

Saving Energy, Saving Lives

The Health Impacts of Avoiding
Power Plant Pollution with Energy Efficiency

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Contents

About the Authors	3	Energy Efficiency Strategies for Public Health Gains	21
Acknowledgments	4	Energy Efficiency Resource Standards	22
Executive Summary	5	Building Codes	22
Energy Efficiency and Air Pollution	10	Appliance and Equipment Standards	23
Energy Efficiency Cost Effectively Reduces Power Plant Pollution	11	Regional Initiatives	23
Energy Efficiency Helps Meet Greenhouse Gas Commitments	13	Compounding the Health Benefits of Energy Efficiency	24
Energy Efficiency Helps States Comply with Environmental Regulations	14	In-Home Interventions	24
Our Analysis	15	Reducing Energy Burdens	25
Results	17	Uplifting Vulnerable Communities	26
National	17	Conclusion	27
States	18	References	29
Cities	19	Appendix A. Methodology and Assumptions	32
		Appendix B. Avoided Health Harms for States and Cities	35



McDowell County, West Virginia, where weatherization programs have helped residents improve their health and comfort.
Source: still image from “West Virginia Homes Get Healthier with Weatherization.” ACEEE 2017.

About the Authors

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Pittsburgh, Pennsylvania, where efforts have been made to improve polluted air.
Source: still image from “Energy Retrofits Clear the Air in Pittsburgh.” ACEEE 2018b.

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Baltimore resident, Nikia Pickett, watches over her son, an asthma sufferer whose symptoms were alleviated by energy efficiency upgrades. Asthma disproportionately affects children and it's made worse by power plant pollution. In the US, 1 in 10 children suffer from asthma. Source: still image from "Baltimore Breathes Easier with Energy Retrofits." ACEEE 2018a.

Executive Summary

People are harmed by power plant pollution even when they cannot see the smoke stacks. A report by the American Lung Association found that in recent years more than 125 million people—4 out of every 10 Americans—were exposed to unhealthy levels of air pollution, much of which came from power plants.¹ Infants, children, the elderly, pregnant women, and people with respiratory and cardiovascular illnesses are the most vulnerable to this type of pollution.

Energy efficiency improvements in buildings and industry decrease the amount of fossil fuels we burn and thereby reduce air pollution, resulting in substantial health benefits. We improve energy efficiency when we replace outdated practices and technologies with new, less wasteful approaches. In our homes and offices, for example, we can save energy by replacing incandescent light bulbs with LEDs, tightening building envelopes so that conditioned air does not leak out, and swapping out old appliances with new ones.

The health benefits of reducing pollution through energy efficiency extend throughout the United States. However the complexity of the electric grid, the location of power plants, wind patterns that carry pollution from one place to another, and many other factors influence where energy efficiency's greatest health benefits will be realized. In order to home in on those places, we developed a simple scenario as the foundation for our study.

¹ American Lung Association, *State of the Air* (Washington, DC: American Lung Association, 2017).

Executive Summary

Our scenario applies a hypothetical but readily achievable 15% reduction in annual electric consumption evenly across the country. We entered these electricity savings estimates into the Environmental Protection Agency's AVOIDed Emissions and geneRATION Tool (AVERT) to identify the amounts of fine particulate matter (PM_{2.5}), nitrogen oxides (NO_x), and sulfur dioxide (SO₂) that would be reduced and the counties where emission reductions would occur as a result of electricity savings from energy efficiency.² Next we took AVERT's pollution reduction outputs for more than 3,000 counties and entered them into the EPA's CO-Benefits Risk Assessment (COBRA) health impacts screening and mapping model.³

We used these outputs to rank states and the 50 largest US cities based on where our scenario's energy savings could have the greatest positive impact on the health of people living there. These results are based on avoided trips to the emergency room to treat asthma, fewer heart attacks, reductions of respiratory illnesses and symptoms, and avoided premature deaths. All of these health outcomes are due to improvements in ambient air quality that result from reducing the amount of electricity we waste.

Nationwide, reducing electricity consumption by 15% for a single year would result in

- More than six lives saved each day
- Up to \$20 billion in avoided health harms
- Nearly 30,000 fewer asthma episodes

The dollars saved through avoided health harms in our scenario would be enough to pay the annual health

insurance premiums for nearly 3.6 million families.⁴ The avoided health harms in that one-year period would average more than \$70 per person in 15 cities; the cost of avoided harms would be highest in Pittsburgh, where they would be more than \$200 per person on average. The reduced electricity consumption would decrease pollution by millions of tons in a single year, including

- An 11% reduction in PM_{2.5} pollution (a total of more than 20,000 tons)
- A decrease in NO_x emissions of 18% and in SO₂ emissions of 23% (approximately 192,000 and 267,000 tons, respectively)
- A 14% reduction in carbon dioxide (CO₂) pollution (approximately 285 million tons)

These emissions reductions represent pollution avoided in a single year, due to the energy saved in that year. In fact, however, an energy efficiency measure typically lasts many years, meaning that it will reduce emissions year after year. Though we have not quantified the cumulative benefits of our scenario in this paper, they would accrue over many years, multiplying emissions reductions and public health benefits. These benefits would also accrue to some states and cities more than others. Our ranking of states based on the dollar value of avoided health harms shows that Pennsylvania would realize the greatest benefits, followed by New York and Ohio. Illinois, Texas, Michigan, Florida, Indiana, Tennessee, and North Carolina round out the top 10. Figure ES1 shows the top 15 states by avoided health harms.

² AVERT is an EPA tool that estimates the emissions benefits of energy efficiency and renewable energy policies and programs. See www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert.

³ COBRA is an EPA tool that estimates the health and economic benefits of emission reduction strategies. COBRA includes a simplified air quality model to convert air pollution changes to air quality impacts. It translates the estimated air quality changes to health impacts based on the methods, health benefit assumptions, and economic values EPA uses for its own health impact analyses. See www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool.

⁴ Based on covered workers' average 2017 premium contributions of \$5,714 per family as reported in the Kaiser Family Foundation and Health Research & Educational Trust's *Employer Health Benefits: 2017 Summary of Findings* (Menlo Park, CA: Kaiser and HRET, 2017).



Pittsburgh homeowner, Cathy Guilli, and her family experienced health benefits from energy efficiency retrofits in their home. Source: still image from “Energy Retrofits Clear the Air in Pittsburgh.” ACEEE 2018b.

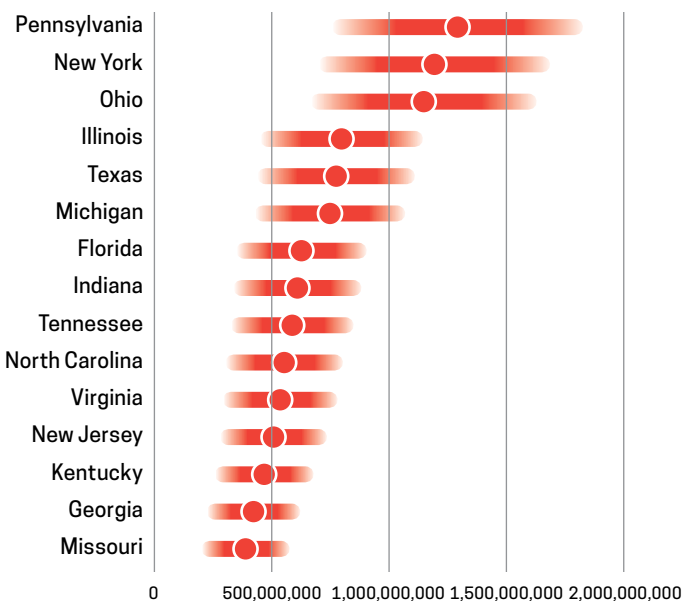


Figure ES1. Top 15 states by avoided annual health harms from a 15% electricity savings scenario, low and high range (US\$)

Rank	State	Dollars per capita
1	West Virginia	\$184
2	Kentucky	\$148
3	Pennsylvania	\$140
4	Ohio	\$137
5	Indiana	\$128
6	Tennessee	\$124
7	Alabama	\$106
8	Michigan	\$105
9	Delaware	\$103
10	Arkansas	\$98
11	Missouri	\$89
12	Virginia	\$89
13	Mississippi	\$89
14	Illinois	\$87
15	Maryland	\$87

Table ES1. Top 15 states based on avoided health harms, per capita (US\$)

A different list of states emerges when we consider per capita benefits. Table ES1 lists the 15 states with the greatest avoided health harms per person. In these states, the avoided health harms are more than \$85 per person. The states highlighted in pink are also in the top 15 when ranked by total dollar value of avoided health harms.

Executive Summary

We also ranked the impacts of our scenario on the 50 largest cities (see figure ES2); New York City is at the top of the list, followed by Chicago, Philadelphia, Pittsburgh, and Detroit. Rounding out the top 10, we see cities from other regions: Washington, DC, Cleveland, and the Dallas-Fort Worth area are next on the list, followed closely by Cincinnati, Atlanta, and Baltimore. Some of the greatest opportunities to garner health benefits from energy efficiency investments are in the upper Midwest, Mid-Atlantic, and Southern United States. Eight of the top 10 states and 8 of the top 10 cities are from these regions.

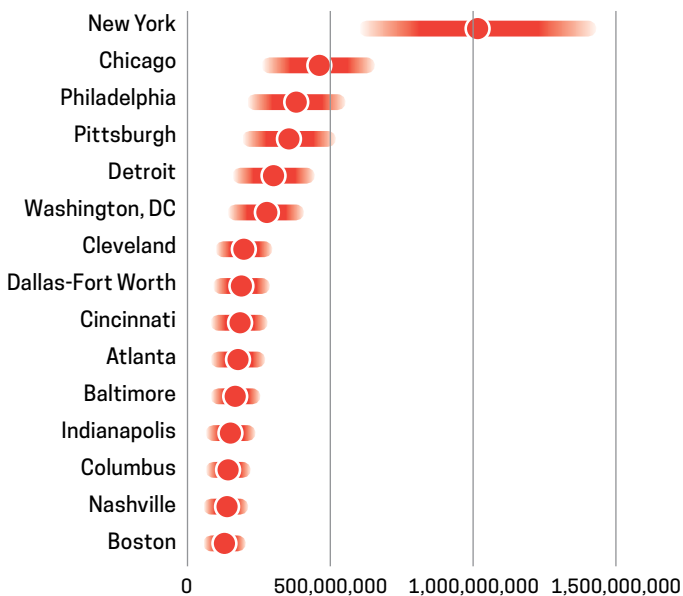


Figure ES2. Top 15 cities by avoided health harms, low and high range (US\$)

When we look at avoided health harms on a per capita basis, the list of cities changes. Table ES2 lists the top 15 cities where avoided health harms are highest per capita. In all of these cities, the avoided health harms are more than \$70 per person. The cities highlighted in pink are also in the top 15 when ranked by total dollar value of avoided health harms.

Rank	City	Dollars per capita
1	Pittsburgh	\$210
2	Buffalo	\$150
3	Louisville	\$135
4	Cleveland	\$132
5	Cincinnati	\$119
6	Birmingham	\$109
7	Indianapolis	\$106
8	Nashville	\$105
9	Columbus	\$101
10	Memphis	\$100
11	Detroit	\$98
12	Richmond	\$88
13	Philadelphia	\$87
14	Baltimore	\$86
15	Hartford	\$73

Table ES2. Top 15 cities based on avoided health harms, per capita (US\$)



A child walks her bike in residential Pittsburgh. Outdoor air quality in Pittsburgh is still some of the worst in the nation.
Source: still image from “Energy Retrofits Clear the Air in Pittsburgh.” ACEEE 2018b.

This analysis reveals an opportunity to improve public health goals using energy efficiency, with the greatest benefits to be realized when cities and states act collectively and across entire regions. Proven strategies with the greatest potential to achieve significant energy savings and public health gains include energy efficiency resource standards, building energy codes, and appliance standards. At the regional level, investments in energy efficiency through the Regional Greenhouse Gas Initiative have resulted in big gains to public health.

In addition to improving ambient air quality, energy efficiency programs can be designed to consider the disproportionate environmental and health burdens that some communities face. Efficiency policies and programs can be designed to ameliorate the challenges of living with asthma and other respiratory illnesses, address the energy burdens of families struggling to heat their homes or put food on the table, and extend benefits to the most vulnerable in a community. Energy efficiency addresses many of the social determinants of health by improving housing conditions, protecting the environment, creating economic opportunities, and reducing costs for families. Tremendous opportunity to affect positive public health outcomes rests in a more energy-efficient future.



A historical image of the Pittsburgh, Pennsylvania skyline.
Source: still image from “Energy Retrofits Clear the Air in Pittsburgh.” ACEEE 2018b.

Energy Efficiency and Air Pollution

Energy efficiency aims to replace outdated technologies and practices with those that eliminate needless waste, while also maintaining or improving our reliability and comfort.

Energy efficiency improvements can be made at many points in the energy system. A power plant can be upgraded to burn less coal or natural gas while still producing the same amount of electricity, if not more. Cars can be designed to go further on a gallon of gas. In our homes and offices, energy efficiency can replace incandescent light bulbs with LEDs, tighten building envelopes so that conditioned air does not leak out, and swap out old appliances and equipment with new ones.

Improvements made at the point where energy is consumed are called *end-use energy efficiency*. For the remainder of this paper, we use the term *energy efficiency* to refer to these end-use opportunities in buildings and industry. Energy efficiency reduces the amount of electricity we waste, which lessens the amount of fossil fuels we burn, reducing all of the pollutants that power plants generate.

Power plant pollution affects the quality of the ambient air that we all breathe. While progress toward cleaning the air is ongoing, pollution from fossil-fueled power plants continues to cause nearly 20 deaths in the United States every day (Clean Air Task Force 2017). These power plants generate a long list of health-harming pollutants, including fine particulate matter (PM_{2.5}) and nitrogen oxides (NO_x), which contribute to serious respiratory health problems—including lung cancer, which kills more men and women in the United States than any other form of cancer (ALCF 2017). These same pollutants exacerbate chronic obstructive pulmonary disease (COPD), which is the third leading cause of death in the country (NIH 2017). Pollution from power plants also triggers asthma, a chronic disease already at epidemic levels (Akinbami, Simon, and Rossen 2016).

In addition to respiratory harm, air pollutants such as NO_x, sulfur dioxide (SO₂), and PM_{2.5} produced by burning fossil fuels harm cardiovascular health. They contribute to coronary heart disease, the leading cause of death in the United States (Physicians for Social Responsibility 2011). These pollutants also lead to increased hospitalizations for heart attacks and congestive heart failure, and the mercury they include causes serious neurological damage (WHO 2017). Finally, power plants emit greenhouse gases that contribute to climate change, deemed the greatest public health threat of the 21st century (Costello et al. 2009). Climate change causes extreme weather events such as heat waves, extreme storms, and droughts; the resulting consequences—including heat effects, floods, increases in waterborne and insect-borne diseases, drops in crop production, and wildfires—can severely affect the health of people living in those communities (Pachauri et al. 2015)

People are harmed even when they cannot see power plant smoke stacks in their backyards. A recent report by the American Lung Association (2017) found that more than 125 million people, or 4 out of every 10 Americans, live in a county with unhealthy air pollution levels, many of which come from fossil-fuel-fired power plants. This report assigned letter grades for metropolitan areas based on air quality and exposure to pollution, illustrating that the amount and type of pollution people are exposed to varies by location. For instance, for high ozone days, Baltimore, Pittsburgh, and New York City all receive an F while Indianapolis gets a C⁵.

Energy Efficiency Cost Effectively Reduces Power Plant Pollution

It costs money to generate electricity, but it generally costs less to invest in energy efficiency, so each saved megawatt-hour saves money. An energy efficiency investment can pay for itself over time by earning a net financial return in the form of reduced utility bills for households, businesses, and government. Efficiency investments also reduce costs to the public as a whole. Further, as figure 1 shows, saving a kilowatt-hour of energy costs less than generating a kilowatt of electricity using any of the other commonly available generation technologies. Thus, when we save energy, we reduce electric system costs.

⁵ See the American Lung Association's Compare Your Air tool. www.lung.org/our-initiatives/healthy-air/sota/city-rankings/compare-your-air.html

Energy Efficiency and Air Pollution

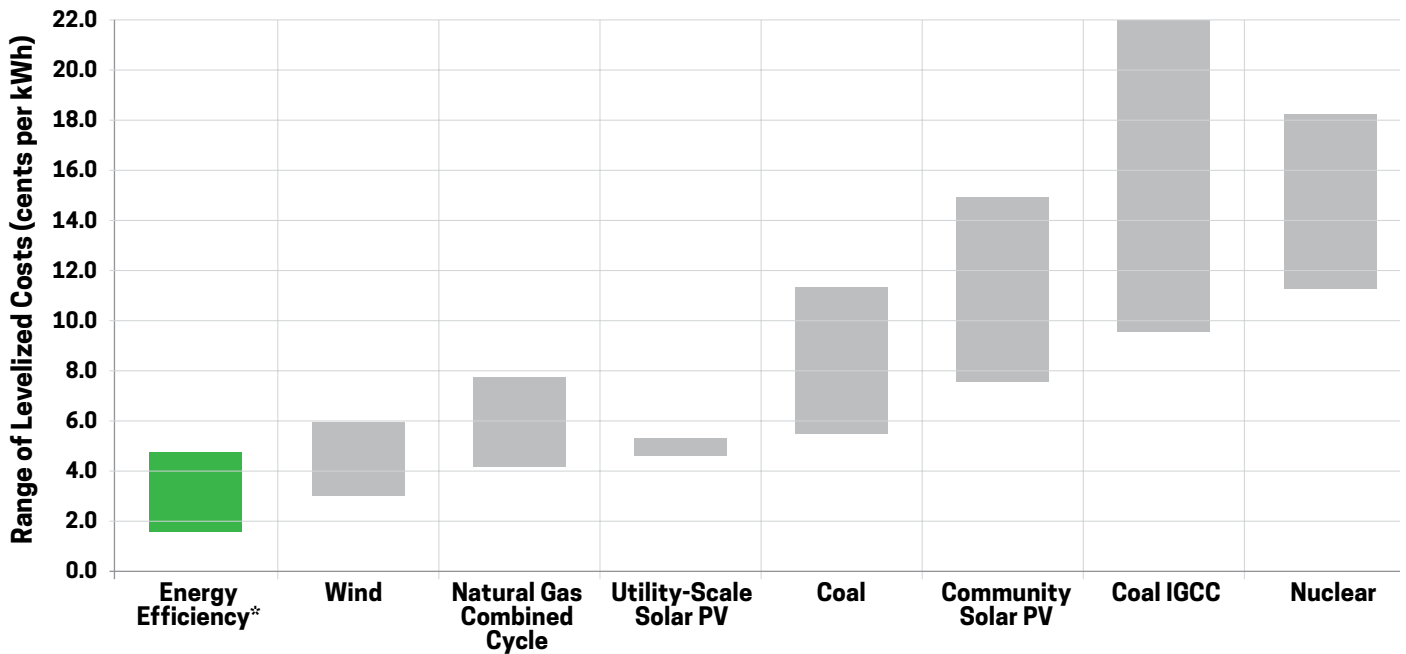


Figure 1. Levelized cost of electricity resources. High-end range of coal includes 90% carbon capture and compression. IGCC stands for integrated gasification combined cycle. *Source: Gilleo 2017.*

The economics of energy efficiency make it a financially attractive pollution control strategy. Traditional approaches to reducing power plant pollution have included pollution control technologies that require substantial upfront capital investments and primarily target one pollutant at a time. This approach is a lost opportunity to reduce system costs as it forgoes all the savings that would have been achieved if energy waste had been reduced instead.

Figure 2 shows a pollution control strategy's costs and benefits with and without energy efficiency. The example is based on the use of point-source control technologies, selective catalytic reduction (SCR), and scrubbers on a single 500 MW coal-fired power plant in Ohio. This approach is compared with the same approach plus a statewide electricity savings target of 1% per year. The results in the figure reflect cumulative tons of avoided pollution and cumulative net costs over a 10-year period.

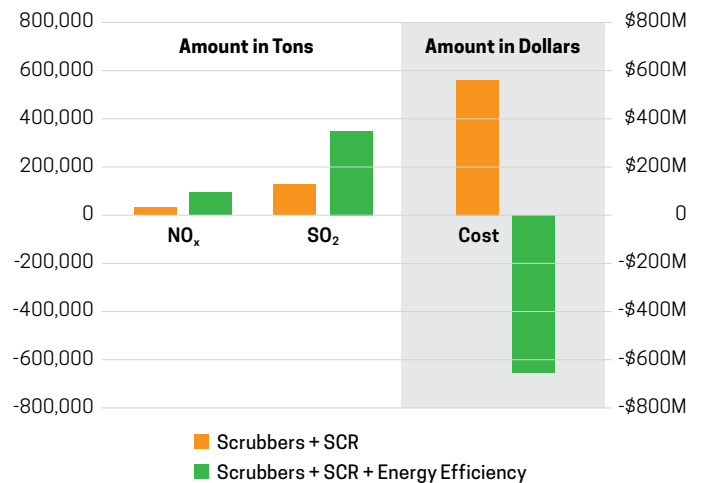


Figure 2. Single-pollutant controls versus a strategy that also includes energy efficiency. We derived these results from ACEEE's SUPR 2 calculator, which does not include estimates of particulate matter impacts. Energy efficiency reduces particulate emissions that can have direct and indirect impacts on respiratory and cardiovascular diseases. *Source: Kubes, Hayes, and Kelly 2016.*

Figure 2 shows that including energy efficiency in the Ohio pollution control strategy would reduce more SO₂ and NO_x pollution than installing SCR and scrubbers alone. It would also shift the overall cost of reducing pollution; including energy efficiency in the scenario avoids so much spending on electric generation that the total cost shifts to a net savings of approximately \$650 million. Adding energy efficiency to the state's pollution control strategy would also reduce PM_{2.5}, carbon dioxide (CO₂), mercury, and other pollutants.

Energy Efficiency Helps Meet Greenhouse Gas Commitments

Climate change causes major disruptions in world weather patterns that manifest as extreme weather events including heat waves, droughts, and extreme storms. Such events lead to lethal heat effects, wildfires, floods, increases in the number and/or the range of waterborne and insect-borne diseases, drops

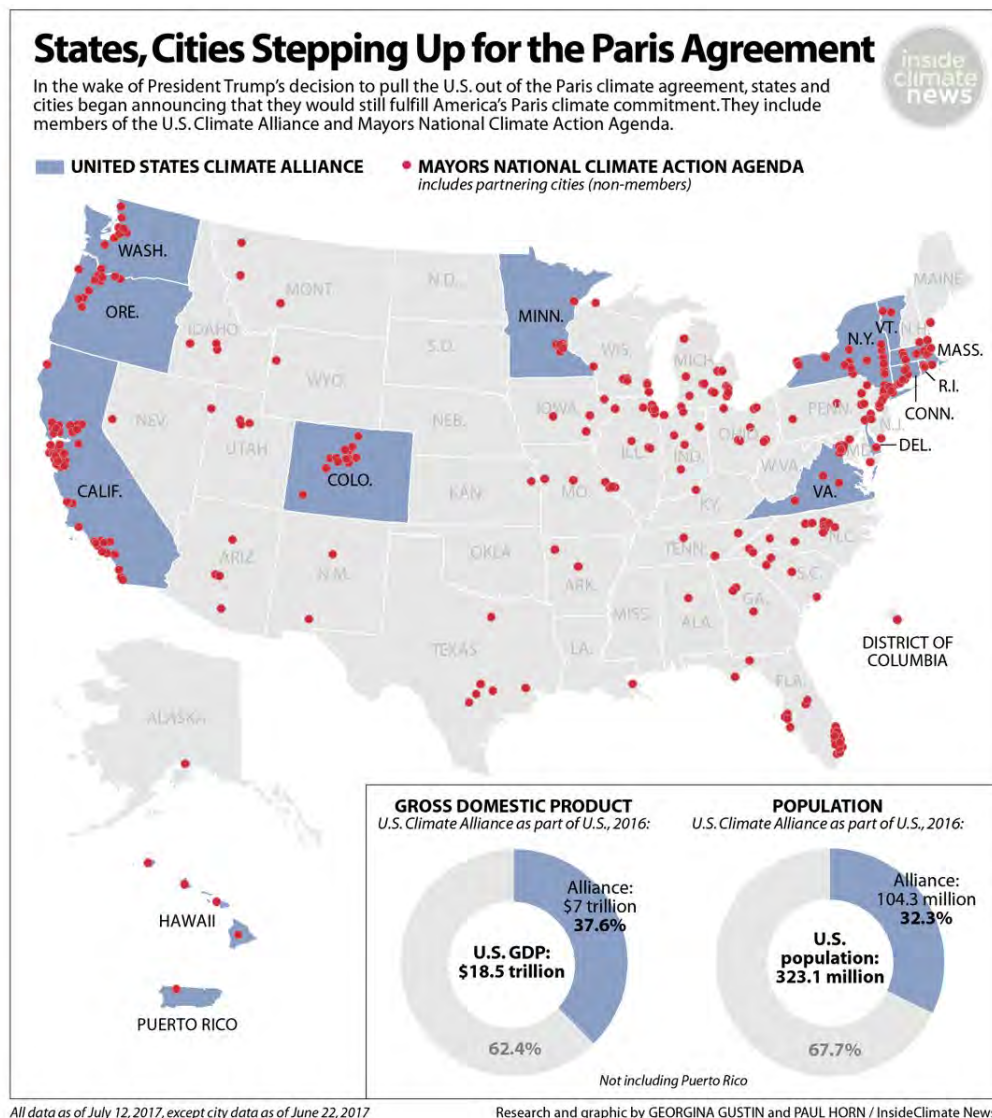


Figure 3. City and state support for the Paris climate agreement. Source: Gustin 2017.

Energy Efficiency and Air Pollution

in crop production, and other perils—all of which can severely affect the health of people living in those communities (Pachauri et al. 2015). Climate change can also increase ground-level ozone, exacerbating community health challenges.⁶

Although the United States has yet to develop a national strategy for addressing climate change, more than 200 US cities have stepped forward as leaders (see figure 3), embracing clean energy solutions that will simultaneously reduce emissions of both climate pollutants and health-damaging conventional pollutants.

Energy efficiency is a proven strategy for reducing greenhouse gas emissions, often at a lower cost than other approaches (Gowrishankar and Levin 2017). ACEEE estimates that energy efficiency efforts targeting electricity savings have avoided the need to build the equivalent of 313 large power plants since 1990 (Molina, Kiker, and Nowak 2016). We estimate that adoption of a suite of proven electric efficiency policies would reduce power sector greenhouse gas emissions over time by more than 25% relative to 2012 levels (Hayes et al. 2014).

As state and local governments set targets for greenhouse gas reductions, they can take advantage of energy efficiency as a primary mitigation strategy that also provides net savings to their economies. By reducing energy demand, cities and states will reduce the scale of new investment needed to meet demand with clean energy sources. This can reduce the cost of switching to less-polluting electricity sources, such as wind and solar, and lessen the impact of fossil-fuel-fired plants that continue to operate during the transition.

6 More information about the links between air quality and climate change is available at EPA 2016: www.epa.gov/air-research/air-quality-and-climate-change-research.

Energy Efficiency Helps States Comply with Environmental Regulations

Energy efficiency automatically reduces power plant pollution by saving electricity, and it also reduces pollution emitted by burning fuel oil and natural gas in homes. These air quality benefits make it easier for states to provide clean air to the public. In addition to these inherent air quality improvements, states can proactively comply with federal air regulations by taking advantage of multiple, ongoing opportunities to engage in efficiency policies and programs.⁷ The Clean Air Act requires the US Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for criteria pollutants such as ozone, SO₂, NO_x, and PM_{2.5}. These NAAQS are intended to protect public health by setting limits on the concentration of criteria pollutants in the ambient air. When NAAQS are not met, states are required to develop implementation plans that demonstrate how they will reduce these pollutants. States across the country are in various stages of developing plans and adopting strategies to comply with federal air regulations by reducing criteria pollutants. A forthcoming ACEEE report will identify the states that can most effectively use energy efficiency in plans to comply with NAAQS.⁸



Workers prepare for a home insulation retrofit in Baltimore, Maryland. Adding insulation to a home can help maintain consistent temperatures and a comfortable environment. Source: still image from “Baltimore Breathes Easier with Energy Retrofits.” ACEEE 2018a.

7 See Hayes and Young 2012 for a discussion of how energy efficiency can be used as a compliance strategy for major air regulations.

8 The report is scheduled for release in March 2018.



Judy Bailey and her husband discuss energy efficiency improvements in their West Virginia home. Source: still image from "West Virginia Homes Get Healthier with Weatherization." ACEEE 2017.

Our Analysis

Our analysis focuses on improvements that energy efficiency makes to ambient air quality by reducing the amount of electricity we waste.

The health benefits of reducing power plant pollution through energy efficiency extend throughout the United States. However the complexity of the electric grid, the location of power plants, wind patterns that carry pollution from one place to another, and many other factors influence where the greatest health benefits will be realized. The map in figure 4 illustrates the interstate upwind-downwind linkages and flow of ground-level ozone between states. This map represents just one of several complex factors that affect the degree to which energy efficiency implemented in one state might affect public health in other states and cities.



Figure 4. The interconnected nature of interstate ozone pollution. CSAPR refers to the Cross-State Air Pollution Rule, an emissions regulation limiting power plant pollution that crosses state lines. Source: EPA 2017d.

Our Analysis

We conducted this analysis to discern which states and cities would see the greatest health impacts from energy efficiency investments and to better understand the scale and nature of those benefits. Our analysis does not quantify the benefits from specific energy efficiency policies and programs. Instead, it explores a national scenario to identify where the biggest opportunities exist to positively affect health through energy efficiency.

Our analysis involved a three-step process. First, we selected a flat percentage reduction in electric use representative of a goal that is readily achievable in various ways and in any US region. States and cities are already relying heavily on energy efficiency to meet electric needs and, as a result, people are already seeing health benefits. States across the nation are currently saving 7–18% of electricity sales per year due to federal standards setting energy performance minimums for appliances and equipment (deLaski and Mauer 2017). Multiple states already have policies in place to reduce annual electric consumption by 20% or more through energy savings targets implemented by utilities (Berg, Gilleo, and Molina 2017). For this analysis, we hypothesized annual energy savings of 15%; that is, we assumed that the state or city consumes 15% less electricity per year than what it would have used if no energy efficiency measures were in place. It might take a state or city several years to achieve annual savings of this magnitude, though many are already on this path. We chose this level of savings because it is attainable everywhere and has already been widely reached. Our analysis does not identify an upper or lower bound of what is possible.

Once we selected the 15% electricity savings target, we entered electricity savings estimates into AVERT to identify the amounts of PM_{2.5}, NO_x, and SO₂ that would be reduced and the counties where emission reductions would occur as a result of electricity savings from energy efficiency. AVERT represents the changes in electricity dispatch based on historical generation patterns (EPA 2017b); however, unlike a dynamic

dispatch model, it does not account for forward-looking changes to the electrical grid.⁹

Next, we took AVERT's pollution reduction outputs for more than 3,000 counties and entered them into the COBRA model to estimate the health and economic benefits (EPA 2017c). COBRA includes a simplified air quality model to convert the estimated air quality changes to health impacts based on the methods, health benefit assumptions, and economic values the EPA uses for its own health impact analyses. COBRA calculates reduced health care costs based on the number of avoided

- Premature deaths
- Respiratory and cardiovascular-related hospitalizations
- Heart attacks
- Cases of acute bronchitis
- Upper and lower respiratory symptoms including asthma exacerbations or emergency room visits
- Minor restricted-activity days
- Illness-related work-loss days

COBRA is a screening tool. More sophisticated modeling approaches are currently available to obtain a more refined picture of the air quality, health, and economic impacts of power plant emission changes.

Here, we present our analysis results for states and the 50 largest US cities. Appendix A discusses the methodology and tools we used in our analysis in greater detail.

⁹ As older power plants retire, the amount of pollution emitted per kilowatt-hour of electricity generated will likely decline. We did not attempt to forecast those changes in this analysis and instead relied on actual historical 2016 emissions data included in AVERT.



Former Pittsburgh Steelers safety, Will Allen, stands in front of Uptown Lofts, an energy-efficient building in Pittsburgh. Source: still image from "Energy Retrofits Clear the Air in Pittsburgh." ACEEE 2018b.

Results

Improvements in air quality due to energy efficiency can result in avoided trips to the emergency room to treat asthma, fewer heart attacks, reduced respiratory-related hospitalizations and symptoms, and longer lives.

The avoided health harms included here are calculated based on the ascribed value of avoided premature deaths, plus the number of avoided respiratory and cardiovascular-related hospitalizations, heart attacks, incidence of acute bronchitis, upper and lower respiratory symptoms (including asthma exacerbations or emergency room visits), minor restricted-activity days, and illness-related work-loss days. All of these health outcomes result from ambient air quality improvements that accrue when we cut power plant pollution by improving energy efficiency.

National

Nationwide, reducing annual electricity consumption by 15% means that we would see

- An 11% reduction in PM_{2.5} pollution (a total of more than 20,000 tons)
- A decrease in emissions of NO_x of 18% and SO₂ of 23% (approximately 192,000 and 267,000 tons, respectively)
- A 14% reduction in CO₂ pollution (approximately 285 million tons)¹⁰

These emissions reductions represent what would occur in a single year. In fact, however, an energy efficiency

¹⁰ Percentage reductions are derived by dividing estimated tons of emissions avoided from AVERT by total power sector emissions in 2016 from EPA's Air Pollutant Emissions Trends Data (EPA 2017a). Estimates of 2016 power sector greenhouse gas emissions are from EIA 2017.

Results

measure typically lasts many years, meaning emissions reductions of this magnitude would occur year after year. The scope and scale of the health benefits are substantial. In one year, we would see

- More than six lives saved each day
- Up to \$20 billion in avoided health harms
- Nearly 30,000 fewer asthma episodes

In our scenario, not only are lives saved, but also total health harms are reduced by up to \$20 billion—all from just a single year of energy savings. The dollars saved through avoided health harms in our scenario are enough to pay the annual health insurance premiums for nearly 3.6 million families.¹¹ Avoided health harms would average more than \$70 per person in 15 cities and would be highest in Pittsburgh, where they would be more than \$200 per person on average.

Avoided premature adult mortality is generally responsible for the vast majority of the monetized benefits. The value of avoided adult mortality ranges from approximately \$7.5 million to \$8.4 million. This value is based on 26 published studies and is identical to the value used by EPA in regulatory analyses of air pollution rules.¹² Other values are smaller, such as the per-incident values of nonfatal heart attacks (\$31,446–263,795) and hospital admissions (\$15,430–41,002).

States

Ranking states based on total dollar value of health harms avoided in our scenario shows that Pennsylvania would realize the greatest benefits, followed by New York and Ohio. Illinois, Texas, Michigan, Florida, Indiana, Tennessee, and North Carolina round out the top 10. Figure 5 shows the top 15 states based on the range of low and high avoided health harms in a single year. The full list of results is available in Appendix B.

11 Based on the average 2017 premium contributions by covered workers of \$5,714 per family (Kaiser and HRET 2017).

12 See Chapter 7 and Appendix B of EPA 2014.

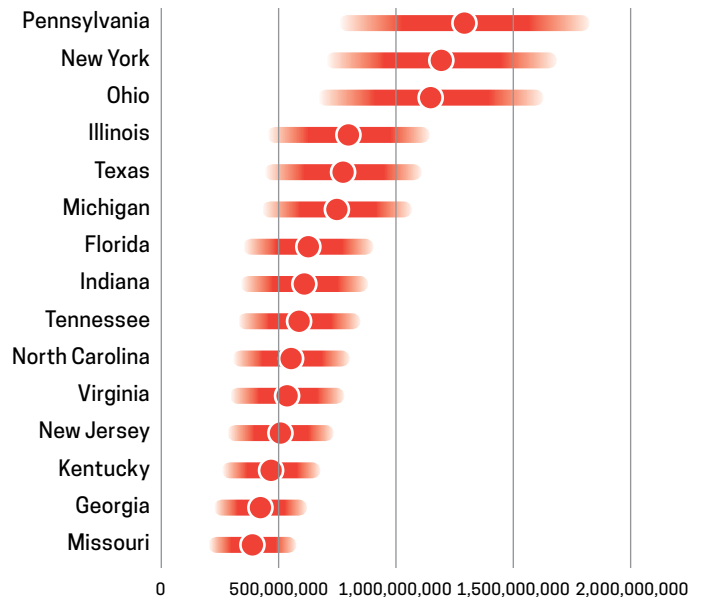


Figure 5. Top 15 states by avoided health harms, low and high range (US\$)

Table 1 lists the dollar value of avoided health harms on a per capita basis by state. In one year, all states on the list would save more than \$85 per person in avoided health harms. The citizens of West Virginia would benefit the most, with each person saving

Rank	State	Dollars per capita
1	West Virginia	\$184
2	Kentucky	\$148
3	Pennsylvania	\$140
4	Ohio	\$137
5	Indiana	\$128
6	Tennessee	\$124
7	Alabama	\$106
8	Michigan	\$105
9	Delaware	\$103
10	Arkansas	\$98
11	Missouri	\$89
12	Virginia	\$89
13	Mississippi	\$89
14	Illinois	\$87
15	Maryland	\$87

Table 1. Top 15 states based on avoided health harms, per capita (US\$)

\$184 in avoided health harms. Kentucky, Pennsylvania, Ohio, and Indiana complete the top five. The states highlighted in pink also appear in the list of the top 15 states based on the total dollar value of avoided health harms.

Cities

We also looked at avoided health harms in the 50 largest US cities for the 15% energy-savings scenario.¹³ As figure 7 shows, by far the highest total avoided health harms would accrue to New York City residents. Chicago, Philadelphia, Pittsburgh, and Detroit round out the top 5, followed by cities from other regions of the country: Washington, DC, Cleveland, and the Dallas-Fort Worth area. Cincinnati, Atlanta, Baltimore, Indianapolis, Columbus, Nashville, and Boston complete the top 15. All US geographic regions accrue health benefits in our scenario, though cities in the west tend to fall further down the list. The upper Midwest and mid-Atlantic states show the greatest opportunities for health

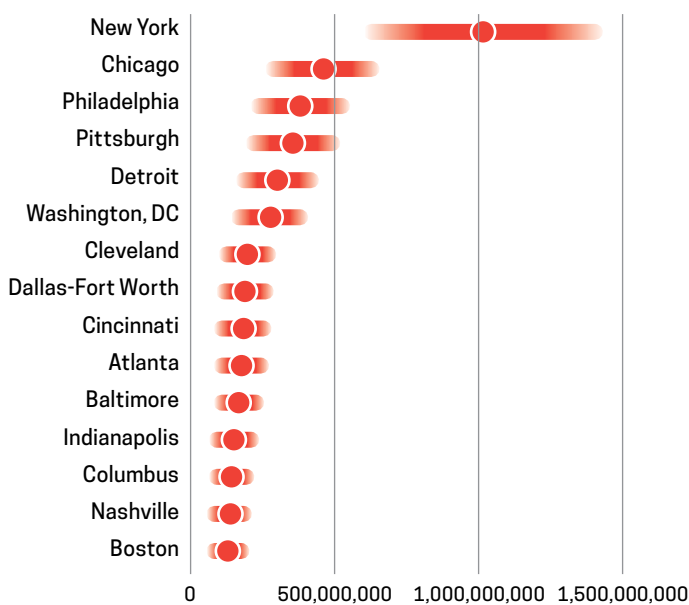


Figure 6. Top 15 cities by avoided health harms, low and high range (US\$)

¹³ COBRA results are presented at the county level. To identify results at the city level, we summed results for all counties included in each of the 50 most-populous US metropolitan statistical areas as defined by the US Bureau of the Census. See bea.gov/regional/docs/msalist.cfm for more information about how these areas are defined.

benefits from energy efficiency investments; 8 of the top 10 cities are from these regions, as are 8 of the top 10 states.

We also identified the average dollar value of avoided health harms per capita for each city. Table 2 and figure 7 show the top 15 cities where avoided health harms are highest on a per capita basis. In New York City, this would translate to \$69 in avoided health harms per person. In Pittsburgh, the avoided health harms amount to \$210 per person. The benefits are greater than \$70 per person in all 15 cities.

Rank	City	Dollars per capita
1	Pittsburgh	\$210
2	Buffalo	\$150
3	Louisville	\$135
4	Cleveland	\$132
5	Cincinnati	\$119
6	Birmingham	\$109
7	Indianapolis	\$106
8	Nashville	\$105
9	Columbus	\$101
10	Memphis	\$100
11	Detroit	\$98
12	Richmond	\$88
13	Philadelphia	\$87
14	Baltimore	\$86
15	Hartford	\$73

Table 2. Top 15 cities based on avoided health harms, per capita (US\$)

Results

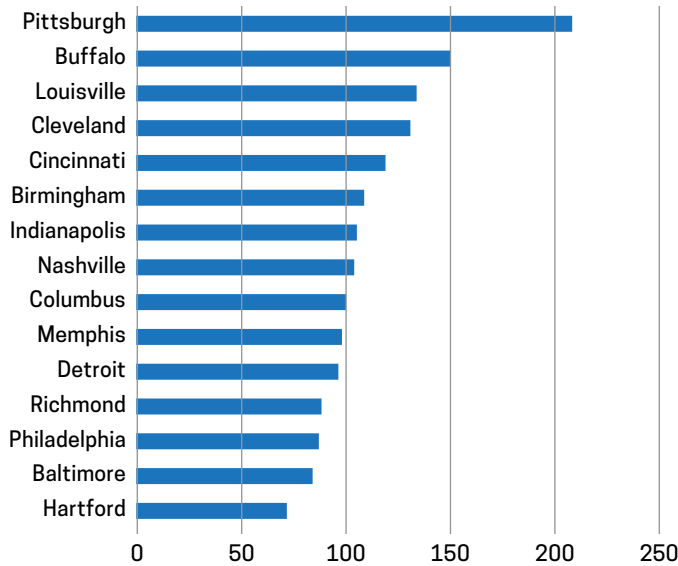


Figure 7. Top 15 cities by avoided health harms per capita (US\$)

Table 3 combines results from figures 6 and 7, listing the 15 cities with the highest avoided harms and highlighting in pink those that are also in the top 15 for total avoided health harms.

Rank	City	Dollars per capita
1	Pittsburgh	\$210
2	Buffalo	\$150
3	Louisville	\$139
4	Cleveland	\$132
5	Cincinnati	\$119
6	Nashville	\$110
7	Birmingham	\$109
8	Indianapolis	\$106
9	Columbus	\$101
10	Detroit	\$98
11	Richmond	\$88
12	Memphis	\$88
13	Philadelphia	\$87
14	Baltimore	\$86
15	St. Louis	\$81

Table 3. Top cities with both high dollars per capita health benefits and total health benefits (high range)

Table 4 breaks down avoided health harms by category for our scenario in Chicago. As this table demonstrates, adult mortality is responsible for the vast majority of total avoided health harms.

Type of benefit	Avoided cost (US\$)
Adult mortality ^a	620,189,786
Nonfatal heart attacks ^a	5,546,079
Minor restricted-activity days	2,007,599
Infant mortality	823,063
Lost work days	797,240
Cardiovascular hospital admissions	576,418
Respiratory-related hospitalizations and symptoms ^b	491,740
Total	630,431,926

^a We calculated a low and high estimate for adult mortality and nonfatal heart attacks. In this table, we report the high estimates.

^b Estimates include respiratory hospital admissions, asthma exacerbations, upper respiratory symptoms, acute bronchitis cases, lower respiratory symptoms, and asthma emergency room visits.

Table 4. Avoided health harms in Chicago, by category

Many of the cities in the rankings are leaders in energy efficiency, so health benefits of this magnitude are already occurring in those cities and states due to existing efficiency policies and programs. The following sections outline some of the biggest opportunities for saving even more energy and describe some complementary strategies for maximizing the public health benefits of energy efficiency programs and policies.



After participating in a weatherization program, the Ball family's Baltimore home is more comfortable, and instances of asthma attacks in the home have gone down significantly. Source: still image from "Baltimore Breathes Easier with Energy Retrofits." ACEEE 2018a.

Energy Efficiency Strategies for Public Health Gains

The results of our analysis show a significant opportunity to achieve public health goals using energy efficiency. However, as with efforts to combat climate change, no single city or state can do it alone.

While our analysis highlights where health outcomes would be greatest, the ability to affect those outcomes may not rest with any given city or state. The electric grid spans state and even national boundaries, and multiple agencies and offices within each level of government regulate power generators. Authority to effect programs and policies that will save energy is similarly dispersed across local, state, and federal government agencies. Furthermore, the electric grid's interstate nature combined with the transport of air pollution across geographic boundaries mean that energy saved in Ohio might, for example, benefit the health of people living in New York.

It follows that the greatest benefits will be realized when cities and states act collectively and across entire regions. This suggests that state and city efforts to advance energy efficiency should be augmented by regional and/or federal solutions to maximize health benefits. We describe several proven strategies that have the greatest potential to achieve significant energy savings and public health gains at all government levels. Many states and cities are already using these strategies to meet electric needs, but significant potential remains to do more (Molina, Kiker, and Nowak 2016).

Energy Efficiency Resource Standards

Energy efficiency resource standards (EERS) establish mandatory energy savings targets for electric utilities. Utilities typically offer programs for residential, commercial, and industrial customers that support and sometimes pay for energy efficiency improvements in buildings. Twenty-six states now have fully funded EERS policies that set binding, multiyear targets for electricity or natural gas savings (Berg, Gilleo, and Molina 2017). Many of those states have policies to reduce electric consumption by 20% or more. The average energy efficiency spending and savings levels of states with an EERS policy in place are more than three times those of states without such a policy (Molina and Kushler 2015). While EERS policies are typically established at the state level via public service commissions and/or state legislation, cities responsible for municipally owned utilities can set targets as well. Cities can also intervene in periodic review processes to expand program offerings (Ribeiro et al. 2017). Congress has considered a federal EERS on several occasions, but it has never been enacted.

Building Codes

Building energy codes set minimum requirements for energy-efficient design and construction for new and renovated buildings. Buildings are large energy users with long life spans; limiting energy use can therefore significantly impact local air quality and public health. Adopting building codes that require efficiency measures during design and construction is one of the most cost-effective ways to reduce energy consumption in residential and commercial buildings (Berg et al. 2017). While no mandatory national code exists, the federal government has taken an active role in developing national model energy codes for adoption at the state and local levels. The International Code Council (ICC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) update the national residential and commercial model codes, respectively, every three years.¹⁴ Local jurisdictions can participate in developing national model energy codes through the ICC, including providing public comment and voting on code changes. Most states have adopted model building codes, but several lack a statewide code or have yet to adopt the latest code update (BCAP 2017a). In some cases, cities have taken the lead in adopting building energy codes and are often responsible for compliance and enforcement (BCAP 2017b).

¹⁴ The ICC develops the residential model code (International Energy Conservation Code [IECC]), and the ASHRAE develops the model commercial codes (ASHRAE Standard 90.1).

Appliance and Equipment Standards

Appliance and equipment efficiency standards apply to many common devices that consume energy and water. These standards both set minimum efficiency performance requirements for products sold in the United States and assure consumers that their purchases will meet those requirements. Federal appliance and equipment standards are currently responsible for saving 7–18% of state electricity sales per year (deLaski and Mauer 2017). Many standards are adopted at the federal level, but states can also adopt standards for products not regulated by federal standards. Researchers estimate that new state standards could reduce another 1.5% of total annual electric use (Mauer, deLaski, and DiMascio 2017).

Regional Initiatives

The Regional Greenhouse Gas Initiative (RGGI) is a regulatory program designed to reduce greenhouse gas emissions from power plants in nine Northeast states and supports investments in energy efficiency programs in states across the region (RGGI 2017). For every dollar of RGGI auction proceeds invested in energy efficiency, \$2.30 in avoided energy costs is saved (Chang et al. 2012). In addition to energy savings, over the first six years of the program, RGGI reduced criteria pollutant emissions, creating major benefits to public health. Working collectively, RGGI states used strategies such as energy efficiency to avoid hundreds of premature deaths and tens of thousands of lost work days (Manion 2017).



Energy efficiency programs are operating in communities across the country and can be designed to mitigate health harms and help those most vulnerable. *Source:* still image from “West Virginia Homes Get Healthier with Weatherization.” ACEEE 2017.



A yoga class in Pittsburg takes advantage of the city's fresh air and sunshine. Reducing power plant pollution through energy efficiency improves residents' quality of life. Source: still image from "Energy Retrofits Clear the Air in Pittsburgh." ACEEE 2018b.

Compounding the Health Benefits of Energy Efficiency

Various strategies can be used to maximize the public health benefits of energy efficiency programs and policies. This can be particularly important in low-income communities, which are often exposed to higher levels of pollution.

For example, an NAACP analysis of 378 coal-fired power plants found that the average per capita income of the 6 million people living within three miles of the plants was \$18,400 per year (Wilson et al. 2012). Living near a coal plant means higher exposures to the pollution they produce. Further, these same families generally spend a higher percentage of their income to pay energy bills than families with greater financial resources (Drehobl and Ross 2016). Efficiency policies and programs can be designed to ameliorate the challenges of living with asthma and other respiratory illnesses, address the energy burdens of families struggling to heat their homes or put food on the table, and extend benefits to the most vulnerable in a community. When energy efficiency programs are designed to consider the disproportionate environmental and health burdens

that some communities face, the programs' benefits multiply. The following discussion highlights some of the best opportunities for tailoring energy efficiency programs, policies, and technologies so that the health and economic benefits of energy efficiency reach the families and communities that need them most.

In-Home Interventions

On average, Americans spend 90% of their time indoors (Klepeis et al. 2001). Energy efficiency measures can protect health by reducing exposure to hazards in indoor environments. For example, a typical weatherization program involves adding insulation and sealing holes and cracks where cold air and drafts can come into a house. These steps reduce exposure to extreme and

Compounding the Health Benefits of Energy Efficiency

fluctuating temperatures, both of which trigger asthma attacks (AAFA 2017). Air sealing also keeps out pests such as cockroaches and mice, which bring asthma-triggering allergens and carry disease (ACAAI 2014). It also reduces excessive moisture that can lead to mold growth and exacerbate a variety of respiratory illnesses including asthma (CDC 2017a).

As contractors seal up a building's envelope, they can protect and even improve indoor air quality by ensuring that homes are receiving fresh air and by reducing sources of moisture and indoor air pollution. Further, efficiency measures to repair or replace old or malfunctioning appliances can eliminate backdraft, which introduces carbon monoxide and other air pollutants into the home (CDC 2017c). Finally, a program's initial assessment of energy savings opportunities can identify malfunctioning smoke detectors, lead paint, radon exposure, and trip and fall hazards, and the program can subsequently mitigate them. These measures can save lives.

Although these benefits accrue to program participants of all ages and socioeconomic status, they particularly benefit children, the elderly, and families of color—all of whom suffer disproportionately from respiratory illnesses such as asthma (ODPHP 2017). These benefits translate directly to fewer hospital visits and a better quality of life in communities where energy efficiency programs are operating.¹⁵

Reducing Energy Burdens

Energy efficiency improvements reduce utility bills and the costs of keeping a home warm and comfortable, mitigating energy burdens for families. Income-based energy efficiency programs are currently available in most states and many cities. These programs typically have limits on funding and available measures that

¹⁵ In early 2018, ACEEE will release a report identifying exemplary programs that both save energy and protect the health and safety of participating families. Many of these programs target specific communities or populations, and some have documented measureable health improvements for program participants. The final report will be available at: aceee.org/topics/health-environment.

restrict the number of families they can serve and the type of assistance they can provide. There are many opportunities to strengthen and expand these programs, including by targeting communities with high energy burdens.

A household's energy burden is its total annual utility spending (electric, gas, and/or other heating fuel) as a percentage of annual household income. Families who face high energy burdens experience many negative effects on their health and well-being. These families are at greater risk for respiratory diseases and increased stress, and they can experience increased economic hardship and difficulty in moving out of poverty. High energy burdens can cause very real mental and physical health problems for household members due to thermal discomfort, inadequate lighting, unsafe housing conditions, and constant financial and social stress (Hernández and Bird 2010).

ACEEE research on the distribution of energy burdens has found that African-American and Latino households pay a higher percentage of their household income to meet energy needs (Drehobl and Ross 2016). Further, the majority of low-income households and renting households experienced higher energy burdens than the average household in the same city (Drehobl and Ross 2016). In addition to paying a higher portion of their total income on energy, low-income households spend much more per square foot on utilities, with an average cost of \$1.23 per square foot for low-income households versus \$0.98 for non-low-income households (EIA 2013).

A recent ACEEE report summarizes the findings of a number of studies on the relationship between energy burden and health (Drehobl and Ross 2016). Families sometimes cope with high energy burdens by heating or cooling fewer rooms in their home, reducing lighting use, and sacrificing nutrition, medicine, and other necessities to avoid shutoffs. Studies have found that living in homes that are not properly heated or cooled increases symptoms of respiratory illnesses, heart disease, arthritis, and rheumatism. These effects are especially detrimental to younger family members. Living in underheated homes puts adolescents at double the risk of respiratory problems.

Compounding the Health Benefits of Energy Efficiency



Nikia Pickett and her son enjoying a park in Baltimore, Maryland. Reducing power plant pollution through energy efficiency improves air quality, allowing children with asthma to spend more time playing outside. Source: still image from “Baltimore Breathes Easier with Energy Retrofits.” ACEEE 2018a.

High energy burdens also affect mental health by creating more stressful environments, increasing social isolation, and negatively impacting educational achievement and emotional resiliency. These stresses can hinder the ability of adolescents to study and complete school assignments, which negatively affects their academic success. Stresses related to high energy burdens can contribute to the fivefold increase in the risk of mental health problems for children in these homes.

High energy burdens can also cause societal problems extending well beyond the household. For example, 5.5% of low-income customers in California experienced utility disconnections for nonpayment in 2011 as compared with 2.9% of non-low-income customers. Half of the disconnected households owed less than \$315, and 6% of those disconnected did not reconnect within the year. Because of the disconnections, some of these families improvised hazardous methods to light and heat their homes. Finally, research in northern Kentucky, St. Paul, and Philadelphia found utility shutoffs to be one of the primary factors that led to homelessness.

Uplifting Vulnerable Communities

Power plant pollution disproportionately impacts infants, children, pregnant women, people with respiratory and cardiovascular illnesses, and the elderly (Lockwood et al. 2009). Babies are much more susceptible to the irreversible toxic effects of mercury exposure (WHO 2017). Further, approximately 10% of children aged 5–17 have asthma (CDC 2017b), with higher rates for certain groups (Akinbami, Simon, and Rossen 2016). For example, while less than 8% of white children under the age of 18 have asthma, the rate is much higher—more than 13%—among African-American children (CDC 2017b).

Energy efficiency offerings can be designed to target families and communities that are disproportionately burdened by the electric generating system. Programs can prequalify participants based on a needs assessment and offer services that target particular communities and populations. For example, Baltimore’s Green and Healthy Homes Initiative operates a program that provides energy efficiency upgrades and weatherization aimed specifically at households in which one or more occupants has asthma (Norton and Brown 2014).



Nikia Pickett and her son enjoying a park in Baltimore, Maryland. Reducing power plant pollution through energy efficiency improves air quality, allowing children with asthma to spend more time playing outside. Source: still image from “Baltimore Breathes Easier with Energy Retrofits.” ACEEE 2018a.

Conclusion

Energy efficiency improves people’s health and saves lives by reducing the dangerous, sometimes lethal pollution emitted by fossil-fuel-fired power plants.

The complexity of the electric grid, weather patterns, and other factors affect where those benefits accrue most. Our analysis indicates that some states and cities would experience more health benefits from energy efficiency than others; it also indicates where those opportunities might be greatest.

Our analysis focused on a narrow question: How does reducing power plant pollution through end-use energy efficiency affect public health? However the opportunities for energy efficiency to improve public health in other ways and across multiple sectors are much broader. Some of the greatest potential to improve health outcomes with energy efficiency in buildings and industry will be realized by individual program participants who improve the health and safety of their homes and schools. Health and safety benefits that accrue directly to the people who occupy those buildings may well be even greater in scale than the ambient impacts on air quality. Opportunities for energy

efficiency to improve public health in these ways are worthy of additional research.

Air pollution attributable to the transportation sector is another example. Mobile pollution sources such as cars and trucks are responsible for a considerable portion of the most harmful smog- and soot-forming pollutants in cities. Federal fuel economy emissions regulations not only save energy, but they also reduce this pollution and the health hazards that attend it.

All cities and states have opportunities to reduce energy waste, yielding multiple benefits. Energy efficiency lowers energy costs and reduces pollution, while increasing grid reliability and protecting health. Energy efficiency addresses many of the social determinants of health by improving housing conditions, protecting the environment, creating economic opportunities, and reducing costs for families. Efficiency policies and programs can be designed to ameliorate the challenges of living with asthma and other respiratory illnesses,

Conclusion

address the energy burdens of families struggling to heat their homes or put food on the table, and extend benefits to the most vulnerable in a community. Energy efficiency can improve people's lives by protecting the health and safety of families and offering a better quality of life to communities—particularly to the sick and the poor among us, who need those improvements the most. Saving energy saves lives.

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Appendix A. Methodology and Assumptions

For this report, we conducted our analysis in three steps. First, we selected a hypothetical target for electricity savings from energy efficiency, based on what has been achieved and what is possible. Second, we entered electricity savings estimates into an Environmental Protection Agency (EPA) tool, the AVOIDed Emissions and geneRation Tool (AVERT), to identify the amounts of particulate matter (PM_{2.5}), nitrogen oxides (NO_x), and sulfur dioxide (SO₂) that would be reduced and the counties in which those reductions would occur as a result of electric savings from energy efficiency. AVERT is an EPA tool that estimates the emissions benefits of energy efficiency and renewable energy policies and programs. Next, we entered the pollution reductions from AVERT into CO-Benefits Risk Assessment (COBRA), an EPA tool that estimates the health and economic benefits of air quality policies. We present the results of this analysis for 48 states and the 50 largest metropolitan statistical areas.

Step 1. Estimate Electricity Savings

For this analysis, we assume that every region achieved energy savings of 15% in 2016. This illustrative number represents a moderate amount of savings that each state can achieve in a cost-effective way. Indeed, many states are already exceeding 15% savings (Berg, Gilleo, and Molina 2017). ACEEE estimates show that, based on available 1990–2015 data for appliance standards, utility-run efficiency programs, and building codes, energy efficiency is already meeting 18% of our nationwide electricity needs (Molina, Kiker, and Nowak 2016). Further, substantial energy efficiency is occurring beyond what is included in those estimates. Private sector investments and technologies such as combined heat and power (CHP), which uses wasted heat to make American manufacturing more competitive, also offer significant opportunities to save energy. A forward-looking ACEEE analysis estimates that a modest basket of efficiency policies (updated building codes, energy targets for utilities, state appliance standards,

and modest investment in CHP) would reduce power demand by 25% (Hayes et al. 2014).

Unlike pollution control measures, efficiency is not typically brought online all at once. Rather, efficiency investments typically accrue over time. For example, a state might work up to energy savings of 15% in Year 15 by investing in new efficiency measures in Years 1 through 15 and thereby save an additional 1% each year. A look at 45 energy efficiency potential studies found estimates of average annual savings potential at around 1% new savings per year (Neubauer 2014). In our report's Results and Discussion section, we further describe specific policy and regulatory approaches that could achieve these results.

Step 2. Estimate Pollution Reductions with AVERT

AVERT is an EPA tool that estimates the emissions benefits of energy efficiency and renewable energy (EE/RE) policies and programs. AVERT estimates the displaced emissions from energy efficiency and renewable energy by representing the dynamics of electricity dispatch based on the historical patterns of actual generation in a specific year. For this analysis, we relied on actual 2016 emissions included in AVERT.¹⁶

EPA describes how AVERT works as follows:

- AVERT's Statistical Module uses hourly "prepackaged" data from EPA's Air Markets Program Data (AMPD) to perform statistical analysis on actual behavior of past generation, heat input, SO₂, NO_x, PM_{2.5}, and carbon dioxide (CO₂) emissions data given various regional demand levels. (AVERT's Statistical Module can also analyze user-modified data created in AVERT's Excel-based Future-Year Scenario Template). AVERT's Statistical Module produces regional data files that are input files used in AVERT's Excel-based Main Module.
- AVERT's Main Module prompts users to select one of 10 AVERT Regional Data Files and enter EE/RE impacts (MWhs or MW) from a selection of options.

- The AVERT Main Module performs the emissions displacement calculations based on the hourly electric generating unit information in the regional data files and the EE/RE impacts entered into the tool.

Additional detail about AVERT and a downloadable version of the tool are available at www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert.

For this analysis, we assumed that 15% energy savings are achieved for each of AVERT's 10 electric grid regions. As the map below shows, many states straddle multiple grid regions. We summed all the results before entering them into COBRA, adding together the impacts that occur in a single county due to changes in different grids.

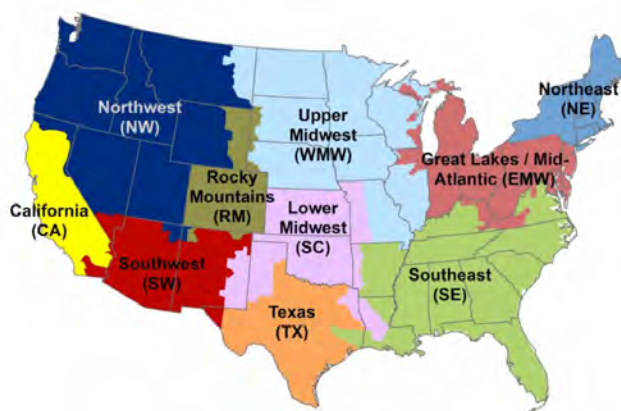


Figure A1. AVERT regional divisions

In our analysis, we use AVERT's 2016 emissions data. We did not make any changes to the emissions profiles of any regions (see figure 6).

¹⁶ AVERT currently has data for 2007–2016.

Appendix A. Methodology and Assumptions

Step 3. Estimate Health Benefits with COBRA

EPA describes how COBRA works as follows:

- COBRA contains detailed emission estimates of PM_{2.5}, SO₂, NO_x, NH₃, and VOCs for the year 2017 and 2025 as developed by the US EPA. Users create their own scenario by specifying increases or decreases to the baseline emission estimates. Emission changes can be entered at the county, state, or national levels, and outcomes can be modeled nationwide or for smaller geographic areas.
- COBRA uses a reduced form air quality model, the Source-Receptor (S-R) Matrix, to estimate the effects of emission changes on ambient PM.
- Using an approach to estimating avoided health impacts and monetized benefits that is generally consistent with EPA practice, the model translates the ambient PM changes into human health effects and monetizes them.

Additional detail about COBRA and a downloadable version of the tool are available at www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool.

Inputs for our COBRA analysis came from the 10 runs we conducted for each of the AVERT grid regions. We entered avoided pollution in a single year for NO_x, SO₂, and PM_{2.5} at a county level. COBRA has a built-in limit on the number of counties it can model in a single run. We were able to access a version of the tool that allowed us to complete the analysis in two separate runs.

Appendix B. Avoided Health Harms for States and Cities

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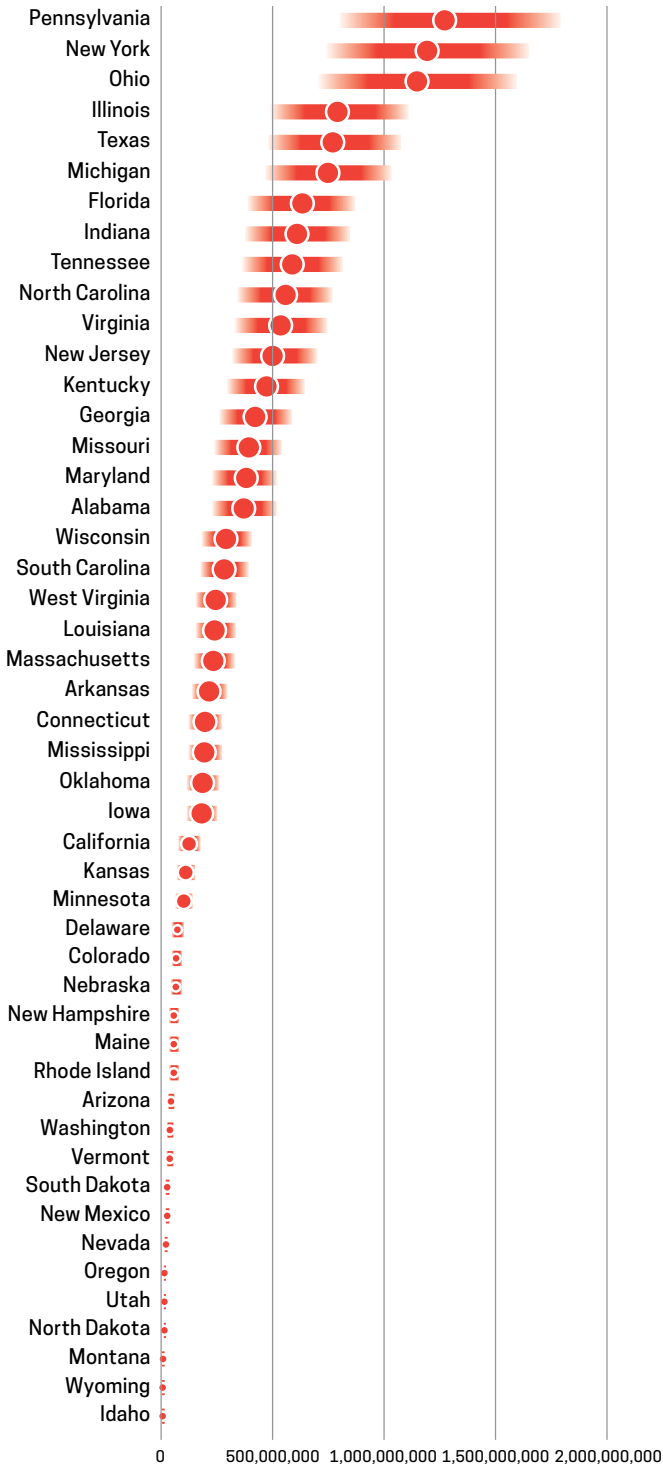


Figure B1. Avoided health harms for states, low and high range (US\$)

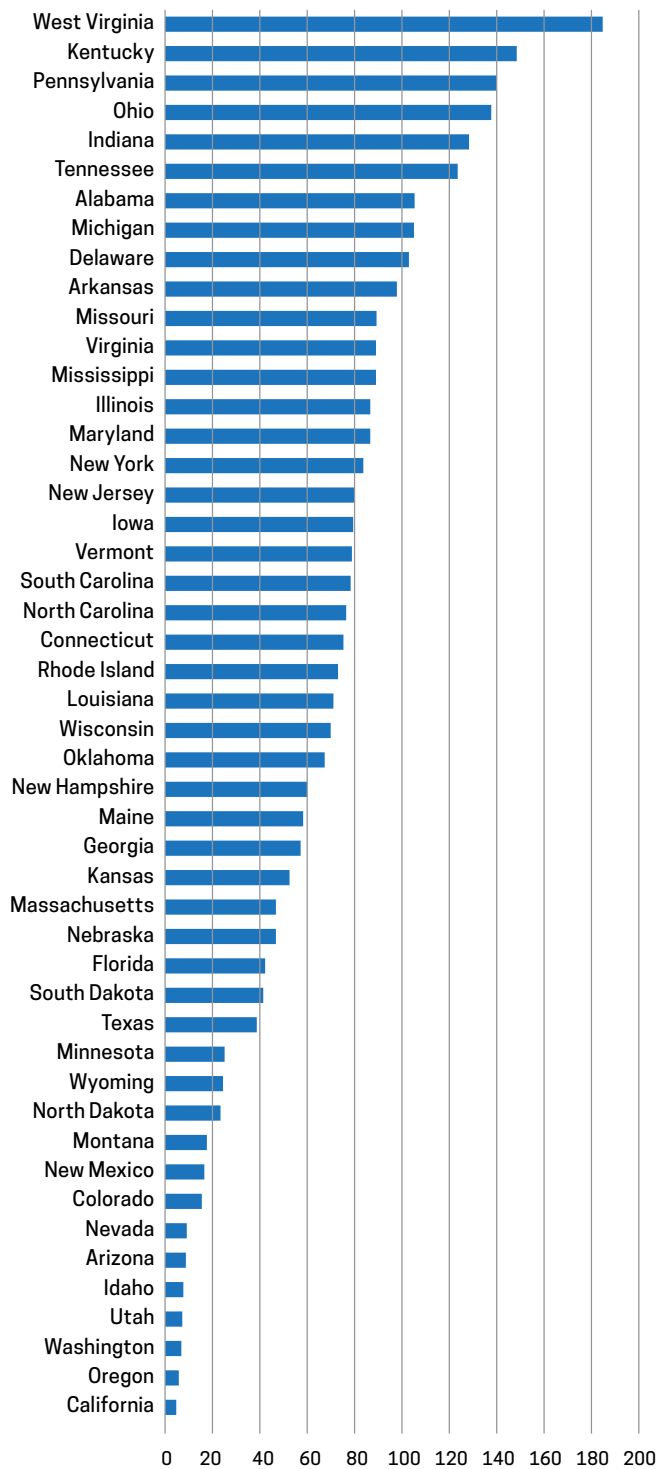


Figure B2. Avoided health harms for states (US\$ per capita)

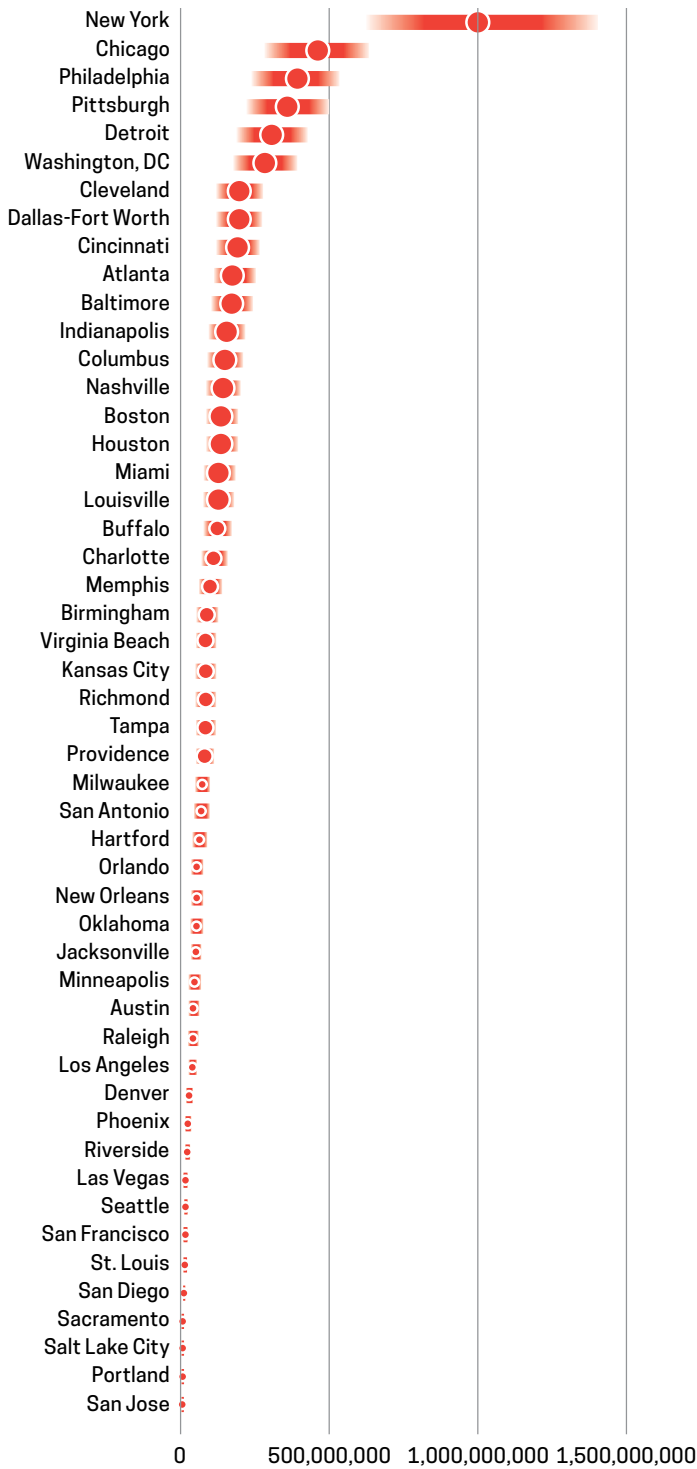


Figure B3. Avoided health harms for 50 largest US cities, low and high range (US\$)

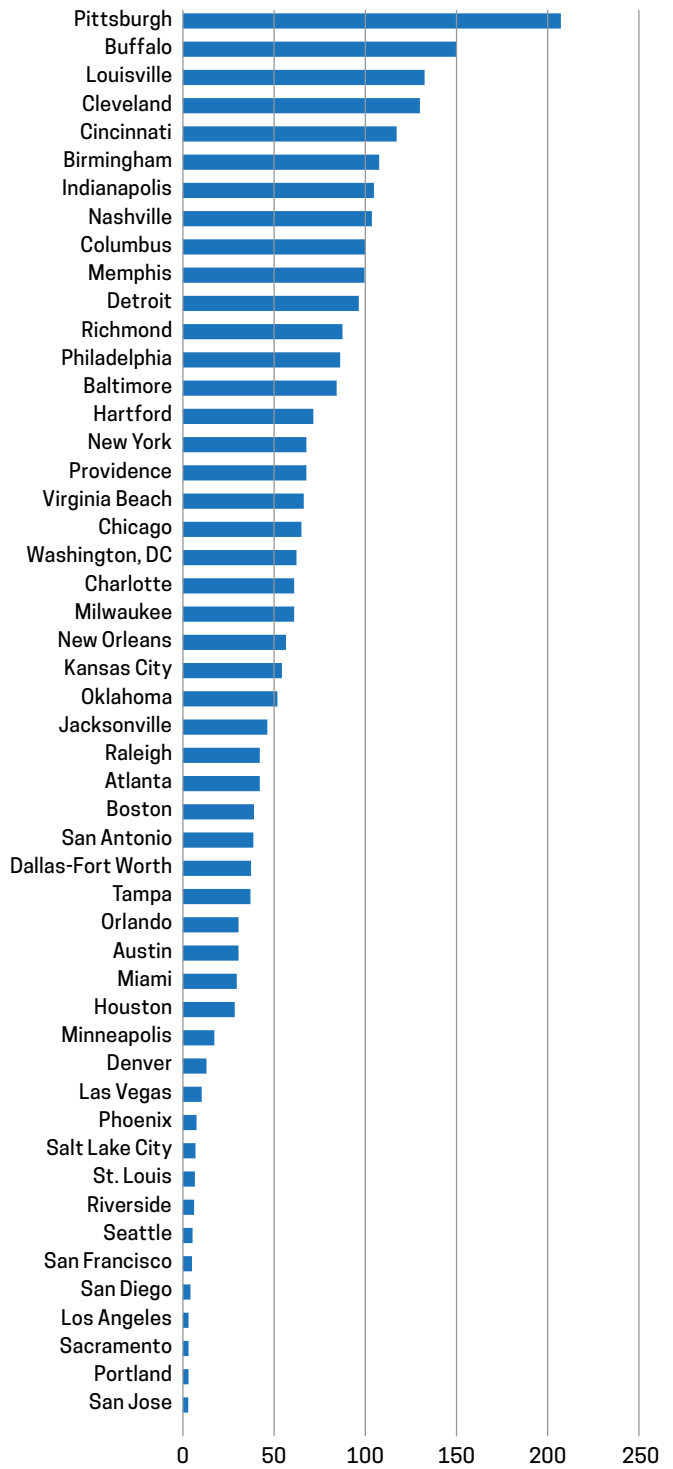


Figure B4. Avoided health harms for 50 largest US cities (US\$ per capita)

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