# The value of energy efficiency as a public health and climate mitigation strategy

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## Abstract

Saving energy in buildings and making vehicles more fuel-efficient reduces the harmful pollution emitted by fossil fuel consumption. Pollution avoided by energy efficiency results in substantial improvements to public health through reduced morbidity and mortality. However, the public health benefits of energy efficiency are oftentimes underestimated or omitted when communicating the value of energy efficiency as a climate change mitigation strategy. Communicating the health benefits of energy efficiency creates an opportunity to motivate leaders to take action on climate change.

As described in a recent IPCC special report, any increase in global warming is projected to negatively affect human health. In order to achieve the levels of emission reductions required to prevent further warming, countries participating in the Paris Agreement will need reaffirm and ramp-up commitments. However, the United States continues to lag behind. The US and countries worldwide have an opportunity to mitigate climate change and realize significant health benefits by advancing energy efficiency.

Building on previous research, this paper identifies existing and proposed policies to regulate carbon in the US and compares these with examples from countries in the European Union, emphasizing strategies that incentivize energy efficiency and maximize public health gains. This paper presents findings from two analyses that model the emission reductions and associated public health gains from a combination of energy efficiency policies in the power sector and through electric vehicle adoption. These estimates underscore the magnitude of public health benefits that can be achieved by using energy efficiency and make the case for an increased commitment from the US to mitigate climate change.

## Introduction

Pollution avoided by energy efficiency results in substantial improvements to public health through reduced morbidity and mortality, as will be shown in this paper. However, the public health benefits of efficiency are oftentimes underestimated or omitted when communicating its value as a climate change mitigation strategy. Using analyses performed by the American Council for an Energy-Efficient Economy (ACEEE), this paper presents findings that model the emission reductions and associated public health gains from energy efficiency policies in the power sector and through electric vehicle adoption. These estimates underscore the magnitude of public health benefits that can be achieved through using efficiency to address climate change and make the case for an increased mitigation commitment from the United States.

In order to achieve the levels of emission reductions that are required to prevent the harmful effects of further global warming, countries participating in the Paris Agreement will need to reaffirm and ramp-up commitments. Under President Obama, the US became a leader in climate change action. The administration signed the Paris Agreement after striking a deal with the Chinese government and led on cutting greenhouse gas (GHG) emissions in the US through several regulations. The Clean Power Plan set carbon dioxide ($CO_2$) reduction limits for existing fossil fuel power plants, projecting significant health benefits and a 32 % reduction in $CO_2$ emissions from the power sector by 2030. The rule allowed flexibility in state compliance approaches, including adopting carbon pricing and investing in energy efficiency and renewable energy (US EPA 2015b). The Obama administration's joint fuel economy and GHG emissions standards – the first national GHG standards for vehicles – were projected to achieve an average fuel economy of about 4.8 L/100 km in model year 2025 (Langer 2016).

Since the start of the Trump administration, these regulations are among the many energy and environmental regulations that are in the process of being rolled back. In an effort to mitigate climate change, state and local governments in the US are focused on pricing GHG emissions, adding to the 51 carbon pricing initiatives that are underway worldwide (World Bank 2018). This paper discusses market-based policies that put a price on GHG emissions and identifies approaches in use, including the European Union's emissions trading system (EU ETS) and several active and proposed carbon pricing programs in the US. We highlight the role of energy efficiency in these programs and identify approaches that could be adopted in the US to achieve the significant emission reductions and public health benefits.

## Climate Change and Health

Considered the greatest global health challenge of the 21st century, climate change threatens the health of every community (Costello, et al. 2009). Higher temperatures, rising sea levels, increasing air pollution and more extreme weather events will expose vulnerable populations to increased morbidity and mortality. Already, people in more than 90 % of cities worldwide breathe polluted air that is toxic to their respiratory and cardiovascular health (Watts, et al. 2018). Vulnerable populations, including children, the elderly, pregnant women and low-income communities, bear the greatest burden of health harms. The existing conditions that impair health among these populations, such as polluted air and water, drought, extreme heat, flooding and mental health stresses, are exacerbated by climate change (WHO 2018). Figure 1 demonstrates these health stressors and their impact on increased morbidity and mortality (CDC 2014).

### THE ROLE OF ENERGY EFFICIENCY TO REDUCE GREENHOUSE GASES

Carbon dioxide emitted from the combustion of fossil fuels is the leading GHG contributing to climate change. In 2017, global energy-related $CO_2$ emissions reached a historic high of 32.5 gigatonnes (Gt) after three years of flat emissions (IEA 2018a). While this represents a 1.4 % increase from 2016, without energy efficiency improvements, global emissions would have been nearly 12 % higher in 2017 (Figure 2 depicts these scenarios showing energy efficiency investments since 2000) (IEA 2018b). Energy efficiency can play a significant role in helping to achieve the levels of emission reductions required to prevent further warming. Seen as a critical strategy in most of the IPCC pathways limiting global warming to 1.5 °C, energy efficiency could deliver over 40 % of the abatement required to achieve the goals of the Paris Agreement (IPCC 2018).

Energy efficiency is a proven and cost-effective strategy for reducing greenhouse gas emissions. Saving energy costs less than generating electricity using other technologies (Gilleo 2017). In the US alone, ACEEE estimates that energy efficiency efforts targeting electricity savings have avoided the need to build the equivalent of 313 large power plants since 1990, reducing $CO_2$ emissions by 490 million tons in 2015 (Molina, et al. 2016). In the transportation sector, the federal fuel economy standards in the US avoided 83 million metric tons (MMT) of $CO_2$ per year and 500,000 barrels of oil a day (equivalent to gasoline use of 14 million typical cars and light trucks) in 2016 (ACEEE 2018b).

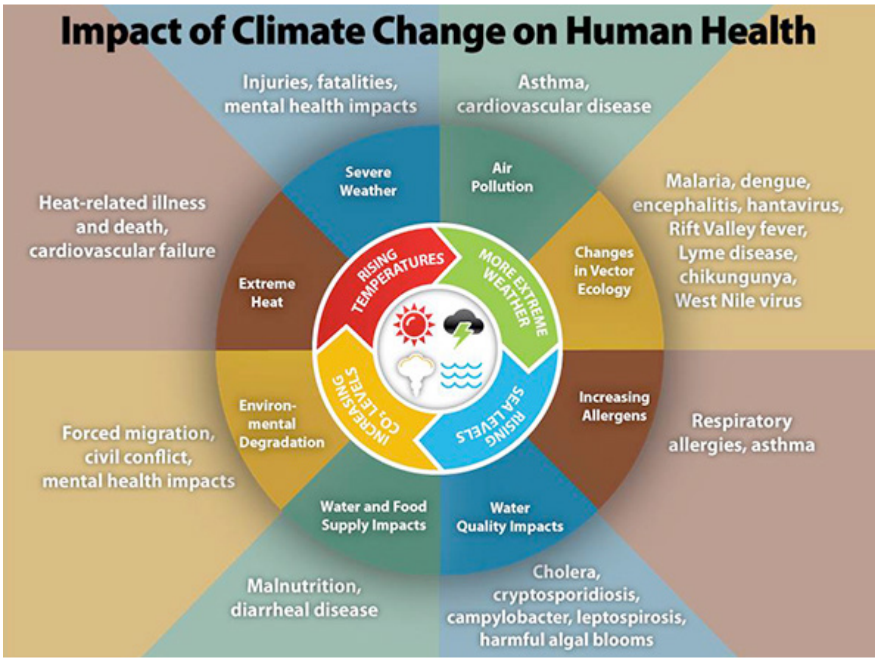


*Figure 1. Impact of Climate Change on Human Health (CDC 2014).*

## Health Benefits from Energy Efficiency

Deploying energy efficiency as a GHG reduction strategy can result in big public health gains through reduced air pollution and mitigation of climate change impacts. Energy efficiency can also help to alleviate respiratory ailments and asthma triggers by improving indoor air quality for building occupants (Denson & Hayes 2018). Energy efficiency is an ideal component of any climate resilience strategy because it aids emergency response and recovery, helps with climate change adaptation and mitigation, and provides social and economic benefits (Ribeiro, et al. 2015). By reducing energy demand in buildings, improving transportation efficiency, and deploying combined heat and power, communities can experience important resiliency benefits that reduce vulnerability and increase capacity to cope with the impacts of climate change.

In addition to $CO_2$, energy efficiency reduces a variety of pollutants emitted through the combustion of fossil fuels in power plants and the transportation sector. These pollutants include fine particulate matter (PM2.5), nitrogen oxides ($NO_x$), and sulfur dioxides ($SO_2$), which contribute to the formation of acid rain and smog and lead to serious health problems. Emitting these pollutants into the air contributes to lung cancer, chronic obstructive pulmonary disease, and increased hospitalizations for heart attacks and congestive heart failure (ACEEE & PSR 2015). These pollutants also trigger asthma, a chronic disease that is already at epidemic levels (Akinbami, et al. 2016). In addition, mercury and other toxics emitted from the burning of fossil fuels can cause serious neurological damage (WHO 2017a). The World Health Organization estimates that 23 % of all premature deaths could be prevented by reducing exposure to harmful pollutants that contribute to noncommunicable diseases (WHO 2017b). Reducing fossil fuel pollution through energy efficiency limits emissions and can result in significant health benefits.

### Methodology

ACEEE performed an analysis to determine which states and cities in the US would see the greatest health benefits from energy efficiency investments. We modelled a scenario of a 15 % reduction in electricity consumption nationwide and estimated the annual emission reductions from fossil fuel-fired power plants (Hayes & Kubes 2018). The scenario applies a hypothetical but readily achievable reduction in annual electric consumption evenly across the country that can be cost-effectively achieved in buildings. We chose this level of savings because it is attainable everywhere in the US and has already been widely reached (deLaski & Mauer 2017 and Berg, et al. 2017). We entered these electricity savings estimates into the United States Environmental Protection Agency's (US EPA) AVoided Emissions and geneRation Tool (AVERT), an emissions quantification model, to identify the amounts of pollutants that would be reduced and the counties where emission reductions would occur as a result of electricity savings from energy efficiency (US EPA 2018a). We estimated displaced emission from these energy savings using a 2017 baseline estimate of power plant emissions. AVERT captures the actual historical behaviour of fossil-fuel powered electric generating units' operation on an hourly basis to predict how these units will operate when energy efficiency is added to the grid (US EPA 2018b).

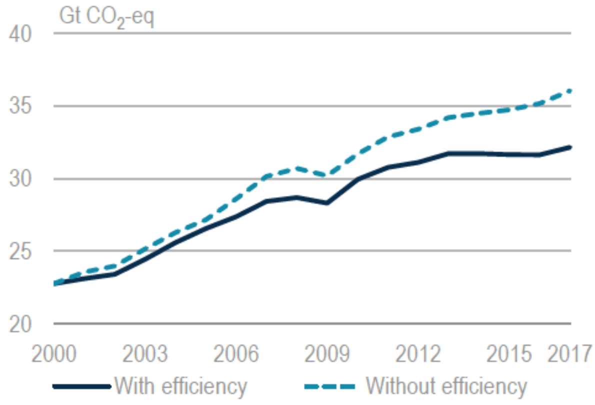


*Figure 2. Energy-related GHG emissions with and without energy efficiency from 2000–2017 (IEA 2018b).*

The resulting reductions in PM2.5, SO2 and NOx for more than 3,000 counties were then entered into the US EPA's CO-Benefits Risk Assessment (COBRA) model, a health impacts screening and mapping model, to quantify the health harms avoided by our energy efficiency scenario (US EPA 2018c). COBRA estimates the health and economic benefits of emission reduction strategies, and includes a simplified air quality model to convert air pollution changes to air quality impacts. The model translates the estimated air quality changes to health impacts (including health care costs) based on the methods, health benefit assumptions, and economic values that the US EPA uses for its own health impact analyses. For this analysis we relied on the default health dataset, which is based on an up-to-date assessment of published scientific literature to determine the relationship between particulate matter and the adverse health effects associated with changes in exposure (US EPA 2018f).[1] The model estimates the change in population exposure to air pollution using projections based on US Census of Population and Housing (2010) and a database developed by Woods & Poole (2011) that contains county-level projections of population by age, sex, ethnicity, and race out to 2040 (US EPA 2018f).[2]

### Results

The results demonstrated that reducing electricity consumption by 15 % nationwide for a single year would result in an estimated reduction of six premature deaths each day, up to $20 billion (US dollars) in avoided health harms, and nearly 30,000 fewer asthma episodes (occurring in children aged 6 to 18) (Hayes & Kubes 2018). Avoided premature adult mortality is responsible for the majority of the monetized benefits ($7.5 million–$8.4 million).[3] Other values are smaller, including the per-incident values of nonfatal heart attacks ($31,446–263,795) and hospital admissions ($15,430–41,002). The results

1. Based on a population with ages ranging from 0–99.

2. Projections in each county are determined simultaneously with every other county in the US to consider patterns of economic growth and migration. The sum of growth in county-level populations is constrained to equal a previously determined national population growth, based on Bureau of Census estimates.

3. Based on calculations of the value of a statistical life.

show that avoided health harms would average more than $70 per person in 15 cities and would be highest in Pittsburgh, where they were estimated to be more than $200 per person on average (Hayes & Kubes 2018). The analysis estimated the reduced electricity consumption would decrease pollution in the US by millions of tons in a single year, resulting in reductions of 11 % in PM2.5, 18 % in $NO_x$, 23 % in $SO_2$, and 14 % in $CO_2$ pollution (Hayes & Kubes 2018). In practice, pollution reductions from energy efficiency investments accrue over multiple years, delivering cumulative health and air quality benefits over the life of the energy efficiency measures.

The air quality benefits of reducing pollution from power plants with energy efficiency extend throughout the country. However, the locations of avoided health harms from this analysis demonstrate several factors that can impact where health benefits accrue to populations. Due to the nature of the electric grid, energy efficiency occurring in one state may reduce demand and associated emissions in a different geographic area. The types of generating sources that will be scaled back due to efficiency is dependent on where and when the efficiency takes place. In addition, wind patterns that move pollution from one place to another and secondary chemical formation occurring in the atmosphere can transform the location and composition of pollutants. While pollutants are transported across jurisdictional boundaries, it is the city centres with high populations that will experience the greatest monetized health benefits from energy efficiency (Hayes & Kubes 2018).

### QUANTIFYING THE HEALTH BENEFITS FROM GHG REDUCTION STRATEGIES TARGETING MULTIPLE SECTORS

A key factor in human exposure to air pollution is whether populations are located near polluting sources (Liu, et al. 2012). Communities living near fossil fuel-fired power plants are more likely to experience health harms from air pollution, while populations located near roads and refineries are similarly exposed to greater levels of pollution from vehicles (Chu 2013). Power plants tend to be located in rural communities while roads tend to impact more urban communities (Requia 2018). Often, low-income communities and communities of colour bear a disproportionate burden due to their proximity to polluting sources (Holmes-Gen & Barret 2016, Casey 2018, and CATF & NAACP 2017). Vehicle electrification shifts the pollution from the roads to the power plants, thereby shifting the impact on certain populations. The fuel mix of the electric grid is an important factor in determining whether communities located near power plants are disproportionally impacted from the increased emissions due to electric vehicle charging needs. Similarly, proximity to roadways is an important factor in understanding the emissions and associated health impacts from eliminating vehicle tailpipe emissions.

In the US, transportation energy use accounts for approximately 28 % of overall energy consumption and is the biggest consumer of energy economy-wide (EIA 2018a). The transportation sector surpassed electricity production in the US in generating the largest share of GHGs (US EPA 2018e). Over 90 % of the fuel used for transportation is petroleum based, including gasoline and diesel, with light duty vehicles representing the greatest energy use in the sector (EIA 2018b). Recent efforts at the federal level to reduce GHG emissions through coordinated emissions and fuel economy standards avoided 83 MMT of $CO_2$ per year and 500,000 barrels of oil a day in 2016 (ACEEE 2018a). While energy saving policies such as the federal fuel economy standards have been instrumental in reducing harmful emissions from light duty vehicles, vehicle electrification presents an additional opportunity to reduce air pollution from the transportation sector that could help to mitigate climate change and improve public health.

#### Methodology

ACEEE performed a second analysis to estimate the air pollution and health impacts that might accrue from market penetration of light-duty battery electric vehicles (BEVs). We conducted the analysis in two phases. Phase 1 modelled the net emissions impacts from a reduction in tailpipe emissions and an increase in power sector emissions due to vehicle charging. Phase 2 of the analysis incorporated a scenario representing increased energy efficiency in buildings to offset the increase in demand from vehicle charging. We then estimated the emissions and public health impacts resulting from the from the combined BEV adoption and energy efficiency in buildings adoption scenarios. Replacement of petroleum-fuelled vehicles with BEVs will reduce tailpipe emissions, but the increased demand for electricity will increase emissions from the power sector. The net emissions effects depend on many factors.

Our analysis focused on the Southeast region of the US due to the diverse fuel generation mix in the region, with 9 of the 13 states relying on coal or natural gas as their top fuel source and 3 relying predominantly on nuclear power (Muyskens, et al. 2017 and Popovich 2018). Further, the Southeast US is a region dependent on private vehicle travel, with limited investment having been made in public transit relative to other regions of the US (APTA 2018). We defined the Southeast as distinguished in the Emissions & Generation Resource Integrated Database (eGRID) (US EPA 2018d). The Southeast region we modelled includes full and partial states, comprised of 175 counties across 13 states, as shown in Figure 3.[4]

For Phase 1 of the analysis, we estimated emission impacts of a scenario where BEVs replace 10 % of gasoline vehicles and the charging needs are met from the existing electric grid. Using the US EPA's Motor Vehicle Emissions Simulator (MOVES), an emissions modelling system that estimates energy and emissions impacts by simulating the activity of mobile sources, we limited the analysis to model year 2017 gasoline and battery electric light-duty vehicles (US EPA 2015a). Our analysis accounted for one calendar year on an hourly basis, adjusting for vehicle population in MOVES, while the rest of the inputs relied on MOVES defaults for factors including energy consumption and emission rates. We also adjusted EV energy consumption to reflect modern BEVs rated at 4 miles per kilowatt hour (kWh).

We then created two BEV charging scenarios, one with uncontrolled charging and one with time-of-use (TOU) charging that helps to move charging to off-peak periods, impacting the power source and rate of emissions. We applied these charging scenarios to Phases 1 and 2 of the analysis. The TOU charging scenario peaked between 11pm to 5am due to lower

4. States in this region include: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

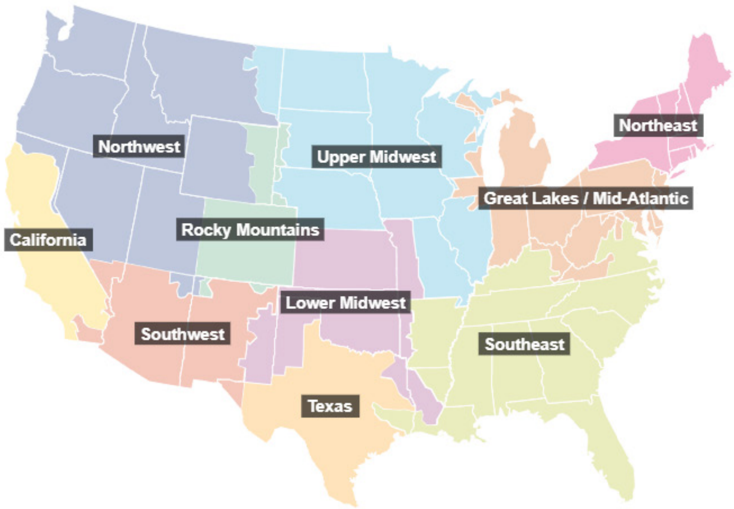


*Figure 3. eGRID regions in the US (US EPA 2018d).*

**Table 1. Phase 2 net reductions in emissions (15 % energy efficiency with 10 % BEV adoption, metric tons).**

| Emissions | Uncontrolled charging scenario | TOU charging scenario |
|---|---|---|
| $SO_2$ | 35,515 | 35,530 |
| $NO_x$ | 39,220 | 39,300 |
| $CO_2$ | 927,140 | 970,160 |
| $PM_{2.5}$ | 4,730 | 4,730 |

market prices, while the uncontrolled charging scenario occurred throughout a 24-hour period, with an increase during peak times between 6pm to 8pm. The MOVES model provided us with estimates of the total daily electric consumption of all BEVs in the region disaggregated by the type of day (weekday or weekend) and the month. We then developed two charging profiles based on a report by the US Department of Energy's (DOE) that collected regional charging demand by time and type of day for various locations, both with and without time-of-use charging (DOE 2013). We created load profiles showing the total power demand from BEV charging for uncontrolled charging based on the DOE data for Nashville, TN and for TOU rates based on data for San Diego, CA. These hourly charging scenarios were then input into a second model, AVERT, to determine the change in $PM_{2.5}$, $SO_2$, $NO_x$ and $CO_2$ emissions due to EV charging needs from the grid. We estimated the increase in emissions from this additional energy needs using a 2017 baseline estimate of power plant emissions (US EPA 2018b).

For Phase 2 of the analysis, we combined the results above with an energy efficiency adoption scenario in buildings totalling 15 % of regional fossil load to demonstrate how energy efficiency could offset increased demand from vehicle charging. Similar to the first ACEEE analysis described in this paper, this energy efficiency scenario represents a moderate amount of electric savings that can be cost-effectively achieved in buildings and is attainable everywhere in the US (deLaski & Mauer 2017 and Berg, et al. 2017). We then calculated the emission reductions from this scenario using AVERT, combined with the net emissions from Phase 1, to determine the net reduction in emissions from the combined 10 % BEV adoption and 15 % EE in buildings adoption scenarios (US EPA 2018a). Using these results, we estimated the pubic health impacts from the reduction in $PM_{2.5}$, $SO_2$, and NOx with EPA's COBRA model, as described previously (US EPA 2018c).

**Results**

Our results for Phase 1 of the analysis show a net decrease in annual $CO_2$ emissions and a slight increase in net emissions for PM2.5, $SO_2$, and $NO_x$ due to a reduction in transportation sector emissions and an increase in power sector generation due to charging needs (Junga 2018).[5] In our Phase 2 scenario, 10 % BEV adoption coupled with adoption of energy efficiency in buildings equal to 15 % of regional fossil load, we saw an overall decrease in annual emissions of PM2.5, $SO_2$, $NO_x$ and $CO_2$ relative to Phase 1 (results are shown in table 1). We estimated that the emission reductions in our Phase 2 combined policy scenario for the Southeast would result in \$1.0 to \$2.4 billion (US dollars) in reduced health harms in a single year. These results are based on avoided premature deaths, avoided trips to the emergency room to treat asthma, fewer heart attacks, and reductions of respiratory illnesses and symptoms (US EPA 2018c). These reductions would accrue beyond the single year

5. The results showed a reduction in CO2 emissions by 848,630 tons and 891,650 for the uncontrolled and TOU charging scenarios, respectively.

modelled in the analysis, delivering cumulative health and air quality benefits over the life of the energy efficiency measures and full life of the vehicles. Emission reductions could become more significant from electric vehicles in future years with a cleaner electric grid, and assuming that emissions from conventional gasoline vehicles persist or slowly increase over the life of the vehicle.

Several factors play a role when considering the impact of electrifying vehicles on overall air quality and public health. ACEEE's analysis considered impacts over one year, however vehicles have an average lifetime of about 15 years (ACEEE 2018c). A life cycle assessment could include emissions over each year of a vehicle lifetime and the upstream emissions impacts from the extraction, refining, and transport of fossil fuels to power vehicles or to generate electricity for BEVs. Charging scenarios can have an impact on the power sector emissions, therefore considering smart chargers, technological innovations, and siting considerations can help to achieve better outcomes. In our analysis, the charging scenarios had a modest impact on the emission reductions, with the TOU charging scenario resulting in fewer emissions. This could be due to the way the AVERT model estimates emission impacts, using only fossil-fuelled power plants in the model to estimate reductions from a region with high fossil fuel generation. In addition, looking beyond light duty passenger vehicles to all on-road vehicles can take into account the added emissions reductions that would accrue when switching from diesel-powered vehicles to BEVs. This analysis was limited in scope and meant to provide high-level estimates of the net emissions and health impacts of BEV adoption when considering charging needs. While other studies have been conducted to demonstrate the emissions impacts of electric vehicles, more analysis is needed to better understand the site-specific impacts of adopting electric vehicles and whether there are disproportionate emissions impacts for certain communities.

## Policy Mechanisms to Address Climate Change

In order to prevent the harmful effects of further global warming, countries participating in the Paris Agreement will need to reaffirm and ramp-up commitments to reduce GHGs (IPCC 2018). In this section we discuss market-based policies that put a price on GHG emissions. We identify several approaches in use, including the European Union's emissions trading system (EU ETS) and several active and proposed carbon pricing programs in the US. We highlight the role of energy efficiency in these programs and identify approaches that could be adopted or expanded in the US to achieve the significant emission reductions and public health benefits described in our analysis.

### CARBON PRICING INITIATIVES WORLDWIDE

Placing a price on $CO_2$ emissions is becoming more common throughout the world. According to the World Bank, currently 51 carbon-pricing initiatives are underway, as summarized in Figure 3. This carbon pricing initiatives in effect and scheduled for implementation would account for 11 GT of $CO_2$ equivalent, or about 20 % of annual global GHG emissions (World Bank 2018). The two main types of carbon pricing initiatives include a carbon tax, which charges a fee for every ton of carbon dioxide that is emitted, and a cap-and-trade system, which places a cap on GHG emissions and issues emissions certificates. Typically, one certificate allows the owner to emit one ton of $CO_2$, and emitters can trade these certificates so that the market finds the lowest-cost emissions reductions available.

### EU ETS

As the largest and world's first international trading system, the EU ETS informed cap and trade programs worldwide following its adoption in 2005. The third phase of the program (2012–2020) includes a single, EU-wide cap on emissions, with each allowance covering one ton of $CO_2$ or the equivalent amount of nitrous oxide ($N_2O$) and perfluorocarbons (PFCs). Operating across 31 countries, the program limits emissions from the power, industrial and aviation sectors, with a goal of reducing emissions 43 % below 2005 levels by 2030 (European Commission 2019).

Allowances are distributed partially through auction, however the share of free allocations will decrease to 0 % by 2030, producing a greater share of auction revenue to invest in energy- and climate-related purposes, including energy efficiency.[6] At least 9 countries reported investing between 50–100 % of their auction revenue for 2016 in energy efficiency efforts (Wiese, et al. 2018).[7] Over the period between 2013–2015, Member States reported spending 27.4 % on energy efficiency (EUR 1.95 billion) and 10.9 % on sustainable transport initiatives (EUR 774 million) (Le Den, et al. 2017). These investments make for important contributions to specific energy efficiency programs, and with the anticipated increase in auction revenue, these investments could be expanded further in future years (Wiese, et al. 2018). In addition to investing auction revenues, EU countries have made significant progress on energy efficiency policy and program adoption. ACEEE tracks progress on efficiency policies and programs in the top 25 energy-consuming countries. In the 2018 report, 6 of the 7 EU countries ranked among the top 7 countries, leading in adoption of energy efficiency in buildings, industry, transportation, and national efforts (Castro-Alvarez, et al. 2018). In addition, recent modelling by the Regulatory Assistance Project (2018) demonstrates that energy efficiency policies enacted in sectors outside of those regulated by the ETS will be essential for achieving the GHG goals outlined in the Paris Agreement (Rosenow, et al. 2018).

### CURRENT AND PROPOSED US INITIATIVES

The US federal government's refusal to act on climate change mitigation has prompted over 2,700 signatories, including state and local governments, businesses, universities, and organizations to affirm their support of the Agreement through the We Are Still In pledge (We Are Still In 2019). Nearly 30 health care organizations are among the signatories, highlighting the significance of public health in the context of climate change action. As the leading contributor to global GHG emissions, the US has an opportunity to realize significant health benefits through advancing policies to limit $CO_2$ emissions (Ritchie & Roser 2017). State efforts to price GHG emissions, such as the Regional Greenhouse Gas Initiative (RGGI) and Cali-

6. This applies to sectors not at risk for carbon leakage.

7. Countries include France, Latvia, Croatia, Estonia, Lithuania, Slovakia, Italy, Germany, and Czech Republic.

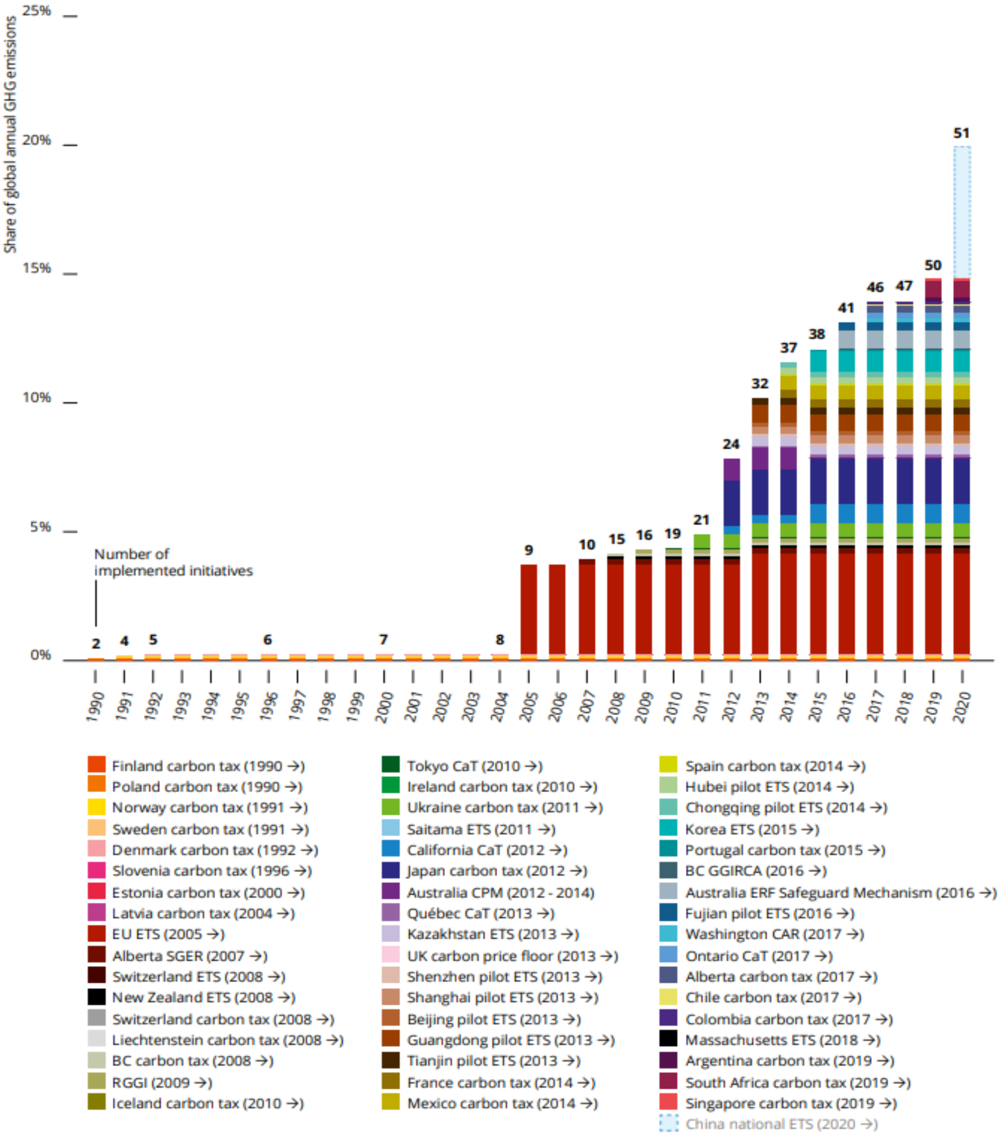


*Figure 4. Regional, national, and subnational carbon pricing initiatives (World Bank 2018).*

fornia's Cap-and-Trade Program, have been in place over the last 10 years and more states are planning to initiate their own carbon pricing programs. Despite the recent introduction of a carbon-pricing proposal in the US Congress, much of the activity around pricing carbon is occurring at the state level (Nadel & Kubes 2019).

#### Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative was the first mandatory cap-and-trade program for reducing greenhouse gas emissions in North America. In 2005 seven states committed to develop the program under the leadership of regional governors representing both major political parties; three other states joined in 2007. Currently composed of nine Northeast and Mid-Atlantic states (with two additional states planning to join in 2020), RGGI began its first compliance period in January 2009. The program caps $CO_2$ emissions from the power sector with a goal of reducing emissions 45 % below 2005 levels by 2020, with an additional 30 % reduction in the regional cap by 2030.[8] Electric-generating units burning fossil fuels and having the capacity to generate 25 megawatts (MW) or more are required to reduce emissions or acquire allowances to cover each US ton of $CO_2$ emitted. For distribution of allowances, 90 % of allowances are offered in quarterly regional auctions that result in a single clearing price.

The RGGI program has succeeded in meeting its emission reduction goals, resulting in net positive benefits in the form of decreased emissions, lower customer bills, lower wholesale power prices, and job gains (Hibbard, et al. 2018). Since 2005, emissions from plants subject to RGGI have declined about 100 million metric tons (Hibbard, et al. 2018). These reductions are primarily due to a shift to lower-emitting generating sources, but efficiency also played a role, helping to reduce total electricity consumption over the 2005–2016 period despite

8. Projected reductions between 2020 and 2030 amount to 2.275 million tons per year. These additional reductions were determined as part of the second program review, held in 2017.

substantial economic growth.[9] RGGI states have spent more than half of the $3 billion in revenue proceeds to fund a variety of efficiency programs. These investments are augmented by complementary policies in RGGI states, including energy efficiency resource standards, building energy codes, state government-led initiatives, transportation and land-use policies, and appliance standards (Nadel & Kubes 2019).

An analysis by Abt Associates assessed the public health impacts associated with changes in air quality due to RGGI implementation from 2009 to 2014. The results estimate the program saved 300 to 830 lives, realized $5.7 billion in health savings and other benefits, and avoided more than 8,200 asthma attacks. The analysis highlights the impact of energy efficiency investments contributing to the high emission reductions and health gains in the start of the analysis period and targeting peak demand periods with high emissions (Manion, M., et al. 2017). These findings underscore the significant health gains that can be achieved through policies to combat climate change that include investments in energy efficiency.

#### California's Cap-and-Trade Program

The California legislature adopted the Global Warming Solutions Act in 2006, authorizing the California Air Resources Board to establish a cap-and-trade program for GHG emissions. Implementation began in 2013 covering emissions in the power sector. However, in 2017 the transportation sector and the use of natural gas outside the power sector were added as covered sources, totalling about 85 % of GHG emissions in the state. Entities responsible for emissions of at least 25,000 tonnes per year are covered, and while some allowances are distributed for free, most are auctioned (CARB 2018). The goal of the program is to achieve 40 % emission reductions below 1990 levels by 2030.

Over the course of the program from 2013 through 2017, California invested about 9 % of auction revenues in low-income weatherization and agricultural efficiency and nearly 60 % of revenues in public transit and alternative vehicles, saving energy relative to conventional vehicles. California requires that 35 % of spending across all revenue spending categories benefit disadvantaged communities and that 25 % be spent in those communities (Nadel & Kubes 2019). California's energy efficiency efforts through complementary policies set the standard for other states across multiple policy categories, including utility efficiency programs, sustainable transportation, and building energy codes. In 2017, California ramped up long-term energy savings goals, doubling electricity and natural gas savings by 2030. In 2018, the state adopted net-zero energy building energy codes and joined with eight other states in rolling out a zero-emission vehicle action plan.

#### Pending US State Proposals

There are several ongoing efforts in state legislatures to advance carbon pricing. The states of Washington and Massachusetts have been seriously considering a carbon tax, with proposals possibly moving forward in 2019. Carbon tax proposals have also been considered to varying degrees in Rhode Island, Alaska, Hawaii, New York, Vermont and the District of Columbia. In addition, Oregon has been in discussions with California and other nearby states and provinces to align carbon-pricing efforts through cap and trade (Nadel & Kubes 2019). Regionally, nine states involved in the Transportation and Climate Initiative, announced in 2018 their agreement to develop a cap-and-trade program for transportation emissions (TCI 2018). These efforts would establish policies to limit emissions, while providing a platform to further invest in energy efficiency.

### Key Takeaways

Looking to past programs in the EU and US as examples, there are several takeaways regarding the incorporation of energy efficiency into carbon taxes or cap and trade programs. First, funds from a carbon pricing program can be invested in energy efficiency, including allocation of auction revenues to provide a funding stream for programs, as is done in countries in the EU ETS, California's program, and states participating in RGGI. Second, a variety of investment options exist. In the EU ETS, countries invest in a number of national programs to advance efficiency in public buildings, and programs targeted for the residential, commercial and industrial sectors. California invests most of its revenues in public transit and alternative vehicles, and in the RGGI states, much of the funds are invested in utility energy efficiency programs or programs run by state energy offices. Third, complementary policies exist to support additional energy efficiency progress. The emissions reductions and economic benefits of energy efficiency can be amplified by implementing efficiency policies alongside a carbon tax or cap and trade program (Nadel & Kubes 2019). Policies that establish utility energy savings goals, improve the fuel economy of vehicles, or increase the stringency of building energy codes can help a jurisdiction to make progress toward meeting GHG goals. While we focus on policies to price GHG emissions in this paper, there are many other strategies to reduce emissions through energy efficiency, some of which may be more effective at reducing GHGs, including banning the sale of fossil fuel vehicles, adopting policies to become carbon neutral, or ramping up energy efficiency policies and programs to reduce demand.

Pollution avoided by energy efficiency results in substantial improvements to public health through reduced morbidity and mortality. The air quality benefits of reducing pollution from power plants with efficiency extend throughout the country. However, the locations of avoided health harms from this analysis demonstrate several factors that can impact where health benefits accrue to populations. Analyses conducted by ACEEE demonstrate the variety of health benefits that can accrue to the public due to investments in energy efficiency in buildings and the adoption of electric vehicles. In addition, these analyses highlight the complexity involved in estimating avoided emissions and public health benefits, and additional considerations for modelling future scenarios. Understanding the shift in emissions, human health impacts, and the effects on vulnerable populations are key considerations for decisionmakers as BEV adoption increases.

Valuing the health co-benefits of energy efficiency creates an opportunity to drive countries toward action on climate change. Estimates highlighted in this paper underscore the magnitude of public health benefits that can be achieved through using energy efficiency to address climate change and can help to

9. A simple calculation based on total electricity sales in the nine RGGI states shows a 6 % decline in electricity consumption over this period (EIA 2017).

make the case for an increased GHG reduction commitment from the US. As the leading contributor to global GHG emissions, the US has an opportunity to realize significant health benefits through advancing policies to limit $CO_2$ emissions. As more states are planning to initiate carbon pricing programs it is important to learn from existing efforts, including the EU ETS, RGGI and California's Cap-and-Trade Program, to apply strategies for increasing the role of energy efficiency. Energy efficiency is a critical strategy to address climate change, with the potential to contribute over 40 % of the abatement required to be in line with the Paris Agreement. Deploying energy efficiency as a climate change mitigation strategy can result in significant public health gains from reduced air pollution and improved resiliency, while limiting the GHG emissions that lead to rising temperatures and sea levels, and extreme weather events faced by vulnerable populations worldwide.

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