, etc. as those identified for past participants.
- Assumes all implementation costs will be incurred to the manufacturer in the same year as the assessment is completed. Historical IAC data suggests that implementation typically takes place over multiple years.

Table 2 - Summary of Program	2015	2020	2030
Total # of Companies	125	750	2000
Total kWh saved per company	1,143,000	1,143,000	1,143,000
Total mmBTU saved per company	5,435	5,435	5,435
Projected cost of electricity ($/kWh - EIA 2014 AEO)	0.089	0.090	0.099
Projected cost of NG ($/mmBtu - EIA 2014 AEO)	5.225	5.671	8.692
Projected savings due to electricity per company	$101,186	$102,445	$112,663
Projected savings due to Natural Gas per company	$28,398	$30,822	$47,241
Total Projected energy savings per company	$129,584	$133,267	$159,904
Average cost of assessment per company (2.5% annual increase)	$16,667	$18,857	$24,139
Average cost of implementation per company (2.5 % annual increase	$152,519	$172,561	$220,893
Total cost of assessment + implementation per company	$169,186	$191,418	$245,032
Implementation Rate	50%	50%	50%
Total annual cost ($ million)	$10.57	$11.96	$15.31
Total annual savings ($ million)	$8.10	$49.98	$159.90
Net annual cost ($ million)	$2.48	-$38.01	-$144.59
CO2 Emission Rate (lb/MWh)	1,101	1,074	1,021
CO2 Emission Reduction from electricity (MMTCO2e)	0.0357	0.2087	0.5293
CO2 Emission Rate (lb/mmBTU)	117	117	117
CO2 Emission Reduction from Natural Gas (MMTCO2e)	0.0180	0.1081	0.2884
Total CO2 Emission Reduction (MMTCO2e)	0.0537	0.3168	0.8177
Cost Effectiveness ($ / MTCO2e)	46.1	-120.0	-176.8
Cumulative CO2 Emission Reduction (MMTCO2e)	0.05	1.12	7.07

	2030 Annual			**2030 Cumulative**		
	Reductions (MMTCO2e)	**Cost ($MM)**	**Cost-Effectiveness ($/MtCO2e)**	**Reductions (MMTCO2e)**	**Total NPV ($MM)**	**Cost-Effectiveness ($/MtCO2e)**
Manufacturing Energy Technical Assistance	.82	-144.59	-176.8	7.07	-587	-83.05

Macroeconomic Analysis of Manufacturing Energy Technical Assistance Work Plan:
This initiative looks to ensure that each year, 125 energy assessments are conducted at qualifying small and medium-sized manufacturing facilities in Pennsylvania. The energy assessment criteria will be primarily designed by the DEP Energy Office, and will also include assessments performed through PennTAP, the IAC program, and/or other similar governmental-sponsored endeavors.

Summary Table of Policy Impacts

Manufacturing Energy Technical Assistance				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	-20	-30	-30	-25
GDP ($Millions)	-$10	-$10	-$10	-$10
Income ($Millions)	0	-$1	-$2	-$1

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work and discussion with the technical analysts who completed the analysis were as follows:

- Costs associated with state government spending on educational services.
- Costs associated with manufacturing companies spending on implementing the suggestions. given by the assessment, mainly through improving management internally. This work plan assumes that 50 percent of the manufacturing companies will implement the assessment.
- Savings associated with manufacturing companies saving on electricity and natural gas bills due to the improvement use efficiency of electricity and natural gas.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with state government spending on educational services:
  - These are an increase in demand for educational services. The government pays the universities to carry out assessment on manufacturing companies. in sales to the construction and household appliance manufacturing industries.
  - Those spending costs must be funded somehow, however. Spending on educational services means the state government has to use a proportion of money from its original budget, which means a general decrease in the government spending.
- Costs associated with manufacturing companies spending on implementing the suggestions:
  - These are an increase in management of companies.
  - Those spending costs must be funded somehow, however. Production cost will increase for manufacturing companies due to increased spending on management

  - training. The companies bear the costs of implementing the assessment, which lies mainly in management training.
- Savings associated with the reduction of use in electricity and natural gas:
  - These are characterized as reductions in demand for electricity and natural gas.
  - For business, these reductions represent a lower production cost – an input needed in smaller quantities in order to produce the same amount of product.

<u>*How this Work Plan Changes the Economy of Pennsylvania*</u>
In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:

Changes in Output (Total Value of Goods or Services Produced):
- Total output decreases gradually by 13 million by 2030.
- The individual sectors that increase most are:
  - The management of companies' sector contributes to Pennsylvania's economy by nearly $12 million by 2030.
  - Basic chemical manufacturing and educational services also show increases in output by approximately $1.5 million and 1.2 million, respectively, by 2030.
  - Several sectors also show an increase in output but not over $1 million by 2030, such as iron and steel mills manufacturing, the resin, synthetic rubber industry etc.
- The sectors that have the worst results are:
  - Electric utilities lose output steadily over time, decreasing by nearly $5.8 million in annual output by 2030.
  - Pharmaceutical and medicine manufacturing also falls steadily over time, by nearly $3.8 million by 2030.
  - Natural gas supply and the construction sector both decrease slightly, but by less than $1.7 million by 2030.
  - Indirect impacts show up on other sectors such as retail trade and communication equipment manufacturing, but not larger than electric utilities and natural gas supply industry.

Changes in Demand (Willingness to Buy Goods and Services):
- Overall demand within Pennsylvania reduces by approximately $13 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-time or Part-time):
- Total employment increases slightly by 18 jobs by 2015 and drops a bit by 33 jobs lost by 2030.
- The sectors that have the highest employment changes are:
  - The management of company's sector grows in this policy scenario by around 30 jobs by 2030.
  - The education services sector gains about 16 additional jobs by 2030.

    - No other sectors show up significant employment increase.
- The sectors with the lowest employment changes are:
    - Only the construction sector and retail trade lose more than five jobs by 2030, by about eight and seven positions, respectively.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):
- Total compensation for work decreases by about $0.8 million by 2030.
- The average compensation per person does not change in this policy scenario.

Work Plan 10: Energy Efficiency Finance in Pennsylvania

Summary: Propel increases in non-utility delivered demand-side energy efficiency by providing education, access and funding for innovative energy efficiency finance tools.

Background and Overview:
Energy efficiency and conservation are often the least-cost resources to meet our energy needs, reduce GHG emissions, and save consumers money.

- Cost-effective GHG abatement – As noted by numerous studies, energy efficiency strategies often dominate cost-effective approaches to GHG abatement (Figure 2).
- Consumer cost savings – The cost saving opportunities and successes of energy efficiency are well documented in public utility law. In Pennsylvania, the first phase of the state's energy efficiency requirement for electric utilities (Act 129 of 2008) provided $2.79 in benefits to consumers for every $1 in cost.[150]

While energy efficiency and conservation are proven effective resources for GHG abatement and economic development, access to capital can be a barrier to implementing energy efficiency and energy conservation projects in Pennsylvania homes and businesses. Innovation in the design of energy efficiency financing programs are creating easier access to capital, helping minimize initial out-of-pocket project costs, and employ repayment strategies tethered to the predictive performance of the energy efficiency and energy conservation measure implemented. The use of these innovative financial tools are in addition to traditional one-time grant and rebate programs, and also serve to recycle funding dedicated for use in future projects. These financing mechanisms are encouraging home and business owners to consider investing in energy efficiency improvements with greater regularity; drawing private capital to the efficiency marketplace. The core contents of an energy efficiency financing program include:

- Predictive energy savings from energy efficiency and energy conservation projects resulting in reduced energy bills.
- Monetary gain from energy savings, cost per energy unit not consumed, can be leveraged over time to pay back the capital cost improvements with minimal immediate out-of-pocket expenses.
- Energy efficiency project deployment is both an investment in goods and services which in turn creates jobs, drives the economy and creates competition in the energy efficiency, energy conservation deployment marketplace.
- Competition drives down the cost of projects, creates consumer confidence, and results in deeper penetration of energy efficiency and conservation measures deployed.
- Deeper penetration of energy efficiency and conservation measures increases GHG abatement.

Existing Programs:
Pennsylvania has already demonstrated overall success at achieving cost-effective energy efficiency outcomes through energy efficiency and conservation measures implemented via its

[150] PA PUC, Act 129 Statewide Evaluator Final Annual Report for Phase 1 (June 1, 2009 – May 31, 2013). p. 205

energy efficiency standard, Act 129 of 2008. The Statewide Evaluations report for Phase 1 achieved pursuant to Act 129 is summarized below in Table 1.

Table 1: Summary of Statewide Technical Reference Manual Verified Savings:

	CPITD Reported Gross Impact	CPITD TRM Verified Gross Impact	Savings Achieved as % of 2013 Targets
Total Energy Savings (MWh/yr)	5,567,257	5,403,370	123%
Top 100 hours Demand Reduction (MW)	1,405.12	1,349.92	113%
Total Demand Reduction	1,608.64	1,540.61	N/A
TRC Benefits ($1,000)	N/A	$4,192,389	N/A
TRC Costs ($1,000)	N/A	$1,755,384	N/A
TRC Costs-Benefits Ratio	N/A	2.4	N/A
CO2 Emissions Reduction (Tons)	3,535,208	3,431,140	N/A

TRC = total resource cost

Furthermore, Pennsylvania has the following electric energy efficiency potential over a 10-year period as a percentage of forecasted kilowatt hour sales for the baseline period of June 2009 through May 2010:[151]

- 32.6 percent technical potential (i.e. technically feasible)
- 27.2 percent economic potential (i.e. technically feasible and cost-effective)
- 17.3 percent achievable potential (i.e. technically feasible, cost-effective, and minimal market and adoption barriers)
- 5 percent program potential (i.e. technically feasible, cost-effective, minimal market and adoption barriers and within staffing/time/budget constraints

In addition to measures implemented via its energy efficiency standard, Act 129 of 2008, Pennsylvania is further tapping into energy efficiency savings potential by undertaking several effective energy efficiency financing programs:

Keystone HELP: This energy efficiency loan program is designed to help homeowners improve energy efficiency with special loan financing for high efficiency heating, air conditioning, insulation, windows, doors and whole house improvements. HELP also included special offers such as a residential geothermal energy efficiency loan program. Since inception, the Pennsylvania Treasury together with AFC First Financial and their network of certified contractors has made 13,000 loans, putting to work $108 million in financing. HELP loans have

[151] PA PUC, Electric Energy Efficiency Potential for Pennsylvania, Final Report, May 10, 2012, prepared by GDS Associates

allowed homeowners to save an estimated 40 MWh of electricity, 100,000 MCF of natural gas and 300,000 gallons of heating oil.

Energy Service Performance Contracting (ESPC) and Guaranteed Energy Savings Act (GESA): ESPC is a financing approach to accomplish facility improvements that reduce energy and water use while improving building operational efficiency. A new program entitled Pennsylvania Sustainable Energy Fund (PennSEF) will use the ESPC and GESA model to target municipal and state governments, universities and colleges, K-12 schools, and hospitals (MUSH) sector. The Pennsylvania Treasury Department has recently partnered with the Foundation for Renewable Energy and Environment (FREE), with financial support from the West Penn Power Sustainable Energy Fund, to develop a prudent, market-based investment vehicle that promotes energy and water efficiency, clean energy generation, economic development, and environmental improvement. PennSEF's design is intended to provide cost clarity, financing through Treasury bonds, legal assistance, contractor pre-approval, and result in significant risk reductions for public entities looking to deploy ESPC project through the GESA model.

In general, a facility owner partnering with an energy service company (ESCO) uses ESPC mechanism to pay for facility upgrades by leveraging predictive energy savings without tapping into capital budgets. ESPCs provide technical, engineering and managerial expertise while private sector financial institutions fund the retrofit projects. The ESCO guarantees that the improvements will generate energy cost savings to pay for the project over the term of the contract. To further create confidence and overcome antiquated procurement processes, GESA provides a procurement tool that allows for the best qualified, best value, and best fit selection of a pre-qualified ESCO rather than utilization of a design-build, lowest responsible bidder process.

Following is a sampling of past projected savings from ESPC projects under the GESA program:[152]

- Total Project Savings: $359.7 Million
- Guaranteed Savings: $323.5 Million
    - Operational Savings: $25.2 Million
    - Utility Savings: $306.9 Million
    - Avoided Capitol: $53.1 Million
    - Net Savings: $44.1 Million *(savings, repayment, annual ESCO payment)*
- Emissions (26 Projects)
- Annual Avoided CO2: *111,442 Tons*
- Annual Avoided Greenhouse Gas: *112,406 Tons*
- Annual Avoided MMBTU: *857,354*

Small Business Pollution Prevention Assistance Account: The Pollution Prevention Assistance Account (PPAA) offers low-interest loans to help small businesses (100 full-time employees or less) located within the state to implement energy efficiency and pollution prevention projects. Loans may be issued for 75 percent of project costs up to $100,000 within any 12-month period, with terms of up to 10 years at a 2 percent interest rate. The program is only available to

[152] PA Department of General Services, 2010: Guaranteed Energy Savings Act Presentation

qualifying businesses that adopt or install pollution prevention or energy efficient equipment or processes that reduce or reuse raw materials on-site, reduce the production of waste, or significantly reduce energy consumption and are directly related to the business activity. Renewable energy systems are eligible for loans under this program if they meet the project eligibility criteria.[153]

Qualified Energy Conservation Bonds (QECBs): QECBs were created by the 2008 Energy Improvement and Extension Act and the American Recovery and Reinvestment Act of 2009. They were issued to states and territories and a portion was allocated to large local governments and municipalities with a population of 100,000 or more. Pennsylvania received a total allocation of $129 million. To date, approximately $41 million of QECBs have been issued in Pennsylvania, including $15.8 million for an ESPC project with the Pennsylvania Department of Corrections. QECBs are a long-term financing option usually from 12 to 26 years. QECB can be used for a variety of energy project types including reduction of energy consumption in publically owned buildings by at least 20 percent and, to implement, green community programs (including the use of grants, loans, or other repayment mechanisms to implement such programs. Some allocations of QECBs are not being used for energy projects due to administrative burdens, transactional costs, or inability to match projects with the bond capital. Some municipalities have expressed concerns about using QECBs because federal budget sequestration efforts can impact (even retroactively) the QECB subsidy amount, leaving the remaining liability with the municipal issuer. Some states have explored, and have used different approaches to, encourage the use of QECBs allocated to municipalities, including implementing processes by which large local governments may return their sub-allocations to the states for use.

Potential New Programs:
In addition to the cost-effective activities implemented through Act 129 and additional energy financing opportunities, other public-private energy-efficient financing program models could be promoted and used in Pennsylvania to broaden and enhance the impact and overall penetration of energy efficiency project deployment in Pennsylvania. A sampling of these programs includes the following:

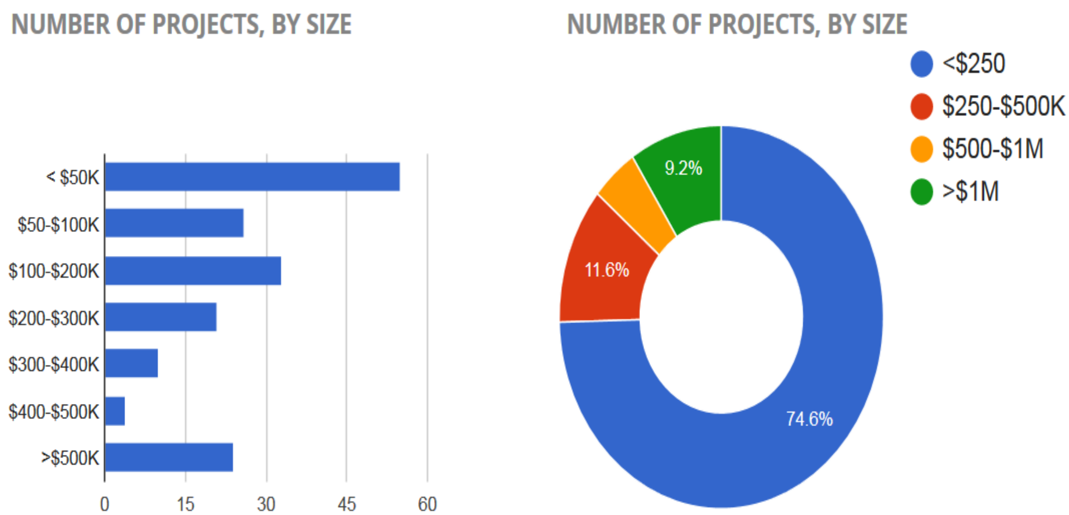
Commercial Property Assessed Clean Energy (CPACE) – CPACE programs pay for 100 percent of an energy efficiency project’s costs. These costs are repaid over a term of up to 20 years. PACE is based on the concept of special municipal tax districts. PACE districts are established at the local government level to issue loans to residential and commercial property owners who would like to make a voluntary effort to implement energy efficiency retrofits or install small renewable energy systems. With property tax financing, the loan payments take the form of an assessment added to (but separate from) the property tax on the home or building. The financing and repayment stays with the building upon sale, enabling larger energy efficiency retrofits with longer payback periods to be built, because property owners are not obligated to maintain ownership for the full payback period. PACE can be used for commercial and residential properties (though currently there are federal limitations to residential programs) and

[153] PA Dept. of Economic and Community Development, 2015: Pollution Prevention Assistance Account Program (PPAA)

can work well with multi-family dwellings. More recent versions of PACE finance have allowed third-party lenders to provide capital, reducing the burden on debt-laden municipalities and enabling the bond to be brought to market in a more-timely manner. The senior lien of the tax obligation, coupled with property securitization and the well-documented technical performance of energy efficiency investments, have attracted numerous private sector entities to the PACE market.

The data in Figure 1 show the total number of commercial PACE projects and average value of projects provided by PaceNow.[154] Nationally, over 327 commercial PACE programs have been initiated.

Figure 1



The Connecticut CPACE Program has allocated $65 million in capital for over 60 projects, with the average energy efficiency projects achieving 20 - 40 percent energy savings and solar projects delivering 50 - 90 percent energy cost savings.[155] For Pennsylvania, the assumption is that 100 percent of CPACE projects would be enabled through municipal districts, but funded by third-party capital. Table 2 calculations assume funding levels comparable to Connecticut's CPACE program and national figures provided by PaceNow.

Table 2 : Potential CPACE in Pennsylvania			
Project Size	Number of Projects	Project Distribution	Potential PA Program
$1,000,000	16	9.2%	$16,468,000
$750,000	8	4.6%	$6,175,500
$425,000	39	11.6%	$16,575,000
$200,000	115	74.6%	$23,000,000
	Total Potential PA Program = $ 62,218,500		

[154] Pace Now, 2010: Pace Market Dashboard
[155] Bridge Port News, 2015: C-PACE Marks Successful First Two Years. March 13, 2015

A Green Bank for PA - A green bank is a public or quasi-public financing institution that provides low-cost, long-term financing support deployment of clean, low-carbon projects by leveraging public and/or private funds. A green bank may conform to a variety of structures, utilize many different public (or private) funds, and create a diverse array of financial products. In general a green bank could serve to encourage a shift from one-time subsidies and grants towards market-catalyzing financial tools and propel innovation in policy, incentive structures, financial tools, and marketing. Green bank finance enables a return on investment for tax payer-supported capital (as opposed to grants) and has delivered up to a 10:1 leverage on capital.

Accelerating Energy Savings Performance Contracting - According to the American Council on an Energy-Efficient Economy (ACEEE) State and Utility Pollution Reduction Calculator (SUPR),[156] energy savings performance contracting programs in Pennsylvania have the potential to achieve 8 percent of emissions reductions required by EPA's Clean Power Plan and save over $2.6 billion through energy efficiency measures by 2030. Table 3 shows the summary results for Pennsylvania from the SUPR tool, which assumes performance contracting in the traditional MUSH market as well as the private commercial sector. According to SUPR, the size of the program in Pennsylvania is based on historic ESCO market growth trends of 8.3 percent annually.

Table 3: Pollution Reductions from Energy Savings Performance Contracting in PA

Summary results

	2020	2025	2030
Cumulative NOx reductions (tons)	4,200	10,400	19,700
Cumulative SO2 reductions (tons)	12,200	30,200	57,200
Cumulative CO2 reductions (tons)	6,743,000	16,775,000	31,721,000
Annual CO2 reductions (tons)	1,570,000	2,338,000	3,484,000
Cummulative net cost (million 2011$)	686	1,687	3,112
Cumulative energy saved (MWh)	7,894,100	19,638,100	37,135,000
Annual energy saved (MWh)	1,838,000	2,737,000	4,078,000

* Results are for all selected measures combined reported cumulatively.

Implementation Steps:

- Energy Savings Performance Contracting:
    - Promote funding for ESPC program through the PennSEF program and appropriations process.
    - Ensure the state government has expert and technical resources available for state and local governments and school districts to utilize in order to provide non-biased facilitation and information services about ESPC contracts.

[156] ACEEE, 2015: The State and Utility Pollution Reduction (SUPR) Calculator. April 21, 2015

- As part of the technical resources, ensure the Commonwealth provides model documents and a standardized process for procuring and contracting energy efficiency projects. These model documents should be developed in cooperation with ESCOs in order to ensure financial feasibility and consumer protection.
- Implement an outreach program together with Pennsylvania Treasury to facilitate widespread deployment of the PennSEF programs.

- Create a green bank or similar entity to provide a clearinghouse for state led energy financial mechanisms which can evaluate energy funding opportunities vs. public and private financing opportunities
  - Evaluate all financing programs currently available (Figure 3) to determine what current financial assistance opportunities may have energy efficiency outcomes or correlating uses which may result in further leverage for energy funding opportunities.
  - Consolidate appropriate state energy grant and loans making authority from existing dispersed system to the green bank.

- Pass legislation to allow for voluntary development of CPACE, to enable low-cost, property-secured financing for efficiency improvements at commercial and industrial facilities.

Cost Estimates:
In order to create a measurable impact in the public and private marketplace through energy efficiency financing programs, a suggested baseline size of programs is suggested herein to provide a relative scale regarding public and private funding support necessary to implement the Program discussed.

- $60 million to support a CPACE program, funds anticipated to be provided mainly from private sector investment. A small percentage of funding, 1 percent, is provided by public funds for support of investment grade audits or cost share for implementation to help attract candidate projects and spur implementation.
- $50 million to support PennSEF program and supporting GESA and ESPC contracts. This initial funding is anticipated to be supported with public sector funds (e.g. municipal bonds) and private funding for projects aimed at the MUSH sectors. Additional funding could come from other sources of public/state funding to provide for further implementation of deeper energy savings and cover initial costs.
- $70 million in public sector funds for initial development of a green bank capitalization. The goal of a green bank would be to leverage 10:1 the initial investment for a potential impact of $700 million. The initial funds could potentially be raised through the use of state acquisition of public sector bonding authority such as QECBs allocated to Pennsylvania municipalities that are yet to be unused. As of December 2014, Pennsylvania had approximately $87 million in remaining QECB allocations.[157]

[157] EPC, 2014: Qualified Energy Conservation Bonds (QECBS). December 2014

GHG Reductions Estimates:
This plan does not include GHG reduction estimates due to uncertainties in funding availability, program design and the resultant difficulty in quantifying the reductions based on those variables.

Figure 2 – McKinsey GHG Abatement Curve for US[158]

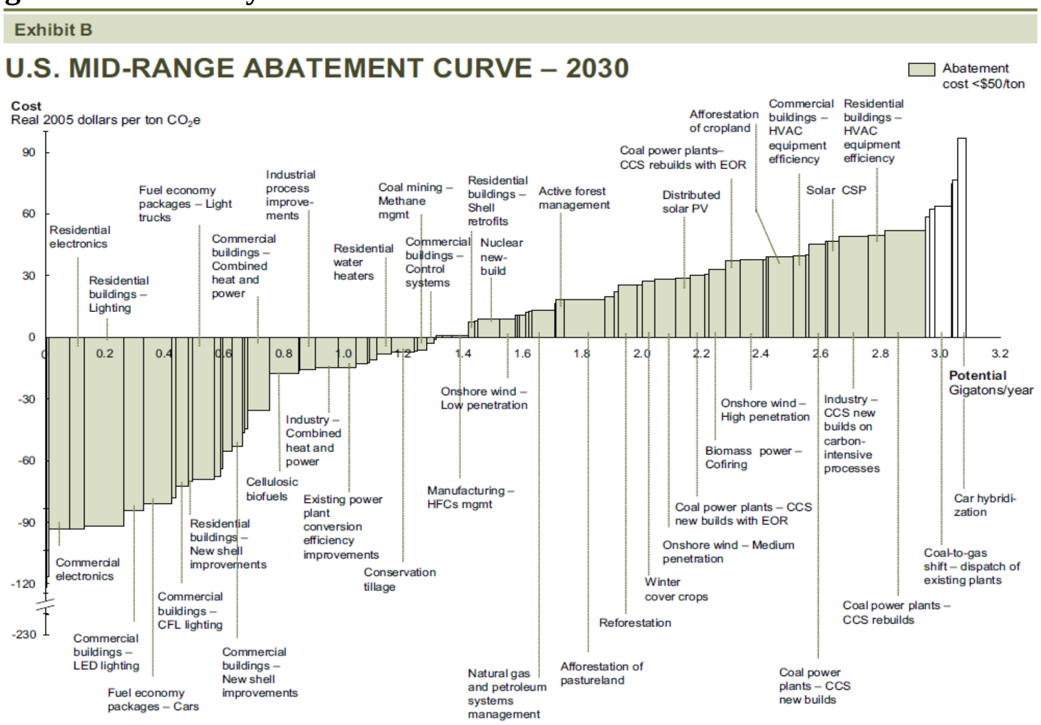


Figure 3 New Pennsylvania Business Financing Matrix[159]

	FUNDING TYPE					FUNDING APPLICANTS & BENEFICIARIES			
Program Title	**Grant**	**Loan**	**Loan Guarantee**	**Tax Credit**	**Bonds**	**Business**	**Community/ Nonprofit**	**Local Governments**	**Program Website**
Abandoned Mine Drainage Abatement and Treatment Program (AMDATP) – Act 13	●					●	●	●	newPA.com/amdatp
Alternative and Clean Energy Program (ACE)	●	●	●			●	●	●	newPA.com/ace
Baseline Water Quality Data Program – Act 13	●					●	●	●	newPA.com/bwqdp
Ben Franklin Technology Partners Challenge Grant & Alt. Energy Dev Prog (AEDP)	●					●			newPA.com/ challenge
BFTDA – University Research Commercialization Grant Funding	●					●	●		newPA.com/ bftda-university
Broadband Outreach & Aggregation Fund (BOAF)	●					●	●		newPA.com/boaf
Building PA		●				●			newPA.com/ building-pa
Business in Our Sites Grants and Loans (BOS)		●				●	●		newPA.com/bos
Business Opportunities Fund (BOF)		●				●	●		newPA.com/bof
Community Economic Development Loan Program (CED)		●				●			newPA.com/ced

[158] McKinsey & Company, 2015: Reducing US Greenhouse Gas Emissions: How Much at What Cost?
[159] PA Dept. of Economic and Community Development, 2014: Pennsylvania, Built to Advance, Business Assistance.

	FUNDING TYPE					FUNDING APPLICANTS & BENEFICIARIES			
Program Title	**Grant**	**Loan**	**Loan Guarantee**	**Tax Credit**	**Bonds**	**Business**	**Community/ Nonprofit**	**Local Governments**	**Program Website**
Discovered and Developed in PA Program (D2PA)	●					●	●	●	newPA.com/d2pa
Educational Improvement Tax Credit Program (EITC)				●		●	●		newPA.com/eitc
Export Financing Program		●				●			newPA.com/efp
Film Tax Credit Program				●		●			newPA.com/film
First Industries Fund (FIF)		●	●			●			newPA.com/fif
Flood Mitigation Program (FMP)	●					●	●	●	newPA.com/fmp
Global Access Program (GAP)	●					●			newPA.com/gap
Greenways, Trails and Recreation Program (GTRP) – Act 13	●					●	●	●	newPA.com/gtrp
Guaranteed Free Training Program (GFT-WEDnetPA)	●					●			newPA.com/gft
High Performance Building Program (HPB)	●	●	●			●			newPA.com/hpb
Historic Preservation Tax Credit (HPTC)				●		●			newPA.com/hptc
Industrial Sites Reuse Program (ISR)	●	●				●	●	●	newPA.com/isr
Infrastructure and Facilities Improvement Program (IFIP)	●					●	●	●	newPA.com/ifip
Job Creation Tax Credits (JCTC)				●		●			newPA.com/jctc
Keystone Innovation Network (KIN)	●					●	●		newPA.com/kin
Keystone Innovation Zone Tax Credit Program				●		●			newPA.com/kiztc
Keystone Opportunity Zones (KOZ)				●		●			newPA.com/koz
Keystone Special Development Zone (KSDZ)				●		●			newPA.com/ksdz
Multimodal Transportation Fund	●					●	●		newPA.com/ multimodal
Machinery and Equipment Loan Fund (MELF)		●				●			newPA.com/melf
Marketing to Attract Tourists	●					●	●		newPA.com/ marketing-tourists
Neighborhood Assistance Program (NAP)				●		●	●		newPA.com/nap
Neighborhood Assistance, Enterprise Zone Tax Credit (NAP/EZP)				●		●			newPA.com/nap-ezp
New PA Venture Capital Investment Program		●				●			newPA.com/ venture-capital-investment
Opportunity Scholarship Tax Credit Program (OSTC)				●		●	●		newPA.com/ostc
Orphan or Abandoned Well Plugging Program (OAWP) – Act 13	●					●	●	●	newPA.com/oawp
Partnerships for Regional Economic Performance (PREP)	●					●	●		newPA.com/prep

	FUNDING TYPE					FUNDING APPLICANTS & BENEFICIARIES			
Program Title	**Grant**	**Loan**	**Loan Guarantee**	**Tax Credit**	**Bonds**	**Business**	**Community/ Nonprofit**	**Local Governments**	**Program Website**
PEDFA Tax Exempt Bond Program					●	●	●		newPA.com/pedfa-tax-exempt-bond
PEDFA Taxable Bond Program					●	●	●		newPA.com/pedfa-taxable-bond
Pennsylvania Capital Access Program (PennCAP)			●			●			newPA.com/penncap
Pennsylvania Community Development Bank Loan Program (PCD Bank)		●				●	●		newPA.com/pcdbank
Pennsylvania First	●	●	●			●			newPA.com/pafirst
Pennsylvania Industrial Development Authority (PIDA)		●				●	●		newPA.com/pida
Pennsylvania Infrastructure Bank (PIB) (PA Dept of Transp Program)		●				●	●	●	newPA.com/pib
Pennsylvania Infrastructure Technology Alliance (PITA)	●					●			newPA.com/pita
Pennsylvania Minority Business Development Authority (PMBDA)		●				●			newPA.com/pmbda
Pennsylvania Small Business Credit Initiative (SSBCI)		●				●			newPA.com/ssbci
Pollution Prevention Assistance Account Program (PPAA)		●				●			newPA.com/ppaa
Regional Investment Marketing (RIM)	●					●	●		newPA.com/rim
Renewable Energy Program – Geothermal and Wind Projects	●	●	●			●	●	●	newPA.com/renewableenergy
Research and Development Tax Credit (R&D)				●		●			newPA.com/rd
Second Stage Loan Program			●			●			newPA.com/second-stage-loan
Small Business First (SBF)		●				●			newPA.com/sbf
Solar Energy Program (SEP)	●	●	●			●	●	●	newPA.com/sep
Tax Increment Financing Guarantee Program			●			●			newPA.com/tif
The Pennsylvania Regional Center – New American Development Fund		●				●			newPA.com/nadf
Water Supply and Wastewater Infrastructure Program (PennWorks)	●	●				●	●	●	newPA.com/pennworks
Watershed Restoration and Protection Program (WRPP)	●					●	●	●	newPA.com/wrpp

Work Plan 11: Semi-Truck Freight Transportation

Summary: This initiative presents a specific measure that can be adapted to decrease GHG emissions from the state's semi-truck freight transportation sector. This sector is forecast for continued growth, despite the economic downturn and decreased transportation funding. Primarily, this measure's aim is to improve the fuel efficiency of semi-trucks registered in the Commonwealth. A target of installing trailer fairings, also known as trailer side skirts, on 50 percent of the Commonwealth's registered tractor and trailer fleet by 2030 is the intent of this work plan.

Other Agencies Involved: PennDOT

Improve Trucking Fuel Efficiency

Semi-Truck Transport: About 61 percent of the freight that is moved in the U.S. is carried by truck transport. In the U.S. more than 36 billion gallons of diesel fuel is used by truck transport.[160] In Pennsylvania alone approximately 851 million gallon of diesel fuel was used by semi-trucks hauling freight in 2015. In a program to reduce GHG emissions and improve fuel efficiency of tractor trailers and other heavy duty vehicles, the EPA and the National Highway Traffic Safety Administration (NHTSA) have developed the Heavy Duty National Program (HDNP). This program will be adopted for heavy duty vehicles in two phases, with phase I affecting model years 2014-2018 and phase II affecting model years 2018 -2025. The program is designed to increase fuel efficiency standard of newly manufacture heavy duty engines and vehicles. The initiative brought forth in this work plan is a voluntary program designed to encourage owner operators and fleets to reduce air pollution and GHG emissions through lower fuel consumption on tractor trailers not subject to the HDNP by retrofitting vehicles with add-on aerodynamic technologies. The option explored her entails deployment of available fuel use reduction technology. By identifying and promoting fuel-saving retrofit technologies, the program enables the owners and operators of truck fleets to better understand how to reduce fuel consumption via the most economical means available. In many cases, fuel-saving retrofits can result in net cost savings over the long run. The technology option analyzed here is listed below:

Trailer Fairings: Adding side fairings (e.g., skirts) to trailers reduces aerodynamic drag and improves fuel economy by 3– 7 percent.[161] For the purpose of this analysis a fuel savings of 4.5 percent is used. Side skirts have the largest rate of adoption among aerodynamic technologies for trailers, around 40 percent of new box trailers are sold with side skirts and roughly 50 percent of side skirt market is for retrofitting existing trailer.

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[160] U.S. DOE, 2013. U.S. Department of Energy, Energy Information Administration, " Sales of Distillate Fuel Oil by End Use" November 2013 at http://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm
2009.
[161] ICCT, 2014 International Council on Clean Transportation "Costs and Adoption of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector" February 2014.

The technology option, considered in the semi-truck analysis, is based on EPA's SmartWay Transport Partnership.[162] The option considered is the installation of fairings (e.g., side skirts) to improve vehicle aerodynamics.

While the cost associated with installing trailer fairings ($1,100) is modest compared to the cost of a tractor-trailer, any up-front cost may be prohibitive for some truck owners. Low interest revolving loan programs are good financial assistance options. With a payback period of roughly 0.6 year, the money loaned from the initial fund is quickly returned and used for new loans. A loan program partnered with a government agency and an organization like Lending Tree, where individuals and companies are provided with access to a network of loan lenders, would be beneficial to owners. The advantage is that these lenders will bid on the loan request, lowering the interest rate and simplifying the process of acquiring a loan.

<u>Potential GHG Reductions and Economic Costs:</u>

Table 1 summarizes the emission benefits and costs of the measures applied to truck freight.

Table 1: Estimated GHG Emissions Reductions and Cost-Effectiveness

GHG emission savings (2030)	0.243	MMTCO2e
Net Present Value (2013-2030)	-48.4	$million
Cumulative Emissions Reductions (2013-2030)	2.07	MMTCO2e
Cost-effectiveness (2013-2020)	-309	$/tCO2e

GHG = greenhouse gas; MMTCO2e = million metric tons of carbon dioxide equivalent; $/tCO2e = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate cost savings.

The estimated GHG emission reductions from installing trailer fairings are based on diesel fuel savings. To calculate these emissions, the total 2011 Pennsylvania tractor trailer Fleet Vehicle Miles Traveled (VMT) data was projected out to 2030 using a 1 percent increase rate, as recommended by the Argonne National Laboratory/RITA. The fraction of VMT traveled by the number of vehicles adopting the technologies was then calculated and the amount of fuel needed to travel those miles at the average 6.5 MPG was obtained. Fuel usage required by the vehicles that have been fitted with the technology was then calculated. Emission reductions were then calculated by using the fuel usage reduction figures extended over the implementation period of 2015 through 2030. Total fuel savings is multiplied by GHG emissions per gallon of diesel fuel consumed (25.02 pounds CO2e/gal Argonne Lab/Greet) to obtain the total annual GHG emission reduction. Total fuel savings realized for the implementation period at a 50 percent installation rate is 182 million gallons.

Heavy-Duty Trucks*:* Costs Associated with Installing Fairings

The cost of retrofitting a trailer with side fairings is approximately $1,100.[163]The total cost of retrofitting is calculated by multiplying the number of trailers being retrofitted in a given year by

[162] Bynum, 2009. Personal communication, Jonathan Dorn, E.H. Pechan & Associates, with Cheryl Bynum, U.S. Environmental Protection Agency, SmartWay Transport Partnership, 28 May 2009.
[163] ICCT, 2014 International Council on Clean Transportation "Costs and Adoption of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector" February 2014.

$1,100. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel.[164] Net costs are the installation costs minus the fuel cost savings.

Heavy-Duty Trucks: GHG Reduction from Installing Fairings

At highway speeds, aerodynamic drag accounts for the majority of truck energy losses.[165] Reducing drag improves fuel efficiency. Since a majority of long-haul tractor trucks on the road already contain aerodynamic features, such as air deflectors mounted on the top of the cab, drag-reduction options should focus on trailer aerodynamics.[166] The addition of side fairings to a trailer can reduce fuel consumption by 4.5 percent.[167]. These panels are attached to the side or bottom of the trailer and hang down to enclose the open space between the rear wheels of the tractor and the rear wheels of the trailer. Such enclosure reduces wind resistance. The estimated GHG emissions reductions from installing side fairings on trailers are based on diesel fuel savings.[168] Fuel savings are based on the total diesel fuel used, the percent fuel savings associated with the retrofits, and the penetration rate for tractor-trailer combinations. Since there are more trailers than tractor-trucks, the probability of realizing the fuel savings associated with a trailer retrofit is a one to one ratio of tractor-trucks to trailers.

Table 2. GHG Emission Reduction, Fuel Savings and Installation Cost for Installing Fairings

50% adoption						
	Cumulative Adoption @1377 annually	**Fuel Reduction (gal)**	**Emissions Reduction (tons)**	**Fuel Savings ($MM)**	**Installation Cost**	**Delta Cost**
2015	2754	1,338,875	16,749	5.06	$3,029,400	-$2,031,547.50
2016	5508	2,677,750	33,512	10.26	$3,029,400	-$7,226,382.50
2017	8262	4,016,626	50,268	15.58	$3,029,400	-$12,555,108.88
2018	11016	5,355,501	67,024	20.99	$3,029,400	-$17,964,163.92
2019	13770	6,694,376	83,780	26.38	$3,029,400	-$23,346,441.44
2020	16524	8,033,251	100,536	31.89	$3,029,400	-$28,862,606.47
2021	19278	9,372,126	117,292	37.58	$3,029,400	-$34,552,825.26

[164] U.S. Energy Information Administration, Annual Energy Outlook 2014 Early Release, December 16, 2013.
[165] U.S. EPA, 2004b. U.S. Environmental Protection Agency, SmartWay Transport Partnership, "A Glance at Clean Freight Strategies: Improved Aerodynamics," EPA420-F-04-012, February 2004, at http://www.epa.gov/smartway/transport/documents/carrier-strategy-docs/aerodynamics.pdf, accessed 28 May 2009.
[166] Bynum, 2009. Personal communication, Jonathan Dorn, E.H. Pechan & Associates, with Cheryl Bynum, U.S. Environmental Protection Agency, SmartWay Transport Partnership, 28 May 2009.
[167] U.S. EPA, 2009b. U.S. Environmental Protection Agency, SmartWay Transport Partnership, "Technologies, Policies, and Strategies: Upgrade Kits," at http://www.epa.gov/smartway/transport/what-smartway/upgrade-kits-tech.htm, accessed 28 May 2009.
[168] U.S. DOT, 2008c. U.S. Department of Transportation, Federal Highway Administration, "Trailer and Semitrailer Registrations - 2007," Table MV-11 in Highway Statistics 2007, November 2008, at www.fhwa.dot.gov/policyinformation/statistics/2007/mv11.cfm

50% adoption						
	Cumulative Adoption @1377 annually	**Fuel Reduction (gal)**	**Emissions Reduction (tons)**	**Fuel Savings ($MM)**	**Installation Cost**	**Delta Cost**
2022	22032	10,711,001	134,048	43.27	$3,029,400	-$40,243,044.04
2023	24786	12,049,877	150,804	49.04	$3,029,400	-$46,013,599.39
2024	27540	13,388,752	167,560	54.89	$3,029,400	-$51,864,483.20
2025	30294	14,727,627	184,316	61.41	$3,029,400	-$58,384,804.59
2026	33048	16,066,502	201,072	67.48	$3,029,400	-$64,449,908.40
2027	35802	17,405,377	217,828	72.93	$3,029,400	-$69,899,129.63
2028	38556	18,744,253	234,584	79.10	$3,029,400	-$76,071,347.66
2029	41310	20,083,128	251,340	85.55	$3,029,400	-$82,524,725.28
2030	44064	21,422,003	268,096	92.11	$3,029,400	-$89,805,212.90
TOTAL	44,064	169,084,620	2,278,812	735.55	$48,470,400	-$705,075,331.06
		Mt	2,066,882.87			
		MMT	2.07	-$309.40		

Ease of Implementation:

The ease at which implementation depends on the perceived savings, which is heavily dependent on education and on the price of fuel.

Barriers to Implementation:

- The trucks and the trailers can oftentimes be owned by different people, so the benefits are diffused between the owners, truck owner/operator vs. trailer owner/operator.
- In some cases, the fleet that owns the trailer doesn’t have as much of an incentive to retrofit because they don’t pay for fuel.

Implementation Steps:

- Modify the Small Business Advantage Grant Program criteria to allow independent owner/operators to qualify for a grant/or loan to retrofit their vehicles.
- Promote EPA SmartWay truck transport initiative loan programs.
- Introduce an education program by distributing fuel saving technology information pamphlets to owner/operators and trucking companies.

Key Assumptions:

- The trucking analysis assumes that the penetration rates for the and fairing retrofits are feasible by 2030.
- The cost of trailer aerodynamic technologies – particularly side fairings (skirts) have decreased in recent years due to more market entrants driving competition and higher deployment volumes reducing the cost per unit. Since the technology options analyzed

for trucks are retrofit options, new trucks entering the fleet are not considered. Under business as usual, the fuel economy of the existing truck fleet is assumed to remain constant through 2030.
- For fleets, where more trailers than tractors are owned, the payback period is longer.

Key Uncertainties:
- The fuel efficiency gains for truck and trailer retrofits are based on test track conditions. The actual on-road fuel efficiency improvement may be less.
- The diesel fuel consumed by heavy-duty trucks in Pennsylvania is approximated based on an estimate of heavy-duty truck VMT in the state.
- The actual diesel fuel consumed may be different.

Potential Benefits:
Additional potential benefits of changing behaviors to decrease GHG emissions from freight transportation include:
- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM;
- Decreased motor fuel use;
- GHG emissions reductions;
- Direct support of Smart Transportation initiatives, projects, and programs.

Potential Interrelationships with Other GHG Reduction Measures:
These measures aimed at changing behavior need to be implemented in coordination with system changes within the transportation sector, and with transportation-focused land-use measures.

Macroeconomic Analysis of the Semi-Truck Freight Transportation Work Plan:

This initiative presents a specific measure that can be adapted to decrease GHG emissions from the state's semi-truck freight transportation sector. This sector is forecast for continued growth, despite the economic downturn and decreased transportation funding. Primarily, this measure's aim is to improve the fuel efficiency of semi-trucks registered in the Commonwealth. A target of installing trailer fairings, also known as trailer side skirts, on 50 percent of the Commonwealth's registered tractor and trailer fleet by 2030 is the intent of this initiative.

Summary Table of Policy Impacts

Semi-Truck Freight Transportation				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+320	+680	+1,030	+500
GDP ($Millions)	+$25	+$60	+$100	+$45
Income ($Millions)	+$25	+$70	+$130	+$50

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the cost or price, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with purchasing and installing trailer fairings. These additional spending changes stay level over the 2015-2030 period, as the industries utilizing truck freight gradually implement this policy to a similar number of additional trucks each year.
- Savings associated with the reduction of diesel-fuel demand as fairing-equipped trucks become more efficient. These savings actually grow each year, as more and more trucks in the on-road fleet are equipped with fairings.

Direct Economic Impacts Caused by Costs and Savings

Once the additional spending, savings, costs and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with purchasing and installing trailer fairings:
  - These are increases in sales to the fiberglass and metals manufacturing sectors that dominate production of trailer fairings.
  - Those sales must be funded somehow, however. The burden of paying for the fairings over time is characterized as a higher production cost to the sectors that heavily utilize on-road freight, as they must take on this additional cost in order to carry out the same activity they were carrying out before.
- Savings associated with the reduction of diesel-fuel demand:
  - These are reductions in demand for petroleum products, lowering sales of petroleum in the state.
  - These reductions, however, represent savings to the same sectors that had to pay to install the fairings. Just as the fairings installation represented an increase in production cost, the lower fuel requirement represents a reduction in production cost – an input needed in smaller quantities in order to carry out the same amount of activity.

How this Work Plan Changes the Economy of Pennsylvania

In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):

- Total output rises steadily over time, reaching a gain of nearly $230 million total by 2030. The Pennsylvania economy is producing more as a result of this policy.
- The individual sectors that grow most are:
  - Truck transportation grows by approximately $130 million by 2030.
  - Construction, retail trade, and real estate all grow by around $10-15 million by 2030.
  - A range of other sectors are projected to see smaller gains in output, which should be interpreted as slight improvements in their business environment.
- The sectors that have the worst results are:
  - The petroleum products sector shrinks by approximately $20 million in annual output by 2030.
  - Oil and gas extraction also shrinks, but by less than $5 million, in 2030, too small a change over such a large period to treat as reliably non-zero.
  - No other sectors report negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):

- Demand within Pennsylvania rises by approximately $160 million by 2030.
- This policy does not change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):

- Total employment rises steadily throughout the forecast period, adding 80-100 jobs per year in Pennsylvania. By 2030, Pennsylvania's economy supports approximately 1,350 more positions.
- The sectors that have the highest employment changes are:
  - The truck transportation sector grows in this policy scenario by around 625 jobs by 2030, and is not surprisingly the largest area of growth.
  - Retail trade and construction both see growth in employment of approximately 100 jobs by 2030.
  - Indirect benefits show up in sectors like employment services, medical offices and retail food service, which all show small gains (approximately 20 additional positions in 2030).
- The sectors with the lowest employment changes are:
  - Only the oil and gas extraction sector actually shows a loss of jobs (eight fewer by 2030) that is probably a non-neutral result.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work rises by about $140 million by 2030. This is approximately $100,000 per new position created.
- There is no significant change to compensation *rates* as a result of this policy.

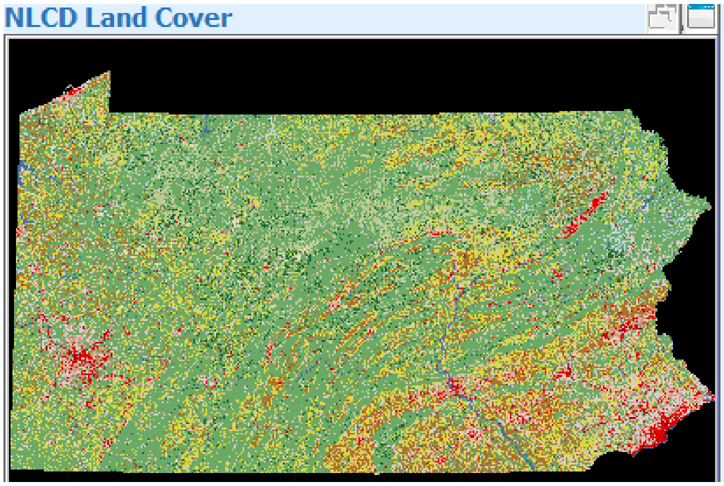
Work Plan 12: Urban and Community Forestry

Initiative Summary:
This work plan seeks to utilize the planting and maintenance of trees in urban and community settings to increase carbon storage and to reduce residential, commercial, and institutional energy use for heating and cooling purposes. Trees in urban and suburban settings have the advantage of providing value-added benefits beyond carbon storage and energy savings. Properly planted and maintained trees have been shown to improve air quality, reduce flooding, increase property values, stimulate economic development, reduce crime rates, reduce stress and aggression, and much more.

Carbon stocks in trees and soils in urban land uses – such as in parks, along roadways, and in residential settings – can be enhanced in a number of ways, including planting additional trees, reducing the mortality and increasing the growth of existing trees, and avoiding tree removal (or deforestation). Properly designed forest canopy cover can also lower energy demand by reducing a building's heating and cooling needs.

Background Regarding Potential Carbon Sequestration Calculations:
For purposes of this report, i-Tree Vue software was used. i-Tree Vue is one of eight urban and community forestry analysis and benefits assessment programs that make up i-Tree Tools, available through the USDA Forest Service at http://www.itreetools.org. i-Tree Tools have become the standard tool within the forestry profession for tree benefit analyses. Some of the tools utilize ground inventories of trees, while others use various types of aerial imagery. i-Tree Vue was determined to be the most suitable for a statewide assessment of the benefits provided by trees growing in developed areas and for estimating benefits that might be provided if tree cover was increased.

i-Tree Vue utilizes National Land Cover Database (NLCD) satellite-based imagery, most recently collected in 2011 and released to the public in March 2014 (http://www.mrlc.gov/nlcd11_data.php). Vue utilizes three data layers: percent tree canopy, percent impervious cover, and land cover classifications. NLCD imagery is sorted into eight different land cover types: forest, shrub, herbaceous, wetlands, water, barren land, planted/cultivated, and developed land. Each of these is further defined to create the 20 different "land cover classifications." The composite of all 20 land classifications are visible as the various colors and hues shown in the map below.



The areas of interest in this analysis, however, are only developed lands, which cover 12.3 percent of the total land mass of the state. Developed land is divided into four land cover classifications, each with an increasing amount of land occupied by constructed impervious surfaces. They are defined as:

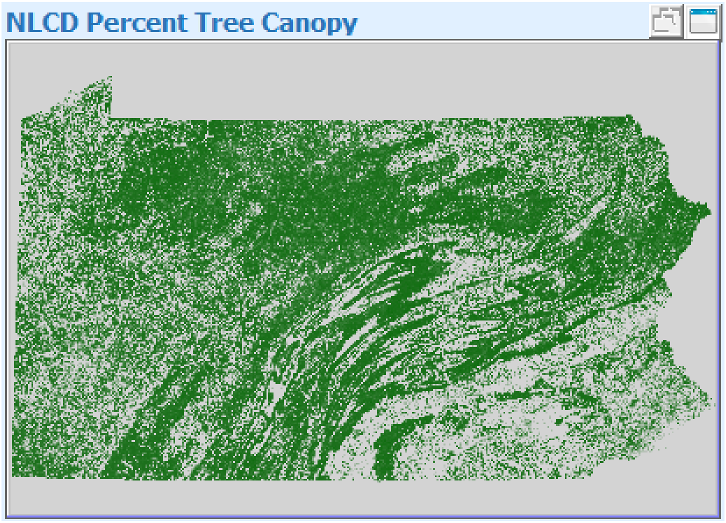
Developed, Open Space – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Developed, Low Intensity – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20 to 49 percent of total cover. These areas most commonly include single-family housing units.

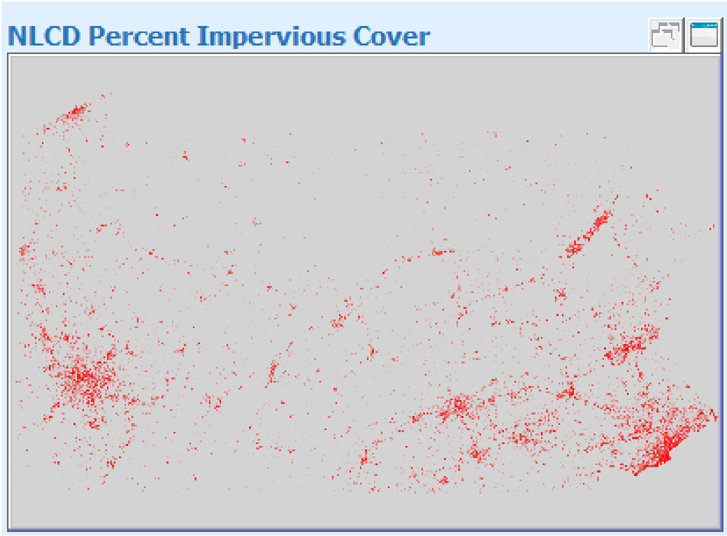
Developed, Medium Intensity – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas most commonly include single-family housing units.

Developed, High Intensity – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

For each of the 20 land cover classifications, a percent tree canopy cover is determined. A graphic portrayal of canopy cover across the state follows:



The map below is another good way to represent the amount of developed land in Pennsylvania, as it shows the percentage of impervious cover throughout the state. There are certainly larger concentrations of developed land in the metropolitan areas, but as the map below shows, development occurs statewide. Developed land is where increased canopy cover can result in increased carbon sequestered and significant energy savings from shading.



Based on the percent canopy cover in a given developed area, i-Tree models calculate the amount of carbon sequestered by those trees. The i-Tree Vue program also allows the user to adjust the level of canopy cover, and it then calculates the resulting benefits that could be realized with additional tree cover. The tables that follow show carbon sequestration benefits in each of the four developed land cover categories at present, as well as what they would be if tree canopy cover increased by a few percentage points. Also shown is the estimated number of trees that would have to be planted annually over fifteen years to achieve the higher levels of cover. The commonly accepted standard for urban tree calculations of 100 trees per acre was used.

Limitations of the Calculations:
Given the complexity of factors that contribute to tree mortality and the unavailability of long term data from planting initiatives, it must be understood that for purposes of this report, mortality is not factored in. Estimates of carbon sequestered and energy saved are based simply on the current canopy cover and on the targeted increased canopy cover sought. The number of trees to be planted to achieve the higher canopy cover assumes no loss of trees.

Goal: Maintain and/or increase urban and suburban tree cover through one of the following scenarios. Implementation Period: 2015-2030
Calculations are reported based on current conditions in each of the four developed land classifications, and with two higher levels of canopy cover in each. The potential for increased canopy cover, and the resulting increased carbon sequestration, is greatest in less intensively developed areas. However, even a moderate increase in canopy cover in heavily developed areas has the potential to significantly reduce energy consumption for cooling in those areas.

	Developed Land Cover Types			
	Developed, Open Space <20% impervious	**Low Intensity Developed 20-49% impervious**	**Medium Intensity Developed 50-79% impervious**	**High Intensity Developed 80-100% impervious**
Baseline Conditions	Maintain existing tree canopy of 32.3% at present level	Maintain existing tree canopy of 13% at present level	Maintain existing tree canopy of 5.9% at present level	Maintain existing tree canopy of 1.3% at present level
Goals	Increase tree canopy to 35%	Increase tree canopy to 15%	Increase tree canopy to 8%	Increase tree canopy to 3%

Carbon Sequestration and Carbon Storage
Carbon sequestration is the capture of carbon dioxide (CO2) from the atmosphere; trees sequester carbon by absorbing CO2 from the atmosphere and combining it with sunlight in a process known as photosynthesis. This process creates the sugars, cellulose, and carbohydrates that are used to sustain the tree. Carbon storage is the storage of that carbon within the structure of the tree, which is approximately 50 percent carbon by dry weight. Trees will continue to store carbon efficiently until they begin to decay or are burned.

The following tables refer to the four developed land cover classifications and show the amount of CO2 annually by the tree canopy at present, followed by the amount that would be sequestered annually if canopy cover was increased. The suggested canopy increases are lower in the more intensively developed the land. This is because there is less open space available for additional tree cover in more intensively developed areas, and it is generally more difficult to find suitable planting sites.

Urban Tree Canopy Expansion with Carbon Sequestration

1. **Cost-benefit on least developed land - "Developed, Open Space" where less than 20% of the land is occupied by impervious surfaces**

A	B	C	D	E	F	G	H
Tree Canopy Goal	**Annual CO2 Sequestered**	**Increase in CO2 Sequestered From Previous Canopy Cover**	**Cumulative Number of Trees Present When Canopy Goal is Reached**	**Number of Trees to be Planted to Achieve Canopy Goal by 2030**	**Number of Trees to be Planted Annually for 15 Years**	**Total Cost of Trees to Be Planted to Reach Canopy Goal[169]**	**Annualized Cost Per Ton of CO2 Sequestered over 15 Years**
Percent	**Tons CO2 per Year**	**Tons CO2 per Year**	**Trees**	**Trees**	**Trees per Year**	**Dollars**	**Dollars per Ton CO2**
Baseline (32.3%)	3,375,470	N/A	67,673,700	N/A[170]	N/A	N/A	NA
Increase to 35%	3,653,376	227,906 (B2 – B1)	73,245,350	5,571,650 (D2 – D1)	371,443/ yr (E2 / 15)	$835,747,500 (E2 * 150)	$200/ton ((G2/ C2)/15)

2. **Cost-benefit on low intensity developed land, where 20-49% of the land is occupied by impervious surfaces**

A	B	C	D	E	F	G	H
Tree Canopy Goal	**Annual CO2 Sequestered**	**Increase in CO2 Sequestered From Previous Canopy Cover**	**Cumulative Number of Trees Present When Canopy Goal is Reached**	**Number of Trees to be Planted to Achieve Canopy Goal by 2030**	**Number of Trees to be Planted Annually for 15 Years**	**Total Cost of Trees to Be Planted to Reach Canopy Goal**	**Annualized Cost Per Ton of CO2 Sequestered over 15 Years**
Percent	**Tons CO2 per Year**	**Tons CO2 per Year**	**Trees**	**Trees**	**Trees per Year**	**Dollars**	**Dollars per Ton CO2**
Baseline (13%)	575,889	N/A	11,545,800	N/A	N/A	N/A	N/A
Increase to 15%	664,263	88,374 (B2 – B1)	13,317,590	1,771,790 (D2 – D1)	118,119/ yr (E2 / 15)	$265,768,500 (E2 * 150)	$200/ton ((G2/ C2)/15)

[169] A conservative cost of $150 per tree is used for the tree, mulch, stakes, and water bag; volunteer labor is assumed.

[170] Tree planting will be needed in order to maintain existing tree cover, but the number of trees necessary for no net loss is unknown at this time.

3. Cost-benefit on medium intensity developed land, where 50-79% of the land is occupied by impervious surfaces

A	B	C	D	E	F	G	H
Tree Canopy Goal	**Annual CO2 Sequestered**	**Increase in CO2 Sequestered From Previous Canopy Cover**	**Cumulative Number of Trees Present When Canopy Goal is Reached**	**Number of Trees to be Planted to Achieve Canopy Goal by 2030**	**Number of Trees to be Planted Annually for 15 Years**	**Total Cost of Trees to Be Planted to Reach Canopy Goal**	**Annualized Cost Per Ton of CO2 Sequestered over 15 Years**
Percent	**Tons CO2 per Year**	**Tons CO2 per Year**	**Trees**	**Trees**	**Trees per Year**	**Dollars**	**Dollars per Ton CO2**
No net loss (remain at 5.9%)	123,699	N/A	2,479,990	N/A	N/A	N/A	N/A
Increase to 8%	168,084	44,385 (B2 – B1)	3,369,860	889,870 (D2 – D1)	59,325/ yr (E2 / 15)	$133,480,500 (E2 * 150)	$200/ton ((G2/ C2)/15)

4. Cost-benefit on high intensity developed land, where 80-100% of the land is occupied by impervious surfaces

A	B	C	D	E	F	G	H
Tree Canopy Goal	**Annual CO2 Sequestered**	**Increase in CO2 Sequestered From Previous Canopy Cover**	**Cumulative Number of Trees Present When Canopy Goal is Reached**	**Number of Trees to be Planted to Achieve Canopy Goal by 2030**	**Number of Trees to be Planted Annually for 15 Years**	**Total Cost of Trees to Be Planted to Reach Canopy Goal**	**Annualized Cost Per Ton of CO2 Sequestered over 15 Years**
Percent	**Tons CO2 per Year**	**Tons CO2 per Year**	**Trees**	**Trees**	**Trees per Year**	**Dollars**	**Dollars per Ton CO2**
Baseline (1.3%)	10,608	N/A	212,680	N/A	N/A	N/A	N/A
Increase to 3%	24,900	14,292 (B2 – B1)	499,200	286,520 (D2 – D1)	19,101/ yr (E2 / 15)	$42,978,000 (E2 * 150)	$200/ton ((G2/ C2)/15)

Energy Savings

According to American Forests, properly selected, well-placed trees that provide shade for homes and businesses can reduce air conditioning needs by 30 percent. Trees can also help in the winter by acting as wind breaks for cold winter winds. This can add up to 20-50 percent energy savings during the winter months. Find out more about these uses at the National Arbor Day Foundation's website: http://www.arborday.org/globalwarming/treeshelp.cfm/. The following goal summaries detail the potential additional energy savings yielded, in dollars, upon reaching the set urban tree canopy goals for three of the four land cover types associated with the urban and suburban environments of Pennsylvania. A goal summary was not prepared for the developed, open space land cover type because the assumption is that the trees planted in this land cover type are not likely to be shading structures.

Background Regarding Potential Energy Savings Calculations:

For the potential energy savings calculations below, several assumptions and generalizations were used:

Generalizations and Basic Information:

- American Forests indicates that properly placed trees can save 30 percent on cooling costs and 20-50 percent on heating costs. For the purposes of these calculations, we used 30 percent savings across the board.
- The average yearly energy expenditure per household in Pennsylvania (not including transportation costs) is $2,400, and approximately 53 percent of that is for heating and cooling. Therefore, the average yearly heating and cooling costs per household are estimated at $1,240.[171]

Assumptions:

- Within the high intensity developed land cover type, 100 percent of trees planted have potential to shade structures.
- Within the medium intensity developed land cover type, 60 percent of trees planted have potential to shade structures.
- Within the low intensity developed land cover type, 35 percent of trees planted have potential to shade structures.
- Within the open space developed land cover type, 0 percent of trees planted have potential to shade structures.
- Of the percentage of new trees planted that are likely to shade structures, all will be planted in the optimum locations for energy savings.
- For one average house to save 30 percent on energy costs, two properly selected, well-placed trees are needed.

The Energy Savings Calculation:

Part 1: Figure out the number of goal-related trees that are likely to be planted where there is potential to shade structures. Do this by taking the total number of trees for each land cover type goal and multiplying that by the percentages listed in the assumptions above.

Part 2: The number of trees needed to increase tree canopy to the desired goal divided by two trees per household equals number of households affected.

Part 3: The number of households affected multiplied by $1,240 average yearly spending per household equals the total amount spent on energy by affected commonwealth households without the benefit of tree shading and wind-blocking.

Part 4: The total amount spent on energy by affected commonwealth households without the benefit of tree shading and wind-blocking multiplied by 0.3 (the 30 percent savings) equals the amount of money saved by residents of the Commonwealth from the planting of properly selected, well-placed trees.

[171] http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/pa.pdf

The estimated 30 percent annual energy savings will take place once the planted trees have reached maturity. The length of time for the trees to reach maturity will vary from tree to tree. The calculated energy savings are incorporated during the timeframe of this work plan, even though some of the trees will not reach maturity until after 2030. Mature trees will provide energy savings to nearby homes and buildings for significantly longer than 15 years on average.

The calculations used might be expressed as a formula as:

(# trees to be planted annually to reach canopy goal) X (% of those trees that shade structures in this intensity of development) / 2 well placed trees per home are needed **X** ($1,240 average annual energy cost per household for heating & cooling) X (30% savings reasonably expected from shading) = Energy Savings per Year in Dollars

EXAMPLE: Low Intensity Developed Land with tree canopy increased to 15%

- Number of trees to be planted to achieve canopy goal: 1,771,790
- 35% of trees planted in low intensity developed land are likely to shade structures

$$\frac{1{,}771{,}790 \times 0.35}{2} \times \$1{,}240 \times 0.30 = \$115{,}343{,}529$$

Low Intensity Developed Land Goal Summary (35% of trees planted assumed to shade structure)

Tree Canopy Goal for Low Intensity Developed	# Trees to Plant to Reach Goal	One-Time Planting Costs	Additional Energy Savings Realized by Increased Tree Canopy Cover	Years Needed to Pay for Costs Via Energy Savings
		Dollars	Dollars	Years
Increase to 15%	1,771,790	265,786,500	$115,343,529	2.3

Medium Intensity Developed Land Goal Summary (60% of trees planted assumed to shade structure)

Tree Canopy Goal for Medium Intensity Developed	# Trees to Plant Annually for 15 Years to Reach Goal	One-Time Planting Costs	Additional Energy Savings Realized by Increased Tree Canopy Cover	Years Needed to Pay for Costs Via Energy Savings
		Dollars	Dollars	Years
Increase to 8%	889,870	133,480,500	$99,309,492	1.3

High Intensity Developed Land, Goal Summary (100% of trees planted assumed to shade structure)

Tree Canopy Goal for High Intensity Developed	# Trees to Plant Annually for 15 Years to Reach Goal	One-Time Planting Costs	Additional Energy Savings Realized by Increased Tree Canopy Cover	Years Needed to Pay for Costs Via Energy Savings
		Dollars	Dollars	Years
Increase to 3%	286,520	42,978,000	$53,292,720	0.8

Limitations of this Calculation

This formula provides a broad overview of what additional properly selected and properly-placed trees might contribute to energy savings. These savings are calculated in today's dollars and are not discounted for future inflation. Calculating existing savings from current tree canopy was not calculated. The $1,240 average annual energy expenditure per household for heating and cooling certainly includes some houses that are already shaded by trees; however, it is likely that the actual energy savings realized if the stated goals are reached would be much, much greater than estimated here. Part of the reason for the likely underestimation is that this calculation does not include specific numbers related to industrial facilities and other businesses, which would also benefit greatly from energy savings derived from tree planting. Industrial and business energy savings are more easily calculated on an individual basis due to wide variation in building size and location. This calculation also does not include savings related to transportation. For example, the shade provided by trees in parking lots helps keep gasoline from volatizing (due to heat) from vehicle gas tanks into the air, especially on particularly hot days when parking lots become intense heat islands.

Implementation Steps:

- Continue to leverage and expand the Commonwealth's TreeVitalize program.
- Develop a comprehensive approach to school tree planting.
- Educate homeowners about the cost-saving potential of planting trees in residential areas.
- Encourage businesses to plant trees on their properties through outreach efforts that promote the use of trees for carbon capture and energy efficiency.
- Support non-profit entities and municipalities in the planting, care, and maintenance of their local trees.
- Develop new sources of non-federal and non-state funding for tree planting programs:
    - Potential sources include the Arbor Day Foundation, other private foundations, and community in-kind services as matching funds, such as those used in TreeVitalize.
    - Work with PennVEST to solicit corporate donations as carbon credits and sustainability credits to plant trees in Pennsylvania instead of overseas.
- Create financial and other incentives for business owners and civic managers to add trees, such as grants for adopting shading and cooling measures.
- Meet with PennDOT and utility companies to work out more flexible options, like allowing smaller trees under power lines, tree pruning agreements, etc.
- Pursue small-scale and large-scale urban retrofit efforts (see Philadelphia) to create new planting areas during streetscape revisions during bike lane additions, traffic calming engineering, stormwater improvements, etc.
- Link UTC expansion to MS4 stormwater retrofits so carbon sequestration benefits can be realized with stormwater retrofits.
- Where feasible, explore opportunities to incorporate disease-resistant American chestnut in urban tree planting projects.
- Work with tree planting programs (like TreeVitalize) to educate both landowners and municipal staff on tree maintenance needs, costs, and leaf pickup.

Ongoing Efforts to Maintain and Increase Urban Tree Canopy

The TreeVitalize Program began in 2004 after a study by American Forests indicated that the tree canopy in Philadelphia and surrounding counties had decreased significantly. The program initially sought an $8 million investment in tree planting and care in southeastern Pennsylvania for a 4-year period of time. The goals of the program included planting 20,000 street trees, restoring 1,000 acres of streamside forests, and training 2,000 citizens to plant and care for trees. It has since expanded to Pittsburgh and throughout the rest of the state while also growing in scope to include all urban and community forestry-related work done by the DCNR Bureau of Forestry. To date, nearly 430,000 trees have been planted through community grants and partnerships; approximately 7,000 citizens have received training; many communities have acquired tree inventories; and urban tree canopy analyses have been completed for many large cities in the state. To find out more about TreeVitalize, visit www.treevitalize.net.

Cost of Increasing Canopy Cover
The cost of increasing canopy cover is difficult to ascertain because there are so many variables involved. The cost of site preparation varies drastically depending on where the tree is to be planted. In open areas and low intensity developed areas, little site preparation may be required, while in intensively developed areas, concrete cuts and significant subsurface improvements may be needed to support the growth of a tree. The cost of planting will vary based on whether volunteer or paid labor is involved, and whether heavy equipment is required. Maintenance of trees is an essential component of successfully increasing canopy cover that is often overlooked. Early structural pruning of young trees can significantly reduce hazardous defects in mature trees, and a regular pruning cycle is necessary to ensure long term health.

Assuming a cost of $150 per 2” caliper tree and the use of volunteer labor to plant and establish the trees:

- The cost of planting a sufficient number of trees to reach the <u>lower percent canopy goals</u> in developed land cover classes across the state of 35 percent in open space, 15 percent in low intensity development, 8 percent in medium intensity development, and 3 percent in high intensity development, is estimated at $86 million per year (over the course of 15 years).

In addition, there may be less expensive sources of native trees, including wholesale nurseries and county conservation district tree sales. For best results in urban settings, however, larger trees and extra care in siting and planting will be essential for long-term survival. Additional costs due to mortality are not included in the above calculations, nor are the costs of ongoing tree maintenance, which are essential for a healthy urban forest. Still, it should be noted that the above costs are one-time expenditures**.** In contrast, the benefits provided by a healthy urban forest are produced annually.

Through i-Tree Vue, the total value of ecosystem services (including carbon stored/sequestered and pollutants intercepted/taken up) that would be provided if the lower percent canopy goals were implemented across all developed land cover classes is $2.6 million annually**.** The value of energy savings from shading, calculated as described previously, would total $268 million annually.

Year	2016	2020	2030
Total # of trees planted	567,989	567,989	567,989
Cumulative # of additional trees	567,989	2,839,943	8,519,830
Amount of CO2 Sequesterd (tons)	28,331	141,656	424,969
# of homes shaded by two new trees	48,019	240,095	720,284
Amount of CO2 reduced by tree shading (tons)	38,895	194,477	583,430
Total CO2 reduction by seq. and shading (MMTCO2e)	0.061	0.305	0.915
Total Money saved in energy spending	17,863,049	89,315,247	267,945,741
Total Money spent in planting trees	85,198,300	85,198,300	85,198,300
Net Cost of planting Trees ($ Million)	67.3	-4.1	-182.7
Cost Effectiveness ($ / ton CO2e)	1104.3	-13.5	-199.8

	2030 Annual			2030 Cumulative		
	Reductions (MMTCO2e)	Cost ($MM)	Cost-Effectiveness ($/tCO2e)	Reductions (MMTCO2e)	Total NPV ($MM)	Cost-Effectiveness ($/tCO2e)
Urban Forestry	.915	-182.7	- 199.8	7.32	-431.60	-58.99

Macroeconomic Analysis of the Urban and Community Forestry Work Plan:

This plan seeks to utilize the planting and maintenance of trees in urban and community settings to increase carbon storage and to reduce residential, commercial, and institutional energy use for heating and cooling purposes. Trees in urban and suburban settings have the advantage of providing value-added benefits beyond carbon storage and energy savings. Properly planted and maintained trees have been shown to improve air quality, reduce flooding, increase property values, stimulate economic development, reduce crime rates, reduce stress and aggression, and much more.

Carbon stocks in trees and soils in urban land uses – such as in parks, along roadways, and in residential settings – can be enhanced in a number of ways, including planting additional trees, reducing the mortality and increasing the growth of existing trees, and avoiding tree removal (or deforestation). Properly designed forest canopy cover can also lower energy demand by reducing a building's heating and cooling needs.

Summary Table of Policy Impacts

Urban and Community Forestry				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+250	+250	+270	+250
GDP ($Millions)	-$45	-$120	-$20	-$90
Income ($Millions)	-$20	-$30	-$50	-$30

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the cost or price, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the analysis and from discussion with the technical analysts who completed the analysis were as follows:

- Costs associated with buying trees and the use of labor and equipment to plant trees. Spending on trees is constant each year from 2016 to 2030, as this work plan plans to increase canopy gradually in Pennsylvania.
- Savings associated with the reduction use of electricity as tree shade reduces the cooling need of buildings. These savings actually grow each year, as more and more buildings benefit from the increase of canopy each year.

Direct Economic Impacts Caused by Costs and Savings

Once the additional spending, savings, costs, and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with buying trees and the use of labor and equipment to plant trees:
    - These are increases in sales to the forestry industry. According to policy makers in Pennsylvania, 75 percent of the trees needed by this policy will be bought from nurseries operating within Pennsylvania in 2016, and this percentage will increase to 100 percent by 2019.
    - Those sales must be funded somehow, however. According to policymakers in Pennsylvania, the ongoing TreeVitalize project uses state and private matching funds to buy and plant the trees. State funding for that program requires a 1:1 match of local support, which can include in-kind support such as volunteer labor and donated equipment, from any community that wants state funds to plant urban trees. More often than not, communities overrun the grant by significant amount. State and local funding therefore was assumed to cover the cash costs, with volunteering and donations assumed to cover the required labor and equipment.
    - The consequence of this spending is that both state and local governments must reduce some spending from their overall budgets, and they therefore spend less on all the other activities planned on in their initial budget.
- Savings associated with the reduction of use of electricity:
    - These are a decrease in household spending on electricity.
    - This reduction, however, represents a higher spending on a mix of consumer goods and services, ranging from basics like food, clothing, housing and transportation to all manner of other consumer demands.

How this Work Plan Changes the Economy of Pennsylvania

In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-policy scenario:

Changes in Output (Total Value of Goods or Services Produced):

- The increase of total output holds at about 30 million dollars annually until 2021. The change of total output starts to drop from 2021 more and more significantly and reaches nearly -$130 million by 2030, as electricity generation needs fall more and more with each year.
- The individual sectors that increase most are:
  - Forestry, which grows first and stays at a relative steady level at approximately $85 million by 2030.
  - Retail trade, which grows gradually and reaches $21 million through 2030.
- The sectors that have the worst results are:
  - Electric utilities lose output over time, with an annual loss of $13 million by 2016 falling to a loss of nearly $240 million by 2030.
  - Construction also shrinks over time, by nearly $40 million by the year of 2030.
  - Support activities for mining and oil and gas extraction show slight reductions in size.
  - No other sectors report significantly negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):

- Overall demand within Pennsylvania falls by approximately $246 million by 2030.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):

- Total employment shrinks a little in 2016 (approximately 25 jobs lost), but starts to grow from 2019 on at a steady level at approximately 260 jobs each year in Pennsylvania.
- The sectors that have the highest employment changes are:
  - The forestry sector grows in this policy scenario, gradually adding 430 jobs.
  - The support activities for agriculture and forestry sector also grows at a relatively steady level between 230 and 300 new jobs as a result of the policy.
  - Retail trade sees growth in the employment increase gradually to 175 jobs by 2030.
  - Indirect benefits show up in sectors like offices of health practitioners, food services and drinking places, individual and family services, etc., which all show gains gradually through 2030, but not significantly when compared with the forestry sector.
- The sectors with the lowest employment changes are:
  - Only the construction and electricity supply sectors show significant losses of jobs. The numbers increase gradually and reach approximately 240 and 160, respectively, by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work falls by about $74 million by 2030.
- No sector showed any significant change in per-person earnings, however.

Work Plan 13: Manure Digesters

Initiative Summary:
Anaerobic digestion is a biological treatment process that breaks down manure, thereby producing biogas which can be converted to heat or electrical energy, improving the storage and handling characteristics of manure, and possibly reducing manure odor. This work plan recommendation or initiative analyzes the potential for increasing anaerobic digester deployment at medium to large-sized dairy and swine farms. The produced biogas is typically 60 percent methane, 40 percent carbon dioxide and <1 percent trace gases, which yields a heat content of 600 BTU/scf, which classifies biogas as a medium-BTU fuel.

Currently, there are approximately 25 manure digesters in Pennsylvania, with the majority (19) being located at dairy farms, four at swine farms and two at farms with both swine and dairy herds. Based on the analysis conducted in this work plan, manure digesters using waste from large dairy operations are cost-effective options for reducing greenhouse gases. The use of manure digesters using waste from swine operations can also reduce greenhouse gas emissions, but at a higher cost for a lower rate of reductions. Odor management and reduction of solids are co-benefits of this work plan.

Additionally, these digesters produce biologically derived methane gas, which is defined as a Tier I resource under the Alternative Energy Portfolio Standards Act.

Implementation Period: 2015–2030

Data Sources/Assumptions/Methods for GHG:
Anaerobic digester technology could be applied to beef cattle, poultry, and other animals, although their methane emissions in Pennsylvania are far lower than emissions from dairy cattle. Both dairy and swine manure emissions are considered in this analysis.

Anaerobic digestion systems can reduce GHG emissions in two different ways. Manure management practices on farms sometimes lead to the bulk storage of manure for extended periods of time. Under anaerobic conditions, found in manure management practices which involve creating a slurry or using long term bulk storage, methane gas can be generated as an end product in the breakdown of the solid organics in manure. An anaerobic digester allows for the capture and destruction of methane prior to being released to the atmosphere. Estimates of the amount of CO2e captured are based on factors provided on the EPA State Inventory Tool.

The second area of GHG reductions is obtained by offsetting fossil fuels used in the generation of electricity and for direct use as thermal energy. For the purposes of this analysis, it is assumed that the methane is used in a combined heat and power source. Other co-benefits of using digesters for farm (and other animal manure) are improved odor control, improved quality of the resulting product for use as fertilizer as compared to manure, and the future potential for participation in nutrient management credit trading program relating to the Chesapeake Bay Watershed.

Dairy Cow Anaerobic Digesters
The calculations use two digesters per year and 800 dairy cows per farm to produce approximately 79,900 scf of biogas per day. A 200 kW generator at 34.5 percent efficiency requires 47.47 mmbtu/day, which is equivalent to 79,100 scf of biogas at an average heat content of 600 BTU/scf. The calculations below assume a 200 kW generator will be run from the collected biogas and that the generator will run 24 hours a day year round. The dairy farm portion of this work plan assumes the addition of 30 anaerobic digesters on dairy farms of 500 or greater cows The analysis assumes that two dairy digesters per year are brought on-line. Table 1 displays the projected GHG emission reductions for dairy farms.

Table 1. GHG Emissions Reductions from Dairy Farm Digesters

Year	Total # of digesters	Avg. KW rating of generator	Displaced CO2 emission for electricity (lb/MWh)	Displaced CO2 emission for Steam heat (lb/MWh)	Baseline CH4 Capture (MMtCO2e /Yr)	CO2 Offset from electricity Generation (MtCO2e/yr.)	CO2 Reductions from Waste Heat Utilization (MtCO2e)	Total CH4 emission Reducitons (MMtCO2e)
2015	2	200	1699	299.6	0.01378	2700	476	0.0170
2016	4	200	1699	299.6	0.02756	5400	952	0.0339
2017	6	200	1699	299.6	0.04134	8100	1428	0.0509
2018	8	200	1699	299.6	0.05512	10800	1904	0.0678
2019	10	200	1699	299.6	0.06890	13500	2380	0.0848
2020	12	200	1699	299.6	0.08268	16199	2857	0.1017
2021	14	200	1699	299.6	0.09646	18899	3333	0.1187
2022	16	200	1699	299.6	0.11024	21599	3809	0.1356
2023	18	200	1699	299.6	0.12402	24299	4285	0.1526
2024	20	200	1699	299.6	0.13780	26999	4761	0.1696
2025	22	200	1699	299.6	0.15158	29699	5237	0.1865
2026	24	200	1699	299.6	0.16536	32399	5713	0.2035
2027	26	200	1699	299.6	0.17914	35099	6189	0.2204
2028	28	200	1699	299.6	0.19292	37799	6665	0.2374
2029	30	200	1699	299.6	0.20670	40499	7141	0.2543
2030	30	200	1699	299.6	0.20670	40499	7141	0.2543
							Total	**2.0347**

<u>Dairy Anaerobic Digester Costs</u>
The costs for dairy farm anaerobic digester systems for farms with 500 or more cows will differ based on the type of system installed. This work plan will assume a cost of $1,200,000 for a complete mix type of anaerobic digesters.

Annual operating and maintenance costs are estimated to be approximately $25,000 a year based on DEP estimates. Electricity generated is estimated at $.09/kWh based on historical electricity prices.

Utilization of waste heat from the engine jacket and generator from dairy digester systems represents another cost savings measure. The annual savings from avoided fuel usage is estimated to be $25,000 based on DEP estimates. The end product can be used as bedding on the dairy farm, estimated to generate a savings of $50,000 based on DEP estimates.

The costs and revenues associated with the dairy digester aspect of this work plan recommendation are provided in Table 2.

Table 2. Net Costs / Savings of Anaerobic Digesters for Dairy Cows

Year	Capital Cost	Annual O & M Cost	Value of kWh	Revenue from fiber	Value of avoided fuel	Net Cost
2015	2,400,000	50,000	299,592	100,000	50,000	2,000,408
2016	2,400,000	100,000	599,184	200,000	100,000	1,600,816
2017	2,400,000	150,000	898,776	300,000	150,000	1,201,224
2018	2,400,000	200,000	1,198,368	400,000	200,000	801,632
2019	2,400,000	250,000	1,497,960	500,000	250,000	402,040
2020	2,400,000	300,000	1,797,552	600,000	300,000	2,448
2021	2,400,000	350,000	2,097,144	700,000	350,000	-397,144
2022	2,400,000	400,000	2,396,736	800,000	400,000	-796,736
2023	2,400,000	450,000	2,696,328	900,000	450,000	-1,196,328
2024	2,400,000	500,000	2,995,920	1,000,000	500,000	-1,595,920
2025	2,400,000	550,000	3,295,512	1,100,000	550,000	-1,995,512
2026	2,400,000	600,000	3,595,104	1,200,000	600,000	-2,395,104
2027	2,400,000	650,000	3,894,696	1,300,000	650,000	-2,794,696
2028	2,400,000	700,000	4,194,288	1,400,000	700,000	-3,194,288
2029	2,400,000	750,000	4,493,880	1,500,000	750,000	-3,593,880
2030	0	750,000	4,493,880	1,500,000	750,000	-5,993,880
Total	36,000,000	6,750,000	40,444,920	13,500,000	6,750,000	-17,944,920

Cost-effectiveness is calculated by dividing total, discounted costs (over the entire period) by the cumulative GHG savings of the project to get a $/metric ton figure. For example, in this analysis, the net cost (saving) is $ 17.945 million (found at the bottom of Table 2), and the GHG savings are 2.0347 MMTCO2e (located at the bottom of Table 1). This means that the cost-effectiveness of the implementation scenario is $ -8.819/ metric ton.

Swine Anaerobic Digesters

Pennsylvania currently has anaerobic digesters operating at four swine operations. This work plan recommendation analyzes the potential of adding ten additional anaerobic digesters at swine operations with 3,000 or more animals through the end of year 2030. Among the benefits of farm-based digesters is their ability to control odors. Odor control has a real practical value, particularly at swine farms, even if it cannot be effectively monetized. In fact, one of the longest running anaerobic digesters in Pennsylvania was installed at the Rocky Knoll Swine Farm in 1985 primarily for odor control.

The GHG reductions of this policy were estimated for Pennsylvania pig farms using emission factors provided in the EPA State Inventory Tool. This analysis is based on swine farms with 3,000 pigs, with two new swine digesters brought on-line every three years.

The GHG emissions reductions from Swine farm digesters are provided in Table 3.

Table 3. GHG Emissions Reductions from Swine Farm Digesters

Year	Cummulative Digester Total	Avg. KW rating of generator	Displaced CO2 emission for electricity (lb/MWh)	Displaced CO2 emission for Steam heat (lb/MWh)	Baseline CH4 Capture (MMtCO2e/Yr)	CO2 Offset from electricity Generation (MtCO2e/yr.)	CO2 Reductions from Waste Heat Utilization (MtCO2e)	Total CH4 emission Reducitons (MMtCO2e)
2015	1	30	1699	299.6	0.00355	202	36	0.0038
2016	2	30	1699	299.6	0.00710	405	71	0.0076
2017	2	30	1699	299.6	0.00710	405	71	0.0076
2018	3	30	1699	299.6	0.01066	607	107	0.0114
2019	4	30	1699	299.6	0.01421	810	143	0.0152
2020	4	30	1699	299.6	0.01421	810	143	0.0152
2021	5	30	1699	299.6	0.01776	1012	179	0.0190
2022	6	30	1699	299.6	0.02131	1215	214	0.0227
2023	6	30	1699	299.6	0.02131	1215	214	0.0227
2024	7	30	1699	299.6	0.02487	1417	250	0.0265
2025	8	30	1699	299.6	0.02842	1620	286	0.0303
2026	8	30	1699	299.6	0.02842	1620	286	0.0303
2027	9	30	1699	299.6	0.03197	1822	321	0.0341
2028	10	30	1699	299.6	0.03552	2025	357	0.0379
2029	10	30	1699	299.6	0.03552	2025	357	0.0379
2030	10	30	1699	299.6	0.03552	2025	357	0.0379
							Total	**0.3146**

Swine Manure Management Costs:

The costs for swine farm anaerobic digester systems for farms with 3,000 or more swine will differ based on the type of system installed. This work plan will assume a cost of $1.2 million for a complete mix type of anaerobic digesters.

Annual operating and maintenance costs are estimated to be approximately $25,000 a year based on EPA estimates. Electricity generated is estimated at $.09/kWh based on historical electricity prices.

Utilization of waste heat from the engine jacket and generator from dairy digester systems represents another cost savings measure. The annual savings from avoided fuel usage is estimated to be $5,000 based on DEP estimates.

The costs and revenues associated with the dairy digester aspect of this work plan recommendation are provided in Table 4.

Table 4. Net Costs / Savings of Anaerobic Digesters for Swine

Year	Capital Cost	Annual O&M Cost	Value of kWh	Value of avoided fuel	Net Cost	
2015	1,200,000	25,000	22,469	5,000	1,197,531	
2016	1,200,000	50,000	44,939	10,000	1,195,061	
2017	0	50,000	44,939	10,000	-4,939	
2018	1,200,000	75,000	67,408	15,000	1,192,592	
2019	1,200,000	100,000	89,878	20,000	1,190,122	
2020	0	100,000	89,878	20,000	-9,878	
2021	1,200,000	125,000	112,347	25,000	1,187,653	
2022	1,200,000	150,000	134,816	30,000	1,185,184	
2023	0	150,000	134,816	30,000	-14,816	
2024	1,200,000	175,000	157,286	35,000	1,182,714	
2025	1,200,000	200,000	179,755	40,000	1,180,245	
2026	0	200,000	179,755	40,000	-19,755	
2027	1,200,000	225,000	202,225	45,000	1,177,775	
2028	1,200,000	250,000	224,694	50,000	1,175,306	
2029	0	250,000	224,694	50,000	-24,694	
2030	0	250,000	224,694	50,000	-24,694	
Total	12,000,000	2,375,000	2,134,593	475,000	11,765,407	

Table 5. Annual and Cumulative (2013 – 2020) Cost-Effectiveness

	2030 Annual			2030 Cumulative		
	Reductions (MMTCO2e)	Cost ($MM)	Cost-Effectiveness ($/MtCO2e)	Reductions (MMTCO2e)	Total NPV (2014 $MM)	Cost-Effectiveness ($/MtCO2e)
Manure Digesters – Dairy	.2543	-5.994	-23.57	2.0347	.384	.19
Manure Digesters - Swine	.0379	-.025	-.651	.3146	8.363	26.58

Implementation Steps:

The following implementation steps help to address the financial aspects of digester development:

- Encourage PUC to withdraw proposed net metering regulations set forth as 52 Pa. Code §75.13(a)(3), which was published on July 5, 2014 in the Pennsylvania Bulletin. This proposed regulation would limit the capacity of sources otherwise qualified to participate in net metering to 110 percent of the facility's historical electricity usage. In the alternative, encourage the PUC to exempt either all Tier I resources from the proposed net metering cap, or exempt electricity generated from biologically generated methane gas (as defined in the AEPS) from the proposed net metering cap. The proposed 110 percent size cap on net metering projects, if adopted by the PUC, will eliminate any reasonable possibility of future digester installation in Pennsylvania due to a 50 percent or more reduction in electricity savings. Development of these projects are already difficult given tight financial pro-formas and the difficulty in accessing capital for their development. Withdrawal of the proposed regulation is supported by a broad coalition of farmers, renewable energy stakeholders, and environmental advocacy organizations and industry trade groups, based on comments submitted to the PUC.
- Establish or expand state-funded programs that offer tax breaks to companies that install digesters.
- Encourage state funding through grants and loans for development of these projects through:
    - *Commonwealth Financing Authority's Alternative and Clean Energy Program (ACE).* ACE provides grants and loans that can be used for the development and construction of alternative and clean energy projects throughout Pennsylvania. For each job created, entities could receive $40,000 in grant funding for clean energy generation equipment.
    - *Pennsylvania Energy Development Authority.* This group provides grants to Pennsylvania companies and organizations for clean, advanced energy projects. Manure digesters would likely qualify as advanced energy because they provide biologically derived methane gas.
    - *Pollution Prevention Assistance Account (PPAA) Loan Program*. The PPAA provides low interest loans to small businesses undertaking projects that reduce waste, pollution, or energy use. The maximum loan amount is $100,000 for businesses with 100 or fewer full-time employees.
- Encourage use of food scraps in digesters. This would increase the amount of "fuel" that can be placed in the digester to produce biogas. Due to the tight economics of digesters, it is critical that they operate at or near 100 percent capacity. Modifying existing residual waste and/or municipal solid waste regulations to allow disposal of food scraps into farm-based digesters could increase the utilization rate of digesters and improve these projects economic viability.
- Encourage smaller farming operations to form local community authorities to apply for funding and centralize manure digesters for maximum benefits and reduced costs.

- Encourage private partnerships - large companies looking to locate certain operations in Pennsylvania could finance a portion of a manure digester in exchange for a power-purchase agreement.
- If denitrification of the manure occurs through the oxidization of ammonia (through aerobic *and* anaerobic processes), nitrogen will be removed and the digester may be eligible to sell nutrient credits in the Potomac and Susquehanna River Basins.
- Manure digester operations should be encouraged to sell voluntary carbon emissions credits.

The following implementation steps address other aspects of manure digester systems:

- Outreach training – Educate designating for the support of building digesters with conservation districts, Penn State, and RCM digesters. Ensure that the outreach training includes an economic component that educates potential project developers regarding all possible financial benefits, including AEPS credits, net metering, state and federal grant and loan guarantee programs, etc.
- Encourage single farms and combination farms to build digesters through outreach training and removal of any existing barriers to joint projects and waste transportation between farmers.
- Creation of a general plan approval and general operating air permit for biogas (as defined by the AEPS)-fired internal combustion engines.
- Modification of the general plan approval and general operating air permit for landfill gas-fired simple cycle turbines to include turbines fired on other biogases (as defined by the AEPS).

Macroeconomic Analysis of the Manure Digesters Work Plan:

Anaerobic digestion is a biological treatment process that breaks down manure, thereby producing biogas which can be converted to heat or electrical energy, improving the storage and handling characteristics of manure, and possibly reducing manure odor. This work plan recommendation or initiative analyzes the potential for increasing anaerobic digester deployment at medium to large-sized dairy and swine farms. The produced biogas is typically 60 percent methane, 40 percent carbon dioxide and <1 percent trace gases, which yields a heat content of 600 BTU/scf, which classifies biogas as a medium-BTU fuel.

Currently, there are approximately 25 manure digesters in Pennsylvania, with the majority (19) being located at dairy farms, four at swine farms and two at farms with both swine and dairy herds. Based on the analysis conducted in this work plan, manure digesters using waste from large dairy operations are cost-effective options for reducing greenhouse gases. The use of manure digesters using waste from swine operations can also reduce GHG emissions, but at a higher cost for a lower rate of reductions. Odor management and reduction of solids are co-benefits of this work plan.

Additionally, these digesters produce biologically derived methane gas, which is defined as a Tier I resource under the Alternative Energy Portfolio Standards Act.

Summary Table of Policy Impacts

Manure Digesters				
Economic Indicator	***2020***	***2025***	***2030***	***2016-2030 Avg.***
Employment	+7	+30	+50	+20
GDP ($Millions)	+0	+$3	+$6	+$3
Income ($Millions)	+0	+$3	+$5	+$2

Work Plan Costs and Savings Identified for Inclusion in Analysis

Economic impacts of any policy are assessed by understanding how they change spending levels and how they change the costs and/or prices, and how those changes drive further responses throughout the rest of the Pennsylvania economy. For this work plan, the costs and savings identified from the microeconomic analysis work, and from discussion with the technical analysts who completed said work, were as follows:

- Costs associated with buying, operating and maintaining the manure digesters system. This applies to dairy farms and swine farms in this policy.
- Savings associated with less natural gas used for dairy farms and swine farms due to the natural gas supplied by manure digesters. Farms with such systems also have opportunities to sell the additional natural gas to the grid.

Direct Economic Impacts Caused by Costs and Savings

Once all spending, savings, costs and prices have been identified, they must be characterized for their direct impacts on affected sectors. This characterization determines the way in which the macroeconomic modeling software is used to build a projection of the economy-wide changes based on these direct changes.

- Costs associated with the capital investment of the manure digester system for diary and swine farm:
    - These are increases in demand in the industrial machinery manufacturing sector.
    - Those spending must be funded somehow, however. The burden of paying for the machinery over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Costs associated with the operation and maintenance of the system:
    - These are characterized as and converted to an increase in jobs on dairy farms and swine farms. We assume one unit of labor equals to $25,000.
    - The spending must be funded somehow, however. The burden of paying for the machinery over time results in a higher overall production cost to the sectors carrying out these expenditures, as they must take on this additional cost in order to produce the same amount of product before.
- Savings associated with the reduction in use of natural gas:
    - These are a decrease in demand for natural gas.

  - The spending must be funded somehow, however. The reductions lower production cost – an input needed in smaller quantities in order to produce the same amount of product.
- Savings associated with the sale of surplus natural gas:
  - These are an increase the firm sale in these two kinds of industries.
  - The spending must be funded somehow, however. The sales of surplus natural gas from swine farms and dairy farms decrease the demand for natural gas.

How this Work Plan Changes the Economy of Pennsylvania

In addition to the major indicators described in the initial summary table, the REMI analysis allows us to describe other projections of change in the economy under this scenario. All numbers below represent projected changes to the economy generated by the modeling effort in comparison to a no-work-plan scenario:

Changes in Output (Total Value of Goods or Services Produced):
- Total output keeps growing in the work plan scenario and rises by around $32 million by 2030.
- The individual sectors that increase most are:
  - Dairy product manufacturing contributes the most increase in the output in Pennsylvania's economy, increasing by nearly $27 million by 2030.
  - The animal slaughtering and processing sector also grows, but much slower by only approximately $4 million by 2030.
  - No other sectors show up significant increase in output.
- The sectors that have the worst results are:
  - Natural gas utilities shrink gradually over time, by about $3 million by 2030.
  - No other sectors report significant negative shifts in output.

Changes in Demand (Willingness to Buy Goods and Services):
- Overall demand within Pennsylvania rises by approximately $8.5 million by 2030, but it has a peak at nearly $17 million in 2024.
- This policy does not significantly change the balance of demand for domestic vs. imported goods and services in any sector.

Changes in Employment (Number of Individuals Employed, Either Full-Time or Part-Time):
- Total employment increases slightly, adding 50 jobs in Pennsylvania by 2030.
- The sectors that have the highest employment changes are:
  - The dairy product manufacturing sector and animal slaughtering and processing sector grow in this work plan scenario by around 25 and 7 jobs, respectively, by 2030.
  - No other significant job increase shows up in the policy scenario.
- The sectors with the lowest employment changes are:
  - Several sectors see job losses, such as the natural gas sector and oil and gas extraction sector, but losses are all smaller than two jobs by 2030.

Changes in Compensation (Amount Employees Make, in Wages and All Other Benefits):

- Total compensation for work rises by about $5.3 million by 2030. This is approximately $106,000 per new position created.
- The overall income of jobs in Pennsylvania does not change during the period 2016 - 2030.

Appendix C: CCAC Member Comments

Comments from CCAC Member Patrick Henderson:

As a member of the Climate Change Advisory Committee (CCAC), I would like to express my appreciation to my colleagues who have attended and participated in meetings over the past year to help craft the attached work plans and to discuss and provide feedback on the draft plan. I would also like to express my appreciation to the staff of the Department of Environmental Protection (DEP) who have assisted the CCAC. I offer the following comments for inclusion in the final report.

Consistency in Messaging

The first paragraph of Chapter 1 of the final plan (Overview and Introduction) includes the phrases 'climate change', 'climate disruption', and 'global warming'. Use of multiple terms, including the phrase 'climate disruption' which appears to be a unique term for purposes of this report, can be confusing and sends mixed signals to the plan's audiences. Given that the report is prepared and authorized under the Pennsylvania Climate Change Act, it may be beneficial to use one term – climate change – consistently throughout the report.

Trends in Greenhouse Gas Emissions in PA

While the final plan acknowledges that Pennsylvania has made strides in reduced greenhouse gas emissions in recent years, it would be strengthened by providing more tangible details outlining these trends. The report highlights two contributing factors: an increase in renewable energy generation and utility and ratepayer participation in Act 129 energy efficiency programs. For context, the 29% increase in renewable energy generation between 2012 and 2013 is still a relatively miniscule component of Pennsylvania's overall electric generation; indeed, a 29% increase of 2%-3% overall generation capacity still results in a very small portion of the Commonwealth's electric generation portfolio.

However, by far the greatest contributing factor to decreased greenhouse gas emissions in the Commonwealth is attributable to the increased use of natural gas for electric generation. According to the 2014 Pennsylvania State Energy Plan, natural gas generation will increase from approximately 1% of Pennsylvania's overall electric generation in 2000 to between 25-30% in 2017. Reflective of this, according to DEP's own data, carbon dioxide emissions from point sources (excluding natural gas) *decreased* by nearly 11,500 tons between 2011 and 2013 – nearly 13%. The final report would better inform its audience, as well as more accurately reflect the contributions to reduced greenhouse gas emissions, by including details and data on the increased utilization of natural gas in electric generation.

Data Regarding 'Clean Jobs'

Much has been made publicly regarding the association of direct, indirect and induced jobs with specific sources of energy utilization. In the final report, DEP carries the results of a 'survey' on jobs data which states that Pennsylvania-based 'clean' energy firms support over 57,000 workers (pg 34). According to the final report, this survey was conducted by KEEA and E2. However, in examining this survey, many of the jobs are traditional construction jobs not associated with the utilization of any specific energy resource. Regardless, for the sake of consistency, DEP and the Administration should employ consistent methodologies in representing to the public the jobs contributions of particular energy sectors to avoid characterizations that DEP and the Administration only challenge job estimates which may be contrary to unrelated policy narratives.

Lack of Outlining Clear Benefits to be Achieved Through Plan Implementation

While the plan outlines significant impacts associated with climate change, such as melting ice caps, rising sea levels, wildfires, extended heat waves, extreme storms and flooding, and more acidic oceans, it fails to outline what positive, tangible outcomes (if any) will be realized by the citizens of Pennsylvania if the steps outlined in the plan are implemented.

To this point, it is imperative to note that Pennsylvania is not a micro-climate unto its own. Rather, Pennsylvania is part of a broader national and international climate which is affected by choices and activities which occur far beyond our borders, and indeed literally around the world. It is therefore unclear to the plan's audience, as well as policymakers such as the governor and General Assembly, what benefits associated with climate change will be realized through its implementation. If the plan can cite impacts such as rising sea levels, extreme weather events, flooding, heat waves and other ills with certainty as outcomes of unmitigated climate change, it likewise must demonstrate the benefits – beyond merely 'slowing climate change' – that would be realized in Pennsylvania through its implementation, if any exist. Therefore, proper context of Pennsylvania's place in the nation and the world should be a key component of any final plan.

Incorporation of Public Comments

Outside of some grammatical changes, it appears that few if any substantive changes were made to the final plan based on the comments received from the public. I commend DEP for posting the comments received on DEP's eComment website, and encourage readers of the plan to review those comments which were submitted.

General Disclaimer

While DEP has noted the role of the CCAC in formulating the work plan and final plan in several areas, it is important to reiterate that, under the Pennsylvania Climate Change Act, the *work plans* attached to the plan are the product of the CCAC, but the plan itself is the product of DEP, prepared for the consideration of the governor, and by extension, other elected officials and the public at large. The CCAC has the opportunity to share comments and observations with DEP on the draft plan, but it does not approve or sanction the final plan or its contents.

Appendix D: List of Acronyms

ACEEE	American Council for an Energy-Efficient Economy
AEPS	Alternative Energy Portfolio Standard
AFIG	Alternative Fuel Incentive Grant
AR5	IPCC Fifth Assessment Report
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigeration, Air-Conditioning Engineers
BEE	Behavior-Bases Energy Efficiency
BTU	British Thermal Unit
CAFÉ	Corporate Average Fuel Economy
CCAC	Climate Change Advisory Committee
CCS	CO2 Capture and Sequestration
CCS	Center for Climate Strategies
CFA	Commonwealth Finance Authority
CH4	Methane
CHP	Combined Heat and Power
CMIP5	Coupled Model Inter-Comparison Project Phase 5
CMM	Coal Mine Methane
CNG	Compressed Natural Gas
CO2e	Carbon Dioxide Equivalent
CREP	Conservation Reserve Enhancement Program
DCED	Department of C Economic Development
DCNR	Department of Conservation and Natural Resources
DEP	Department of Environmental Protection
DGS	Department of General Services
DOE	Department of Energy
ECBM	Enhanced Coal Bed Methane Recovery
EDC	Electric Distribution Company
EE&C	Energy Efficiency and Conservation
EERS	Energy Efficiency Resource Standards
EEMs	Energy Efficient Mortgages
EGU	Electric Generating Unit
EIA	Energy Information Agency
EIMs	Energy Improvement Mortgages
EPA	Environmental Protection Agency
ESCO	Energy Service Company
ESPM	Energy Star Portfolio Manager

ESPC	Energy Service Performance Contractor
FIT	Feed-in Tariff
FHA	Federal Housing Agency
FLIR	Forward Looking Infrared
FRC	Field Reversed Configuration
GCM	General Circulation Model
GHG	Green House Gas
GSHP	Ground Source Heat Pump
GSP	Gross State Product
CTG	Control Technique Guidelines
GWP	Global Warming Potential
HDC	Hardwood Development Council
HDNP	Heavy Duty National Program
HEV	Hybrid Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning
I&P	Inventory and Projections
IAC	Industrial Assessment Center
ICC	International Construction Code
IEA	International Energy Agency
IECC	International Energy Conservation Code
IFR	Integral Fast Reactor
IgCC	International Green Construction Code
IGCC	Integrated Gasification Combined Cycle
IMC	International Mechanical Code
IPC	International Plumbing Code
IPCC	Intergovernmental Panel on Climate Change
IRC	International Residential Code
LDAR	Leak Detection and Repair
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LFGTE	Land Fill Gas to Energy
LNG	Liquefied Natural Gas
LPD	Lighting Power Density
LUT	Land Use and Transportation
MHWG	Multifamily Housing Working Group
MMTCO2e	Million Metric Ton COD Equivalent
MSHA	Mine Safety and Health Administration
MSW	Municipal Solid Waste
NGDC	Natural Gas Distribution Companies
NGS	Columbia Gas’s New Area Service Program

NHTSA	Natural Highway Traffic Safety Administration
NLCD	National Land Cover Database
NPV	Net Present Value
NSPS	New Source Performance Standard
NYSERDA	New York State Energy Research & Development Authority
NZEB	Net-Zero Energy Building
OBF	On-Bill Financing
PACE	Property Assessed Clean Energy
PennTAP	Pennsylvania Technical Assistance Program
PITF	Pennsylvania Pipeline Infrastructure Task Force
PJM	PA, NJ, MD Regional Transmission Organization
CPACE	Commercial Property Assessed Clean Energy
PPAA	Pollution Prevention Assistance Account
PSATS	Pennsylvania State Assoc. of Township Supervisors
PUC	Public Utility Commission
PV	Solar Photovoltaic
QECB	Qualified Energy Conservation Bonds
RAC	UCC Review and Advisory Council
RCI	Residential, Commercial and Industrial
RECs	Reduced Emissions Completions
REMI	Regional Economic Models, Inc.
SAVES	Virginia Sustainable and Verifiable Energy Savings
UCC	PA Uniform Construction Code
USDA	United States Department of Agriculture
WAP	Weatherization Assistance Program
WHEEL	Warehouse for Energy Efficiency Loans
WTE	Waste to Energy
VA	Veterans Administration
VMT	Vehicle Miles Traveled