Opinion Dynamics

Boston | Headquarters

617 492 1400 tel
617 497 7944 fax
800 966 1254 toll free

1000 Winter St
Waltham, MA 02451

Ameren Illinois Company

2018 Societal Health Non-Energy Impacts Report

Revised Final
April 9, 2021

Table of Contents

Table of Tables

Table of Figures

1. Executive Summary

This memo presents Opinion Dynamics' analysis of societal health non-energy impacts resulting from Ameren Illinois Company's (AIC) 2018 residential and nonresidential energy efficiency (EE) portfolio. This work is part of our ongoing evaluation of AIC's non-energy impacts. While Illinois utilities have historically excluded NEIs from cost-effectiveness testing, in 2016, the Illinois General Assembly passed the Future Energy Jobs Act (FEJA), which called for the inclusion of certain NEIs in EE program cost-effectiveness testing.[1] These include the avoided costs associated with reduced fuel and water consumption, reduced operation and maintenance costs, as well as "other quantifiable societal benefits". To help AIC meet these statewide policy goals, as well as the stated goals and objectives of the Illinois Stakeholder Advisory Group NEI Working Group (SAG NEI Working Group), Opinion Dynamics conducted an analysis of the reduction of air pollution emissions and resulting health benefits from AIC's 2018 EE portfolio.[2]

To provide context for the societal health non-energy impacts presented in this memo, we provide an explanation of non-energy impacts and the three categories into which they are divided: participant, utility, and societal NEIs. Non-Energy Impacts (NEIs) include positive or negative effects attributable to EE programs apart from energy savings. Non-energy benefits (NEB) frequently refer to positive NEIs, while negative NEIs—non-energy costs—reflect ways that EE measures result in adverse effects. NEIs are further distinguished into participant and societal NEIs.

- Participant NEIs are monetary and non-monetary impacts (positive or negative) that directly affect a program partner, stakeholder, trade ally, participant, or the participant's household. Examples include lower operations and maintenance costs, or increased sales or revenue. Other examples of participant NEIs include changes to occupant comfort and reduced occupancy.
- Utility NEIs arise from energy programs that directly impact a utility / program administrator. Examples include reduced arrears, disconnection notifications, and shutoffs.
- Societal NEIs are the impacts that arise from energy efficiency and affect society at large. Examples include changes in greenhouse gas and pollution emissions, changes in the number of jobs, and differences in tax revenues.

This report focuses on societal health NEIs resulting from residential and nonresidential EE programs.[3] Opinion Dynamics will estimate participant and utility NEIs through subsequent, ongoing, studies. EE programs can lead to reductions of multiple greenhouse gases and criteria air pollutants, which can have positive impacts on air quality, public health, and climate change mitigation. However, many of these benefits are difficult to quantify and/or monetize.[4] Therefore, in this memo, we focus on societal NEIs that are readily quantified and monetized. In particular, we estimate the health benefits associated with reduced exposure to fine particulate

[1] FEJA (Illinois Future Energy Jobs Act). Senate Bill (SB) 2814. www.ilga.gov/legislation/publicacts/99/PDF/099-0906.pdf. (passed December 7, 2016).

[2] Estimated health benefits reflect changes in regional emissions and outdoor air quality, and do not account for changes in indoor air quality. We plan to conduct future research to address the impact of energy efficiency programs on indoor air quality through an evaluation of participant NEIs experienced from participation in the AIC IQ Initiative.

[3] Energy efficiency programs also result in additional participant and societal health NEIs (such as decreased thermal stress, improved workplace safety, improved environmental conditions, etc.). While these impacts are not included in this study, they may be included in future NEI research.

[4] For example, EE programs can reduce emissions of pollutants that react to form ground-level ozone, which can damage human and environmental health. However, the formation of ground-level ozone is governed by complex atmospheric reactions, and therefore is difficult to quantify without advanced air quality modeling tools. In addition, some benefits, such as improved visibility resulting from air quality improvements, can be difficult to monetize.

matter ($PM_{2.5}$), which is associated with multiple health benefits, such as reduced premature fatality and lung disease.[5]

1.1 Study Objectives

The overall goal of this study was to provide monetized societal NEI estimates that reflect changes to human health resulting from program induced reductions in generation and emissions that correspond to decreased energy consumption. To address this goal, Opinion Dynamics focused on the following research objectives:

- Estimate the change in electric generation and emissions of primary fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), and nitrous oxides (NO_X) resulting from AIC's 2018 electric portfolio.
- Estimate the reductions in emissions of primary $PM_{2.5}$, SO_2, NO_X, ammonia (NH_3), and volatile organic compounds (VOCs)[6] associated with decreased natural gas combustion resulting from AIC's 2018 gas portfolio.
- Estimate the health benefits associated with decreased $PM_{2.5}$ concentrations.
- Monetize the health benefits, which AIC can use for cost-effectiveness testing, if desired.

1.2 Overview of Methods

We estimated the reductions in emissions of $PM_{2.5}$, SO_2, NO_X, NH_3, and VOCs resulting from AIC's 2018 EE portfolio. Many of the installed EE measures have lifetimes of up to 25 years and will continue to provide emissions benefits through 2042. We therefore report both the first year (2018) and lifetime emissions reductions for AIC's electric, residential gas, and nonresidential gas portfolios. We present the detailed methodology used to estimate emissions reductions in Section 3.2.

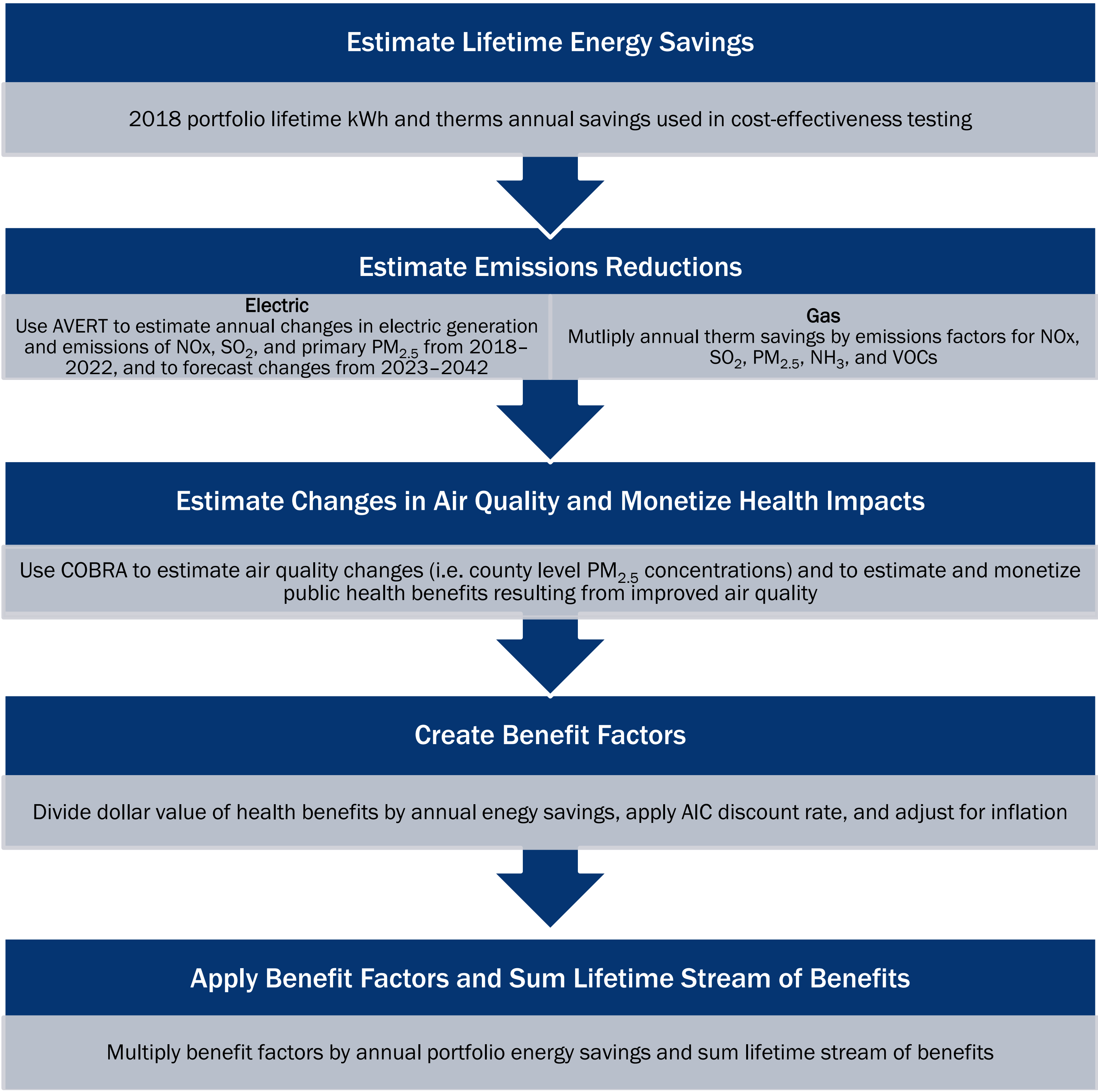
Figure 1 presents an overview of our societal NEI estimation approach. We modeled the total expected health benefits resulting from these emissions reductions and developed benefit-per-therm and benefit-per-kWh values to apply to each year of energy savings (see Section 3.3). These values account for changes in ambient $PM_{2.5}$ concentrations, their impact on human health, and the value of these avoided health costs. Using these factors, we calculated the health benefits attributable to AIC's 2018 EE portfolio by multiplying the benefit factors from the energy savings in each year and summing the lifetime stream of benefits. We report high and low values for benefits, which represent different assumptions about the impact of changes in ambient $PM_{2.5}$ concentration on adult mortality and non-fatal heart attacks. Figure 1 summarizes each step in the analysis process.

---

[5] U.S. EPA. 2016. Health and Environmental Effects of Particulate Matter. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

[6] Primary $PM_{2.5}$ refers to the direct emissions of $PM_{2.5}$ from fossil fuel combustion. Secondary $PM_{2.5}$ forms through a series of reactions between SO_2, NOx, NH_3, and VOCs in the atmosphere.

Figure 1. Steps to Estimate and Monetize AIC 2018 Portfolio Societal Health NEIs from 2018–2042



1.3 Key Findings

AIC's 2018 EE portfolio is expected to save 152 tons of primary $PM_{2.5}$ over the measures' lifetimes and 2,939 and 2,317 tons of SO_2 and NO_X, respectively. In addition, the gas portfolio is expected to reduce emissions of NH_3 and VOCs by 14 and 13 tons, respectively (Table 1).

Table 1. AIC 2018 Energy Efficiency Portfolio Lifetime Emissions Reductions

Sector	PM2.5 (tons)	SO2 (tons)	NOx (tons)	NH3 (tons)	VOC (tons)
Electric	*151.0*	*2,937.5*	*2,083.4*	*NA*	*NA*
Residential Gas	0.3	0.4	62.6	13.3	3.7
Nonresidential Gas	0.7	1.0	170.8	0.8	9.4
Gas Subtotal	*1.0*	*1.4*	*233.4*	*14.2*	*13.1*
Portfolio Total	**152.0**	**2,939.0**	**2,316.8**	**14.2**	**13.1**

Health benefits resulting from air quality improvements are not limited to one geographic region or state, and AIC's EE portfolio produces health benefits outside of Illinois. Therefore, we report both health benefits that accrue nationally and in Illinois alone. Emissions reductions resulting from AIC's 2018 EE portfolio are expected to result in \$92–207 million in national health benefits, as shown in Table 2. Approximately 15% of these benefits occur in Illinois.

Table 2. AIC 2018 Energy Efficiency Portfolio Lifetime Societal Health Benefits

Sector	Verified Savings (GWh)	Verified Savings (Thousand Therms)	National Health Benefits (Million 2018 \$)		Illinois Only Health Benefits (Million 2018 \$)	
			Low	High	Low	High
Electric	*3,571*	*NA*	*\$89.53*	*\$201.86*	*\$11.83*	*\$26.65*
Residential Gas	NA	13,819	\$0.56	\$1.26	\$0.19	\$0.42
Nonresidential Gas	NA	35,417	\$1.64	\$3.71	\$0.55	\$1.23
Gas Subtotal	*NA*	*49,236*	*\$2.20*	*\$4.97*	*\$0.73*	*\$1.65*
Portfolio Total	**3,571**	**49,236**	**\$91.73**	**\$206.82**	**\$12.56**	**\$28.30**

The electric portfolio accounts for 98% of national benefits and 94% of Illinois benefits. Because electric programs impact electric generation on a regional scale, emissions reductions do not always occur in the same region as energy savings. In contrast, gas programs produce emissions reductions in the same location as energy savings, and, therefore, a larger portion of the health benefits occur in Illinois.

The high and low estimates of health benefits primarily reflect uncertainty in the impact of changes in exposure to $PM_{2.5}$ on premature mortality and non-fatal heart attacks. Avoided pre-mature mortality (i.e. the value of a statistical life) is responsible for more than 98% of health benefits.

1.4 Conclusions

EE programs, by reducing demand for fossil fuels and improving ambient air quality, can improve public health. We find benefits are not limited to a single geographic area and are especially sensitive to measure lifetimes and the future fuel mix. While these benefits have traditionally not been included in cost-effectiveness testing by Illinois utilities, we have demonstrated that these benefits are both quantifiable and significant.

1.5 Limitations

Although there are additional societal benefits that may result from improvements to air quality, such as visibility improvements, recreational benefits, avoided damages from decreased timber and agricultural yields, and others, we focused our analysis on monetizing the value of health benefits resulting in decreased exposure to ambient $PM_{2.5}$. The magnitude of these health benefits is highly dependent on the accuracy of measure lifetimes and savings estimates; lower than predicted energy savings would result in lower than expected societal health benefits, while increased savings would result in higher benefits. There is also uncertainty surrounding the future of emissions reductions; unlike sophisticated electricity forecasting models, AVERT relies on historical generation and emissions data, and does not account for factors such as changes in the fuel mix or changes in electric demand.

Additionally, COBRA does not account for much of the complexity of atmospheric $PM_{2.5}$ formation that more sophisticated air quality models do. Finally, there is uncertainty surrounding the impact of changes in $PM_{2.5}$ concentrations on human health, specifically, non-fatal heart attacks and adult mortality. COBRA reports low and high estimates for both impacts derived from different sets of assumptions from the epidemiological literature.

1.6 Recommendations

Opinion Dynamics is providing AIC with societal health benefits resulting from AIC's 2018 EE portfolio. To estimate these societal health benefits, we examined electric emission reductions that occur under two different scenarios. Scenario A assumes avoided emissions per kWh remain the same as they are in 2018, while scenario B assumes they decrease over time (i.e., electric generation generates less pollution per kWh in the future). We recommend using the electric emissions from scenario B, to estimate emissions reductions for years 2023 and beyond. We provide both high and low estimates for health benefits to demonstrate the full range of possible benefits. We recommend using the mid-point between the high and low estimates for cost-effectiveness testing and planning. These values are provided in Appendix A.

2. Introduction

AIC administers dual-fuel EE programs across both the residential and nonresidential sectors that produce both electric (kWh) and gas (therms) savings. By reducing consumption of natural gas and electricity, these programs result in reductions of emissions associated with fossil fuel combustion, including fine particulate matter ($PM_{2.5}$), nitrous oxides (NO_X), sulfur dioxide (SO_2), ammonia (NH_3), and volatile organic compounds (VOCs). These pollutants can negatively impact the environment and human health. In particular, exposure to $PM_{2.5}$ is associated with multiple health impacts, including premature fatality, non-fatal heart attacks, asthma aggravation, and other respiratory diseases.[7] By reducing emissions of primary $PM_{2.5}$ and precursors to secondary $PM_{2.5}$ formation (NO_X, SO_2, NH_3, and VOCs)[8], EE programs represent a significant opportunity to improve regional air quality and increase health benefits.

Opinion Dynamics estimated the emissions reductions associated with measures implemented through AIC's 2018 EE portfolio of programs and quantified and monetized the public health benefits resulting from the subsequent reductions in ambient $PM_{2.5}$ concentrations.[9]

This memo includes the following sections:

- Section 3.1 describes our methods to estimate the lifetime energy savings from AIC's 2018 electric and gas portfolios.
- Section 3.2 describes our methods to estimate reductions in emissions of $PM_{2.5}$, SO_2, NO_X, NH_3, and VOCs resulting from AIC's 2018 EE portfolio.
- Section 3.3 describes our methods to estimate changes in ambient air quality and to quantify and monetize the subsequent health impacts.
- Section 4 describes the results of our emissions reductions and health benefits analysis.
- Section 5 discusses model uncertainty and considerations for future work.

[7] U.S. EPA. 2016. Health and Environmental Effects of Particulate Matter. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

[8] Primary $PM_{2.5}$ refers to the direct emissions of $PM_{2.5}$ from fossil fuel combustion. Secondary $PM_{2.5}$ refers to $PM_{2.5}$ created through a series of reactions between SO_2, NO_x, NH_3, and VOCs in the atmosphere.

[9] Estimated health benefits reflect changes in regional emissions and air quality, and do not account for changes in indoor air quality. We plan to conduct future research to address the impact of energy efficiency programs on indoor air quality and public health.

3. Detailed Methodology

In this section we describe our methodology for monetizing the societal health benefits associated with AIC's 2018 portfolio. First, we estimated the annual portfolio energy savings using inputs for cost-effectiveness testing and modeled their impact on emissions. Next, we modeled the impact of emissions reductions on ambient concentrations of $PM_{2.5}$ and quantified the number and value of public health benefits resulting from changes in exposure $PM_{2.5}$. Because many of the measures implemented through AIC's 2018 EE portfolio continue to save energy beyond the first-year, we modeled the emissions reductions and health benefits associated with the full measure lives of the measures installed through the 2018 portfolio; we calculate emissions reductions and public health benefits for the electric, residential gas, and nonresidential gas portfolio-levels for years 2018–2042.

3.1 Estimate Energy Savings

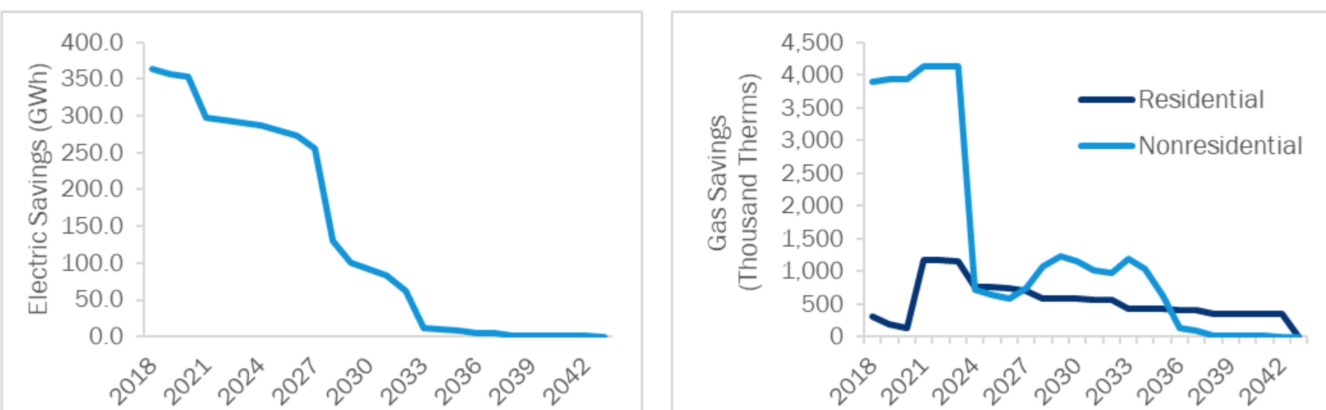
We based energy (kWh and therm) savings estimates on inputs used in cost-effectiveness testing.[10] To develop annual energy savings inputs, we aggregated the annual measure-level savings to the portfolio level and summed the savings from 2018–2042 to develop lifetime savings. Note that because there are interactive effects between electric and gas programs (i.e., heating penalties), gas emissions reductions can be negative (i.e., lead to increased emissions) in some years. First-year and lifetime portfolio savings are displayed in Table 3, and the annual savings estimates from 2018–2042 are displayed in Figure 2.

Table 3. 2018 Portfolio Verified Savings

Portfolio	First-Year (2018)	Lifetime
Electric Portfolio (GWh)	*364*	*3,571*
Residential Gas (thousand therms)	319	13,818
Nonresidential Gas (thousand therms)	3,890	35,417
Gas Portfolio Total (thousand therms)	*4,209*	*49,236*

Source: Opinion Dynamics portfolio analysis.

Figure 2. 2018 Verified Lifetime Electric and Gas Savings



Source: Opinion Dynamics portfolio analysis.

[10] Source: Opinion Dynamics portfolio analysis.

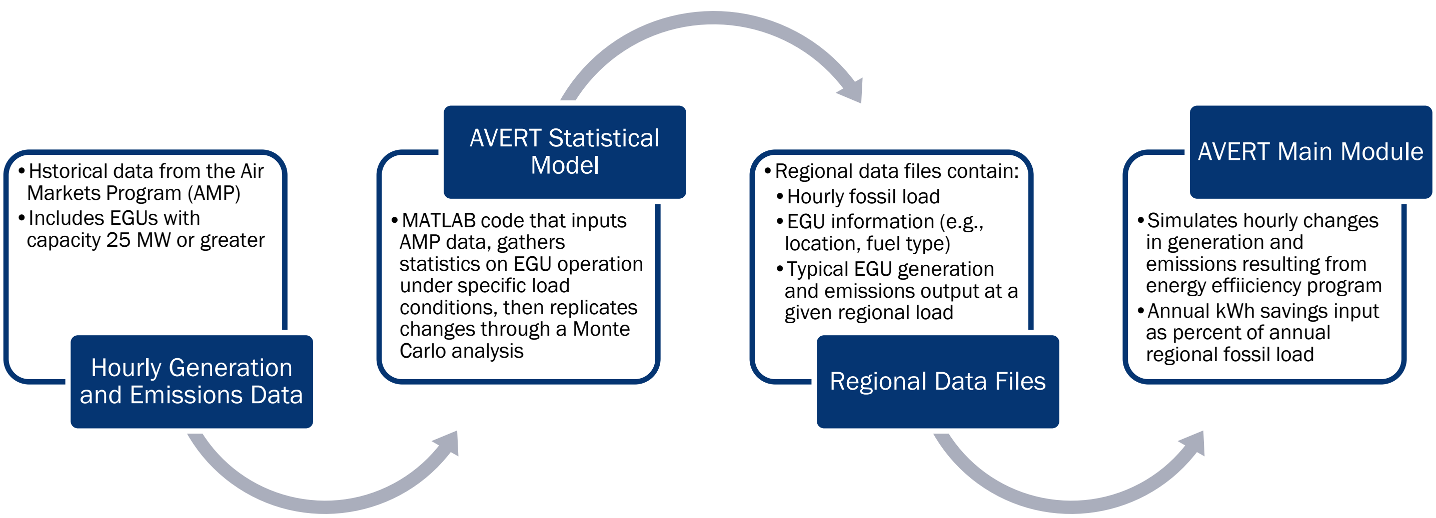
3.2 Estimate Emissions Impacts

3.2.1 Electric Portfolio Emissions Impacts

EE programs can reduce the emissions of criteria air pollutants and greenhouse gases by reducing consumption of electricity produced by the combustion of fossil fuels. However, the dynamic nature of the electric system creates uncertainty regarding the type and magnitude of emissions in future years. The location and magnitude of displaced emissions depends on the balance of electricity supply and demand, the generation fuel mix, the shape of the program's load impact profile, and a variety of other grid dynamics.

To estimate the emissions reductions from AIC's 2018 electric EE portfolio, we utilized the AVoided Emissions and GeneRation Tool (AVERT), a publicly available tool designed by the U.S. EPA to help policy makers and analysts quantify the emissions impacts of EE and renewable energy programs.[11] AVERT performs statistical analysis on historical hourly emissions and generation data to estimate the impact of decreased demand for electricity on the generation of individual fossil fuel electric generation units (EGUs) and the subsequent emissions of SO_2, NO_X, and $PM_{2.5}$.[12] AVERT probabilistically estimates the output of individual electric generating units (EGUs) and uses this statistical information to predict how they are likely to respond to load impacts. This process is demonstrated in Figure 3 below.

Figure 3. Process for Estimating Emissions Reductions from AIC's 2018 EE Portfolio



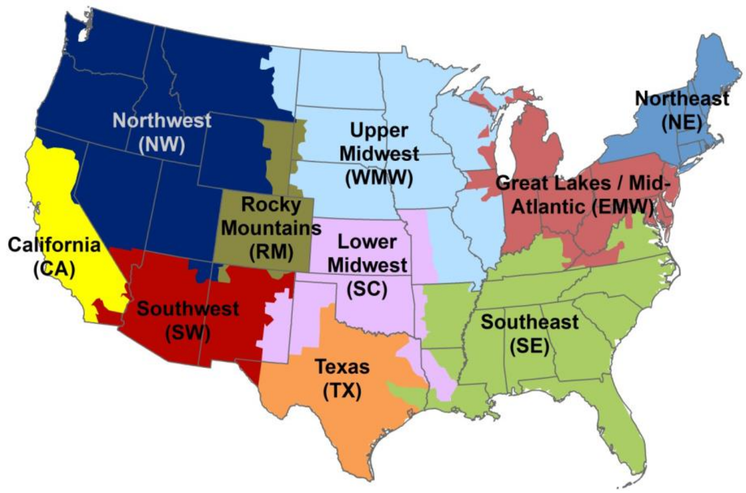
AVERT conducts modeling in one of 10 regions of the continental U.S.[13] AIC's territory is in the Upper Midwest region, which encapsulates most of the Midwest Independent System Operator (ISO). Emissions changes are calculated starting from a baseline year of 2018. Users must select an analysis region and baseline year and input the hourly load impact resulting from the EE program or portfolio of interest (see Figure 4). EPA advises against using AVERT to estimate emissions reductions for small EE projects (under several hundred MW in capacity) because the effects of the EE program may be outweighed by random effects in the historical data. AVERT provides results at the county, state, and regional level.

[11] We conducted the analysis using AVERT v2.3. U.S. EPA released AVERT v3.0 on September 15, 2020.

[12] AVERT does not model reductions in NH_3 or VOCs, which are both precursors to $PM_{2.5}$ formation. However, according to the EPA, the electric generation sector accounts for less than one percent of NH_3 and VOC emissions.

[13] AVERT regions represent relatively autonomous electricity market trading and dispatch areas. While AVERT does account for the dependencies of generation units within a region, it does not account for electricity transfers between regions.

Figure 4. AVERT Regions



Additionally, the EPA does not recommend utilizing AVERT to estimate emissions reductions more than 5 years in the future because AVERT relies on historical data and does not account for future changes to the grid. The most recent year of baseline generation and emissions data is 2018, so we can reliably use AVERT to model changes occurring in 2018–2022. However, many of the measures included in AIC's electric portfolio have measures that will continue to save energy through 2042. Opinion Dynamics therefore made two sets of assumptions to estimate emissions impacts for future years 2023–2042. We used AVERT to estimate the emissions reductions at a county level for years 2018–2022 and leveraged historical decreases in avoided emissions factors (tons of pollutant per kWh avoided generation)[14] to forecast emissions reductions at a regional level for years 2023–2043. We describe the process for calculating emission reductions in both time periods in greater detail below.

Emissions Reductions for Analysis Years 2018–2022 (Based on Historical Dispatch Data)

To estimate the emissions reductions resulting from energy savings occurring in years 2018–2022, we completed a separate AVERT run for each year, and entered energy savings as a percent of the 2018 annual fossil load in the Upper Midwest region (257,932 GWh).

Emissions Reductions for Analysis Years 2023–2042 (Accounts for Uncertainty of Future Emissions)

AVERT relies on historical data and does not account for future potential changes to the grid that may impact grid dynamics, such as increased renewable generation, coal plant retirement, changes in fuel prices, or other technological advances (such as demand response and smart grid updates). These future changes may result in fewer emissions per kWh. Using the 2018 baseline data to estimate reductions in years beyond 2022 will likely result in an over-estimate in emissions reductions,[15] but the magnitude and direction of future emissions changes is uncertain.

To estimate emissions reductions in years 2023–2042, we developed two scenarios.

[14] Avoided emissions factors are most representative of EE programs, because unlike average emissions factors, which include emissions from all generation sources, avoided emissions factors only include the emissions from the generation units affected by the EE portfolio.

[15] U.S. EPA. Public Health Benefits per kWh of Energy Efficiency and Renewable Energy

- Scenario A: We assume future avoided emissions per kWh will remain constant. Scenario A represents the maximum potential emissions reductions resulting from AIC's 2018 electric portfolio. To estimate emissions reductions for scenario A, we calculated the SO_2, NO_X, and $PM_{2.5}$ avoided emissions factors (i.e., tons of emissions saved per kWh) for AIC's 2018 electric portfolio in 2022. We then multiplied these avoided emissions factors by the annual kWh savings in each year from 2023–2042.
- Scenario B: We assume avoided emissions per kWh will decrease over time. This represents a more conservative estimate that is likely to better reflect future grid dynamics. We first calculated the average annual percent reduction in AVERT generated SO_2, NO_X, and $PM_{2.5}$ avoided emissions factors (i.e., tons of pollutant avoided per kWh of electricity saved) from 2007–2018 for portfolio EE programs in the Upper Midwest.[16] We then forecasted future avoided emissions factors (2023–2042) by applying the percent change in each emission factor to the 2022 AIC 2018 electric portfolio emissions factors for each consecutive future year. Finally, we multiplied each year of kWh savings by the respective avoided emissions factors to find total emissions reductions for each year from 2023–2042.

3.2.2 Gas Portfolio Emissions Impacts

Opinion Dynamics used a separate approach to estimate emissions reductions resulting from program induced natural gas savings because AVERT is limited to estimating changes in emissions due to reductions in electric consumption. To estimate the emissions reductions from AIC's 2018 nonresidential and residential gas programs, we used the U.S. EPA's recommended natural gas emissions factors. We aggregated the annual portfolio savings and multiplied each year of savings by emissions factors for $PM_{2.5}$, NO_X, SO_2, NH_3, and volatile organic compounds (VOCs). Table 4 displays U.S. EPA recommended natural gas emissions factors, grouped by sector and emissions type. Emissions factors are displayed as pounds per million cubic feet of natural gas.[17,18,19]

Table 4. Natural Gas Emissions Factors

Pollutant	Nonresidential (lb/MMCF)	Residential (lb/MMCF)
$PM_{2.5}$	0.43	0.43
SO_2	0.6	0.6
NO_X	100	94
NH_3	0.49	20

[16] U.S. EPA. 2020. Avoided Emissions Factors Generated from AVERT. https://www.epa.gov/statelocalenergy/avoided-emission-factors-generated-avert-0

[17] U.S. EPA. 1996. Compilation of Air Pollutant Emission Factors, 5th Edition, (AP-42), Volume I: Stationary Point and Area Sources. Research Triangle Park, NC. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors#5thed

[18] U.S. EPA. 2004. Emission Inventory Improvement Program (EIIP). Estimating Ammonia Emissions from Anthropogenic Sources, Draft Final Report. Prepared by E.H. Pechan and Associates, Inc. Research Triangle Park, NC. https://www.epa.gov/sites/production/files/2015-08/documents/eiip_areasourcesnh3.pdf

[19] U.S. EPA. 2020. 2017 National Emissions Inventory Complete Release: Technical Support Document. Research Triangle Park, NC. (NEI) https://www.epa.gov/sites/production/files/2020-04/documents/nei2017_tsd_full_30apr2020.pdf

3.3 Estimate Changes in Air Quality and Monetize Health Impacts

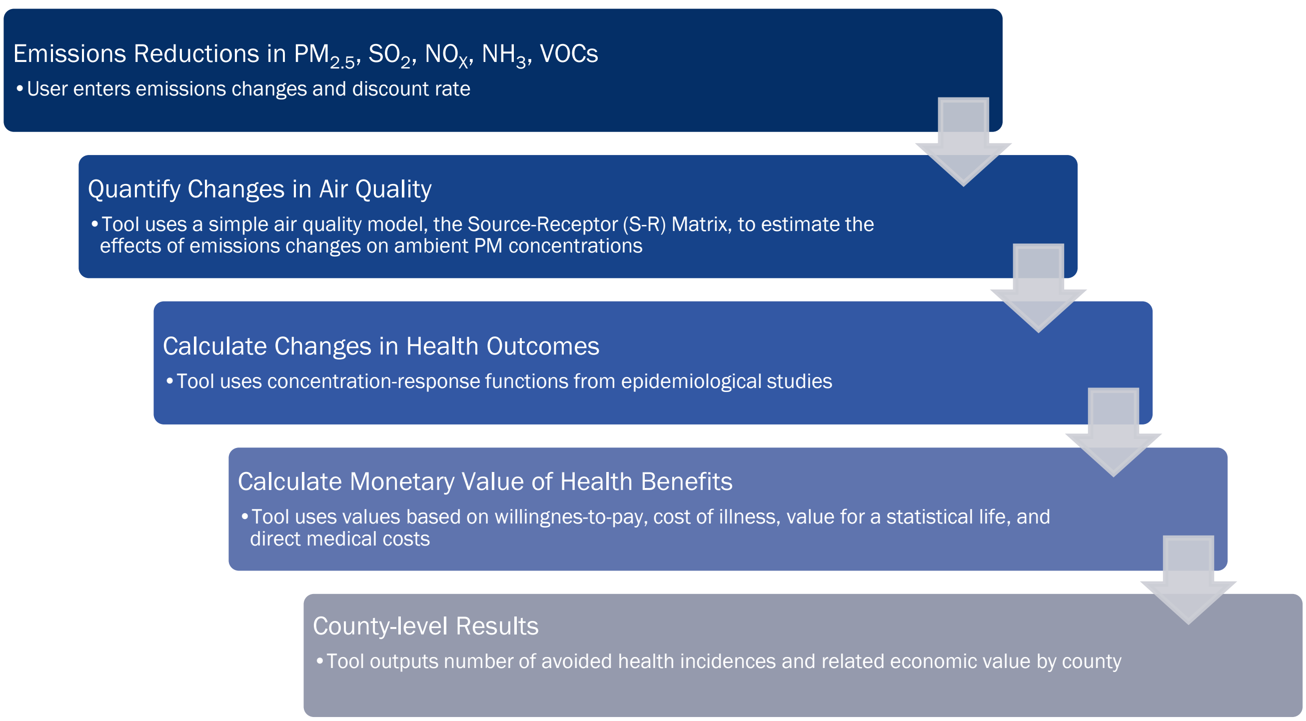
3.3.1 COBRA Model Description

Opinion Dynamics utilized the CO-Benefits Risk Assessment (COBRA) Health Impacts model to estimate changes in ambient air quality, public health impacts, and monetized health benefits resulting from emissions reductions of primary $PM_{2.5}$, SO_2, NO_X, NH_3, and VOCs. COBRA is a peer-reviewed screening tool provided by the U.S. EPA.[20] The COBRA modeling process is summarized in Figure 5.

COBRA uses a reduced form air quality model[21] to estimate how changes in emissions of $PM_{2.5}$ and its precursors will affect ambient $PM_{2.5}$ concentrations in counties throughout the U.S. Next, COBRA uses a series of concentration-response functions to calculate how the change in $PM_{2.5}$ affects health outcomes, and finally, COBRA calculates the value of the avoided health damages valuation functions from the economic literature.[22]

We describe each of these steps below.

Figure 5. Steps to Estimate and Monetize Health Impacts using COBRA



[20] U.S. EPA. 2020. CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool. Version 4.0. https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool. Downloaded June 2020.
[21] COBRA relies on the Phase II Source Receptor (S-R) Matrix, a simplified version of the Climatological Regional Dispersion Model (CRDM), to conduct air quality modeling.
[22] COBRA allows users to input custom valuation functions. However, we used the default functions which are consistent with EPA regulatory analyses.

Quantify Changes in Air Quality

COBRA is based on runs from the EPA's Climatological Regional Dispersion Model (CRDM), a more sophisticated air quality modeling tool, and is calibrated using actual EPA county-level monitoring data. Further, it has been shown to produce results similar to CALPUFF, an advanced air quality model.[23]

Calculate Changes in Health Outcomes

COBRA uses health effect functions from the epidemiological literature to determine the effect of changes in ambient $PM_{2.5}$ concentrations on health impacts. These include number of avoided premature deaths, heart attacks, hospital admissions for respiratory and cardiovascular-related illnesses, incidences of acute bronchitis, upper and lower respiratory symptoms, asthma exacerbations or emergency room visits, minor restricted activity days, and illness-related work loss days.

Calculate Monetary Value of Health Benefits

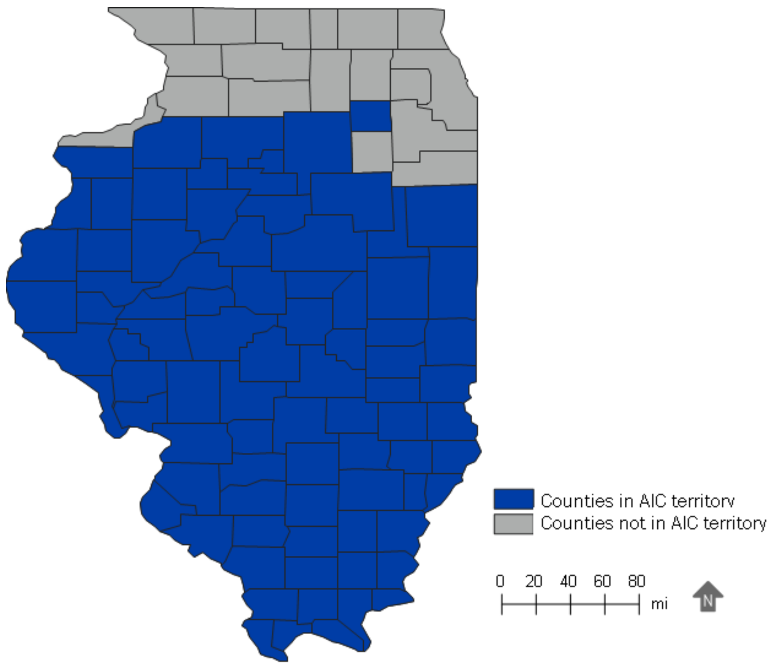
COBRA then estimates the monetary value of these health impacts using valuation functions from the economic literature. While most health effects, like avoided emergency room visits for asthma, occur in the same year as the emissions reductions, avoided mortality and non-fatal heart attacks occur over multiple years.[24] In other words, a decrease in $PM_{2.5}$ exposure in 2018 is expected to result in a decrease in heart attack incidence over a period of 20 years. Therefore, we must discount these benefits back to the year of emissions reductions. We use a custom 2.22% discount rate to ensure consistency with 2018 AIC cost-effectiveness testing. Further detail on the health impact and economic valuation functions used can be found in the COBRA user manual.[25]

3.3.2 COBRA Model Runs Description

COBRA models the improvement in ambient air quality and health outcomes from emission reduction inputs for one of three baseline years: 2016, 2023, or 2028. Each baseline year contains detailed emissions, population, and health incidence estimates. For this analysis, we assume baseline year 2016 is representative of 2018. We conducted COBRA runs at the portfolio level, and ran COBRA separately for AIC's electric, residential gas, and nonresidential gas portfolios.[26] COBRA allows users to specify emissions reductions at the county, state, or national level for 14 emission source categories. In addition, users can select the geography of interest, such as all of Illinois, or a specified group of counties within Illinois. Emissions reductions from gas EE programs occur in the same location where the programs take place (in contrast to electric programs, which have regional emissions impacts). Therefore, for residential and nonresidential gas COBRA runs, we selected Illinois counties in AIC territory, and excluded any territories with 10 or fewer AIC electric or gas customers (Figure 6). We selected the residential and nonresidential gas emissions tiers, respectively.

[23] https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models#calpuff
[24] Avoided mortality accounts for more than 98% of health benefits. The value of a statistical life used in COBRA is based 26 published studies and is used in EPA regulatory analyses. Other health impacts are valued based on willingness-to-pay or the cost of illness.
[25] Ibid.
[26] Because COBRA uses a simplified air quality model, the value of health benefits varies linearly with the magnitude of emissions impacts inputs. Therefore, AIC's electric, residential gas, and nonresidential gas portfolios can be modeled separately.

Figure 6. Selected Counties in Natural Gas COBRA Runs



The method of emissions input for electric programs depended on the analysis year. AVERT produces county-level estimates of emissions reductions formatted as a COBRA input file. Since we used AVERT to estimate emissions reductions through 2022, we uploaded the AVERT outputs directly to COBRA. For analysis years 2023 and beyond, we selected the electric utilities emissions source, and entered the total tons of avoided NO_X, $PM_{2.5}$ and SO_2. Because the electric EE portfolio reduces emissions on a regional scale, we selected counties that are part of the AVERT Upper Midwest region (refer back to Figure 4) and that were predicted to have non-zero emissions reductions in 2018–2022 AVERT results. Because electric emissions from scenario B account for future changes to the grid, we only present health benefit results using these predicted emissions reductions.[27]

3.3.3 Create Benefit Factors

COBRA models air quality changes and health benefits at a county level. For each baseline year, we summed the total health benefits for every county in the U.S. and divided by the energy savings associated with the health benefits for that year to develop portfolio-level benefit-per-kWh or benefit-per-therm factors. Next, to account for the effect of decreasing electric emissions intensities, we applied an emissions factor adjustment.[28] We then applied the 2.22% AIC discount rate to discount the benefit factors back to 2018 benefits. Finally, because COBRA calculates benefits in 2017 dollars, we adjusted to 2018 dollars by applying an inflation rate of 1.91% to each consecutive year's benefits estimates.[29] To estimate total portfolio benefits,

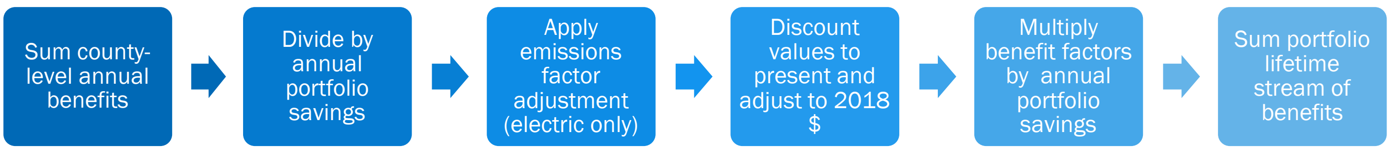
[27] Using the unconstrained emissions estimates from scenario A results in total health benefits that are approximately 13% higher than scenario B.
[28] The emissions factor adjustment reflects the combined impact of declining emissions intensities of SO_2, NO_X, and $PM_{2.5}$, (as described in Section 4.1) on health benefits. We compared the health benefits resulting from a COBRA run with unadjusted emissions to those resulting from adjusted emissions to develop an annual adjustment rate.
[29] Illinois TRM V9.0. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_1_Overview_09252020_Final.pdf

we multiplied the annual savings for the portfolio by the appropriate benefit factor, then summed the annual stream of benefits. These steps are summarized in Figure 7 below.

Table 5. COBRA Baseline Year Used for Portfolio Years 2018 –2042

COBRA Baseline Year	Portfolio Years
2016	2018–2022
2023	2023–2027
2028	2028–2042

Figure 7. Steps to Estimate Portfolio Annual Health Benefits



4. Results

In the sections that follow, we present results of the emissions reduction analysis for electric and gas programs, followed by the corresponding monetized health impacts.

4.1 Emissions Reductions

4.1.1 Electric Portfolio

The results of each AVERT run for the years 2018–2022 are displayed in Table 6 below. The emissions reductions reflect the fuel mix of the Upper Midwest, which generally has higher avoided SO_2 and NO_X emissions rates compared to other regions.[30]

Table 6. AIC 2018 Electric Portfolio Avoided Emissions (2018–2022)

Year	Portfolio Verified Net GWh Savings	Avoided SO_2 (tons)	Avoided NO_X (tons)	Avoided $PM_{2.5}$ (tons)
2018	363.9	343.1	240.1	16.6
2019	356.9	336.6	235.5	16.3
2020	353.8	333.6	233.4	16.2
2021	296.9	280.0	195.9	13.6
2022	294.3	277.6	194.1	13.5

The measures installed as part of AIC's 2018 EE portfolio are expected to save 3,571 GWh over their lifetimes (see Table 3). Table 7 displays the expected emissions reductions resulting from these programs. Scenario B, which accounts for future changes to the grid, results in 8% lower lifetime emissions reductions of $PM_{2.5}$ than in scenario A, which does not account for these changes, and 13 and 12% lower emissions reductions of SO_2 and NO_X, respectively.

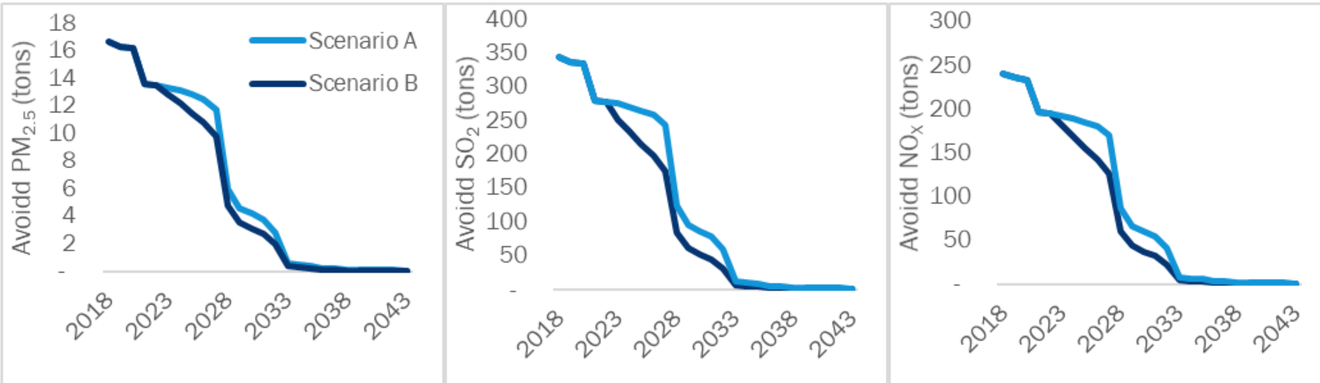
Table 7. AIC 2018 Electric Portfolio Lifetime Emissions Reductions

Pollutant	Scenario A (tons)	Scenario B (tons)	Percent Difference
$PM_{2.5}$	164	151	8%
SO_2	3,371	2,938	13%
NO_X	2,358	2,083	12%

Figure 8 displays the predicted annual emissions reductions in $PM_{2.5}$, SO_2, and NO_X from 2018–2042. While we present both scenario A and scenario B emissions reductions for context, we recommend using scenario B to model future health benefits.

[30] U.S. EPA. 2020. Avoided Emissions Factors Generated from AVERT. https://www.epa.gov/statelocalenergy/avoided-emission-factors-generated-avert-0

Figure 8. AIC 2018 Electric Portfolio Annual Emissions Reductions



4.1.2 Gas Portfolio

AIC's 2018 residential portfolio is expected to save approximately 13,818 thousand therms, and its nonresidential portfolio is expected to save approximately 35,417 thousand therms (see Table 3). Table 8 displays the emissions reductions resulting from these energy savings.

Table 8. AIC 2018 Gas Portfolio Lifetime Emissions Reductions

Pollutant	Residential (tons)	Nonresidential (tons)
$PM_{2.5}$	0.3	0.7
SO_2	0.4	1.0
NO_X	62.6	170.8
NH_3	13.3	0.8
VOCs	3.7	9.4

4.2 Health Benefits

Table 9 and Table 10 present the results of the electric, residential gas, and nonresidential gas COBRA runs. We present results by geography (national vs Illinois only) and both high and low estimates for health benefits associated with the first year and lifetime savings. The high and low estimates of health benefits primarily reflect uncertainty in the impact of changes in exposure to $PM_{2.5}$ on pre-mature mortality and non-fatal heart attacks. AIC's 2018 EE portfolio is expected to produce $92–207 million dollars in national health benefits from 2018–2043. The electric portfolio accounts for approximately 98% of these health benefits. Avoided pre-mature mortality (i.e. the value of a statistical life) is responsible for more than 98% of health benefits.

Table 9. COBRA Results - Portfolio National Health Benefits

Portfolio	First-Year (2018) Health Benefits (Million 2018 $)		Lifetime Health Benefits (Million 2018 $)	
	Low	High	Low	High
Residential Gas	$0.02	$0.04	$0.56	$1.26
Nonresidential Gas	$0.20	$0.46	$1.64	$3.71
Gas Subtotal	*$0.22*	*$0.49*	*$2.20*	*$4.96*

Portfolio	First-Year (2018) Health Benefits (Million 2018 $)		Lifetime Health Benefits (Million 2018 $)	
	Low	High	Low	High
Electric	$11.41	$25.72	$89.53	$201.86
2018 Portfolio Total	**$11.63**	**$26.22**	**$91.73**	**$206.82**

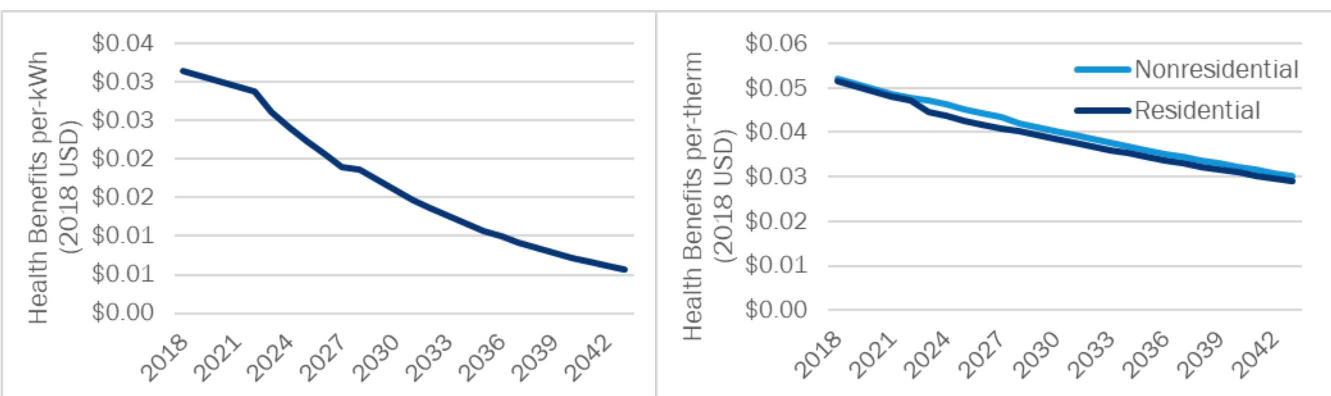
Approximately 15% of the national benefits occur in Illinois; AIC's 2018 EE portfolio is expected to produce $13–$28 million dollars in health benefits in Illinois from 2018–2043. Unlike electric programs, which impact electric generation and emissions on a regional scale, gas programs produce emissions reductions in the same location as energy savings. Therefore, while only 13% of electric benefits occur in Illinois, 33% of gas health benefits occur in Illinois.

Table 10. COBRA Results - Portfolio Illinois Only Health Benefits

Portfolio	First-Year (2018) Health Benefits (Million 2018 $)		Lifetime Health Benefits (Million 2018 $)	
	Low	High	Low	High
Residential Gas	$0.01	$0.01	$0.19	$0.42
Nonresidential Gas	$0.07	$0.15	$0.55	$1.23
Gas Subtotal	*$0.07*	*$0.16*	*$0.73*	*$1.56*
Electric	$1.48	$3.32	$11.83	$26.65
2018 Portfolio Total	**$1.55**	**$3.49**	**$12.56**	**$28.30**

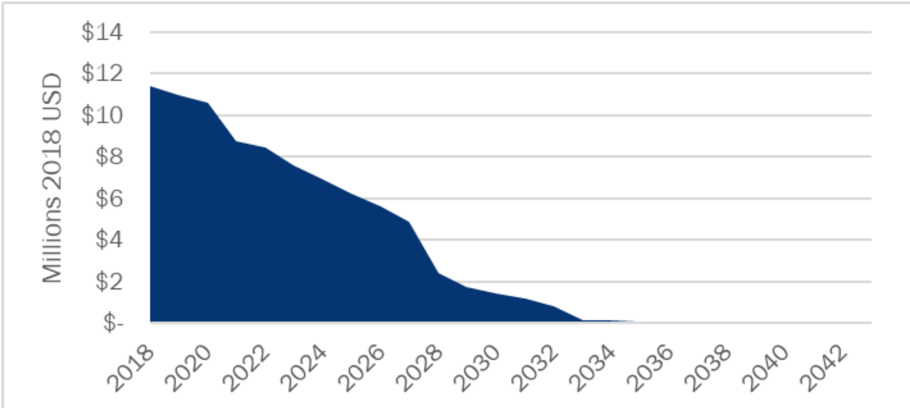
Figure 9 displays the discounted benefit factors for the electric and gas portfolios. These factors represent the value of national health benefits resulting from one saved kWh or therm. Changes in the benefit factors over time are driven by multiple factors, including shifting COBRA baselines, the AIC discount rate, and, for electric factors, decreasing emissions intensity over time.

Figure 9. Electric and Gas Portfolio Emissions Factors (Low Estimate)



Over half (56%) of national health benefits occur in the first five years of analysis (Figure 10). Benefits decline over time for a variety of reasons, and are driven by measure lifetimes, the value of avoided health impacts in the present versus the future (i.e. discount rate), and declining emissions intensities over time.

Figure 10. Lifetime National Societal Health Benefits (Low Estimate) 2018–2042



5. Conclusions, Limitations and Recommendations

5.1 Conclusions

By reducing demand for fossil fuels and improving ambient air quality, EE portfolios can improve air quality and public health. We find benefits are not limited to a single geographic area and are especially sensitive to measure lifetimes and the future fuel mix. While these benefits are often not included in cost-effectiveness testing, we have demonstrated that these benefits are both quantifiable and sizable. The estimates provided in this memo help AIC understand the extent of the societal health benefits stemming from their EE portfolio and allow AIC to include them as inputs into cost-effectiveness tests should they choose to do so.

5.2 Limitations

5.2.1 Emissions Reductions

Unlike sophisticated electricity forecasting models, AVERT does not account for factors such as changes in the fuel mix or changes in electric demand. Therefore, there is significant uncertainty about the future of emissions reductions. We use historical trends in avoided emissions factors to estimate electric emissions reductions beyond 2023, which may over or underestimate emissions. In addition, AVERT assumes that the generation reductions resulting from EE programs only affect fossil fuel EGUs. If generation from other sources (nuclear, solar, etc.) are displaced by EE impacts, this would result in an over-estimation of emissions.

AVERT conducts modeling for one of ten regions which represent relatively autonomous electricity markets and dispatch systems and are meant to account for regional differences in fuel mixes and emissions. However, while AVERT treats each region independently, the grid is interconnected, and electricity transfers occur across regions, which could result in either an over or underestimate of emissions reductions.

Emissions reductions are time sensitive to generation reductions (e.g., peak versus off-peak). Therefore, AVERT requires users to input load impacts on an hourly basis. Because we evaluate energy savings on an annual, rather than hourly, basis, we estimated the timing of load impacts by distributing the energy reductions a percent of baseline generation, which could result in either an under or over-estimate of emissions reductions.

Finally, if measure lives are shorter or longer than estimated, emissions would be over or underestimated, respectively.

5.2.2 Air Quality and Health Benefits

COBRA utilizes a reduced-form air quality model, and thus does not account for much of the complexity of atmospheric $PM_{2.5}$ formation that more sophisticated air quality models do. Therefore, the EPA considers COBRA a screening-level tool. In addition, there is uncertainty surrounding the impact of changes in $PM_{2.5}$ concentrations on human health, specifically, non-fatal heart attacks and adult mortality. COBRA reports low and high estimates for both impacts derived from different sets of assumptions from the epidemiological literature.

There are additional societal benefits of emissions reductions that are outside the scope of this analysis. Reducing the ambient concentration of $PM_{2.5}$ such as visibility improvements, recreational benefits, avoided damages from decreased timber and agricultural yields, among others. In addition, COBRA does not model the health impacts resulting from air quality improvements associated with other pollutants, such as ground level ozone (O_3), and therefore may underestimate total health benefits resulting from emissions reductions. However, according to the EPA, 85 percent of health benefits resulting from air quality regulations are associated with reductions in $PM_{2.5}$.[31] Finally, while it is possible to quantify the reductions in CO_2 resulting from AIC's EE portfolio, we exclude CO_2 from this analysis for several reasons. First, while CO_2 emissions and climate change are associated with public health impacts such as increased heat stress, these impacts are not quantified in COBRA. Furthermore, AIC already applies a carbon adder in their cost-effectiveness testing.[32]

5.3 Recommendations

Opinion Dynamics has produced information for AIC on the value of societal health benefits resulting from its 2018 EE Portfolio. We recommend using scenario B to estimate emissions reductions for years 2023 and beyond, as this scenario assumes a decrease in emissions per kWh over time. This reflects an assumption that the generation of electricity will change over time towards increased reliance on renewable sources for electricity. We provide both high and low estimates for health benefits to demonstrate the full range of possible benefits. We recommend using the mid-point between the high and low benefit estimates for cost-effectiveness testing. While Opinion Dynamics used the most current data available at the time of this analysis, we recommend consideration be given to refreshing the values in the future to leverage most recent available data as AIC continues to use these values in cost-effectiveness testing. [33]

[31] EPA. 2011. The Benefits and Costs of the Clean Air Act from 1990 to 2020. Final Report – Rev. A. April. https://www.epa.gov/sites/production/files/2015-07/documents/fullreport_rev_a.pdf

[32] See "Cost-Effectiveness Table – Oct. Update to Non-Measure Level Inputs" on the Illinois SAG website for further details: https://ilsag.s3.amazonaws.com/TRC_Inputs_Table_All-Utilities_Updated-Oct-2020.xlsx

[33] At the time of this analysis, 2018 was the most recent available baseline year. On September 15, 2020, U.S. EPA released 2019 baseline data, and revised the AVERT modeling regions.

Appendix A. Cost-Effectiveness Inputs

Table 11 displays the annual undiscounted health benefits per kWh or therm values associated with AIC's 2018 electric, residential gas, and nonresidential gas portfolios. Values represent the midpoint between the high and low health benefits estimates.

Table 11. Cost-Effectiveness Inputs

Savings Year	National Health Benefits			Illinois-Only Health Benefits		
	Electric	Residential Gas	Nonresidential Gas	Electric	Residential Gas	Nonresidential Gas
	$/kWh	$/therm	$/therm	$/kWh	$/therm	$/therm
2018	0.0510	0.0837	0.0845	0.0066	0.0286	0.0282
2019	0.0510	0.0837	0.0845	0.0066	0.0286	0.0282
2020	0.0510	0.0837	0.0845	0.0066	0.0286	0.0282
2021	0.0510	0.0837	0.0845	0.0066	0.0286	0.0282
2022	0.0510	0.0837	0.0845	0.0066	0.0286	0.0282
2023	0.0473	0.0808	0.0858	0.0064	0.0268	0.0283
2024	0.0447	0.0808	0.0858	0.0061	0.0268	0.0283
2025	0.0422	0.0808	0.0858	0.0058	0.0268	0.0283
2026	0.0399	0.0808	0.0858	0.0054	0.0268	0.0283
2027	0.0377	0.0808	0.0858	0.0051	0.0268	0.0283
2028	0.0378	0.0814	0.0849	0.0050	0.0270	0.0279
2029	0.0357	0.0814	0.0849	0.0048	0.0270	0.0279
2030	0.0337	0.0814	0.0849	0.0045	0.0270	0.0279
2031	0.0318	0.0814	0.0849	0.0043	0.0270	0.0279
2032	0.0301	0.0814	0.0849	0.0040	0.0270	0.0279
2033	0.0284	0.0814	0.0849	0.0038	0.0270	0.0279
2034	0.0268	0.0814	0.0849	0.0036	0.0270	0.0279
2035	0.0253	0.0814	0.0849	0.0034	0.0270	0.0279
2036	0.0239	0.0814	0.0849	0.0032	0.0270	0.0279
2037	0.0226	0.0814	0.0849	0.0030	0.0270	0.0279
2038	0.0213	0.0814	0.0849	0.0029	0.0270	0.0279
2039	0.0202	0.0814	0.0849	0.0027	0.0270	0.0279
2040	0.0190	0.0814	0.0849	0.0025	0.0270	0.0279
2041	0.0180	0.0814	0.0849	0.0024	0.0270	0.0279
2042	0.0170	0.0814	0.0849	0.0023	0.0270	0.0279
2043	0.0160	0.0814	0.0849	0.0021	0.0270	0.0279

For more information, please contact:

Aaiysha Khursheed, Ph.D.
Principal Consultant

858-401-7638 tel
akhursheed@opiniondynamics.com

7590 Fay Avenue
Suite 406
La Jolla, CA 92037