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This document details the methodology used to calculate the benefits of upgrading Georgia's residential building energy codes from 2015 IECC (with amendments) to both 2021 IECC and Passive House standards. The results on this factsheet were calculated by combining bottom-up building energy modeling with average projections for the evolution of Georgia's electric grid through 2035.

Building Energy Modeling

Energy savings were calculated on a per-building basis and scaled up to reflect the expected rate of new construction in Georgia for the next ten years (i.e., through 2033). Two residential building types are considered: a single-family home and a low-rise multifamily building. The low-rise multifamily building is modeled to contain three stories with 6 apartment units each (for a total of 18 units per multifamily building).

Our modeling accounts for climatic differences in building performance through the use of ASHRAE climate zones. We approximate the percentage of Georgia's population that lies within each climate zone by combining 2022 county population estimates with ASHRAE data on which Georgia counties lie in each climate zone (ASHRAE, 2021; U.S. Census Bureau, 2022, 2023). These estimates are provided in Table 1. For the purposes of this modeling, we assume that the limited number of households in Climate Zone 4A instead reside in its closet geographic in-state neighbor, Climate Zone 3A.

Table 1. Estimate of how much of Georgia's population resides within each ASHRAE climate zone.

Climate Zone	Population	Percentage
2A	1,744,522	15.99%
3A	8,942,567	81.95%
4A	225,787	2.069%

The hourly demand of each building was calculated in EnergyPlus using building prototype models developed and calibrated by Pacific Northwest National Laboratory (PNNL) (U.S. Department of Energy, 2023; U.S. Department of Energy's Building Technologies Office, 2023). We selected models with central heat pump heating systems and slab foundations. These features were chosen to match the most common features of new residential buildings constructed in Georgia since 2010 (see Table 2 and Table 3).

Table 2. Estimated heating system distribution of homes built in Georgia since 2010. Results are drawn from the 2020 Residential Energy Consumption Survey (EIA (U.S. Energy Information Administration), 2023b).

Heating system	Cooling system	Number of homes	Fraction of homes
central heat pump	central ac/hp	217017.426	0.44230659

central gas furnace	central ac/hp	117655.877	0.23979627
electric resistance furnace	central ac/hp	63711.377	0.12985115
no heat	central ac/hp	14993.318	0.03055811
electric baseboard	central ac/hp	13261.068	0.02702759
fuel room heater	central ac/hp	12427.374	0.02532842
other	window/wall unit	9950.269	0.02027980
central heat pump	window/wall unit	9651.284	0.01967043
other	central ac/hp	8693.788	0.01771894
wood or pellet stove	minisplit hp	7910.545	0.01612260
central gas furnace	no cooling	7780.686	0.01585794
no heat	minisplit hp	7596.306	0.01548215

Table 3. Estimated foundation type distribution of homes built in Georgia since 2010. Results are drawn from the 2020 Residential Energy Consumption Survey (EIA (U.S. Energy Information Administration), 2023b).

Foundation	Building type	Number of homes	Fraction of homes
slab	single-family detached	171239.499	0.34900588
basement	single-family detached	51494.091	0.10495091
crawlspace	single-family detached	37602.608	0.07663846
other/NA	single-family detached	24909.743	0.05076893
slab	single-family attached	29968.608	0.06107949
other/NA	single-family attached	6903.728	0.01407059
basement	single-family attached	5402.900	0.01101173
other/NA	manufactured home	32572.763	0.06638706
other/NA	5+units	123806.901	0.25233277
other/NA	2-4 units	6748.477	0.01375418

We modified the base IECC 2015 prototype models developed by PNNL in order to account for Georgia-specific amendments embedded in the state’s current building energy code. These changes are:

- Window solar heat gain coefficient (SHGC) set to 0.27 (instead of 0.25),
- Window U-factor in Climate Zone 2 is 0.35 (instead of 0.4),
- Window U-factor for framed walls in Climate Zone 3 is 0.084 (instead of 0.06), corresponding to R-13 insulation (instead of R-20), modeled by reducing the thickness of insulation/framing by 2 inches.

PNNL's IECC 2021 prototype building models were left unchanged, except for our modifying the window SHGC and U-factor default values to be at the code limit.

We developed beyond-code building energy models subject to Passive House standards by modifying the (modified) IECC 2021 building prototype model in the following ways (Phius, 2023):

- Refrigerator uses 644 kWh/yr
- Clothes washer uses 157 kWh/yr
- Lighting efficacy 83 lumens/watt
- Exterior wall U-factor 0.048 in Climate Zone 2A and 0.028 in Climate Zone 3A (see Appendix C of (Franconi et al., 2023))
- Ceiling U-factor 0.023 in Climate Zone 2A and 0.21 in Climate Zone 3A
- Window U-factor 0.24 (Phius, 2021)
- HSPF 9.6
- SEER 18.0
- HPWH UEF 3.5 (Phius Certification Guide 3.2 states that UEF must be at least median Energy Star)

There were several Passive House requirements that we did not model. The most common reason was an inability or elevated difficulty in translating these requirements into model modifications within the EnergyPlus software. These include:

- Airtightness — Passive House includes strict airtightness requirements, which we did not include because energy models are extremely sensitive to changes in infiltration and do not necessarily represent what is possible in the real world
- Heating and cooling
    - Phius requires certain limits for heating and cooling to be met using WUFI building energy modeling software. This modeling would normally be conducted as part of the design process for Phius but was beyond the scope of this project. Instead, our multifamily models use the same parameters as our single-family models.
    - Passive House certification requires energy recovery ventilation and various measures to reduce heat loss from hot water pipes and drains. We did not include these measures, which makes our stated results somewhat conservative.
- Slab insulation
- Maximum ductwork length
- Fenestration moisture resistance

The magnitude of the per-building savings revealed through building energy modeling are scaled to estimate their impact across the entire state of Georgia. Table 4 reports the number of new single-family and multifamily buildings that are expected be constructed in Georgia through 2033. These projections only extend through 2028. For the following years we assume that the number of new builds equals the average of the annual new builds between the years

2024 and 2028. To determine the number of low-rise multifamily buildings, we multiply the number of expected multifamily family buildings by a constant factor representing the fraction of low-rise multifamily construction (relative to total multifamily), which most recently was 0.78.

Table 4. Number of single-family homes and low-rise multifamily buildings expected to be constructed in Georgia each year from 2024 to 2033. Forecasts were developed by Moody's Analytics in 2023 and reconciled to internal assumptions by Owens Corning (Moody's Analytics, 2023).

Year	Single-family	Low-rise multifamily
2024	50,147	12,405
2025	53,705	11,988
2026	55,197	12,551
2027	54,654	12,426
2028	52,966	12,070
2029–2033	53,334	12,288

There are approximately one hundred utilities in the state of Georgia, the vast majority of which are municipal utilities and cooperatives. There is only one investor-owned utility, Georgia Power, which served 2,315,910 electric residential customers in 2021 (EIA (U.S. Energy Information Administration), 2022). That represents about 59.6% of Georgia's total households, so we use this percentage when we need to translate between values relevant for Georgia Power versus the State of Georgia as a whole.

Fact Sheet Assumptions and Calculations

The savings realized from updating building energy codes are calculated every hour for a single year, and are then extrapolated into the future. More specifically, each run of EnergyPlus (for a single building type in a single climate zone) results in 8760 hourly demand values for that building. These savings are calculated under 2015 IECC (with Georgia amendments), 2021 IECC, and Passive House requirements. The demand savings achieved through the 2021 IECC and Passive House updates are calculated by subtracting their computed hourly demand values from the 2015 IECC baseline case.

Building operations (and their resulting loads) are assumed to be the same every year. Building load depends on weather, and we assume Georgia's buildings are subjected to a typical meteorological year (TMY3) in each climate zone. As a result, our results do not reflect additional savings that might accrue during extreme weather years that would have otherwise increased temperature-dependent loads like water heating and thermal space conditioning.

We assume that the per-building savings achieved by virtue of updated building energy codes will persist for 40 years. In other words, we calculate the lifetime electricity savings attributable to having a building built to updated standards by taking the single-year savings and multiplying it by 40. Each year, a different number of new construction buildings will be built. We choose to count the lifetime savings of all new construction built during a 10-year period (i.e., 2024–2033). The implicit assumption here is that in the absence of Georgia updating its building codes immediately, they will next choose to do 10 years from now by adopting IECC 2021 standards. In other words, our assumed counterfactual (to our codes proposal) is that Georgia will *eventually* update its codes, thereby making any savings that occur in buildings constructed after 2033 bound to happen regardless of what Georgia does with its building energy codes in the near-term.

Energy

To calculate the statewide energy savings, we begin by computing a weighted average of our per-building savings in each climate zone. Savings modeled in Climate Zone 3A are assigned a weighting factor of 0.84 (to reflect the percentage of Georgia's buildings in Climate Zones 3A and 4A) while buildings modeled in Climate Zone 2A are assigned a weighting factor of 0.16. Those per-building savings are scaled by the number of new builds in each year (see Table 4), then multiplied by 40 to return lifetime energy savings. Table 5 shows the annual electric energy savings achieved for single-family homes under IECC 2021, Table 6 shows the same for homes built to Passive House standards, while Table 7 shows the annual electricity savings for low-rise multifamily buildings under both IECC 2021 and Passive House standards.

Table 5. Lifetime electricity savings that would result from updating Georgia's current residential building energy code to IECC 2021. Each cell contains the lifetime savings from all new single-family home building in the indicated year and climate zone. In addition to our base savings case (heat pump plus slab foundation), we also present savings to buildings heated with electric resistance heating and in homes with heated basements. All savings are presented in Gigawatt-hours (GWh).

Climate Zone	3A				2A			
	Electric resistance + slab	Gas furnace + heated basement	Gas furnace + slab	**Heat pump + slab**	Electric resistance + slab	Gas furnace + heated basement	Gas furnace + slab	**Heat pump + slab**
2024	6,254	1,973	1,849	**5,430**	375	276	266	**508**
2025	6,428	2,028	1,900	**5,581**	385	284	274	**522**
2026	6,365	2,008	1,882	**5,526**	382	281	271	**517**
2027	6,168	1,946	1,824	**5,355**	370	272	263	**501**
2028	6,211	1,960	1,836	**5,393**	372	274	264	**504**
2029–2033	6,254	1,973	1,849	**5,430**	375	276	266	**508**
Cumulative savings	62,112	19,596	18,362	**53,926**	3,723	2,743	2,643	**5,041**

Table 6. Same information as Table 5, except savings are those that accrue to single-family homes built to Passive House standards. These buildings are assumed to be conditioned with heat pumps and have a slab foundation (i.e., no basement).

Climate Zone	3A	2A
2024	9,971	1,595
2025	10,678	1,708

2026	10,975	1,755
2027	10,867	1,738
2028	10,531	1,684
2029–2033	10,604	1,696
Cumulative savings	106,044	16,960

Table 7. Lifetime electricity savings that would result from updating Georgia's current residential building energy code to IECC 2021 or Passive House standards. Each cell contains the lifetime savings from all new low-rise multifamily buildings in the indicated year and climate zone. All savings are presented in Gigawatt-hours (GWh).

Climate Zone	3A		2A	
	IECC 2021	Passive House	IECC 2021	Passive House
2024	13,402	21,441	1,734	3,348
2025	12,952	20,719	1,676	3,236
2026	13,560	21,693	1,754	3,388
2027	13,425	21,477	1,737	3,354
2028	13,040	20,861	1,687	3,258
2029–2033	13,276	21,238	1,718	3,317
Cumulative savings	132,758	212,380	17,175	33,168

The total lifetime electricity savings that would accrue by upgrading to IECC 2021 building energy codes is 208,900 GWh. The savings that would accrue by upgrading to Passive House building standards is 368,551 GWh (i.e., 123,003 GWh and 245,548 GWh from single-family and low-rise multifamily, respectively). For the better part of the last 20 years, Georgia's Vogtle nuclear plant, which has been newsworthy due to its billions of dollars in cost overruns, has generated just shy of 20 GWh of electricity per year (EIA (U.S. Energy Information Administration), 2023a). That allows us to make the following statement on the fact sheet:

> *Buildings will save over 200 Gigawatt hours of electricity over their lifetimes. That is equivalent to more than 10 years' worth of generation from Georgia's Vogtle nuclear power plant.*

To make the similar statement of energy savings for Passive House, we have used an average nameplate capacity of conventional steam coal power plants of 788 MW, an average coal plant capacity factor of 0.499, and average transmission and distribution losses of 6%. Cast in this way, the annual energy savings from single-family and low-rise multifamily buildings built to Passive House standards is within about 5% of the energy produced by one and two of these coal power plants per year, respectively.

Utility Bills

We estimate utility bill savings by assuming that all Georgia ratepayers are subject to the electric rates of Georgia Power, by far the state's largest utility. According to Georgia Power's residential electric service tariff, the basic winter rate for all energy is $0.062404/kWh. For summer (i.e., June–September), the rates are:

Basic Service Charge..$0.4603 per day
First 650 kWh...6.6678¢ per kWh
Next 350 kWh...11.0748¢ per kWh
Over 1000 kWh...11.4625¢ per kWh

We calculate the utility bill savings by weighting the utility costs in each climate zone. Under 2015 IECC code that works out to be $0.84 * \$1{,}605 + 0.16 * \$1{,}613 = \$1{,}606.50$ per single-family home per year. Doing a similar calculation for IECC 2021 code yields $1,388.50 per single-family home. **That amounts to a utility bill savings of $218 per single-family home per year.**

The savings per multifamily building are going to be larger because they have multiple apartment units within them. Using the same math, the costs under IECC 2015 and 2021 codes are, respectively, $16,210.70 and $13,814.00. That's an annual savings of $2,396.78 per building, or a **savings of $133.15 per unit per year.**

We can multiply these savings by the number of buildings and by the number of years (40) that we expect the savings to be delivered. Cumulatively, that equates to $4.65 billion in savings for single-family homes and $11.78 billion in savings for multifamily buildings. **In total, that leads to lifetime utility bills savings of $16.43 billion.**

We use the same methodology to estimate the utility bill savings under Passive House standards. These results are summarized in Table 8.

Table 8. Utility bills savings that would be seen in new buildings constructed to Passive House standards rather than IECC 2015 (with Georgia amendments).

	Single-family	Low-rise Multifamily	Total
Per building	$460.06	$3,960.87	
Per unit	$460.06	$220.05	
40-year savings	$9,814,699,211	$19,468,468,224	$29,283,167,435

Electricity System Benefits

We report electricity system benefits of updated building energy codes on the fact sheet in two ways. First, we estimate peak load reductions by assuming load savings across the state of Georgia are representative of those that would be experienced by Georgia Power. In other words, we're assuming that the peak load reduction in Georgia Power's service territory on a percentage basis is the same as that outside its service territory.

To do this, we draw upon the hourly demand profiles for balancing authorities as reported as part of FERC Form 714. The peak demand Georgia Power's balancing authority in 2020 was

15,831 MW, which occurred on July 20 between 3pm–4pm. According to the Planning Area Forecast Demand file, Georgia Power expects their peak load to stay roughly even through 2030 with peak summer and winter forecasts of 15,913 MW and 15,306 MW, respectively. The percentage reduction in peak demand reported on the fact sheet is calculated in 2033, or the year in which all buildings we assume will be built to updated IECC 2021 or Passive House standards will have been constructed. We subtract the annual load reduction in each hour (scaled by a factor of 0.596 to transform the Georgia total load reduction to the portion experienced in Georgia Power's service territory) from Georgia Power's 2020 reported load to generate a new hourly load profile. The peak load from that new load profile is subtracted from 15,831 to calculate the peak load reduction, which is then converted into and reported as a percentage reduction.

To estimate the future avoided electricity system costs we use the Cambium tool (Gagnon et al., 2023). We assume a Mid-case scenario for our grid evolution pathway. This scenario is described in the Cambium documentation as, "central estimates for inputs such as technology costs, fuel prices, and demand growth. No nascent technologies. Electric sector policies as they existed in September 2022. IRA's PTC and ITC are assumed to not phase out." For this scenario, Cambium reports hourly emission, cost, and operational data every five years through 2050 under least-cost hourly dispatch assumptions.[1] The Cambium cost metrics (all measured in $/MWh) of interest for our present analysis are:

Energy cost: marginal cost of the additional energy to serve an increase in end-use load

Capacity cost: marginal cost of the additional firm generation capacity and transmission infrastructure needed to maintain resource adequacy when end-use load is increased

The avoided cost benefits for IECC 2021 are provided in Table 9, while the benefits for Passive House are provided in Table 10. Because Cambium only reports avoided cost data in 5-year increments, for the fact sheet we take the average of the avoided costs in 2030 and 2035 to estimate the avoided costs in 2033.

Table 9. Avoided energy and capacity costs in Georgia achieved through updating residential building energy codes to IECC 2021.

	2030	2035
Single-family	$53,255,054.79	$57,597,360.70
Low-rise multifamily	$138,305,568.95	$150,864,553.08
Total	$191,560,624	$208,461,914

[1] Load growth assumptions in Cambium are based on the EIA's Annual Energy Outlook 2022 reference scenario for electricity demand growth rate. Electricity generation technology costs are based on the 2022 Annual Technology Baseline moderate projections.

Table 10. Avoided energy and capacity costs in Georgia achieved through updating residential building energy codes to the Passive House standard.

	2030	2035
Single-family	$121,557,197.95	$133,966,693.49
Low-rise multifamily	$244,625,513.07	$271,807,783.60
Total	$366,182,711	$405,774,477

Air Quality and Health Benefits

We evaluate the air quality impacts in terms of five air pollutants that can have a direct negative impact on human health—sulfur dioxide (SO_2), nitrogen oxides (NO_x), fine particular matter ($PM_{2.5}$), volatile organic compounds (VOCs), and ammonia (NH_3)—and carbon dioxide (CO_2). Using the hourly load reductions, we statistically sample the U.S. Environmental Protection Agency's (EPA) Air Markets Program Data to estimate the resulting emissions benefits. We do this using the EPA's AVERT tool, which splits the contiguous United States into 14 independent electricity regions, each of which is organized around one or more balancing authorities. The results we report are for the Southeast grid region, which includes all but the northern-most sections of Georgia and Alabama, the western panhandle of Florida, and the southeast corner of Mississippi.

Table 11 shows the expected emissions reductions that would result from updating Georgia's building energy code to IECC 2021. The percentage reduction in pollutant emissions is reported in Table 12.

Table 11. Total projected emissions reduction from fossil generation fleet in the Southeast U.S. if new single-family and low-rise multifamily buildings are constructed to IECC 2021 standards.

	Original	Post Change	Change
Generation (MWh)	177,023,500	171,407,950	-5,615,560
Heat Input (MMBtu)	1,510,683,470	1,460,016,490	-50,666,980
Total Emissions from Fossil Generation Fleet (short tons)			
SO_2	11,420	11,000	-420
NO_X	41,710	39,910	-1,810
Ozone season NO_x	18,200	17,450	-740
CO_2	112,593,290	108,989,670	-3,603,630
$PM_{2.5}$	3,800	3,640	-150
VOCs	1,950	1,890	-70
NH_3	2,100	2,010	-90
AVERT-derived Emission Rates (short tons/MWh)	Average Fossil		Marginal Fossil
SO2	0.000		0.000
NO_X	0.000		0.000
Ozone season NO_x	0.000		0.000
CO_2	0.636		0.642
$PM_{2.5}$	0.000		0.000
VOCs	0.000		0.000
NH_3	0.000		0.000

Table 12. Total projected reduction in pollutants from the fossil generation fleet in the Southeast U.S. if new single-family and low-rise multifamily buildings are constructed to IECC 2021 standards.

Pollutant	Reduction
SO_2	3.70%
NO_x	4.33%
$PM_{2.5}$	4.03%
VOCs	3.38%
NH_3	4.23%

We translate these emission reductions into health benefits using EPA's CO-Benefits Risk Assessment Health Impacts Screening and Mapping (COBRA) tool. In order to quantify the economic impacts, we need to specify a discount rate. COBRA uses a discount rate to express future economic values in present terms because not all health effects and associated economic values occur in the year of analysis. (CORBRA assumes changes in adult mortality and non-fatal heart attacks occur over a 20-year period.)

Because changes in air quality can impact multiple locations due to the movement of emissions over state lines, health impacts are reported for the entire contiguous United States. In Table 13, positive numbers indicate annual reductions in the number of cases and the associated costs avoided. Negative numbers signify increases in the number of cases and associated costs accrued. The following description from inside the COBRA tool further explains the output:

> *Incidence refers to the number of new cases of a health endpoint over a specified period of time. The change in incidence is not necessarily a whole number because COBRA calculates statistical risk reductions which are then aggregated over the population. For example, if 150,000 people experience a 0.001% reduction in mortality risk, this would be reported as a 1.5 "statistical lives saved." This statistical life, and its associated monetary value, represents the sum of many small risk reductions and does not correspond to the loss or value of an individual life. COBRA calculates the monetary value of each health endpoint based on data on the health care costs of the health endpoint and research into the willingness to pay to avoid the health endpoint. Results are presented in 2017 dollars.*

Table 13. Reduction in incidence of negative health outcomes and avoided health expenses that would result from updating Georgia's residential building energy code to IECC 2021

Health Endpoint	Change in Incidence (cases, annual)		Monetary Value (dollars, annual) – 3% discount rate		Monetary Value (dollars, annual) – 7% discount rate	
	Low	High	Low	High	Low	High
Mortality *	0.832	1.885	$9,101,773	$20,627,608	$8,106,665	$18,372,368
Nonfatal Heart Attacks *	0.100	0.933	$16,417	$152,545	$15,330	$142,448
Infant Mortality	0.005	0.005	$61,220	$61,220	$61,219	$61,219
Hospital Admits, All Respiratory	0.230	0.230	$8,300	$8,300	$8,300	$8,300
Hospital Admits, Cardiovascular **	0.235	0.235	$12,037	$12,037	$12,037	$12,037
Acute Bronchitis	1.100	1.100	$679	$679	$679	$679
Upper Respiratory Symptoms	19.883	19.883	$850	$850	$849	$849
Lower Respiratory Symptoms	13.984	13.984	$378	$378	$378	$378
Emergency Room Visits, Asthma	0.457	0.457	$257	$257	$257	$257
Asthma Exacerbation	20.820	20.820	$1,545	$1,545	$1,545	$1,545
Minor Restricted Activity Days	600.709	600.709	$52,661	$52,661	$52,660	$52,660
Work Loss Days	101.679	101.679	$20,355	$20,355	$20,354	$20,354

Total Health Effects			$9,276,472	$20,938,435	$8,280,273	$18,673,094

[*] The Low and High values represent differences in the methods used to estimate some of the health impacts in COBRA. For example, high and low results for avoided premature mortality are based on two different epidemiological studies of the impacts of $PM_{2.5}$ on mortality in the United States.
[**] Except heart attacks.

The health benefits of upgrading to a Passive House standard are shown in the following tables. Tables 14–16 show the results for single-family homes, Tables 17–19 shows the results for low-rise multifamily buildings, and Tables 20–22 show the combined residential results.

Table 14. Total projected emissions reduction from fossil generation fleet in the Southeast U.S. if new single-family buildings are constructed to Passive House standards.

	Original	Post Change	Change
Generation (MWh)	177,023,500	173,719,180	-3,304,330
Heat Input (MMBtu)	1,510,683,470	1,480,348,490	-30,334,990
Total Emissions from Fossil Generation Fleet (lb)			
SO_2	22,835,650	22,339,290	-496,360
NO_X	83,422,800	81,213,900	-2,208,910
Ozone season NO_x	36,395,900	35,519,070	-876,820
CO_2	225,186,588,880	220,895,205,690	-4,291,382,150
$PM_{2.5}$	7,591,830	7,405,290	-186,540
VOCs	3,904,720	3,825,510	-79,200
NH_3	4,201,670	4,090,970	-110,700
AVERT-derived Emission Rates (lb/MWh)	Average Fossil		Marginal Fossil
SO2	0.129		0.150
NO_X	0.471		0.668
Ozone season NO_x	0.427		0.265
CO_2	1,272.072		1,298.715
$PM_{2.5}$	0.043		0.056
VOCs	0.022		0.024
NH_3	0.024		0.034

Table 15. Total projected reduction in pollutants from the fossil generation fleet in the Southeast U.S. if new single-family buildings are constructed to Passive House standards.

Pollutant	Reduction
SO_2	2.17%
NO_x	2.65%
$PM_{2.5}$	2.46%
VOCs	2.03%
NH_3	2.63%

Table 16. Reduction in incidence of negative health outcomes and avoided health expenses that would result from single-family buildings from updating Georgia's residential building energy code to Passive House standards.

Health Endpoint	Change in Incidence (cases, annual)		Monetary Value (dollars, annual) – 3% discount rate		Monetary Value (dollars, annual) – 7% discount rate	
	Low	High	Low	High	Low	High
Mortality [*]	1.651	3.741	$18,061,519	$40,932,112	$16,087,107	$36,457,581

Nonfatal Heart Attacks *	0.199	1.852	$32,569	$302,622	$30,415	$282,616
Infant Mortality	0.01	0.01	$121,100	$121,100	$121,100	$121,100
Hospital Admits, All Respiratory	0.457	0.457	$16,486	$16,486	$16,486	$16,486
Hospital Admits, Cardiovascular **	0.466	0.466	$23,876	$23,876	$23,876	$23,876
Acute Bronchitis	2.174	2.174	$1,342	$1,342	$1,342	$1,342
Upper Respiratory Symptoms	39.303	39.303	$1,679	$1,679	$1,679	$1,679
Lower Respiratory Symptoms	27.642	27.642	$746	$746	$746	$746
Emergency Room Visits, Asthma	0.902	0.902	$508	$508	$508	$508
Asthma Exacerbation	41.156	41.156	$3,054	$3,054	$3,054	$3,054
Minor Restricted Activity Days	1,186.80	1,186.80	$104,040	$104,040	$104,040	$104,040
Work Loss Days	200.863	200.863	$40,210	$40,210	$40,210	$40,210
Total Health Effects			$9,276,472	$18,407,130	$41,547,777	$16,430,566

Table 17. Total projected emissions reduction from fossil generation fleet in the Southeast U.S. if new low-rise multifamily buildings are constructed to Passive House standards.

	Original	Post Change	Change
Generation (MWh)	177,023,500	170,423,440	-6,600,060
Heat Input (MMBtu)	1,510,683,470	1,450,549,880	-60,133,590
Total Emissions from Fossil Generation Fleet (lb)			
SO_2	22,835,650	21,850,040	-985,610
NO_X	83,422,800	79,128,010	-4,294,800
Ozone season NO_x	36,395,900	34,509,460	-1,886,440
CO_2	225,186,588,880	216,654,587,520	-8,531,999,690
$PM_{2.5}$	7,591,830	7,224,460	-367,370
VOCs	3,904,720	3,747,490	-157,220
NH_3	4,201,670	3,986,250	-215,420
AVERT-derived Emission Rates (lb/MWh)	Average Fossil		Marginal Fossil
SO2	0.129		0.149
NO_X	0.471		0.651
Ozone season NO_x	0.427		0.286
CO_2	1,272.072		1,292.715
$PM_{2.5}$	0.043		0.056
VOCs	0.022		0.024
NH_3	0.024		0.033

Table 18. Total projected reduction in pollutants from the fossil generation fleet in the Southeast U.S. if new low-rise multifamily buildings are constructed to Passive House standards.

Pollutant	Reduction
SO_2	4.32%
NO_x	5.15%
$PM_{2.5}$	4.84%
VOCs	4.03%
NH_3	5.13%

Table 19. Reduction in incidence of negative health outcomes and avoided health expenses that would result from low-rise multifamily buildings from updating Georgia's residential building energy code to Passive House standards.

Health Endpoint	Change in Incidence (cases, annual)		Monetary Value (dollars, annual) – 3% discount rate		Monetary Value (dollars, annual) – 7% discount rate	
	Low	High	Low	High	Low	High
Mortality *	3.259	7.386	$35,663,960	$80,823,442	$31,765,322	$71,988,154
Nonfatal Heart Attacks *	0.394	3.657	$64,309	$597,545	$60,058	$558,043
Infant Mortality	0.02	0.02	$239,069	$239,069	$239,069	$239,069

Hospital Admits, All Respiratory	0.903	0.903	$32,556	$32,556	$32,556	$32,556
Hospital Admits, Cardiovascular **	0.919	0.919	$47,144	$47,144	$47,144	$47,144
Acute Bronchitis	4.292	4.292	$2,649	$2,649	$2,649	$2,649
Upper Respiratory Symptoms	77.586	77.586	$3,315	$3,315	$3,315	$3,315
Lower Respiratory Symptoms	54.567	54.567	$1,474	$1,474	$1,474	$1,474
Emergency Room Visits, Asthma	1.781	1.781	$1,004	$1,004	$1,004	$1,004
Asthma Exacerbation	81.245	81.245	$6,029	$6,029	$6,029	$6,029
Minor Restricted Activity Days	2,342.72	2,342.72	$205,374	$205,374	$205,374	$205,374
Work Loss Days	396.498	396.498	$79,374	$79,374	$79,374	$79,374
Total Health Effects			$36,346,256	$82,038,973	$32,443,366	$73,164,183

Table 20. Total projected emissions reduction from fossil generation fleet in the Southeast U.S. if new single-family and low-rise multifamily buildings are constructed to Passive House standards.

	Original	Post Change	Change
Generation (MWh)	177,023,500	167,116,120	-9,907,380
Heat Input (MMBtu)	1,510,683,470	1,420,683,530	-89,999,940
Total Emissions from Fossil Generation Fleet (lb)			
SO_2	22,835,650	21,405,060	-1,430,590
NO_X	83,422,800	77,038,740	-6,384,070
Ozone season NO_x	36,395,900	33,662,640	-2,733,260
CO_2	225,186,588,880	212,430,569,510	-12,756,020,460
$PM_{2.5}$	7,591,830	7,043,730	-548,100
VOCs	3,904,720	3,670,030	-234,690
NH_3	4,201,670	3,880,030	-321,640
AVERT-derived Emission Rates (lb/MWh)	Average Fossil		Marginal Fossil
SO2	0.129		0.144
NO_X	0.471		0.644
Ozone season NO_x	0.427		0.276
CO_2	1,272.072		1,287.527
$PM_{2.5}$	0.043		0.055
VOCs	0.022		0.024
NH_3	0.024		0.032

Table 21. Total projected reduction in pollutants from the fossil generation fleet in the Southeast U.S. if new single-family and low-rise multifamily buildings are constructed to Passive House standards.

Pollutant	Reduction
SO_2	6.26%
NO_x	7.65%
$PM_{2.5}$	7.22%
VOCs	6.01%
NH_3	7.66%

Table 22. Reduction in incidence of negative health outcomes and avoided health expenses that would result from single-family and low-rise multifamily buildings from updating Georgia's residential building energy code to Passive House standards.

Health Endpoint	Change in Incidence (cases, annual)		Monetary Value (dollars, annual) – 3% discount rate		Monetary Value (dollars, annual) – 7% discount rate	
	Low	High	Low	High	Low	High
Mortality *	4.797	10.871	$52,493,902	$118,964,740	$46,755,483	$105,960,001
Nonfatal Heart Attacks *	0.579	5.383	$94,661	$879,565	$88,402	$821,408
Infant Mortality	0.029	0.029	$352,146	$352,146	$352,146	$352,146
Hospital Admits, All Respiratory	1.329	1.329	$47,908	$47,908	$47,908	$47,908
Hospital Admits, Cardiovascular **	1.353	1.353	$69,399	$69,399	$69,399	$69,399

Acute Bronchitis	6.324	6.324	$3,902	$3,902	$3,902	$3,902
Upper Respiratory Symptoms	114.302	114.302	$4,883	$4,883	$4,883	$4,883
Lower Respiratory Symptoms	80.389	80.389	$2,171	$2,171	$2,171	$2,171
Emergency Room Visits, Asthma	2.624	2.624	$1,479	$1,479	$1,479	$1,479
Asthma Exacerbation	119.691	119.691	$8,882	$8,882	$8,882	$8,882
Minor Restricted Activity Days	3,451.76	3,451.76	$302,598	$302,598	$302,598	$302,598
Work Loss Days	584.214	584.214	$116,952	$116,952	$116,952	$116,952
Total Health Effects			$53,498,885	$120,754,626	$47,754,207	$107,691,730

Carbon Reductions

The carbon dioxide reductions that would result from updated building energy standards are also reported by AVERT in Table 11, Table 14, Table 17, and Table 20. Those reductions are summarized in Table 23. The reported reductions are that would result each year from the full load reduction achieved by improved energy codes in 2033. Emissions reductions are reflective of the current electric grid and do not account for any changes in the distribution of grid resources that could occur over the next ten years.

Table 23. Annual carbon dioxide reductions expected to result from updated building energy standards starting in 2033.

Updated building energy standard		Single-family	Low-rise multifamily	Total
IECC 2021	CO_2 reduction (million U.S. tons)	1.02	2.58	3.60
	Equivalent gasoline-powered passenger vehicles driven for one year	205,888	520,840	726,754
Passive House	CO_2 reduction (million U.S. tons)	2.15	4.27	6.38
	Equivalent gasoline-powered passenger vehicles driven for one year	433,164	861,203	1,287,568

In our conversion between avoided emissions and passenger vehicles, we define “passenger vehicle” as any 2-axle, 4-tire vehicle including passenger cars, vans, pickup trucks, and sports utility vehicles. We assume the weighted average combined fuel economy of these vehicles is 22.9 miles per gallon and that the average vehicle travels 11,520 miles in a year (EPA (U.S. Environmental Protection Agency), 2022; FHWA (Federal Highway Administration), 2021). We assume that these vehicles are powered by gasoline with an emissions rate of 8.9 kg of carbon dioxide per gallon. In combination, these numbers yield a conversion factor of 4,490 kg of CO_2 equivalent per vehicle per year.

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