

Executive summary

The Clean Power Plan provides Pennsylvania with an opportunity to achieve public health and environmental justice benefits across the state while simultaneously reaching its carbon emission reduction goals in the power sector. In this report, we analyze the health, environmental, and equity dimensions of the Clean Power Plan. We first assess the socioeconomic and environmental health burdens and hazards for populations living near plants regulated under the Clean Power Plan. We then model the potential public health impacts of fine particulate matter attributable to combustion at Pennsylvania's power plants. Our findings point to where carbon emission reductions may have the greatest public health benefits, and help identify where increased or decreased power generation may add to or alleviate burdens on vulnerable communities.

The Environmental Protection Agency's (EPA) Clean Power Plan sets carbon emission reduction targets for the power sector in order to mitigate the impact of electricity generation on climate change. Compliance with these objectives can yield significant public health and environmental justice co-benefits in addition to the climate benefits of the rule. However, the geographic and demographic distribution and the scale of these benefits may vary widely depending on the manner in which these carbon dioxide (CO₂) emissions standards are implemented in each state.

Historically, power generation has been associated with numerous environmental health burdens that disproportionately affect vulnerable and already overburdened communities. Power plants are often located near low income and minority populations, which are both more likely to experience a cumulative burden of multiple socioeconomic and environmental stressors, such as poor air quality and proximity to hazardous waste facilities, and to be more susceptible to experiencing adverse health outcomes when exposed to pollutants from fossil fuel combustion. In order to ensure that State Plans do not disproportionately impact these communities or increase the health and environmental burdens borne by these communities, the EPA suggests that states consider the emissions of multiple pollutants beyond CO₂ when developing their Clean Power Plan compliance approach.

The Clean Power Plan gives states significant flexibility to determine their own pathway to meet the 2030 carbon reduction targets. By considering the many dimensions of power generation impacts together, the pathway to carbon mitigation can help achieve public health and equity benefits as well as climate benefits. The EPA provided an initial analysis of the nationwide public health benefits from reductions in co-pollutant emissions under the Clean Power Plan [1], along with an initial proximity analysis of populations living within three miles of regulated power plants to identify potentially vulnerable and overburdened communities [2]. In this report, we model the regional health burden associated with emissions from each power plant covered by the Clean Power Plan in Pennsylvania and analyze toxic releases and environmental hazards associated with these plants. We also assess socioeconomic and environmental hazard burdens for populations living near the plants, and develop a Cumulative Vulnerability Index to reflect these burdens.

Findings and recommendations

1. Our models suggest that fine particulate matter (PM_{2.5}) attributable to Pennsylvania power plant emissions is responsible for thousands of premature deaths a year and tens of thousands of incidents of respiratory symptoms, asthma exacerbations and other health effects. The majority of these particulate matter health impacts are attributed to coal plants. **Reducing CO₂ emissions in Pennsylvania under the Clean Power Plan has the potential to additionally reduce these harmful emissions and associated health impacts, particularly under a multi-pollutant approach that targets plants with high emission rates for multiple pollutants.**
2. Pennsylvania power plants are located disproportionately in low income and minority communities, particularly natural gas combined cycle plants. Populations living near many of these plants are further burdened by multiple socioeconomic, health and environmental stressors. **Increasing use of existing natural gas combined cycle plants for Clean Power Plan compliance may increase generation and associated hazards near already overburdened and vulnerable communities. Renewables and energy efficiency do not carry that same risk, and can help to displace existing fossil fuel pollution.**
3. Pennsylvania power plants are associated with numerous environmental health hazards in nearby communities in addition to their air pollution impacts. Examples include coal ash impoundments at coal plants, and higher rates of environmental statute violations at natural gas combined cycle plants—particularly near state-designated Environmental Justice Areas. **Engagement with local communities can give insight into these and other environmental health concerns near power plants that may be ameliorated by reduced fossil reliance under the Clean Power Plan.**

Our analysis presents a baseline portrait of the impacts, hazards, and risks associated with the power plants in Pennsylvania that are regulated under the Clean Power Plan. This report builds on the EPA's initial national co-benefits and environmental justice analyses to examine three significant facets of power generation in Pennsylvania:

1. We expand on the EPA proximity analysis by adding health vulnerability indicators (e.g., prevalence of disease or poor birth outcomes) and analyzing population characteristics (e.g. race, income level, age) for communities living near power plants (including coal, natural gas combined cycle (NGCC), fossil steam, and recently retired).
2. We analyze specific environmental health hazards at power plants, including coal ash impoundments, toxic releases on- and off-site, groundwater well-monitoring, and power plant compliance, including violations of federal environmental statutes.
3. We analyze historic power plant criteria pollutant emissions and model the health impacts of associated primary and secondary particulate matter pollution, on a per-plant basis and aggregated for each county in the state.

This Executive Summary highlights the main findings from our analysis and discusses the implications of these findings for how Clean Power Plan implementation in Pennsylvania may take into consideration public health and equity.

Vulnerable and overburdened populations

Our research finds that populations living near both coal and natural gas power plants are in many cases burdened with a disproportionate share of environmental health hazards, such as proximity to traffic and hazardous facilities, and have a larger share of socioeconomic and health vulnerabilities, such as large low income populations and high disability prevalence. These vulnerabilities, combined with other environmental stressors, are associated with these populations being more susceptible to impacts from exposures to environmental hazards attributable to power plants. While exposure to primary and secondary air pollutants from power generation affects populations over hundreds of miles, the scientific literature suggests that populations that live near all types of fossil generation sites are at higher risk of experiencing adverse health outcomes [3, 4, 5, 6, 7].

Building on the EPA proximity analysis, we analyze **demographic** (e.g. minority, low income), **environmental** (e.g. air quality, traffic proximity), and **health indicators** (e.g. health insurance rate, disability prevalence) for populations living within three miles of plants subject to the Clean Power Plan. We analyze our results for individual plants and for each power plant class (coal, natural gas combined cycle, etc.). Demographic measures of populations living within three miles of each power plant class, including percent low income and minority, are shown in **Figure 1**.

Our results indicate that populations living within three miles of both coal and natural gas power plants subject to the Clean Power Plan have a larger percentage of low income residents than either the state median or the state average and this trend is most pronounced for natural gas combined cycle plants. Populations within three miles of natural gas combined cycle plants have a five times larger share of racial/ethnic minority residents than the state median. These populations are 44% minority, compared to a state median of 9% and state average of 21%. Furthermore, **half of the affected power plants are located within three miles of a region designated as an Environmental Justice Area by the Pennsylvania Department of Environmental Protection (PA DEP) [8].**

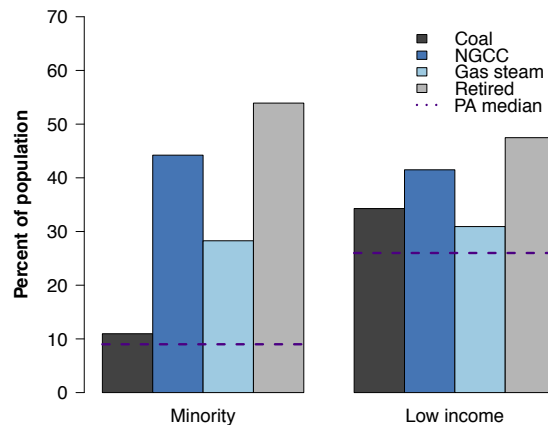


Figure 1: Demographics of populations that live within three miles of Clean Power Plan subject power plants, compared to the state median.

This report creates an aggregate demographic, environmental and health index by averaging percentile rankings for eighteen different indicators (e.g. low income, access to health care, air quality) to reflect cumulative burden for populations living near affected power plants (the “Cumulative Vulnerability Index”). This aggregate metric, shown for the 15 highest-ranking plants in **Figure 2**, reveals that four of the five power plants that rank highest for

cumulative vulnerability of adjacent communities are natural gas combined cycle (the fifth has retired since the EPA baseline year of 2012).

Our Cumulative Vulnerability Index can be helpful to screen for vulnerable and overburdened populations for engagement under the Clean Power Plan, to ensure that no increased burden is placed on these populations from this rulemaking. Ideally, it will also be used to inform approaches to decrease environmental hazard and human health impact burdens on these populations. **A State Plan that relies on increasing electricity generation at existing natural gas plants, rather than replacing coal generation with energy efficiency or renewable generation, for example, may have the potential to increase the utilization of plants located near disproportionately low income and minority populations.**

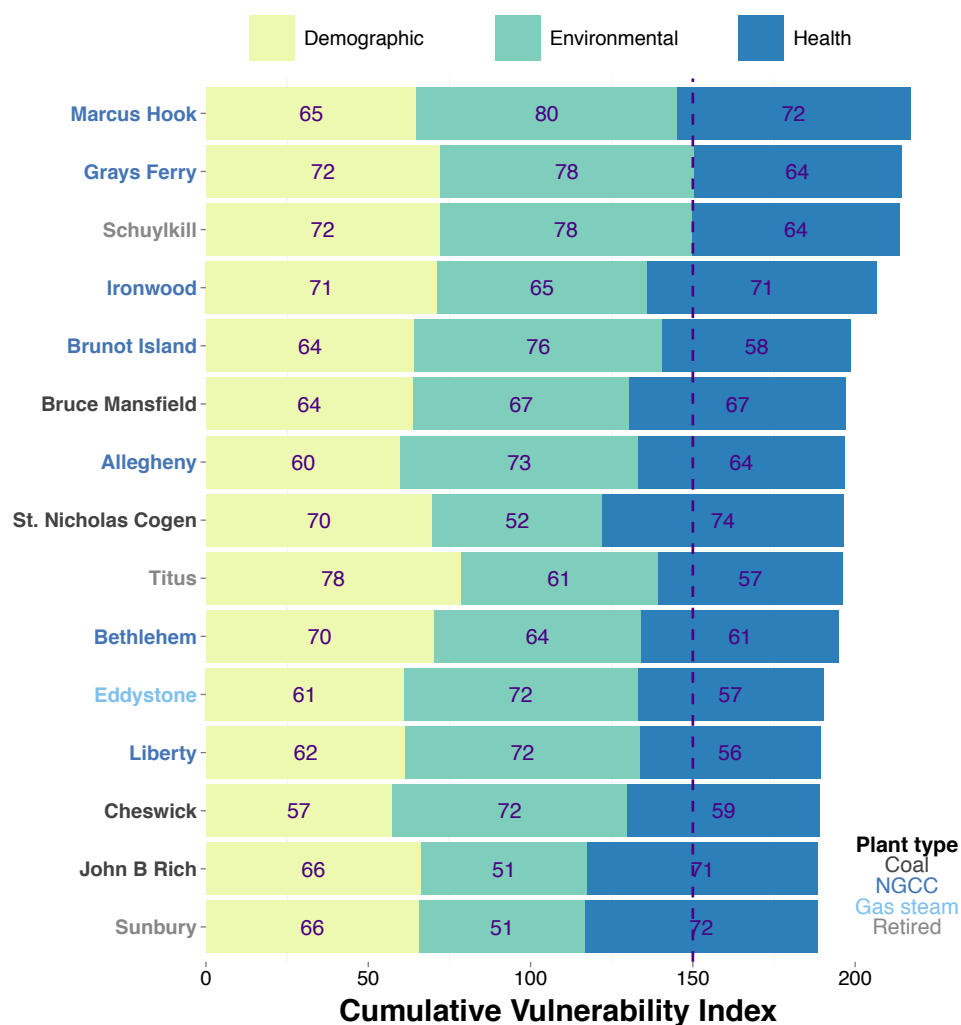


Figure 2: Cumulative Vulnerability Index reflecting aggregate demographic, environmental and health burdens for populations living within three miles of the 15 highest-ranked power plants. A median score on all indicators would give an Index score of 150 (purple dashed line). 14 of these plants (all except Sunbury) are located within three miles of a state-designated Environmental Justice Area.

Table 1: Inspections and violations of federal environmental statutes, 2011-2015. Total violations/inspections and average number of violations/inspections per plant near (< 3 mi.) or not near (> 3 mi.) an Environmental Justice (EJ) Area. 2015 or prior retired plants excluded.

	Total 2011-2015	Average per plant	Average per EJ Area plant	Average per non-EJ Area plant
VIOLATIONS				
Coal	58	2.42	2.80	2.14
NGCC	43	2.69	4.22	0.71
Gas steam	5	2.50	4.00	1.00
INSPECTIONS				
Coal	193	8.04	7.60	8.36
NGCC	62	3.88	5.11	2.29
Gas steam	14	7.00	9.00	5.00

This report also examines environmental health hazards at the sites of power plants subject to the Clean Power Plan by analyzing both power plant inspections and violations of federal statutes, including the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act, and the Safe Drinking Water Act. In our analysis, we find that the largest total number of violations is associated with coal plants, but the highest average number of violations per plant is associated with natural gas combined cycle plants, as shown in **Table 1**. This trend is exacerbated near Environmental Justice Areas, where natural gas combined cycle plants show a 1.5 times higher average number of violations than coal.

Additionally, natural gas combined cycle plants received less than half the number of average inspections compared to coal. The environmental hazards associated with these violations could potentially be reduced or eliminated through reduced demand on these facilities under the Clean Power Plan. But these data also underscore the need for careful, consistent and more frequent inspections of power generation sites, especially in disproportionately vulnerable communities. **The majority of plants are located near low income populations, and similarly the total number of violations received between 2011-2015 were primarily in low income areas,** as shown in **Figure 3**. We find numerous human health hazards associated with coal plants in particular, including multiple plants with coal ash impoundments designated with a high hazard potential and/or poor structural integrity by EPA contractors. These results indicate elevated risks of groundwater and soil contamination, including at six plants in or near Environmental Justice Areas.

Compliance and violations

- Coal received more violations and inspections than other plants.
- Within three miles of a state-designated Environmental Justice Area, natural gas combined cycle plants had a 1.5 times higher rate of violations than coal plants.
- For violations received during a noncompliance period, 33% of natural gas combined cycle plants and 44% of coal plants received at least one violation for contamination.
- Inspection rates at plants near Environmental Justice Areas are nearly 1.5 times higher for coal than natural gas combined cycle.

From well-monitoring data near coal ash impoundments, high levels of toxic releases of heavy metals, persistent bioaccumulative toxins and other health-harming contaminants were found to exceed allowable levels of lead, arsenic and other contaminants at rates hundreds of times higher than the EPA's Maximum Contaminant Level (MCL) standards, although all exceedances cannot necessarily be attributed to impoundments. While background levels prior to the coal ash impoundments' existence were not available, the use of wells for drinking water by rural residents is cause for concern with regards to exceedances above MCL and health advisory standards.

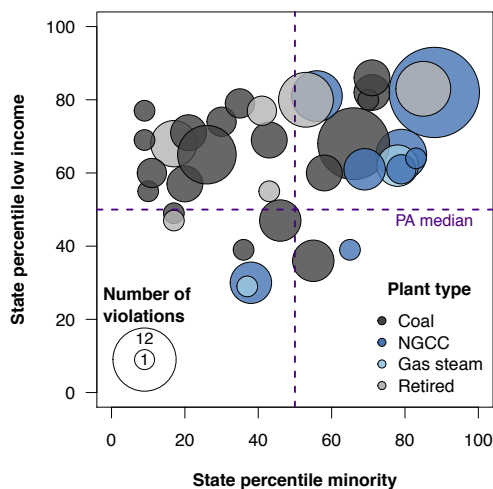


Figure 3: Total 2011-2015 violations for each plant (circle size) plotted by the state percentile for low income and minority populations of the surrounding community.

These results, in aggregate, suggest that there is potential to reduce burdens on vulnerable communities through decreased reliance on fossil generation under the Clean Power Plan. However, if there is a switch from coal to existing natural gas power plants or new power plants sited in vulnerable or historically burdened areas, there is a risk of increasing the burden on socioeconomically and environmentally vulnerable communities or of shifting burdens among vulnerable communities. Given the wide distribution of levels of existing burden for communities living near all classes of power plants, extensive community input and careful modeling of projected changes in generation levels under any compliance plan is needed to provide insight into whether demand, and associated health burdens, are likely to increase near any given population.

Air pollutant emissions and public health

Our models suggest that fine particulate matter ($PM_{2.5}$) attributable to Pennsylvania power plant emissions is responsible for thousands of premature deaths a year and tens of thousands of incidents of respiratory symptoms, asthma exacerbations and other health effects. Consideration of health-damaging criteria pollutants when developing carbon reduction strategies can help reduce or eliminate some of these health burdens. Such multi-pollutant plans may target both the plants with the largest total health impacts, as well as those with the highest intensity of health impacts per megawatt-hour (MWh) of generation or per ton of CO_2 .

We analyze emissions of CO_2 , nitrogen oxides (NO_x) and sulfur dioxide (SO_2) from power plants in Pennsylvania in 2015, and find a wide range among power plants of both total mass of emissions and in rate of emissions per MWh. NO_x and SO_2 contribute to elevated levels of secondary $PM_{2.5}$. NO_x also reacts in the atmosphere to form tropospheric ozone, a strong respiratory irritant which can contribute to a wide range of cardiovascular and respiratory health impacts, particularly among members of already-vulnerable populations (e.g. low income, minority, the elderly, and those with pre-existing diseases).

Power plants that burn coal waste have a higher rate of CO₂ emissions per MWh than any other plant class, a lower rate of NO_x emissions than non-waste burning coal plants, and relatively high rates of SO₂ emissions. Coal plants have higher rates of CO₂, NO_x and SO₂ than natural gas combined cycle plants, and are responsible for the largest total mass of emissions for all pollutants examined. We use estimated primary PM_{2.5} and these historic NO_x and SO₂ emissions to model health impacts from each plant using the EPA-developed Co-Benefits Risk Assessment (COBRA) model and an externally developed Air Pollution Emission Experiments and Policy (AP2) model. COBRA provides two different estimates of impacts (low and high) based on two different underlying epidemiological studies. We find that particulate matter associated with pollution from power plant operations in Pennsylvania in 2015 contributes to an estimated 1000 (low estimate) or 2300 (high estimate) premature deaths nationwide. The annual estimated costs of health burdens attributable to Clean Power Plan-affected power plants from our three models, including both mortality and non-fatal diseases, are \$5.9 billion (AP2), \$8.9 billion (COBRA low estimate), and \$20 billion (COBRA high estimate). Approximately 90% of these PM_{2.5} health impacts are attributable to the ten highest-impact plants.

The mortality estimates for each county are mapped in **Figure 4**. Circle size represents the total nationwide mortality impacts from each plant. The blue lines outline federally designated non-attainment areas for National Ambient Air Quality Standards (NAAQS). Certain areas show both high aggregate health impacts as well as an existing burden of poor air quality on the county level. Important to note is that 70% of the human health impacts from power generation occur outside of Pennsylvania—and similarly, electricity generation outside the state releases pollutant emissions that contribute to poor air quality in Pennsylvania. Finally, while the aggregate health impacts shown in **Figure 4** are heavily weighted by population density, we also analyze the per-capita health impacts and find that there are typically a disproportionate number of health impacts per capita in the counties that contain or are downwind from power plants that emit high levels of SO₂ and NO_x.

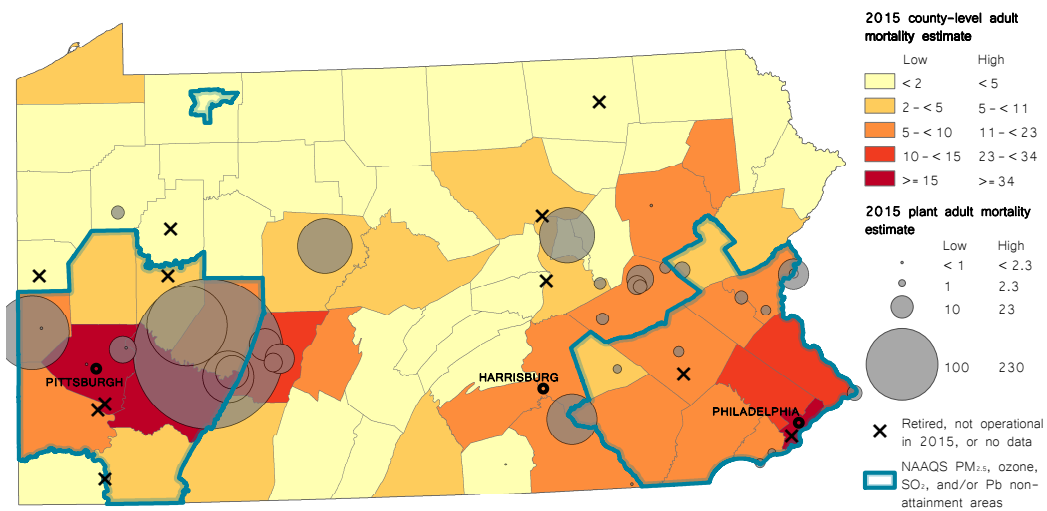


Figure 4: Modeled PM_{2.5} mortality impacts by county from 2015 Pennsylvania power plant emissions. Circle size represents each plant’s nationwide mortality impact (70% of which are out of state). Blue outlines indicate non-attainment areas for ozone, PM_{2.5}, SO₂ or lead under National Ambient Air Quality Standards.

We compare emissions totals and rates to health impacts in **Figures 5a** and **5b**. In **Figure 5a** we compare total CO₂ emissions to the total estimated cost of PM_{2.5} health impacts attributable to that plant. This plot highlights the plants that contribute to the highest total climate and public health burdens.

In **Figure 5b** we compare the rate of CO₂ emissions per MWh to the intensity of this health burden in cost per MWh. This plot highlights where an individual measure to reduce electricity generation may have the greatest climate and public health co-benefits. Our health burden modeling only assesses the health impacts of primary and secondary PM_{2.5}, but an approach to regulation that evaluates the intensity of impacts per MWh can also be extended to reducing NO_x emissions, associated ozone formation, and toxic releases.

Legacy from retired plants

The list of power plants covered by the Clean Power Plan includes nine power plants that were running in 2012, but which have since been retired, and more are expected to retire in coming years. Many of these retired plants have legacy environmental hazards, such as coal ash impoundments at two of these sites, and are located near vulnerable communities, highlighting a need for ongoing monitoring and careful assessment at sites under consideration for repowering with natural gas.

The communities living within three miles of these nine retired plants rank particularly high for multiple socioeconomic, health and environmental hazard burdens. These results suggest that not only is ongoing monitoring important for these plants moving forward, but also that repowering of plants and monitoring of legacy environmental hazards may be important environmental health and equity considerations if retirements continue under the Clean Power Plan. The socioeconomic status of existing nearby populations and the legacy environmental hazards identified in our analysis should also be taken into consideration when considering repowering these retired coal plants to natural gas combined cycle.

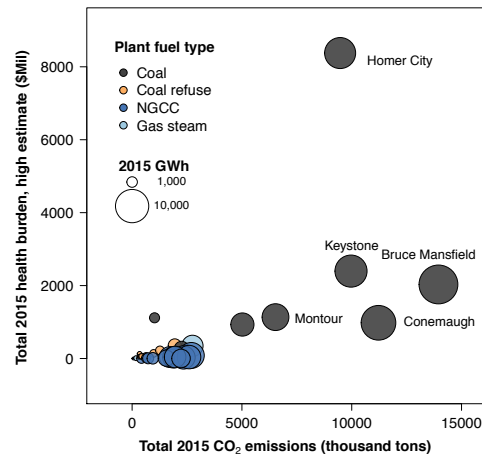


Figure 5a: 2015 cost of PM_{2.5} health impacts from each power plant compared to total CO₂ emissions.

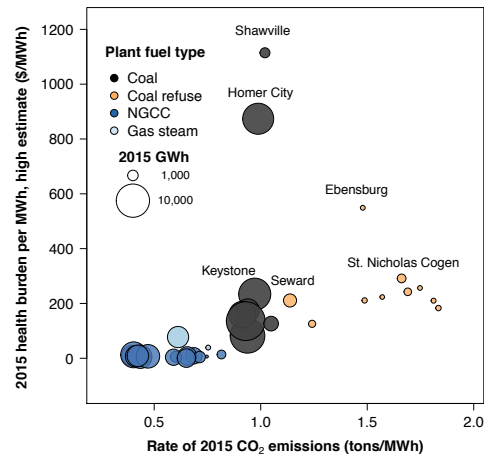


Figure 5b: Intensity of health impacts per MWh compared to intensity of CO₂ emissions per MWh from each power plant in 2015.

Figure 5

Moving forward

Approaches to Clean Power Plan compliance that integrate health, environment and equity measures hold potential to mitigate climate change, improve public health, and alleviate disproportionate cumulative environmental burdens on vulnerable populations all at the same time.

A multi-pollutant strategy that simultaneously considers criteria and hazardous air pollutants and toxic releases along with CO₂ emission reductions holds the potential to reduce the numerous environmental health hazards and public health impacts associated with fossil fuel power generation in Pennsylvania. Integration of climate, health, and equity factors will require careful consideration of the many dimensions of these issues, including considerations of aggregate versus per-capita power plant impacts and hazards, as well as where these impacts and hazards are disproportionately occurring.

There are many potential strategies for Clean Power Plan compliance. These approaches could include shifting the generation from coal to existing natural gas combined cycle plants, or increasing energy efficiency and ramping up generation from renewables like wind and solar, or a combination of these strategies. Given the presence of vulnerable communities near existing natural gas combined cycle generation, an emphasis on renewables and efficiency, rather than increased natural gas combined cycle generation, may be most likely to realize the many co-benefits of the Clean Power Plan without placing a disproportionate impact on vulnerable communities. Deployment of renewables and efficiency at faster rates than required to meet Clean Power Plan targets can help to achieve significant co-pollutant reductions at coal plants without increasing reliance on gas, and potentially provide tradable emission reductions in a regional compliance scheme.

Further engagement with disproportionately burdened communities identified in this analysis can highlight additional environmental and equity considerations and help to ensure that compliance plans ameliorate, rather than aggravate, the burdens of power generation on vulnerable communities. Taken together, the data presented in this analysis provide a baseline of the environmental health and equity burdens associated with power generation in Pennsylvania and can be used to measure potential changes in these burdens when the state considers approaches to Clean Power Plan compliance and other energy regulations.