Quantifying Green House Gas (GHG) Emissions for Small Businesses in the US: Effective Policies to Reduce GHG

Quantifying Green House Gas (GHG) Emissions for Small Businesses in the US:

Effective Policies to Reduce GHG

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Abstract

Small to medium sized enterprises (SMEs) make up 99% of businesses in the United States (US) and account for almost half of GDP. Collectively, SMEs play a large role in the economy and should play a large role in sustainability as well. SMEs might consume more energy than corporations and have the potential to reduce more greenhouse gases. Even though there has been growing pressure on corporations to reduce greenhouse gas (GHG) emissions, SMEs have not been included in the sustainability conversation, perhaps because it’s been difficult to include them, or due to the perception of their irrelevance. Governments and investors have instead put pressure on corporations, which also have multiple reporting tools, tax breaks and incentives to help urge them to participate. It’s hard for SMEs to engage in sustainability initiatives because they can be costly and require time and human resources. Because few small businesses are engaged in sustainability efforts, there is little information on how they contribute to climate change.

This research aimed to quantify GHG emissions from SMEs in the US and evaluate future GHG emissions and reductions based on a variety of scenarios by addressing four main questions: What percentage of GHG emissions can be attributed to SMEs in the US? If every SME incrementally reduced GHG emissions, how much change would be seen? How much GHG can be avoided under different incentive scenarios? And what policies and incentives are available to motivate SMEs to participate? I aimed to test these hypotheses: 1) If small businesses in America reduced

greenhouse gas emissions by 10%, total GHG emissions in the US would be reduced by 1 billion metric tons (t) per year, equivalent to 217 million cars (75% of cars on the road in the US). 2) A financial incentive to achieve LEED or ENERGY STAR certifications could be implemented to avoid 500 million t carbon dioxide equivalents (CO_2e).

The Commercial Buildings Energy Consumption Survey (CEBCS) was used to identify building energy consumption. These data were matched with regional power grids, emission factors and global warming potential, and calculated into metric tons (t) CO_2e emissions. It was determined that SMEs in the U.S. contribute to climate change by emitting 272 million t of CO_2e per year, more than Thailand, the Philippines or Spain, and is responsible for 33% of all commercial building emissions in the US. Over the course of ten years, SMEs will emit almost 3 billion t CO_2e just in building emissions.

A variety of scenarios were analyzed to show how measures that can be taken would affect cumulative GHG emissions through the year 2050. The scenario that included building energy efficiencies, consuming carbon free energy and eliminating the use of natural gas and fuel oil indicated that zero emissions could be achieved before 2050.

To motivate change, a synergistic mix of reporting tools to benchmark, incentives to motivate, regulatory requirements to drive performance, and financial assistance to cover upfront costs where necessary are needed. Some of the methods that could be used include incentivizing LEED or ENERGY STAR certification, carbon taxes or caps, and GHG trading systems. If the global goal of “net zero” emissions by 2050 is to be achieved, this small, but collectively large player is essential to include.

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Chapter I

Introduction

The case can be made that even small and medium sized enterprises (SMEs) should participate in sustainability efforts. In fact, if the widely recognized global goal of “net zero” greenhouse gas emissions (GHG) are to be achieved, SMEs are critical participants. There are 32.5 million SMEs, defined as having less than 500 employees, in the United States. These enterprises are the backbone of the U.S. economy (The World Bank, 2021). SMEs make up 99.9% of businesses, employ 46.8% of the working population (US Small Business Administration, 2021), and account for 43.5% of Gross Domestic Product (GDP) (US Small Business Administration, 2019). These businesses seem to play an important role in the economy and as such could play an important role in sustainability as well.

Individually, small businesses have a small carbon footprint, but collectively, that footprint adds up. It’s estimated that small businesses spend more than $60 billion a year on energy (Energy Star, n.d.). This use of energy produces greenhouse gas (GHG) emissions through the direct use (scope 1), and through the indirect use (scope 2), when accounting for emissions generated from purchased energy. In Europe, it’s been calculated that SMEs contribute 60-70% of commercial pollution, over twice as much as their corporate counterparts (Koirala, 2019).

There are many reporting tools, funding options, and resources available to corporations that are helping them create footprint reduction strategies, but to date, it has been hard for SMEs to contribute to sustainability due to the lack of strategic planning, knowledge on sustainability initiatives, funding for implementation, and time to plan and implement (Luederitz et al., 2021). Shifting practices to be more sustainable can be expensive up front and many small businesses lack those kinds of financial resources. In addition, many small business owners lack the human resources required to report on sustainability, track emissions, and create sustainability standards. Lastly, many SME's rent space that they do not have operational control over and are unable to do the retrofits required to meet efficiency standards.

Because few small businesses are engaged in efforts to reduce GHG emissions, there is little information on how much they contribute to climate change. Therefore, little is known on the overall impact of SMEs, but relevant research could help business owners and policy makers make informed decisions about how to create change. The US federal government has been putting a lot of funding into reducing GHG emissions through various grants, policies, and incentives but very few are available to SMEs. Understanding how any of these could be utilized within the SME population to increase participation of SMEs in GHG reductions efforts could help achieve the global goal of zero emissions by 2050 (United Nations, n.d.).

Research Significance and Objectives

Given the potentially monumental opportunity for SMEs to help reduce GHG emissions and the need to understand their contribution, as well as educate and motivate change, my research will quantify GHG emissions for SMEs and examine potential GHG reduction based on different incentive scenarios.

Therefore, my objectives are to:

- Assess the collective GHG contribution by small businesses in the US and determine the main sources of GHG emissions by SMEs.
- Develop an analytical framework to forecast future GHG reduction based on different incentive scenarios.
- Suggest policies and incentives that are compatible with SMEs limited human and financial resources.

Background

The emission of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) gases, collectively known as greenhouse gases (GHGs), into the air has been exacerbating climate change, shifting temperatures and weather patterns, and inducing a warming of the planet, changing ecosystems, and increasing natural disasters (Ritchie & Roser, 2020a).

In August of 2021, the United Nations (UN) Intergovernmental Panel on Climate Change warned that GHG emissions from economic activity are the main causes of climate change. This means that pollution produced by making, providing, purchasing, and selling goods is causing catastrophic droughts, food shortages, floods, heat waves and destructive storms (Kaplan & Ramanna, 2021). News reports are getting more urgent as time goes by, reflecting the message that nations need to move away from fossil fuel much faster than previously anticipated if there is any hope in preventing an overheated planet (Plumer & Zhong, 2022). In fact, global emissions have reached their highest ever annual concentration and emissions from fossil fuels have been steadily increasing, especially since the middle of the last century. CO_2 emissions from all sources have increased by 90% since 1970, reaching 50 billion tons of CO_2e in 2020 (US Environmental Protection Agency, 2022a). Three-quarters of this CO_2e comes from energy consumption (Figure 1). This energy is critical for economic growth and is used for activities like producing goods and transporting them, as well as household activities like lighting a home and traveling to work.

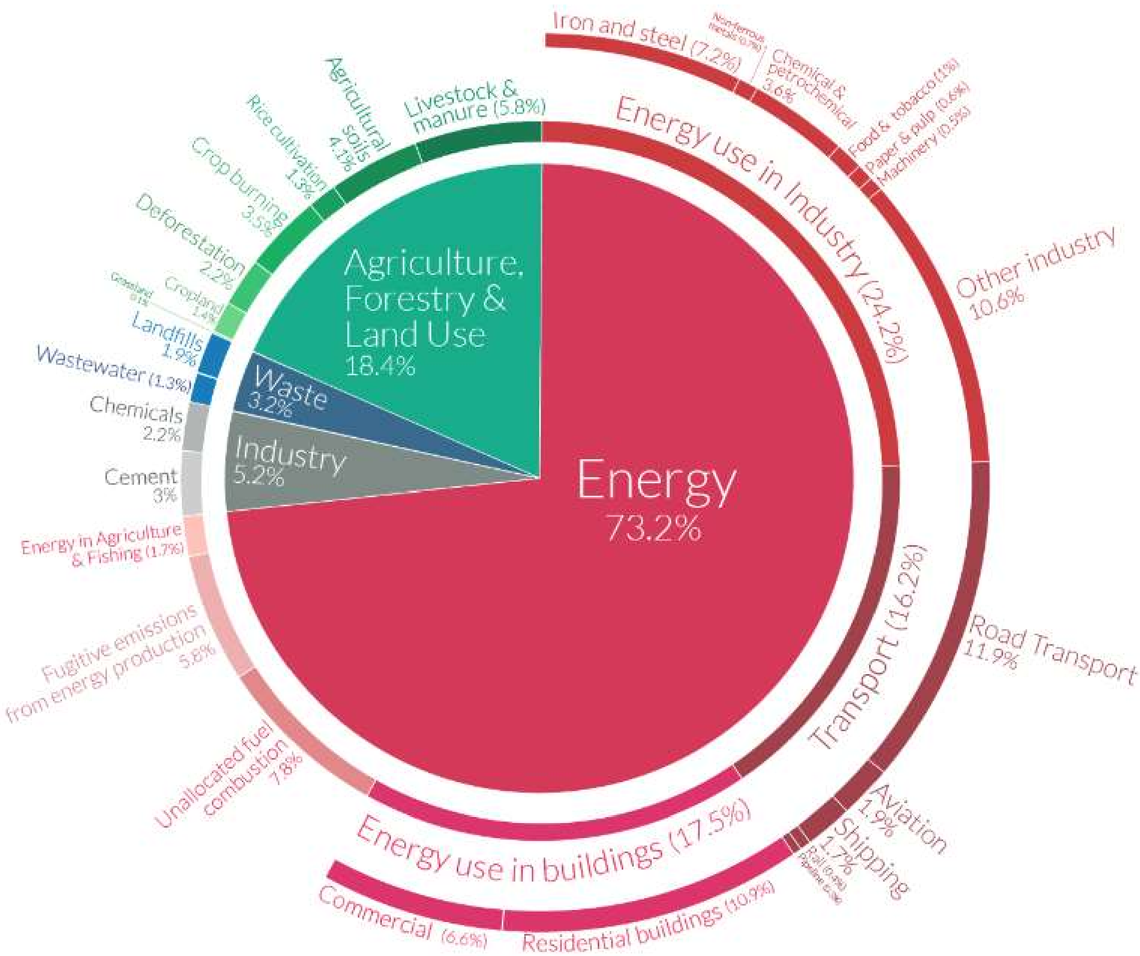

Figure 1. Global greenhouse gas emissions by sector.

Emissions by sector, 2016 (Ritchie & Roser, 2022c)

In 2015, to mitigate this exponential rise of GHG, 196 countries signed a legally binding treaty, the Paris Agreement. All signers agreed to curb global warming to below two degrees Celsius. Though this agreement was a significant signal to all that change is needed, GHG emissions are still on the rise. With Paris and other agreements like the Copenhagen Accord and Glasgow Climate Pact, governments are becoming more accountable for GHG reductions and corporations are leaning in. This issue has attracted increasing attention from global leaders, financial markets, consumers, and governments. Through this increased attention, there are multiple conflicting views on how to best move forward with sustainability initiatives. Many think the task should fall solely on the government, some think corporations should play a large part, and others think the responsibility should fall directly to the consumers. No matter who takes ultimate responsibility, everyone needs to be a part of the change to avoid detrimental consequences (Plumer & Zhong, 2022).

US Corporate GHG Reduction Strategies

The US has emitted more GHGs than any other country to date and is responsible for 25% of historic emissions, twice as much as the second largest contributor, China, at 12.7% (Ritchie & Roser, 2020b). On a yearly basis, the United States accounts for 15% of global emissions and in 2020, U.S. net GHG emissions totaled 5.2 billion metric tons (t) (United States Environmental Agency, 2022c). Emissions in the United States mirror the global breakdown and mainly come from electricity, heat, and transportation (Figure 2). A large focus on reducing this has fallen on large enterprises, or corporations, which are facing growing pressure from investors and advocacy groups to reduce GHG emissions. Nearly 200 CEOs of the Business Roundtable responded to the call for action by issuing a statement on their commitment to improve environmental performance (Kaplan & Ramanna, 2021). This statement has been backed by action. Nearly 90% of S&P 500 companies now report on environmental, social and governance (ESG) which includes an estimate of the company's GHG emissions as well as reduction targets.

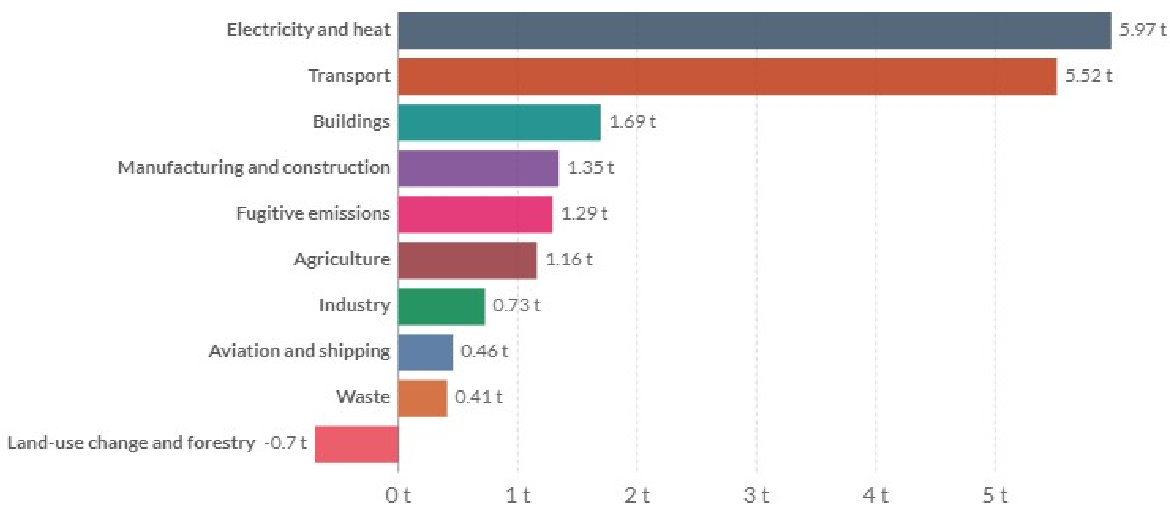

Figure 2. Per capita greenhouse gas emissions by sector in the US.

Emissions by sector in the US, 2019 (Ritchie & Roser, 2022c).

There are many tools available to corporations to assess their sustainability. The Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and Climate Disclosure Project (CDP) are three of the most common, but there are many other reporting tools available. Each has different sustainability foci and requirements. Many of these tools require multiple metrics on ESG indicators; in fact, one reporting agency in the UK requires up to 61 calculated metrics (Tocchini & Cafagna, 2022). Most of these metrics are not accounted for in general business practices. Additional effort and human resources are needed to calculate these and conform to reporting requirements. Because there are so many reporting tools and ESG metrics required, it is difficult for corporations to have one strategy and create alignment. In fact, 85% of corporations are reporting to not just one standard, but to multiple ones in order to satisfy all sustainability measures (Tocchini & Cafagna, 2022).

Though these reporting tools take a fair amount of money and resources to complete, there are many benefits that make them cost-effective and appealing to corporations, like enhancing reputation, differentiating products, and attracting investors. Because there is a growing societal expectation related to climate change, conforming to these practices has allowed corporations to see improvement over many areas of their business (Organisation for Economic Co-operation Development, 2010).

Federal Programs and Sustainability Certifications Available to Corporations

In addition to the many reporting tools that are available to corporations, many policies have been implemented to incentivize companies to make efficiency and energy upgrades. These include carbon taxes and money-making initiatives.

High emitting industrial corporations are incentivized to reduce GHG emissions through a government-imposed tax on carbon emissions. This tax is based on industry and economic activity and is placed on a specified source and amount. A corporation is penalized and must pay additional taxes for exceeding the specified emissions amount. Economists argue that this is the most cost-effective way to regulate GHGs (Haites, 2018). However, assessing the effectiveness of these carbon taxes is difficult because emissions are also affected by other policies and factors. Carbon tax yields only up to a 6.5% reduction over several years from business-as-usual emissions and are seemingly ineffective (Haites, 2018). This is one possible approach to incentivize action, but currently is only utilized for the highest emitting sectors in the US.

Another corporate incentive is an emissions trading system (ETS) where the government sets a limit on the amount of GHG a company can emit and distributes allowances equal to that limit. A company that exceeds its limit must purchase additional allowances. If a company emits less than its limit, any leftover allowances can be sold to other companies that need emissions offsets. These allowances can be bought and sold, and thereby incentivize businesses to reduce their carbon footprint to make additional profit (apcd, n.d.) Governments generally target industrial plants and other large polluters with this type of incentive, but perhaps it can be used on a broader scale (Haites, 2018).

The most prevalent form of an exchange trading system (ETS) is the 'cap and trade' system. It is designed to reduce pollution by giving companies penalties for violating its upper limit cap on total emissions (Environmental Defense Fund, 2022). An organization that exceeds this limit can buy credits from those that haven't used their full limit. Not only does this benefit the environment, but it benefits corporations by selling their unused credits. This kind of model has been used in California for electric and industrial plants and has proven to be successful in reducing GHG emissions from large polluters. Another form of ETS is the 'baseline and credit' system which operates similarly to the cap-and-trade model but sets a baseline on total emissions rather than an upper limit (Haites, 2018). Credits are issued to entities that have reduced emissions below this baseline level. Actual emissions have declined where ETS data are available for both the 'cap-and-trade' system and the 'base-line-and-credit' system. Carbon taxes and ETSs have become popular and now cover 20% of global emissions (Haites, 2018).

Although carbon taxes and ETSs are usually portrayed as alternatives, they could be implemented simultaneously to address emissions by different sources (Haites, 2018).

The city governments in New York City (NYC) and Boston have both enacted policies and regulations that require large buildings over a certain square footage to meet Net Zero by 2050 (25,000 SF in NYC, and 20,000 SF in Boston). NYC has implemented a stringent carbon cap on thousands of commercial properties according to Local Law 97 (Urban Green, 2023b). If any of the properties governed by the law exceed their carbon allotment, fines are imposed. These carbon caps become stricter over time until buildings reach net zero by 2050. Boston set yearly carbon targets and imposes a penalty payment of a certain dollar amount for every ton of CO_2e when those targets are exceeded. This revenue is used to help create equity in the community by providing the funding needed to help environmental justice populations to upgrade buildings.

Many large corporations have been required to make changes or are leveraging the reporting tools, ETSs and other attractive incentives to create GHG reduction plans, but most of these options are not presented or available to SMEs.

SME Challenges and Emissions

Because SME's have a smaller footprint individually, they have mostly been ignored by environmental, social and governance (ESG) reporting standards, governmental policies, and sustainability certifications. These GHG reduction processes, though useful for corporations, are costly and time consuming for lower profit and smaller staffed SMEs. SMEs are not large enough nor do they have the resources to account for CO_2 emissions, and therefore are not eligible for carbon trading systems like the cap and trade and baseline-and-credit. They are also not eligible for large tax breaks or incentives. These challenges make it difficult for small businesses to create strategies and track sustainability improvements like their corporate counterparts.

However, SME buildings are a huge component of GHG emissions. Their largest source of GHG emissions is from burning fossil fuels for electricity, heat, and transportation. For small businesses most emissions show up in two types of emissions: direct emissions, or Scope 1, and indirect emissions, Scope 2. Most of the GHG emissions for small businesses are from the use of energy for space heating, cooling ventilation, cooking, lighting, and electronics (Figure 3). Scope 1 emissions include heating and cooking, and Scope 2 GHG emissions include the consumption of energy purchased for electricity and used for lighting, refrigeration, cooling, computer, and office equipment (The Climate Registry, 2019).

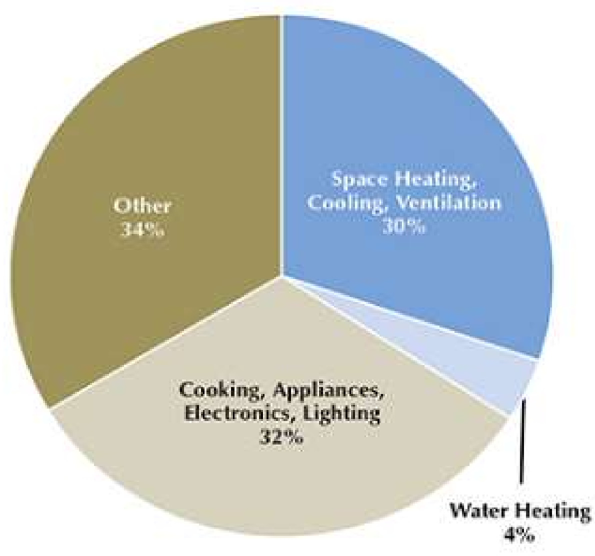

Figure 3. Total CO_2 commercial sector emissions for SMEs.

Emissions from the commercial sector, "Other" includes items such as data servers, medical imaging equipment, ceiling fans, and pool pumps. (Center for Climate and Energy Solutions, 2018).

At a global level, buildings have the largest potential to significantly reduce GHG emissions when compared to other major emitting sectors (World Green Building Council, 2022). In the United Sates, 40% of CO_2 emissions come from buildings which out-consume both the industrial and transportation sectors (USGBC, 2018).

Strategies to Lower SME Carbon Footprints

In 2014, a small subset of SME carbon footprints was compared before and after reduction efforts in a sample of businesses based in Boston, Massachusetts (Meissner, 2014). This analysis compared the key sustainability measures of utility, natural gas, and water consumption before and after participating in a sustainability consulting program. The program offered a variety of ways for businesses to reduce each of these measures. It was found that significant reductions in carbon footprints were achieved, demonstrating that there is a great potential to reduce emissions within SMEs that should be tapped (Meissner, 2014). On average, CO_2e was reduced by 21 metric tons per business per year after engagement. One company reduced emissions by 269 metric tons. Additionally, most businesses reported that participation in the program saved them money as well as realized the positive benefit of improved culture. Meissner (2014) also found that time and money were major barriers in SME GHG reduction and suggested that substantial financial incentives should be provided to decrease those pressures.

Most of the measures these SMEs took were through building improvements and reduced consumption. Businesses can reduce building GHG emissions through reducing energy use, creating energy efficiencies, and improving air conditioning and refrigeration systems (Table 1). Other reduction efforts can come in the form of switching fuel sources to decarbonized fuel sources, using renewable energy, and carbon capture or sequestration (Table 2).

Table 1. Building GHG efficiency opportunities.

Type	How Emissions Are Reduced	Examples
Commercial Buildings	Reducing energy use through energy efficiency.	Homes and commercial buildings use large amounts of energy for heating, cooling, lighting, and other functions. "Green building" techniques and retrofits can allow new and existing buildings to use less energy to accomplish the same functions, leading to fewer greenhouse gas emissions. Techniques to improve building energy efficiency include better insulation; more energy-efficient heating, cooling, ventilation, and refrigeration systems; efficient fluorescent lighting; passive heating and lighting to take advantage of sunlight; and the purchase of energy-efficient appliances and electronics.
Air Conditioning and Refrigeration	Reducing leakage from air conditioning and refrigeration equipment. Using refrigerants with lower global warming potentials.	Commonly used refrigerants in homes and businesses include ozone-depleting hydrochlorofluorocarbon (HCFC) refrigerants, often HCFC-22 and blends consisting entirely or primarily of hydrofluorocarbons (HFCs), both of which are potent greenhouse gases. In recent years there have been several advancements in air conditioning and refrigeration technology that can help homes and businesses reduce both refrigerant charges and refrigerant emissions.

Examples of CO_2 building energy reduction and efficiency opportunities, (US Environmental Protection Agency, 2022b).

There are a few certifications building owners can achieve to reduce GHG emissions. One certification is the LEED building and LEED existing building certifications. LEED was launched in 1998 by the US Green Building Council to become a standard for building sustainability and resource reduction. By successfully reaching LEED certification, business owners can take advantage of several state and government

Table 2. Industry GHG efficiency opportunities.

Type	How Emissions Are Reduced	Examples
Increased Efficiency of Fossil-fired Power Plants and Fuel Switching	Increasing the efficiency of existing fossil fuel-fired power plants by using advanced technologies, substituting less carbon-intensive fuels, and shifting generation from higher-emitting to lower-emitting power plants.	• Converting a coal-fired boiler to use of natural gas, or co-firing natural gas. • Converting a single-cycle gas turbine into a combined-cycle turbine. • Shifting dispatch of electric generators to lower-emitting units or power plants.
Renewable Energy	Using renewable energy sources rather than fossil fuel to generate electricity.	Increasing the share of total electricity generated from wind, solar, hydro, and geothermal sources, as well as certain biofuel sources, through the addition of new renewable energy generating capacity.
Increased End-Use Energy Efficiency	Reducing electricity use and peak demand by increasing energy efficiency and conservation in homes, businesses, and industry.	EPA's ENERGY STAR® partners avoided over 400 million metric tons of greenhouse gases in 2020 alone, helped Americans save over $42 billion in energy costs, and reduced electricity use by 520 billion kWh.
Nuclear Energy	Generating electricity from nuclear energy rather than the combustion of fossil fuels.	Extending the life of existing nuclear plants and building new nuclear generating capacity.
Carbon Capture and Sequestration (CCS)	Capturing CO_2 as a byproduct of fossil fuel combustion before it enters the atmosphere, transporting the CO_2, injecting the CO_2 deep underground at a carefully selected and suitable subsurface geologic formation where it is securely stored.	Capturing CO_2 from the stack of a coal-fired power plant and then transferring the CO_2 via pipeline, injecting the CO_2 deep underground at a carefully selected and suitable nearby abandoned oil field where it is securely stored. Learn more about CCS.

Industry efficiencies that can be utilized to reduce CO_2 emissions, (US Environmental Protection Agency, 2022b).

incentives, reduce operating costs, and reduce GHG emissions. In fact, LEED certified buildings have 34% lower CO_2 emissions and consume 25% less energy (USGBC, 2018).

Another certification is the ENERGY STAR Certification. This certification is sponsored by the Environmental Protection Agency (EPA) and uses a scoring system to track a building's energy performance. ENERGY STAR certified buildings save energy and money as well as reduce GHG emissions (Energy Star, n.d.a). On average, ENERGY STAR buildings use 35% less energy than typical buildings (Energy Star, n.d.b). ENERGY STAR estimated that small businesses spend $60 billion on energy per year in the US alone (Energy Star, n.d.). Because that spending correlates directly with energy use and GHG emissions, this is an indication of the considerable footprint SMEs have and their potential to impact GHG reductions.

SME Sustainability

SMEs are the future economy (SME Climate Hub, 2022). Apple started in a garage and like Apple, many SMEs will grow into larger corporations. Consequently, many organizations urge small businesses to become more sustainable not only for the environment, but for profits as well. Forbes magazine suggests small businesses that adopt sustainable practices improve profits, gain a competitive advantage, improve efficiency, manage business risk, grow brand, enhance access to capital, reduce costs, and attract good publicity (Hodges, 2021).

Increased profits are a result of clients and customers responding positively to companies that choose to place value on people and the planet over profits. Many consumers purchase based on these values and choose brands that represent this over lower cost brands (Hodges, 2021). Additionally, if SMEs are going to stay competitive, they will need to make long term sustainability commitments. Corporations will be looking for this information from SMEs as they pursue ‘net zero’ and start to shift their focus to their supply chain, a lot of which are SMEs.

A survey of 348 Italian manufacturing SMEs found that the social, economic, and formal practices of sustainability positively affected competitive advantage, and contributed to increased financial performance (Cantele & Zardini, 2018). The study found that sustainability had a strategic relevance through reputation, customer satisfaction, and organizational commitment, and this competitive advantage was key to capitalizing on financial performance.

Looking at all the prohibiting factors like high costs of implementation, lack of human and financial resources, and the lack of building control previously mentioned, it’s easy to see why sustainability is largely adopted by corporations and not SMEs. Due to these prohibiting factors, even if SMEs are motivated and understand their importance, management of sustainability is not carried to its full potential (Barbosa et al., 2020). Because of this, small businesses have been overlooked by policymakers and other stakeholders, leaving a huge opportunity to leverage and improve sustainability measures nationally. Because SMEs are so critical to the economy and sustainability, perhaps some of these tools and financial incentives used for corporations and large industries could be altered to fit a small business model.

Research Questions, Hypotheses and Specific Aims

The questions my research aims to answer, and their related hypotheses are:

1. What percentage of GHG emissions can be attributed to SMEs in the US? If every small business in America incrementally reduced greenhouse gas emissions, how much change would be seen?

- Hypothesis 1: If small businesses in America reduced greenhouse gas emissions by 10%, total GHG emissions in the US would be reduced by 1 billion metric tons per year.

2. How much can GHG emissions be reduced under different incentive scenarios and what policies/incentives are available to motivate small businesses to participate?

- Hypothesis 2: A financial incentive to achieve LEED or Energy Star certifications could be implemented to avoid 500 million tons CO_2e.

Specific Aims

To test these hypotheses and address these questions, I:

1. Estimated the amount of CO_2e emitted by small businesses in the US to determine their impact on total global CO_2 emissions.
2. Analyzed a variety of incentives available to reduce sources of GHG emissions for SMEs.
3. Modeled future GHG avoidance over the next 10 years under different policy scenarios.
4. Proposed recommendations to policy makers on most impactful incentives to reduce GHG emissions by SMEs.

Chapter II

Methods

This research examined greenhouse gas emissions by buildings in the US that are considered to be small to medium (SME) sized businesses. The Commercial Buildings Energy Consumption Survey (CBECS), provided by the US Energy Information Administration (US Energy Information Administration, n.d.) was used to collect energy consumption data for a subset of commercial buildings identified as SMEs. It provided detailed consumption measurements of electricity, natural gas, and fuel oil use for the year 2018. This consumption information was then used to calculate GHG emissions.

Census divisions, or a grouping of four states established by the US Census bureau, provided in the CBECS dataset were matched with electric power grid regions from The Emissions and Generation Resource Integrated Database (eGRID), set forth by the United States Environmental Protection Agency (EPA), to identify emissions rates based on electricity consumption for each census division. Because eGRID regions did not align perfectly with CBEC census divisions, data were weighted by population density to provide a more accurate emission rate based on the location of large cities and larger regions that source from specific power plants. eGRID provided emissions for CO_2, CH_4, and N_2O, the largest GHG contributors, which were all converted to CO_2e based on the global warming potential for each. This provided the indirect emissions associated with the purchase of energy (Scope 2), or GHG emissions in metric tons of CO_2e based on electricity consumption.

Subpart C of Part 98 of the Electronic Code of Federal Regulations (eCFR, National Archives and Records Administration's Office of the Federal Register and the

Government Publishing Office) was used to calculate the direct emissions associated with the consumption of natural gas and fuel oil (Scope 1) as GHG emissions in metric tons CO_2e.

The GHG emissions from electricity, natural gas, and fuel oil consumption were then added together to get the total GHG emissions for SMEs in the US. GHG emissions were evaluated by business type, region, climate, owner type, and end use to identify areas of potential improvement and future GHG reduction opportunities based on five scenarios.

Small Business Parameters

The Commercial Buildings Energy Consumption Survey (CBECS) is done by the US Energy Information Administration to analyze and describe commercial buildings in the US and represents the national building stock (US Energy Information Administration, n.d.). CBECS defines commercial buildings as all buildings in which at least half of the floorspace is used for a purpose other than industrial, agriculture or residential. Because of this definition, in addition to traditional building spaces like stores, warehouses, office buildings and restaurants, they include nontraditional buildings like those used for religious worship, correctional institutions, hospitals, and schools (US Energy Information Administration, n.d.). For the purposes of this research, the nontraditional commercial buildings were taken out of the analysis and a more defined subset of traditional buildings was analyzed. This was done to identify buildings that are being used for small business operations and are for-profit. CBECS gathers this information in a two-phase process. The first phase includes collecting building characteristics by reaching out to an onsite respondent at that building or utilizing an interview-style web questionnaire. Information collected includes building size and use, structural characteristics, energy sources, and energy usage data. Phase two includes a follow-up survey to the energy providers for the buildings that responded in phase one. CBECS consistently collects these data from all buildings. Information collected includes many attributes like building use, physical characteristics, and monthly energy usage data for each building. The data are verified, so it provides a complete and accurate picture of the energy used by commercial buildings (Energy Star, n.d). The first CBECS was conducted in 1979 and past years are used to model energy consumption year over year (US Energy Information Administration, n.d.).

This information is used by buildings owners, energy modelers, product developers, government leaders, researchers, and others for benchmarking, forecasting, formulating policy, and gauging market potential. It is used frequently as it is the largest and most established database for comparing buildings in the US. It is also the data behind the ENERGY STAR building certification, which uses the data as the foundation for their rating system targets (US Energy Information Administration, n.d.).

Information provided to the public that was used for my analysis includes a list of buildings in the US by size, number of employees, region, census division, climate, year constructed, owner type, electricity consumption, natural gas consumption, and fuel oil consumption. Because of the way CBECS identifies data in its tables, the microdata codebook published by CBEC proved to be a helpful guide in determining the mnemonics to include in my dataset (Table 3 & 4). CBECS uses shortened acronyms to identify each field and the codebook is necessary to understand the definition of those terms and provides additional detail as to what those acronyms represent.

Table 3. CBECS mnemonics used for building characteristics.

PUBID	REGION	CENDIV	PUBCLIM	FINALWT	YRCONC
SQFT	NWKER	OWNOCC	OWNTYP	WRKHR	PBA

Table 4. CBECS mnemonics used for energy consumption.

ELEXP	ELCNS	ELBTU	NGEXP	NGCNS	NGBTU
FKEXP	FKCNS	FKBTU	ELHTBTU	ELCLBTU	ELWBTU
ELLTBTU	ELCKBTU	ELRFBTU	ELOFBTU	ELPCBTU	ELVNBTU
ELOTBTU	NGHTBTU	NGCLBTU	NGWBTU	NGCBTU	NGOTBTU
FKHTBTU	FKCLBTU	FKWTBTU	FKCKBTU	FKOTBTU	

The 2018 CBECS report with the specified mnemonics in Table 3 were analyzed to determine how to parse out buildings that fit the description for a small to medium sized business. The Principle Building Activity (PBA) field with corresponding numbers associated with those building types was used. Parameters were used to identify buildings that housed 499 or less employees and were utilized by "for-profit" entities, meaning they were not used by a non-profit, government entity, religious organization, or an educational organization. For these reasons, the original data set was then filtered down to buildings with less than 500 employees and that fit these building types: Office, warehouse, storage, food service, mercantile and service. This is in accordance with the way CBECS buckets building types in their analysis and it was determined that they best fit the description of for-profit. All other building types were removed (Table 5). The data set provided a sample size of 3,632,650 buildings and was used to define SMEs with commercial space in the US for the purpose of this analysis.

Table 5. Parameters used to create SME data subset.

Principle Building Activity (PBA) Defined as:	
CBECS Mnemonic	Description
2	Office
5, 11	Warehouse and storage – nonrefrigerated warehouse, refrigerated warehouse
15	Food Service
23, 24, 25	Mercantile – strip shopping center, enclosed mall, retail other than mall
26	Service
And excluding:	
CBECS Mnemonic	Description
12	Religious worship
13	Public assembly
14	Education
1, 4, 6, 7, 8, 12, 13, 14, 16, 17, 18, 91	Other: lodging, laboratory, health care, food sales, public order, vacant, other

This subset of data was analyzed to view the number of buildings and floor space for SME's by building type, number of employees, year constructed, hours open per week, owner type, region, census division, climate, electricity, natural gas, and fuel oil use, and end use of energy consumption (Appendix 1). This dataset was the source used to calculate GHG emissions.

Electricity Consumption and Electric Grid Emission Intensity

The CBEC data provided electricity consumption for all SME buildings. In order to calculate GHG using those data, the Emissions & Generation Resource Integrated Database (eGRID) was used. eGRID is a comprehensive source of data from the EPA's Clean Air Markets Division and provides the characteristics of almost all electric power generated in the US (US Environmental Protection Agency, 2023a). The data includes emissions, rates, heat input, generation, resource mix, and other attributes that are used for greenhouse gas registries and inventories, avoided emissions estimates, and carbon footprints based on power plant outputs in the various regions in the US (US Environmental Protection Agency, 2023a). These data also account for line-loss which is an estimate of the energy lost in the process of supplying electricity to consumers. Information collected from this database was the 2020 outputs for CO_2, CH_4, and N_2O for each eGRID subregion (Figure 4). The numbers provided were converted in metric tons per kWh and then multiplied by their global warming potential to get CO_2e/kWh.

The eGRID subregions don't match up perfectly with the census divisions in CBEC (Figure 5). Some of the census divisions have more than one power plant providing electricity to that division. To identify the percentage of power from each power plant being used in that census division, the eGRID subregion map was overlayed with the census division map (Figure 6). Populous cities were highlighted to capture particular power plants that may be providing more power to that census division. These city weights and percentage of land coverage by each power plant were used to select an appropriate mix of power plant usage for each census division (Table 6). This provided total CO_2, CH_4, and N_2O per Kilowatt hour. Each respective gas was multiplied by its global warming potential and added together which provided total CO_2e based on electricity consumption for each SME building in CBEC.

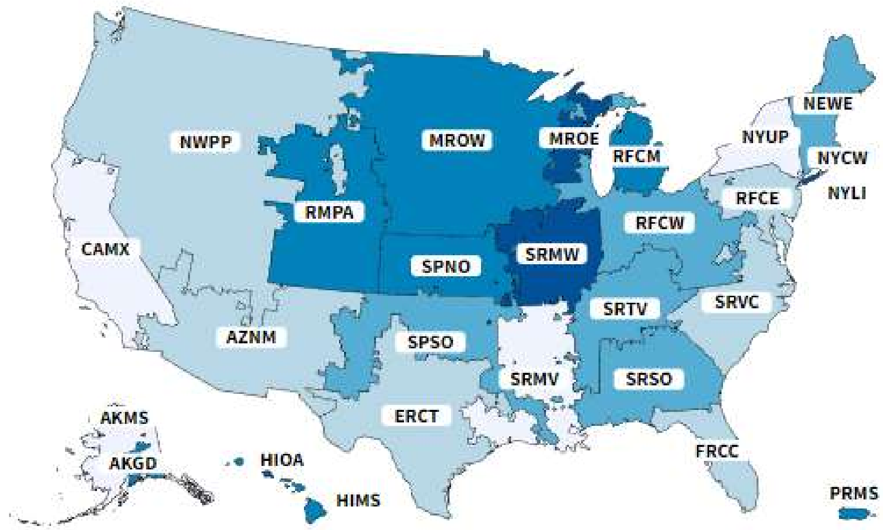

Figure 4. eGRID subregions.

Figure 5. CBECS regions and census divisions.

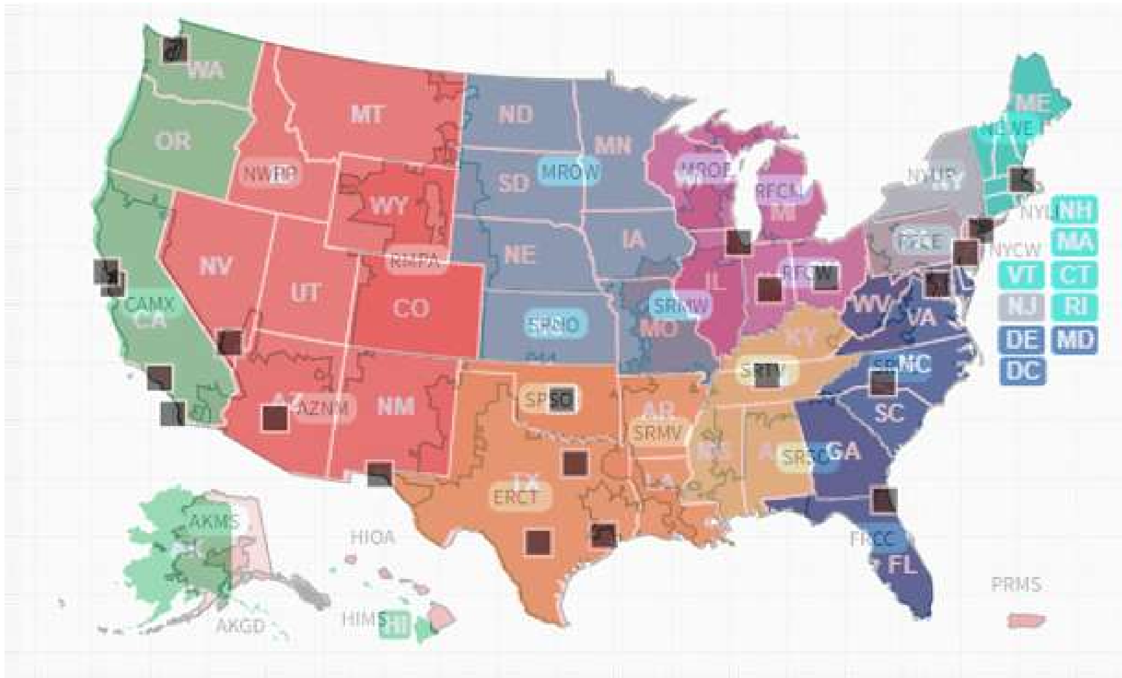

Figure 6. eGRID overlayed on CBEC, with city weights.

Table 6. Mix of power plant data for each census division.

CBEC Census Division	Weight	eGRID Subregion	Weight	eGRID Subregion	Weight	eGRID Subregion
New England	100%	NEWE				
Middle Atlantic	20%	NYUP	50%	RFCE	30%	NYLI
East North Central	15%	MROE	15%	RFCM	70%	RFCW
West North Central	60%	MROW	20%	SPNO	20%	SRMW
South Atlantic	20%	FRCC	10%	SRSO	70%	SRVC
East South Central	80%	SRTV	20%	SRSO		
West South Central	80%	ERCT	10%	SPSO	10%	SRMV
Mountain	25%	NWPP	15%	RMPA	60%	AZNM
Pacific	80%	CAMX	20%	NWPP		

Identifying GHG Emissions from Natural Gas and Fuel Oil Consumption

CBEC provides natural gas and fuel oil consumption which was used alongside Subpart C of Part 98 of the Electronic Code of Federal Regulations (eCFR) to solve for metrics tons CO_2e for buildings utilizing these energy sources. The analysis was first done using The Climate Registry's Table 1.1 US Default Factors for Calculating CO_2 Emissions from Combustion of Fossil Fuel and Biomass, but after speaking with professionals in the field, it was determined the eCFR Part 98 Subpart C is a better source of data for these figures.

The eCFR Part 98 Subpart C is the web version of the Code of Federal Regulations which codifies the general and permanent rules published in the Federal Register by departments and agencies of the Federal Government. It is updated daily and provided as an informational resource to the public (National Archives, n.d.). The default factors for CH_4 and N_2O for natural gas and fuel oil (fuel gas in the Table) are found on Table C-2 to Subpart C of Part 98 – Defaults CH_4 and N_2O Emissions Factors for Various Fuel Types. The default factor for CO_2 for natural gas (weighted US Average in the table) and fuel oil (Distillate Fuel Oil No. 2 in the table) are found on Table C-1 to Subpart C of Part 98 – Default CO_2 Emissions Factors and High Heat Values for Various Types of Fuel. The values for CH_4 and N_2O were converted into kg/cubic feet and multiplied by the global warming potential, providing CO_2e. The total sum for each, natural gas and fuel oil, were placed in the respective EPA calculation (Table 7). The EPA calculations are a GHG equivalencies calculator that can be used to convert various units of energy into GHG emissions. It was used to calculate GHG emissions and provided metric tons CO_2e for natural gas and fuel oil. These numbers were multiplied by the amount of natural gas and fuel oil consumption for each building and provided total CO_2e for each SME building in CBEC.

Table 7. GHG equivalencies calculations.

Natural Gas Consumption	(Amount) cubic feet × 0.0550 kg CO_2/cubic foot × 1/1,000 kg/metric ton = metric tons CO_2
Fuel Oil Consumption	(Amount) gallons × 1/42 barrels/gallon × 426.1 kg CO_2/barrel × 1/1,000 kg/metric ton = metric tons CO_2

EPA's Greenhouse Gases Equivalencies Calculator (US Environmental Protection Agency, 2023b).

Global Warming Potential

Global warming potential (GWP) is critical to calculate to compare the global warming impact of different gases and provides a common unit of measure to add up emissions estimates. GHGs warm the Earth and slow the rate at which energy escapes into space which is factored into the GWP (US Environmental Protection Agency, 2023). Different GHGs have different effects and two keyways to distinguish their GWP are their ability to absorb energy, and how long they stay in the atmosphere.

CO_2 has a GWP of one. It causes increases in atmospheric concentration and remains in the environment for thousands of years. The GWP never changes because it is used as the reference parameter. Other gases are measured against CO_2 based on the amount of energy they absorb over a 100-year period. Methane (CH_4) can have a GWP ranging between 27-30. Methane emitted today lasts about a decade, much shorter than CO_2, but absorbs much more energy and is a precursor to ozone, hence the larger GWP than CO_2. Nitrous Oxide (N_2O) has a GWP of 273. It absorbs less energy than Methane, but remains in the atmosphere for over 100 years, which is why it has such a large GWP.

The US Environmental Protection Agency provides a range of GWP for the gases analyzed in their reports; this research used the highest number in that range (Table 8).

Table 8. Global warming potential numbers used in calculations.

CO_2	Carbon Dioxide	1
CH_4	Methane	30
N_2O	Nitrous Oxide	273

After CO_2e was calculated for electricity, natural gas, and fuel oil based on consumption, it was added to the CBEC dataset and used to identify total metric tons CO_2e emitted by SMEs in the US. The dataset could then be analyzed for CO_2e emissions based on building type, region, census division, climate, owner type, year constructed, number of hours opened, and number of workers.

Potential Future Greenhouse Gas Reduction & Avoidance

This information was also used to model future GHG reductions based on six scenarios: the baseline and scenarios 1-5. These scenarios zero in on what would be required to reduce GHG's from SMEs in order to reach zero emissions by 2050.

The baseline scenario was modeled based on the expected results if no action is taken on the building operational side and the electric power grid remains unchanged. It also assumes current law/regulations remain unchanged and no additional mitigation strategies are required. This model shows accumulated GHG year-over-year at a steady increase over the next ten years. The calculation was the simple addition of all the previous year's CO_2e plus that year's CO_2e resulting in a cumulative calculation for future GHG emissions if no action is taken and consumption stays steady.

Scenario 1 modeled a very generic 10% decrease in GHG year-over-year. This was calculated by taking the previous year's CO_2e and multiplying it by 0.1 and then subtracting that amount from the previous year, (previous year – (previous year*0.1)), and then graphed over 28 years, or until 2050, the year the United Nations has set as the goal to reach ‘net zero’ emissions (United Nations, n.d.).

Scenario 2 modeled how much change year-over-year would be needed for SMEs collectively to reach 0 emissions by 2050. This graph was created dividing the yearly CO_2e by the number of years until 2050 and reducing the total by that amount each year.

Scenario 3 modeled the elimination of fuel oil & natural gas in the first five years as well as a year-over-year reduction of electrical GHG emissions, either through reduced consumption and/or decarbonizing the energy source. Natural gas and fuel oil were phased out equally over a five-year span, and electricity was reduced by 10% year-over-year.

Scenario 4 showed what would happen if all SMEs adopted LEED or ENERGY STAR improvements with no other change. The model assumes that no SMEs currently have this certification and that every SME reduced energy consumption and achieves one of these certifications in the first year of implementation. On average, LEED certified buildings have 34% lower CO_2 emissions (USGBC, 2018), and Energy Star buildings use 35% less energy than typical buildings (Energy Star, n.d.b) The lesser of the two values, or 34%, was used to calculate the first-year reduction.

Scenario 5 modeled those same LEED and ENERGY STAR changes, with the elimination of natural gas and fuel oil, and a 10% reduction of electricity consumption or decarbonizing energy source year-over-year. The same calculation from scenario 4 was used to show the reduction based on the achievement of LEED or ENERGY STAR certificates, as well as the phasing out of natural gas and fuel oil over five years, and the reduction of electricity or decarbonizing of its energy source by 10% year-over-year.

The results from these calculations and future avoidance scenarios shined a light on how much impact SMEs can have on helping reduce GHG emissions and reach climate change goals.

Chapter III

Results

The results of this study are detailed in the three sections below: First is a summary of GHG emissions associated with SMEs for 2018, the baseline year of my study. Then presented are the results for the six scenarios in which various rates of GHG reduction and one avoidance scenario are modeled.

GHG Emissions Associated with SMEs

Total scope 1 and scope 2 emissions from SMEs in the United States were estimated to be 272 million metric tons (t) CO_2e in 2018. SMEs therefore account for 33% of total emissions from commercial buildings in the US, based on the estimate that commercial buildings account for 826 million t CO_2 per year (US Department of Energy, n.d.). They also contribute 5% of total US emissions, based on the estimate that in 2019, the US emitted 5,130 million metric tons of energy-related carbon dioxide (USGS, 2019).

Of commercial buildings in the United States in 2018, 61% of them housed for-profit SMEs, and 49% of square footage can be attributed to them. The average building size was 13,095 sf and buildings under 25,000 sf accounted for 44% of floor space. Even though most buildings are small, 78% of SME buildings are either warehouse, office, or service-related buildings. The majority (55%) of buildings are built between 1960 – 1999. SME buildings are open on average 70 hours per week. Most buildings are in the southern region of the United States (Appendix 1).

How These Buildings Emit CO_2e

The majority of scope 1 and scope 2 SME building emissions come from the consumption of electricity, natural gas, and fuel oil. The consumption of these resources is mainly utilized in commercial buildings for heating, lighting, and ventilation (Figure 7). Natural gas consumption is primarily used (90%) for the purpose of heating and cooking. And 79% of electricity consumption is for lighting, HVAC, and the use of miscellaneous items like computers and TVs. The main purpose for fuel oil consumption is for heating older buildings that were built from <1946 – 1969 (Appendix 1, Figure 40).

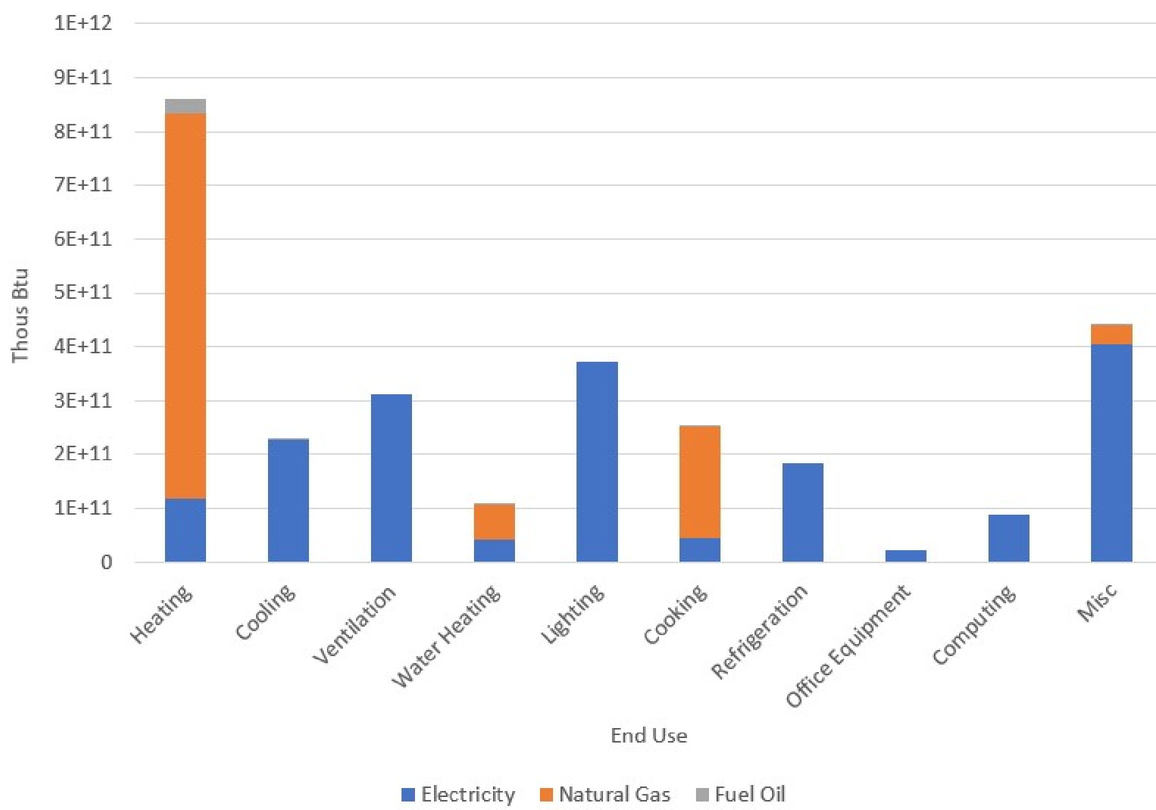

Figure 7. Energy consumption by end use for SMEs in the US, 2018.

CO$_2$e by Square Footage

The smallest SME buildings (1,001 – 5,000 sq ft) emit the most CO$_2$e on average and make up 51% of buildings (Figure 8). Collectively, these buildings emit almost half of SME CO$_2$e. Buildings under 25,000 sq ft constitute 91% of SME buildings and produce 42% of total SME CO$_2$e emissions. Buildings greater than 100,000 sq ft account for less than 4% of SME buildings yet produced 27% of total CO$_2$e emissions.

% OF CO2E BY BUILDING SIZE						
% of Buildings	% by sq ft	Sq ft range	Relative size	% total CO2e	% Co2e by sq ft	Ave CO2e by Sq Ft
51%	11%	1001 – 5,000	Fast food restaurant	13%	14%	0.0069
24%	14%	5,001 – 10,000	Small Office	13%	11%	0.0056
16%	19%	10,001 – 25,000	Car Dealership	16%	10%	0.0049
5%	14%	25,001 – 50,000	Small Retail Store	14%	11%	0.0056
3%	15%	50,001 – 100,000	Sports center	16%	12%	0.0061
1%	12%	100,001 – 200,000	Superstore	13%	13%	0.0062
<1%	10%	200,001 – 500,000	High school	10%	11%	0.0055
<1%	3%	500,001 – 1 million	Warehouse	3%	10%	0.0048
<1%	2%	Over 1 million	Mall	1%	7%	0.0034

Figure 8. CO$_2$e by building size for SMEs in the US, 2018.

CO$_2$e by Building Type

Mercantile buildings (retail malls and strip shopping centers) account for one-third of total CO$_2$e emissions (89.4 million metric tons per year), (Figure 9). The next highest emitter is office buildings, (25% of total emissions, 74.6 million metrics tons per year). Although food service buildings account for less total emissions, those buildings emit the most per square foot (0.024) than any other building (Figure 10). Warehouse and storage account for 75% of floor space (Appendix 1), but only account for 21% of emissions (47.7 million metric tons CO_2e per year).

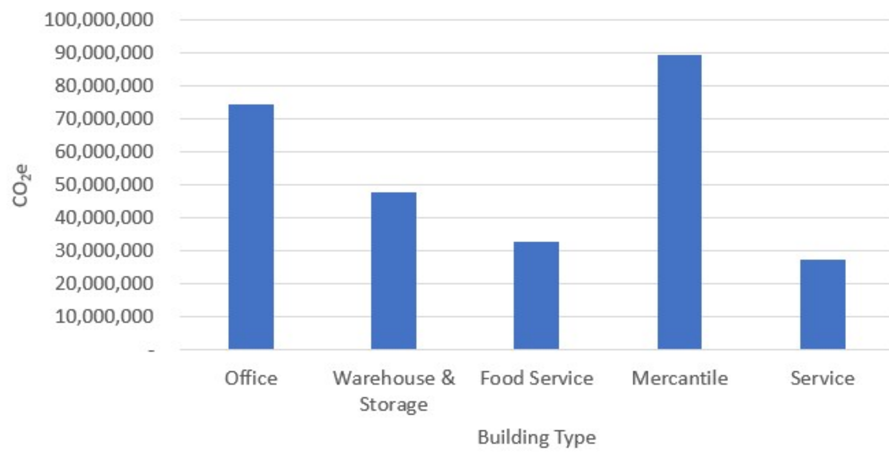

Figure 9. Total CO_2e by building type for SMEs in the US, 2018.

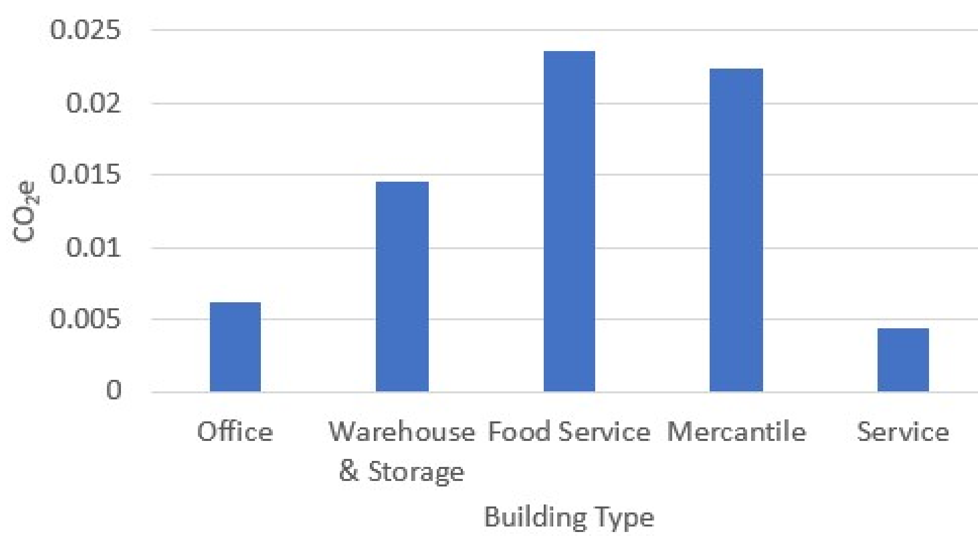

Figure 10. Average CO_2e per sq ft by building type for SMEs in the US, 2018.

CO_2e by Year Constructed

Buildings built before 1999 emit 53% of CO_2e, or 136 million metrics tons CO_2e per year (Figure 11). Even though the majority of emissions are in buildings built before 1999, interestingly, buildings built from 2000-2018 emit the most per square foot (Figure 12).

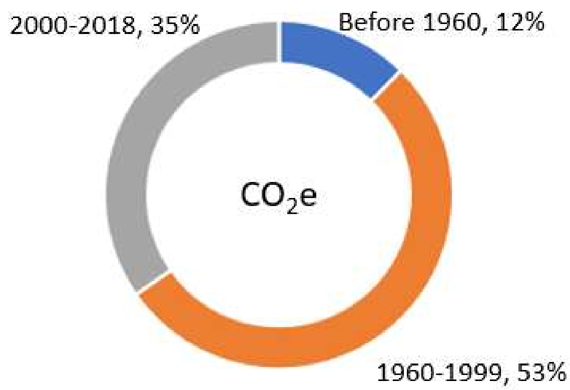

Figure 11. Percent CO_2e by year constructed for SMEs in the US, 2018.

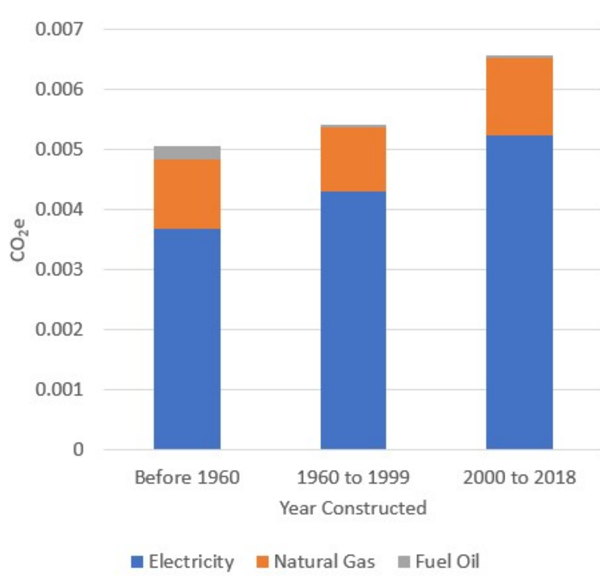

Figure 12. Ave CO_2e per sq ft by year constructed for SMEs in the US, 2018.

CO_2e by Owner Type

Owners occupy 64% of the buildings analyzed. Most of those (78%) are either individually owned or owned by a public or private corporation (Appendix 1). The majority of CO_2e per square foot, however, comes from buildings that are not owner occupied (Figure 13). Of these non-owner-occupied buildings, the majority are mercantile (strip malls and retail/other) and nonrefrigerated warehouse which are generally rented out to tenants. Public and private corporation ownership made up 46% of total CO_2e.

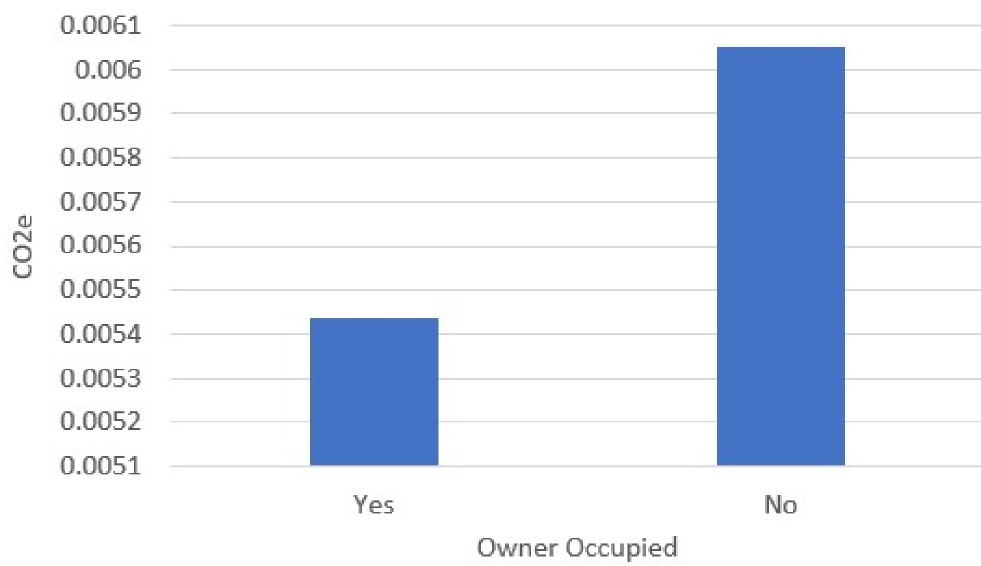

Figure 13. Average CO_2e per sq ft by owner for SMEs in the US, 2018.

CO_2e by Location and Climate

Buildings in the south emit the most total CO_2e (102 million metric tons), which corresponds with the large number of buildings found there (Appendix 1). But buildings in the Midwest emit more CO_2e per square foot (Figure 14). The states in the Midwest that are the highest emitters include Wisconsin, Michigan, Illinois, Indiana and Ohio. Buildings in the West emit the least CO_2e per square foot than any other region (0.004 CO_2e).

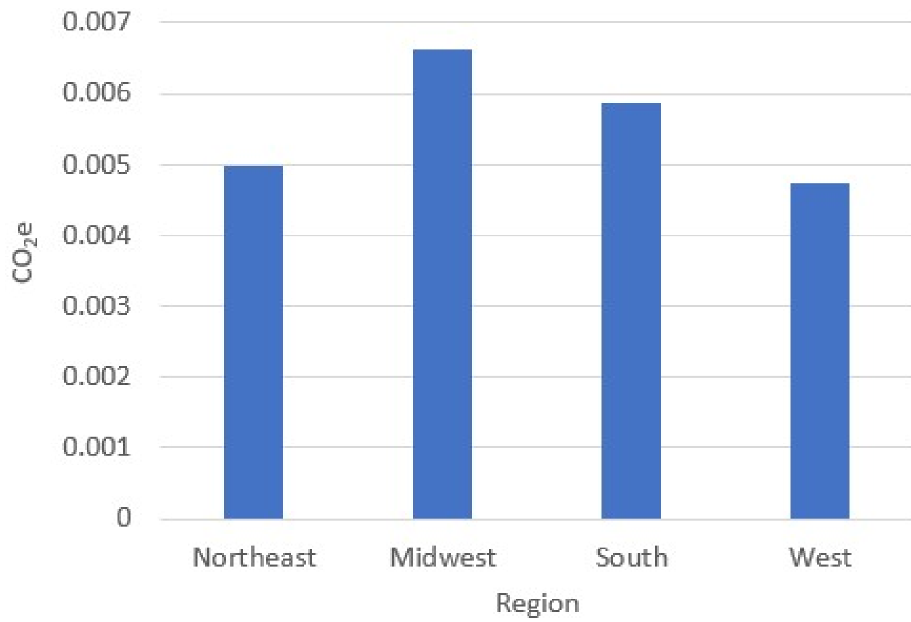

Figure 14. CO_2e per sq ft emitted by region for SMEs in the US, 2018.

CO_2e by Type of Energy Consumed

Electricity produced more CO_2e emissions per square foot in SME buildings than natural gas and fuel oil (Figure 15).

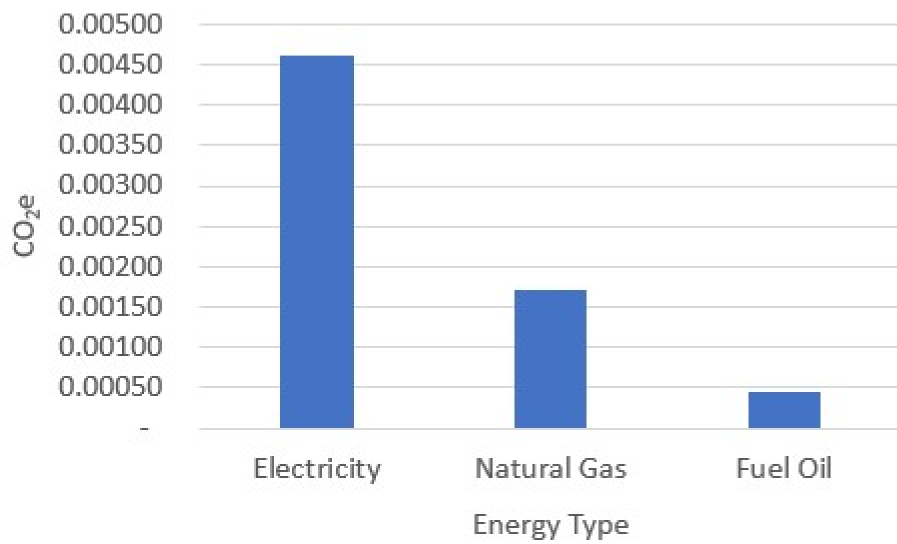

Figure 15. CO_2e emissions per sq ft in SMEs by energy consumption type in 2018.

Future GHG Reduction and Avoidance Scenarios

Information from the above analyses was used to graph a baseline scenario, five reduction scenarios, and one avoidance scenario. These scenarios provide a generalized estimate of how much CO_2e SME's will emit, reduce, and avoid under different action plans.

Baseline Scenario: Business as Usual

If SMEs took no action and continued consuming the same amount of energy they consume today, there would be no reduction in GHG emissions. They would emit 2.7 billion metric tons CO_2e over the next 10 years, and 7.6 billion metric tons through the year 2050 (Figure 16). If 10% uncertainty is added or subtracted from that number, SMEs would still be emitting between 6.9 and 8.4 billion metric tons in 10 years.

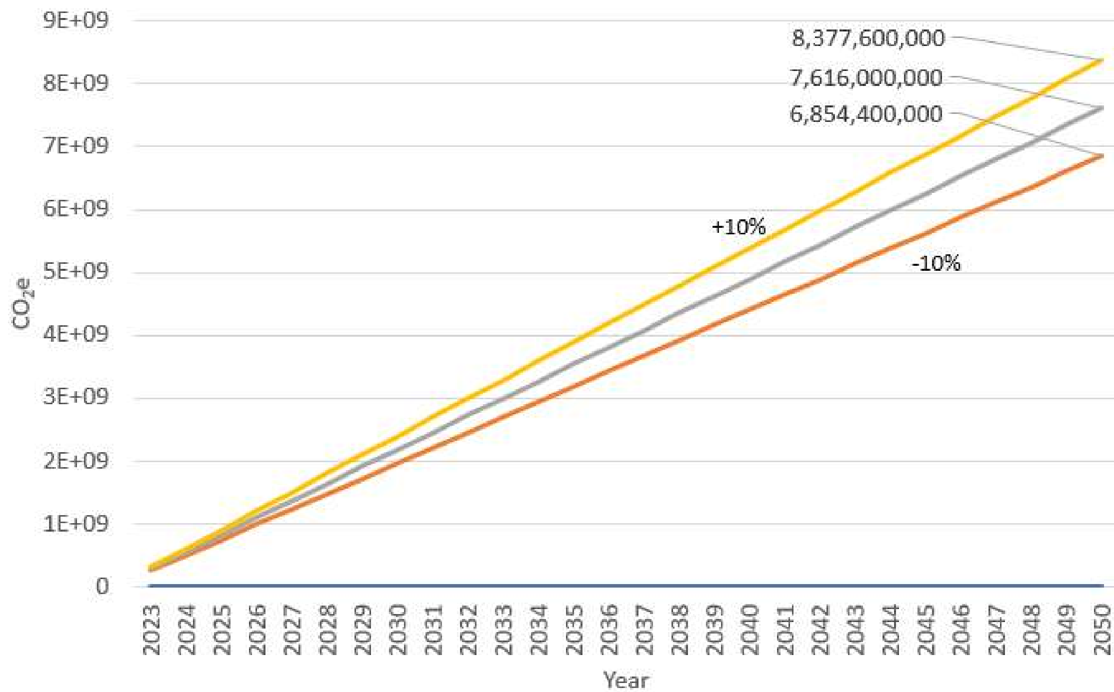

Figure 16. Cumulative emissions through the year 2050 for SMEs in the US.

Scenario 1: 10% reduction each year

If SMEs made yearly, incremental changes to reduce GHG emissions by 10% each year until 2050, five billion tons of CO_2e would be reduced, but buildings would still be emitting, on average, 16 million metric tons in year 2050. There would be large efficiency changes at first, and then smaller and smaller changes as gains in efficiency become harder to achieve. Cumulative emissions would reach 2.6 billion metric tons CO_2e in year 2050 (Figure 17). It would take over 150 years to reach zero emissions in this scenario.

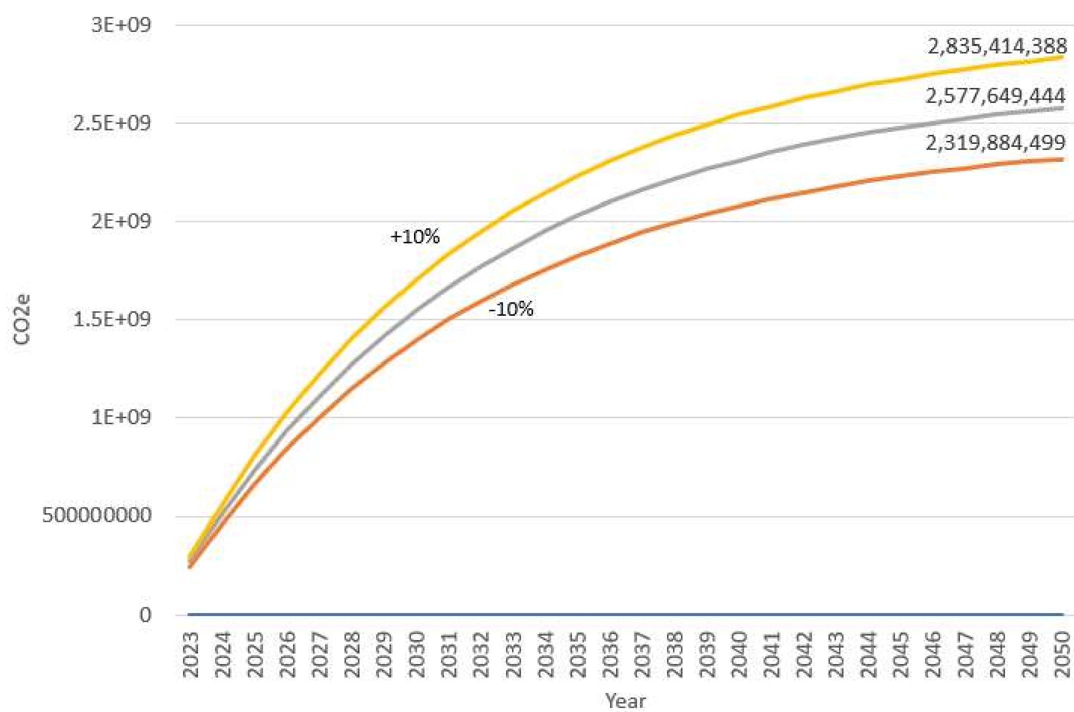

Figure 17. Expected total U.S. SME emissions with 10% reduction in CO_2e emissions each year through 2050.

Scenario 2: 0 by 2050

For SMEs to reach zero emissions by 2050, drastic measures would need to be taken. Each building would need to cut emissions by 75 metric tons per year over the course of 27 years. This means, on average, each building would need to reduce emissions by three metric tons each year to reach this goal. In the year 2050, cumulative SME emissions would reach 3.8 billion metric tons, but no further emissions would be emitted beyond that (Figure18).

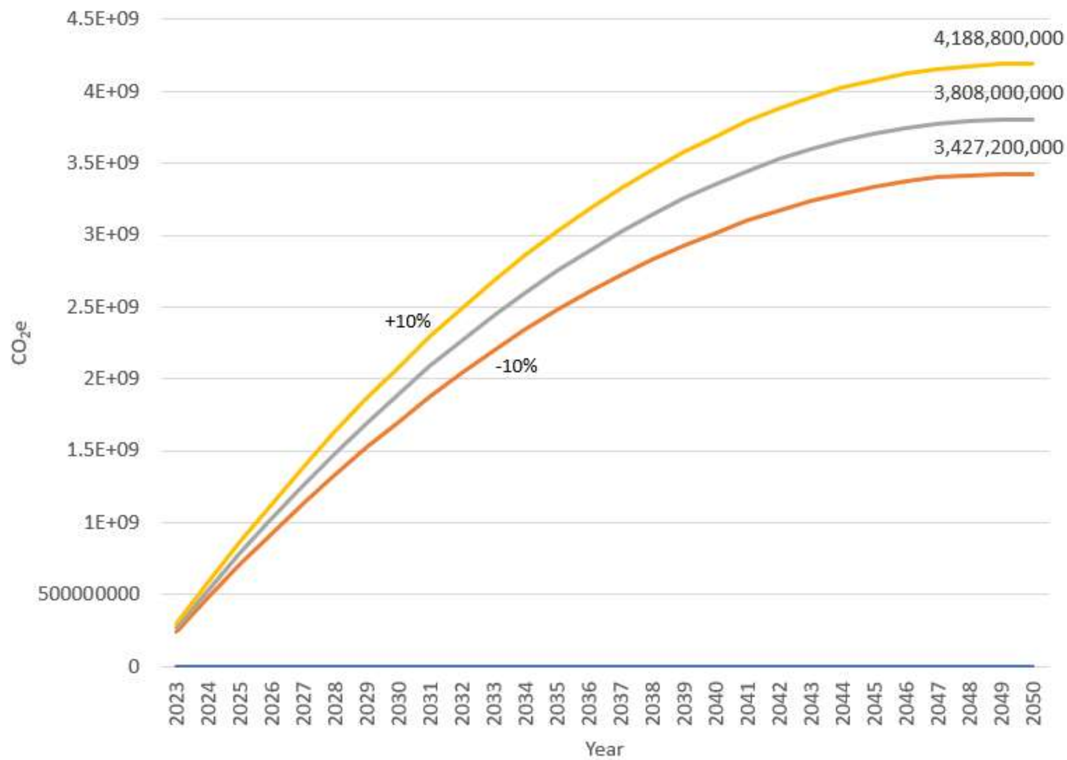

Figure 18. Cumulative emissions with reductions to meet 0 emissions by 2050.

Scenario 3: Eliminate Fuel Oil & Natural Gas, Improve Electric Source and Reduce Energy Use by Fixed 10% Year-over-Year

To analyze how professionals in the GHG accounting field foresee change happening, a scenario combining the elimination of natural gas and fuel oil, as well as reduced energy use and production of carbon-free electricity, was analyzed. In this scenario, natural gas and fuel oil were eliminated by the year 2028 in equal intervals spread over the five years starting in 2023. This was in addition to the reduction of emissions from electricity by 10% year over year for ten years. The electricity reduction could be through either a decrease in consumption, or a reduction in indirect emissions by decarbonization or carbon free energy sources. Within the first five years, 493 million metric tons CO_2e emissions would be avoided, and all emissions would be eliminated by the year 2033. In 2032, cumulative emissions total 1.3 billion metric tons (Figure 19).

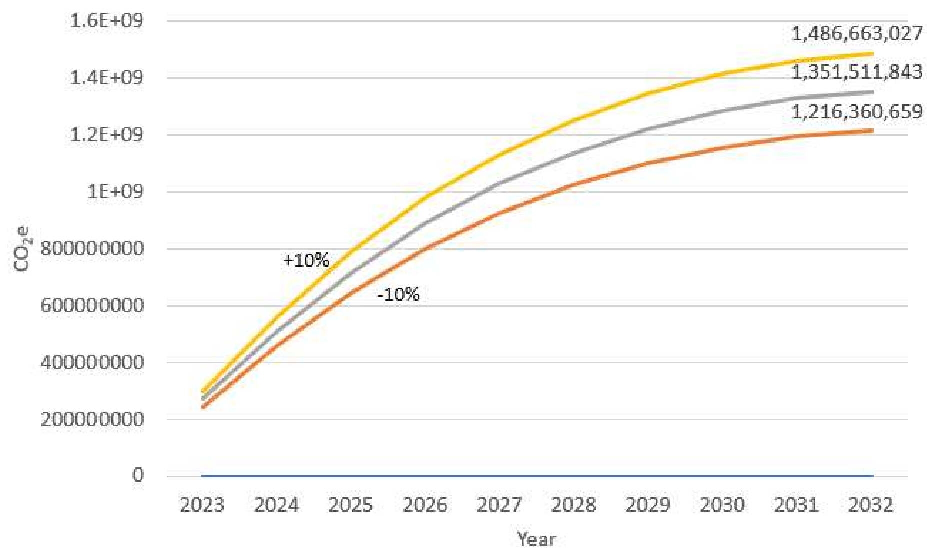

Figure 19. Eliminate natural gas and fuel oil, electricity reduction 10%.

Modeling based on SMEs in the US, 2018. Elimination of natural gas and fuel oil in five years and electricity reduction 10% every year. Electricity consumption can be decreased either through reduced consumption, or through decarbonizing the energy source.

Scenario 4: Incentivize LEED or Energy Star Certifications

To understand the impact of LEED and ENERGY STAR certification achievements, average GHG savings are implemented in this model in all SME buildings in year one, avoiding 92 million tons CO_2e. After certification, buildings would remain as-is and emit at a reduced amount of 180 million metric tons every year. If no other efforts are taken, over the course of ten years, these buildings would still emit, collectively, two billion metric tons CO_2e and five billion metric tons through 2050 (Figure 20). These calculations are based on LEED data that suggests certified buildings emit, on average, 34% lower CO_2 (USGBC, 2018), and ENERGY STAR certified emit 35% less on average than buildings that are not certified (Energy Star, n.d.c). A 10% difference was mapped to show both a high and low scenario. In the high scenario, 207 million metric tons CO_2e would still be emitted each year after the initial reduction, and in the low scenario, 152 million metric tons CO_2e would be emitted yearly.

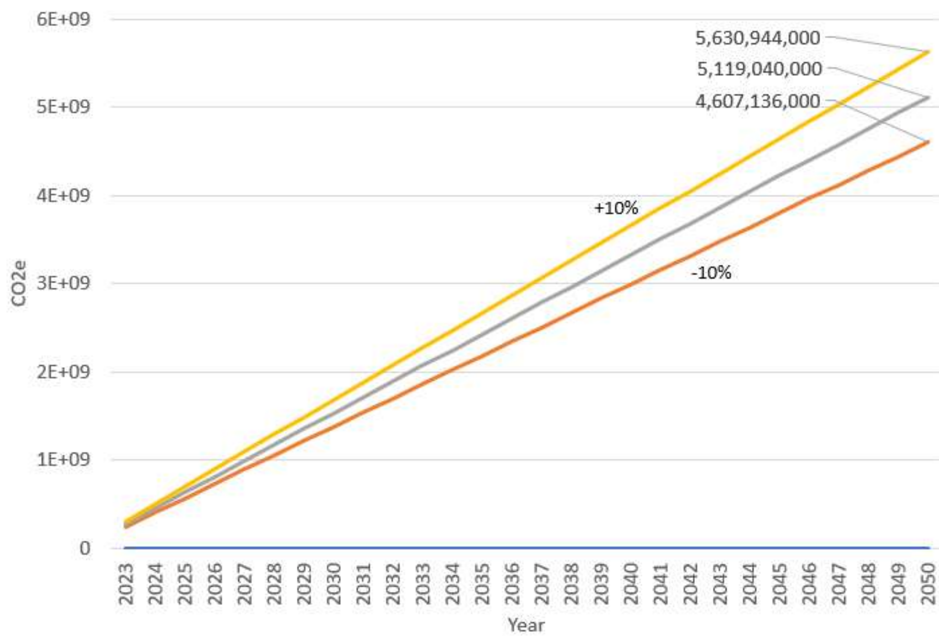

Figure 20. Cumulative emissions with LEED or ENERGY STAR certification.

For SMEs in the US. The certification reduction assumes a 34% decrease in CO_2e *emissions in year one, and that no other efforts are taken in reducing emissions or to decarbonize the electric grid or use carbon free energy sources.*

Scenario 5: LEED or Energy Star Certification, Elimination of Natural Gas & Fuel Oil, and Electric Improvements of 10% YoY

This scenario combines scenarios 3 and 4, providing the quickest path to CO_2e elimination. LEED/ENERGY STAR certifications were assumed to be implemented immediately in all buildings, natural gas and fuel oil were eliminated at a steady rate over five years, and electricity emissions were reduced by 10% year-over-year. Electricity could be reduced either through lower consumption, energy efficiency, using carbon free energy sources or through the decarbonization of the electric grid. This is a net decrease so that as buildings are removed natural gas and fuel oil use, carbon free replacements are assumed. If the replacement energy source is electricity, it is assumed that the increase in consumption plus the 10% would be reduced every year. In the first year, there is a 44% reduction of GHG emissions, or elimination of 106 million tons CO_2e (Figure 21). Within five years, GHG is reduced by 237 million metric tons, and 1.3 billion metric tons is avoided. Within seven years, GHG emissions are eliminated, and all SMEs are carbon neutral. Total cumulative emissions in this scenario are 785 million (Figure 21).

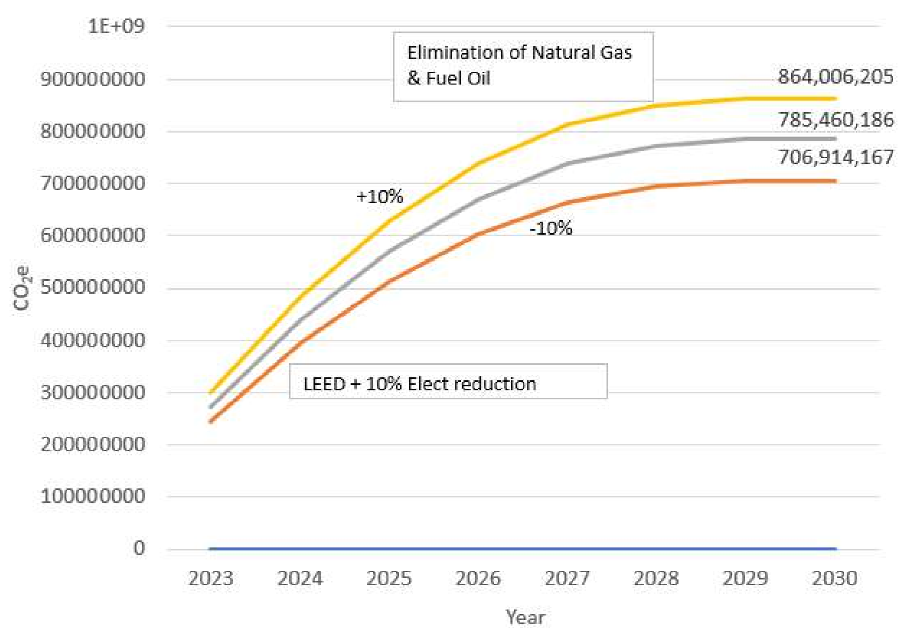

Figure 21. Multiple approaches for SME emission reductions through 2050.

LEED certified reduction in year one, elimination of natural gas and fuel oil over five years, and 10% reduction in electricity every year.

Avoidance Scenario: Implement Carbon Offsets Though Tree Planting and Solar Installation

One way for SMEs to reduce emissions is by installing carbon free energy sources, like solar, wind, geothermal or hydropower. This avoidance of emissions is critical, but in addition, developing negative emissions technologies would help remove CO_2 from the air to offset any additional emissions. To do this, an SME could implement carbon removal and sequestration through planting trees or direct air capture. These options can offset any residual carbon emitted or provide net positive emissions meaning a company removes more carbon from the air than it emits.

If every SME in the US planted ten mature trees in their community, 790,000 metric tons CO_2e could be sequestered every year and 21 million metric tons avoided by the year 2050. Calculations for this come from the USDA who reports that in one year, a mature tree absorbs more than 48 pounds of carbon dioxide (USDA, 2015). If, in addition to planting trees, every one of the 3.6 million SMEs installed one solar panel, 5.8 million metric tons CO_2e would be avoided every year. This estimate for solar panel GHG avoidance is from the Energy Saving Trust (Forbes Advisor, 2021) and provides a generic scenario which does not take into consideration location, building type, roof space or affordability.

Together, planting ten trees each, or 36 million collectively, and installing one solar panel each, or 3.6 million collectively, would avoid 6.6 million metric tons CO_2e per year. If comparing the baseline scenario, where there is no change to current emissions, with implementing this avoidance scenario, 491 million metric tons CO_2e would be avoided through 2050. Though these efforts have a large impact, SMEs would still be emitting 244 million metric tons every year and cumulatively 7.1 billion metric tons through 2050 (Figure 22).

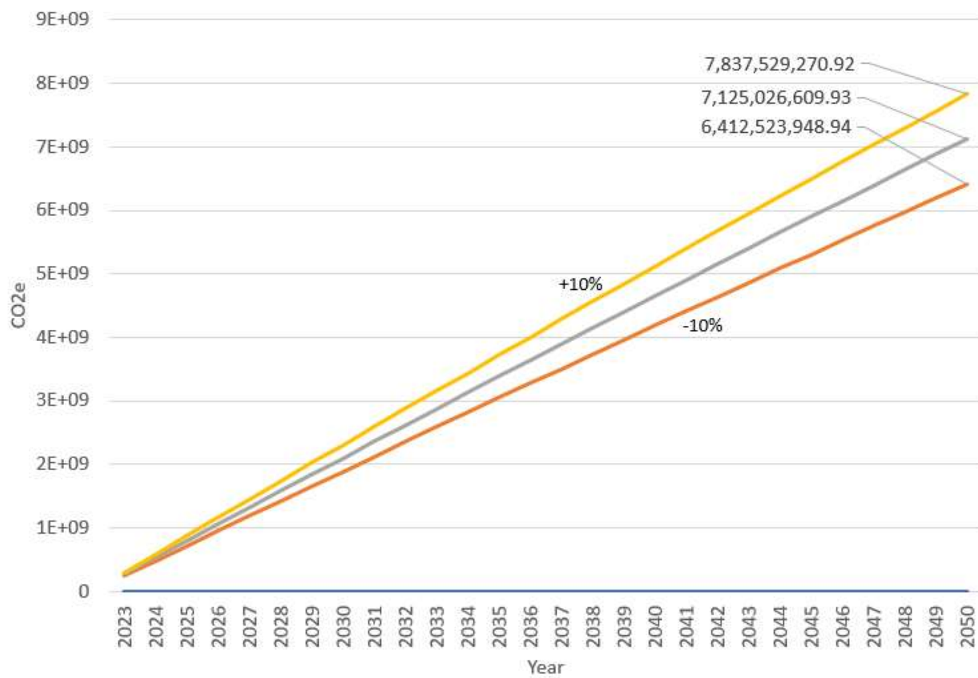

Figure 22. Avoidance scenario forecasted emissions for SMEs through 2050.

This avoidance scenario assumes every SME in the US plants 10 trees and installs one solar panel.

Chapter IV

Discussion

The objectives of this study were to: 1) assess the collective GHG contribution by small and medium businesses (SMEs) in the United States and determine their main source of GHG emissions; 2) develop an analytical framework to forecast future GHG avoidance per square foot based on different incentive scenarios; and 3) suggest policies and incentives that are compatible with SMEs limited human and financial resources. Policy is discussed further in this section. The research required the creation and analysis of an extensive spreadsheet model that included 59 variables, multiple calculations, a sample set of over 3 million SMEs, and modeling to address the two primary hypotheses.

My research findings did not support my hypotheses, which had grossly overestimated potential avoided emissions for SMEs. Because there is very little research on SMEs and their contributions to climate change, it was nearly impossible to make accurate assumptions. I hypothesized that if every SME in the US reduced GHG by 10%, total GHG emissions in the US would be reduced by 1 billion metric tons per year. My research indicated that if every SME in the US reduced GHG emissions by 10%, total GHG emissions would be reduced by 27 million metrics tons per year, 3% of the initial projection.

I also hypothesized that a financial incentive to achieve LEED or Energy Star certifications could be implemented to avoid over 500 million tons CO2e. By my calculations, CO2e would be reduced by 92 million tons in year one, on average, if all buildings received LEED certification or upgraded to Energy Star.

This research found that collectively, SMEs account for 272 million metric tons (t) CO_2e per year. Consequently, 33% of commercial building emissions nationwide are estimated to come from SMEs, and 5% of all US emissions come from SME building energy consumption. This percentage may seem like a small non-impactful amount, but the United States is the second largest contributor of GHG emissions in the world, emitting over 1/10 of global pollution (World Population Review, 2020). And when looking at country emissions, SMEs in the US emit more CO_2e per year than most countries use, including Thailand, Egypt, Ukraine, the Philippines, and Spain individually.

One interesting research finding is that the smallest SME buildings (1,001-5,000 square feet) emit the most CO_2e per sq foot on average. This may be explained by the fact that many of these smaller buildings are utilized for businesses like fast food restaurants which consume more energy to cook and heat than a larger warehouse, that sits mostly static without any cooking or temperature control needs. This research also found that buildings in the Midwest emit more CO_2e per square foot. This is most likely due to the colder Midwest climate which requires more energy consumption to regulate fluctuations in temperatures. Buildings in the west emit less CO_2e per square foot than any other census division (0.004 CO_2e) explained by its moderate temperatures and lower energy consumption.

Another surprising finding was, when calculating emissions from energy consumption, it was found that electricity emits more per square foot than natural gas or fuel oil in these types of buildings. This could be explained by the fact that electricity still largely comes from the use of coal which has the highest carbon footprint related to electricity generation (World Nuclear Association, 2022).

Even though the majority of emissions come from buildings built before 1999, buildings built from 2000-2018 emitted the most per square foot. This could be because most buildings have been transitioning to electricity and based on my analysis, electricity, when using carbonized sources like coal, emits more per square foot than natural gas or fuel oil.

The main source of these GHG emissions is through the consumption of energy for heating, cooling and lighting, which produce scope 1 and scope 2 GHG emissions. A few scenarios make it possible to reach Net Zero by 2050. The scenario that proved to reduce emissions the quickest and emit the least cumulative GHG was scenario 5. In this scenario, a large push for energy efficiency was done in year one along the elimination of natural gas and fuel oil within five years, and a 10% reduction in GHG emissions from electrical consumption every year. A GHG avoidance scenario was also modeled which resulted in an avoidance of 6.6 million t CO_2e per year. Through these findings and modeling, it was determined that SMEs do account for substantial GHGs through their scope 1 and scope 2 emissions, and their support could greatly reduce GHGs in the atmosphere. Perhaps change can be motivated through incentives and policies.

Policies and Incentives Compatible with SMEs

SMEs are uniquely positioned to make quick sustainability changes, respond to government tax incentives or other programs, and could benefit from the cost savings associated with those changes. Unlike large corporations, SMEs are often more flexible and have the ability to adapt quickly to changes. This enables them to explore new technologies, be innovative, and pioneer new approaches (The Green Side of Pink, 2023).

Building energy consumption is a top commercial building contributor to scope 1 and scope 2 GHG emissions for SMEs and was therefore the focus for this research. Many existing policies and incentives directed at large corporations tackle these kinds of building emissions through building efficiency improvements. Because 64% of SME office space is owner occupied, similar efficiency improvements could be easy to implement in these smaller buildings as well. For the 36% that rent, there are opportunities that allow both building owner and tenant to benefit from investments in energy efficiency. With a split incentive, like one that is offered by Green Lease, building owners can amortize and recoup capital costs for retrofit improvements and share in the long-term savings along with the renter (Green Lease Leaders, n.d.)

To motivate change, a synergistic mix of reporting tools to benchmark, incentives to motivate, regulatory requirements to drive performance, and financial assistance to cover upfront costs where necessary are needed.

Reporting Tools and Incentives

Most corporations utilize reporting tools to measure emissions and then benchmark how they stack against other corporations. Some reporting options like the Climate Disclosure Project (CDP) and Global Reporting Initiative (GRI), are slowly becoming available to small businesses, but a more comprehensive tool is needed that is easily available to help them identify their current GHG emissions and future reductions. Ideally one tool could be used to report on all sustainability metrics and include GHG accounting and reporting. The GHG reporting piece of the tool could be similar to the

Zero Tool or ENERGY STAR's Target Finder, which helps identify baseline and reduction targets for existing buildings. With this reporting insight and initial benchmarking information, SMEs would be able to measure and make reduction commitments. But there must be motivation to act.

A few possible certifications that could be incentivized that may help motivate and are popular with commercial building owners are LEED and ENERGY STAR Certifications. These options provide good initial insight into what can be done to improve energy efficiency and reduce consumption. As seen in scenario 5, if done in collaboration with all other SMEs, improving efficiency required to gain one of these certifications will reduce emissions by 92 million metric tons CO_2e in the first year. By creating energy efficiencies and reducing consumption, SMEs benefit by saving monthly on energy bills. ENERGY STAR estimates that SMEs can reduce utility costs by up to 30% without sacrificing comfort or service (EPA, n.d.). As an example, a music store in Pennsylvania upgraded lighting and installed two new air conditioning units and after the initial cost, is saving $1,840 a year and reducing emissions by 47,000 pounds annually (EPA, n.d.). In addition to cost savings, these programs provide national recognition, and certificates that advertise achievements which can be displayed in buildings and may provide a competitive advantage in the real estate market (Urban Green, 2023a). Obtaining a certification like this or using these as a tool to create building efficiency plans is a great way to jump start GHG reductions.

Another incentive similar to the approach that New York City (NYC) took could be adopted. NYC requires buildings that are 25,000 SF and larger to obtain an energy star rating. NYC requires this rating with associated letter grade, A to F, be posted at the front door of each commercial building in hopes that real estate competition will drive efficiency in the market (Urban Green, 2023a). Once that rating, or benchmark, is determined for each commercial building, owner goals can be set for future reductions. Through this benchmarking, stronger performance standards for SMEs can become a reality.

Reporting tools to benchmark and incentives to motivate are important elements to consider, but LEED and ENERGY STAR are not required for a SME to make efficiency improvements. Building owners and renters can realize benefits from making these changes without going through a certification process.

Energy Efficiency & Carbon Free Energy Sources

If a building owner or renter is motivated, there are two key elements to realizing the benefits of reductions: through energy efficiency and using carbon free energy. My research and scenario analysis showed that a piecemeal approach of slowly updating a building to be more energy efficient will not result in necessary emissions reduction targets. To maximize energy efficiency in a building, the recommendation is to do a whole-building approach, which improves the envelope of the building in addition to the interior and smaller efficiencies like lighting and appliances. This deep energy retrofit approach creates greater energy and monetary savings more quickly but may be expensive upfront and disruptive to daily business. This is likely the main obstacle to doing any of these upgrades for SMEs. As this type of renovation becomes more popular, costs and impacts will likely go down (Boston Green Ribbon Commission, 2019). This creates a great opportunity for private investors, foundations and governments to help SMEs with these kinds of changes through covering upfront costs or funding retrofit programs. Almost half of small businesses report they are worried about funding when implementing sustainability projects, and 70% say they need access to external funding to reduce emissions faster (SME Climate Hub, 2022).

In order for SMEs to meet net zero requirements, they would need to rely solely on renewable energy or carbon free energy sources. As seen in scenario 3, eliminating natural gas and fuel oil and using carbon free energy (through switching to renewable energy or a decarbonization of the electric grid) creates a seamless way to reach net zero before 2050. If SMEs rely solely on the electric grid, electricity providers may be taxed and emissions will be determined by utility companies and their strategies to decarbonize. Incorporating solar panels, battery, and energy storage into efficiency strategies would help improve performance and avoid straining electric grid resources by lessening the load taken from the grid. Some back-up systems that cannot be converted to electricity may have the option to be fueled by renewable natural gas or hydrogen if they become available (Boston Green Ribbon Commission, 2019).

Regulatory Requirements

Sometimes incentives and motivation will only go so far, so adding regulatory requirements could help drive performance. A few ways to encourage or mandate reduced carbon emissions are through a carbon cap and GHG trading system.

A carbon cap, like NYC's 25,000 SF or larger building carbon cap, could be implemented for SMEs. In fact, large commercial buildings only make up 14% of buildings; 86% of commercial buildings are less than 25,000 SF. Consequently, if NYC was a typical city with a mix of large and small buildings, the majority of buildings would be missed in the carbon cap regulation. In fact, based on my research, smaller buildings emit more per square foot than their larger counterparts so there may be even more collective GHGs missed in this carbon cap. In Boston, where there are a lot of smaller buildings, buildings under 20,000 SF could be accumulating more GHG emissions than their larger counterparts, which are not covered by Boston's carbon targets. Carbon caps, tax or penalty payments like those in Boston and NYC could be imposed on SMEs to limit the amount of carbon emitted and then reduced year to year until targets of zero are reached in 2050.

GHG emissions trading systems (ETSs), as discussed in detail in the background, are utilized by governments and imposed on heavy polluters. A similar system could be implemented, and SMEs could be incentivized with a money-making method to reduce carbon emissions. California has implemented a cap-and-trade program that targets larger manufacturing facilities, utilities, and refineries (California Air Resources Board, 2023). Their regulatory board has also implemented three other credit-trading programs: one for transportation fuels, one for renewable power for utilities, and a zero-emissions vehicle program which allows for trading of credits across fleet owners. Perhaps a trading system can be implemented for SMEs. Also popular are the use of credits from eligible renewable energy generation (RECs) or greenhouse gas reduction projects (GHG offsets). By installing solar or battery storage onsite, utilizing renewable energy sources like wind, geothermal or hydropower, or utilizing carbon sequestration to help meet regulatory targets, organizations can be provided with offset credits to go toward a portion of their compliance obligation each year.

Recommendations Based on Scenarios

Based on these policy and incentive options, and the scenarios analyzed within this research, the quickest way to realize GHG reductions in SME's is through: 1) incentivizing building improvements like LEED and ENERGY STAR recommendations, 2) eliminating natural gas and fuel oil, and 3) utilizing carbon free energy sources. Initial efficiencies could be subsidized by the federal government or foundations to help cover upfront costs of large retrofit projects. To eliminate the use of natural gas and fuel oil and reduce consumption or utilize carbon free energy, a cap-and-trade program can be initiated for SMEs by setting a carbon cap. An incentive to meet the cap through selling carbon credits if a company doesn't reach that cap could also be provided. Scenario 5 modeled this change and shows how quickly doing these actions will result in zero emissions.

The second recommendation is to incentivize the elimination of natural gas and fuel oil use, specifically in buildings aged from before 1946 to 1970, and utilize carbon free energy sources; this was modeled as Scenario 3. Fuel switching—or changing the main energy source a building uses for heating and hot water—has been primarily defined by gas replacing heavy fuel oil in most benchmarked buildings. Over the next few decades, buildings need to replace gas with clean electricity to meet our collective decarbonization goals.

The third recommendation is to implement either of the above recommendations as well as incentivize carbon offsets to help remove additional carbon being emitted into the air by other sectors.

Limitations and Future Research

A significant limitation of this research is that although various building attributes were separated when calculating GHG emissions, results may not represent specific industry and business GHG emissions. There are many other variables such as industry type, exact location, exact energy source and renewable energy sources that could be analyzed separately to gain a more comprehensive view into specific SME contributions. Also, this research solely evaluated building energy consumption. Emissions from transportation or other SME business-related sources were not considered and require further research for a broader understanding of total SME contributions to US emissions.

Another limitation is the calculation used to identify GHGs from electricity consumption. Although the eGRID was comprehensive in providing emissions based on power plants within each region, those regions didn't align perfectly with the CBEC regions. I compensated by weighting regions with higher populations and larger cities to provide a more accurate emission estimate based on regional power plants. However, a more exact emissions rate for each region could be calculated with more detailed power plant emissions information.

Further research could be done on other innovative solutions that are available to determine their viability and precise impact on SME GHG emissions reductions. For instance, the solar panel avoidance scenario was taken from estimations provided by the Energy Saving Trust (Forbes Advisor, 2021) and provides a generic scenario, but does not take into consideration location, building type, roof space or affordability.

Another interesting area that could be researched further is the total cost to implement building efficiencies and the corresponding return on investment. This could show SMEs whether these changes would be financially beneficial or not.

Conclusions

This research achieved its goals of determining how much GHG is emitted by SMEs in the US, and providing recommendations to eliminate these GHG emissions. Further, it highlighted a variety of scenarios that show cumulative GHG emissions based on different actions that can be taken by SMEs in the United States.

The findings show that SMEs do significantly contribute to GHG emissions, and they should be engaged to help in GHG reduction efforts. There are several ways to help SMEs reduce emissions, including funding that incentivizes efficiency improvements, a carbon tax, or a GHG trading system. The design of a simple, user-friendly reporting tool that is adopted by all SMEs would greatly enhance their understanding of possible emissions reductions and drive results. This research determined that if SMEs made sustainability improvements, many benefits would be realized. It is hopeful that as SMEs become part of the sustainability equation, they do realize these benefits and are willing to make change for a sustainable future.

Appendix 1

SME Building Statistics

% OF BUILDINGS BY SIZE (SF)			
%	Sq ft range	Relative size	% by sq ft
51%	1001 – 5,000	Fast food restaurant	11%
24%	5,001 – 10,000	Fire station	14%
16%	10,001 – 25,000	Fire station	19%
5%	25,001 – 50,000	Sports center	14%
3%	50,001 – 100,000	Sports center	15%
1%	100,001 – 200,000	Superstore	12%
<1%	200,001 – 500,000	High school	10%
<1%	500,001 – 1 million	Hospital	3%
<1%	Over 1 million	skyscraper	2%

Figure 23. SME percent of buildings by size, 2018.

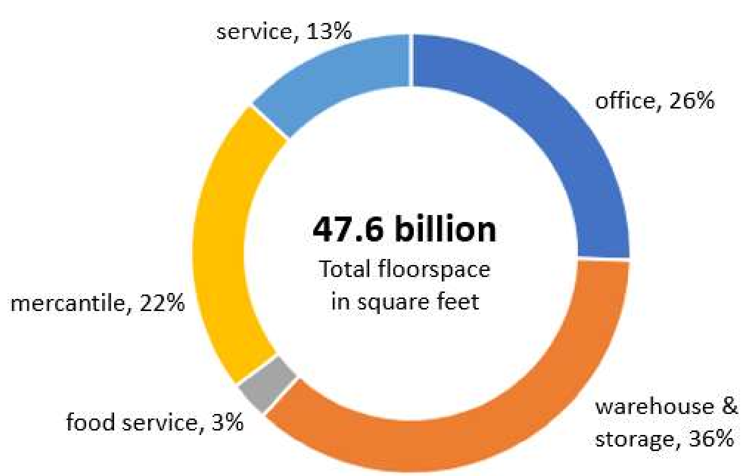

Figure 24. SME percent of floorspace by principle building activity, 2018.

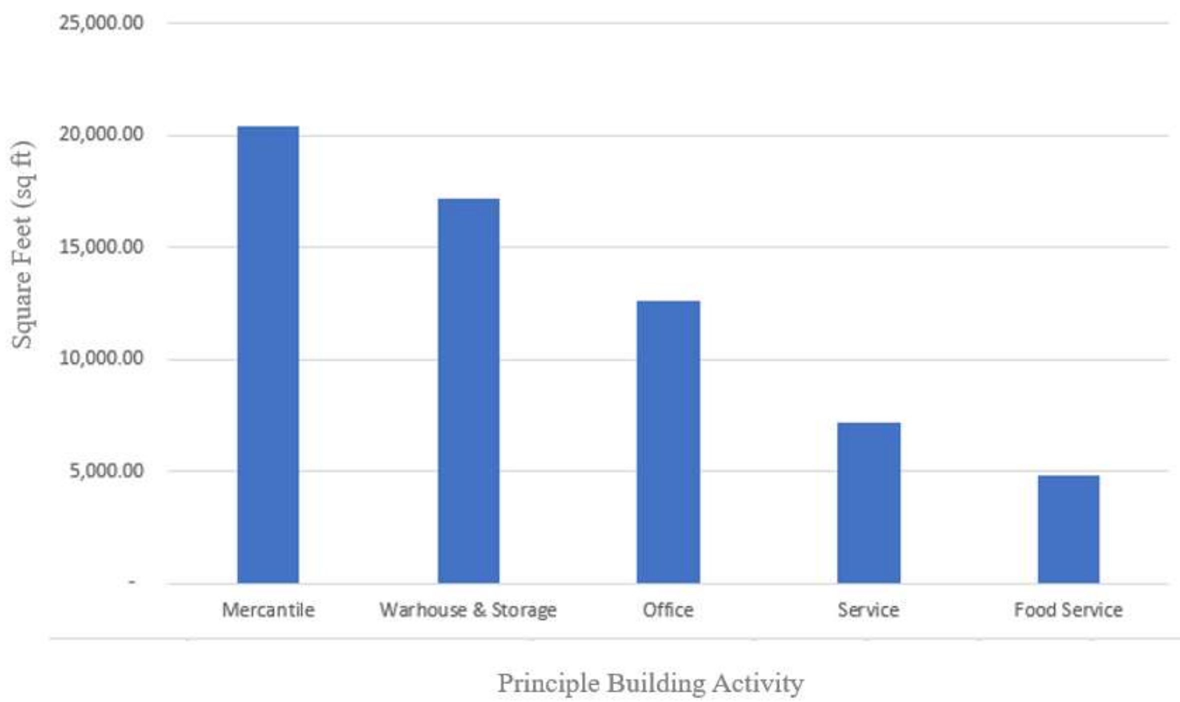

Figure 25. SME average floorspace by principle building activity, 2018.

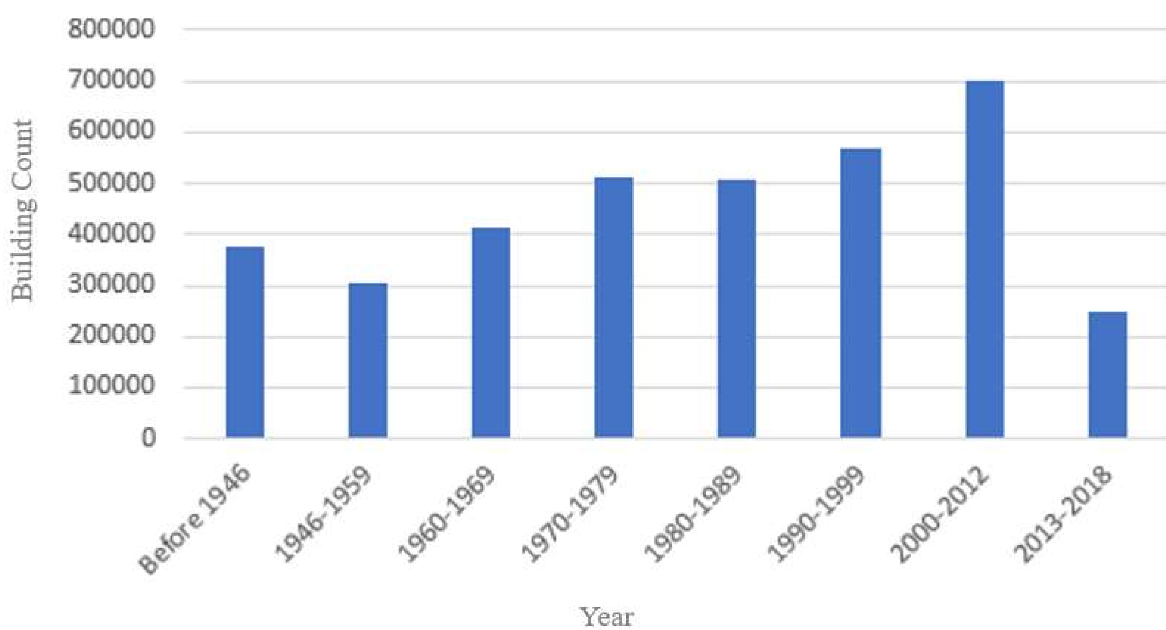

Figure 26. SME number of buildings by year constructed, 2018.

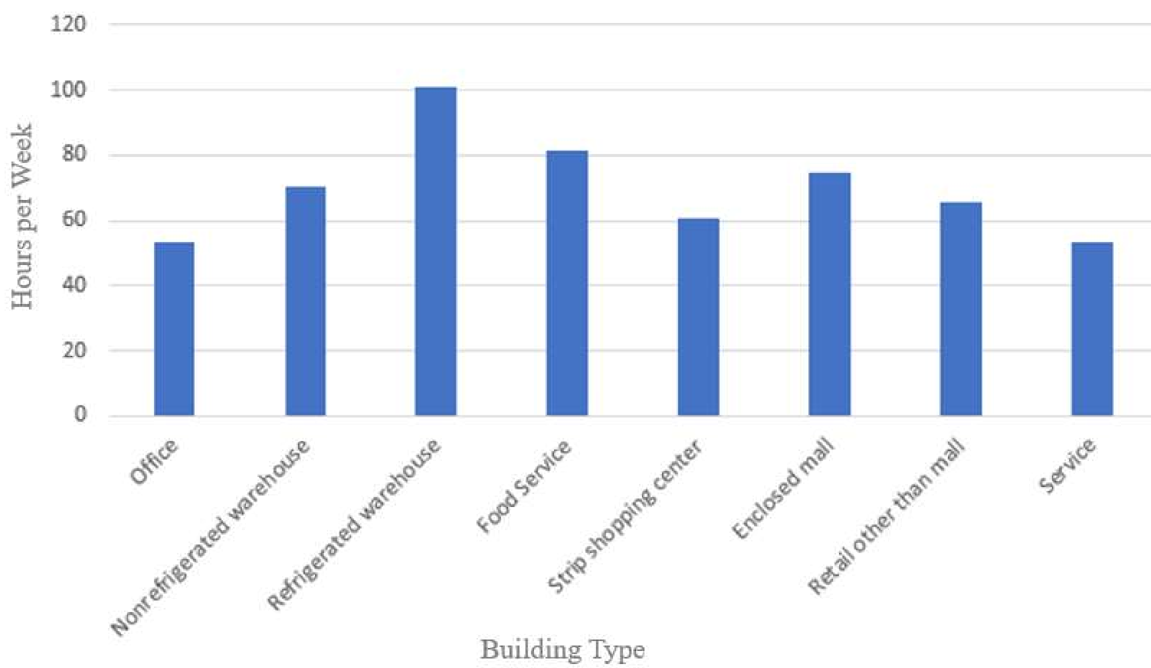

Figure 27. SME average hours open per week by building activity, 2018.

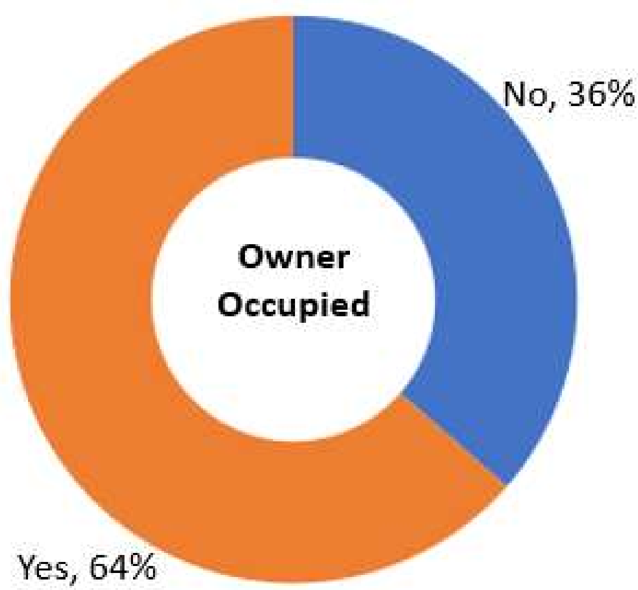

Figure 28. SME owner occupancy in buildings, 2018.

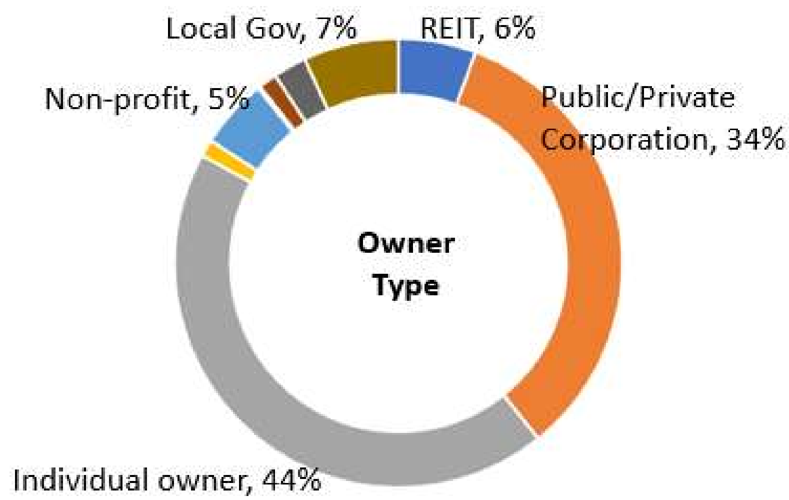

Figure 29. SMEs by owner type, 2018.

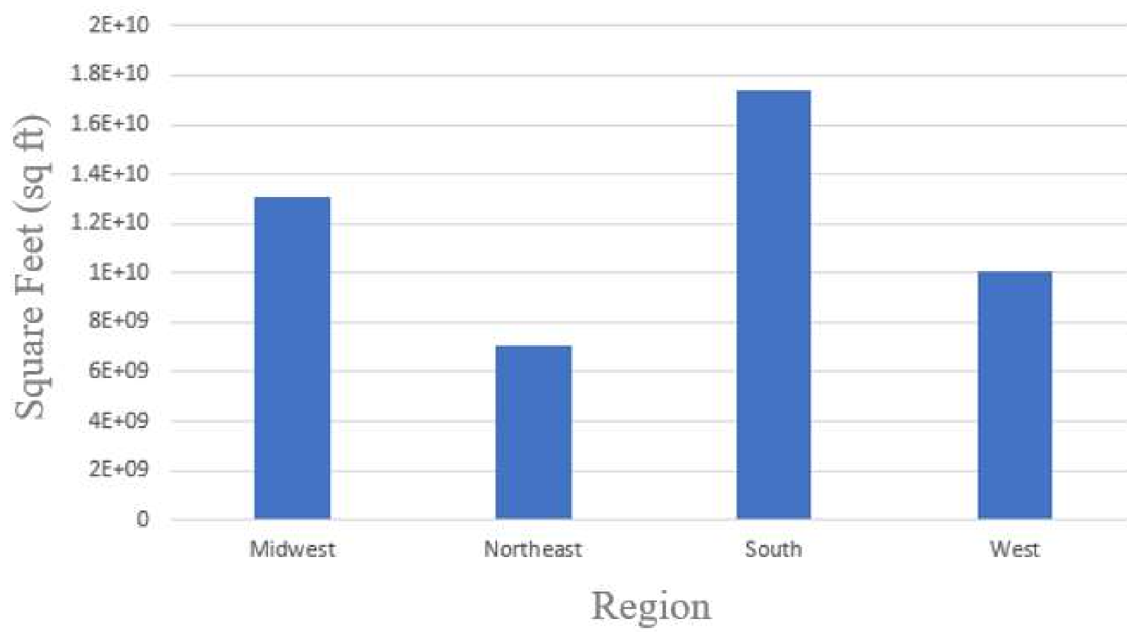

Figure 30. SME total square feet by region, 2018.

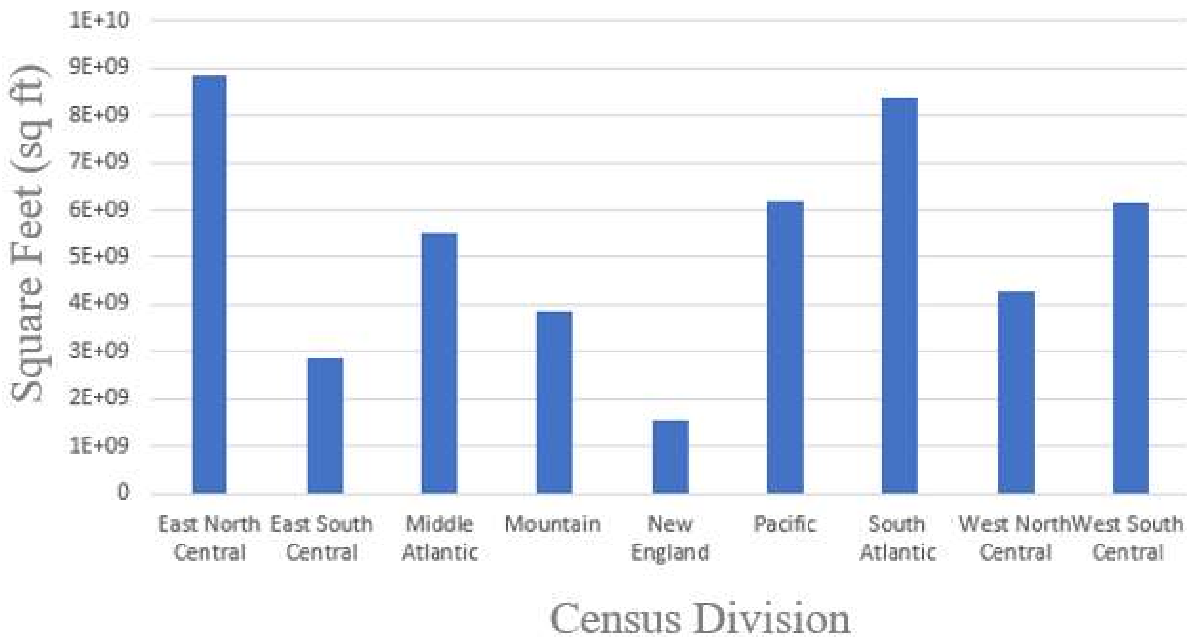

Figure 31. SME total square feet by census division, 2018.

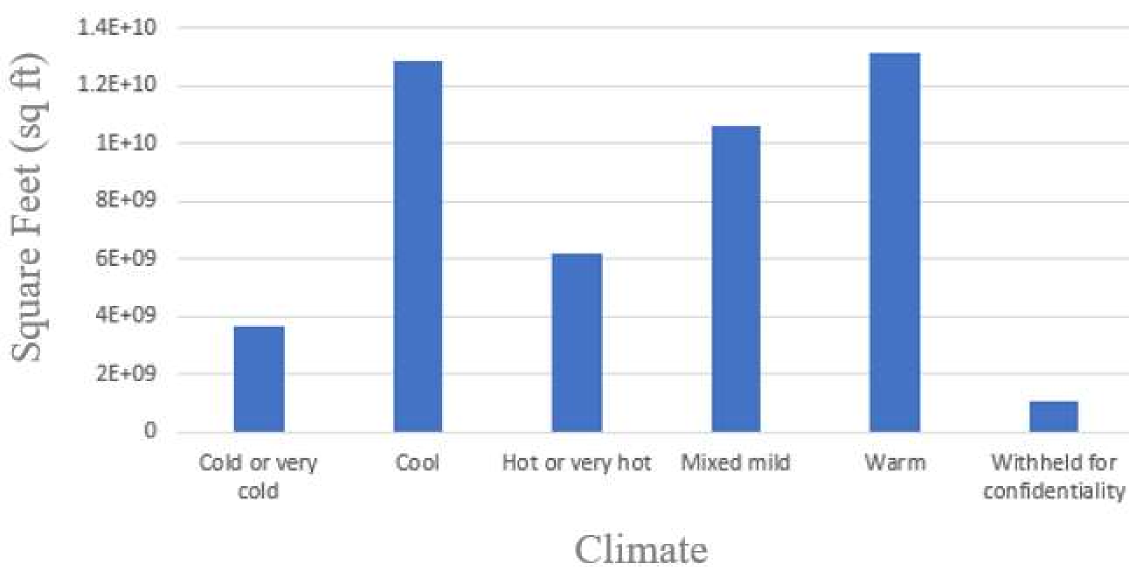

Figure 32. SME total square feet by climate, 2018.

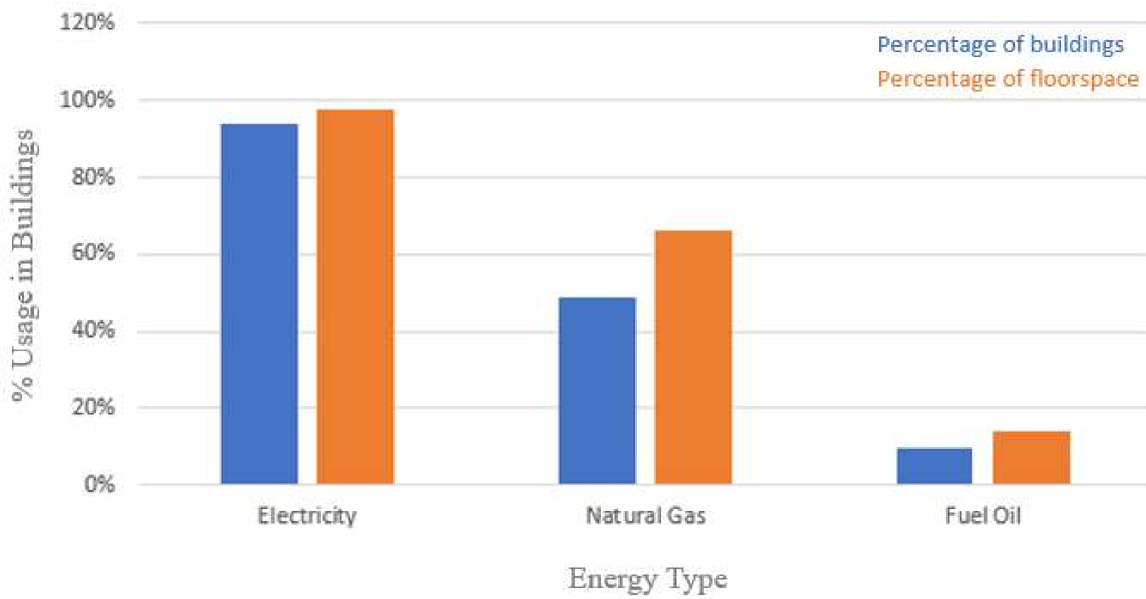

Figure 33. SME percent of buildings by energy use type, 2018.

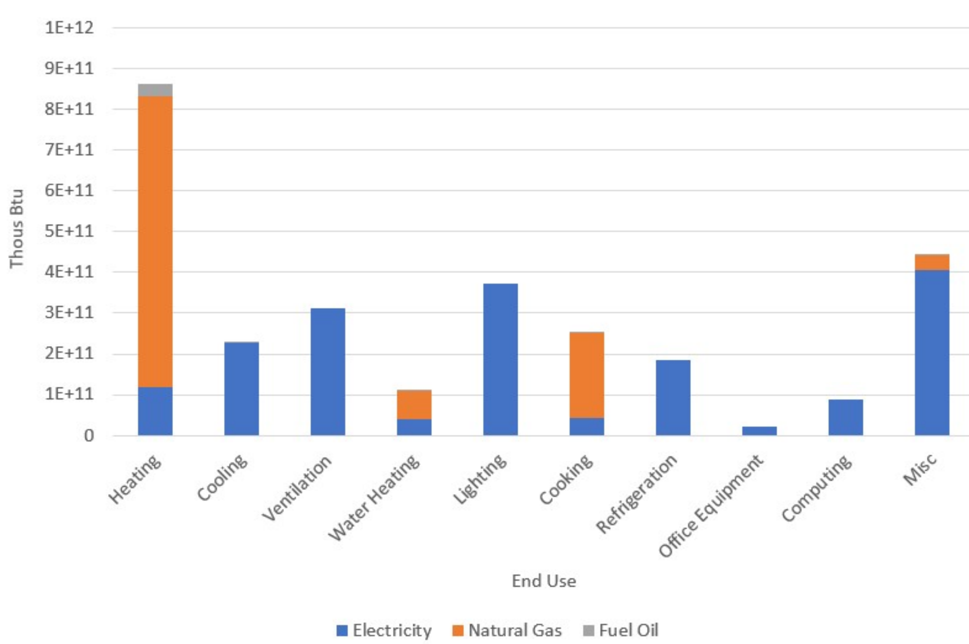

Figure 34. SME total energy consumption, 2018.

Appendix 2

SME GHG Emissions Statistics

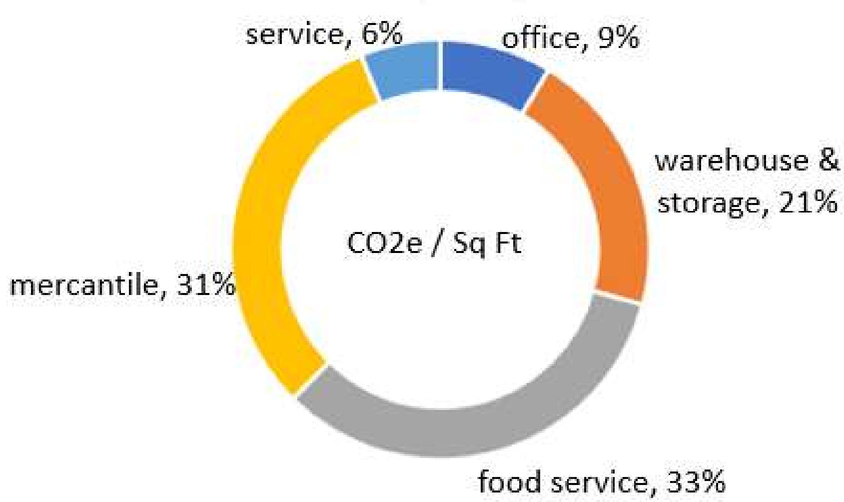

Figure 35. SME CO_2e per square foot by building type.

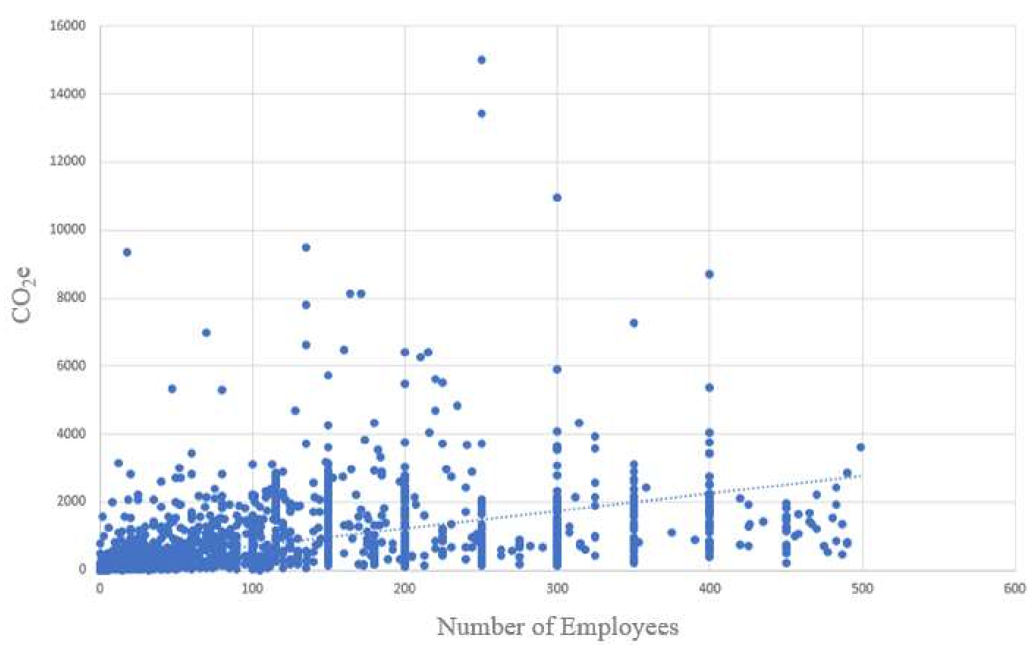

Figure 36. SME CO_2e by number of employees.

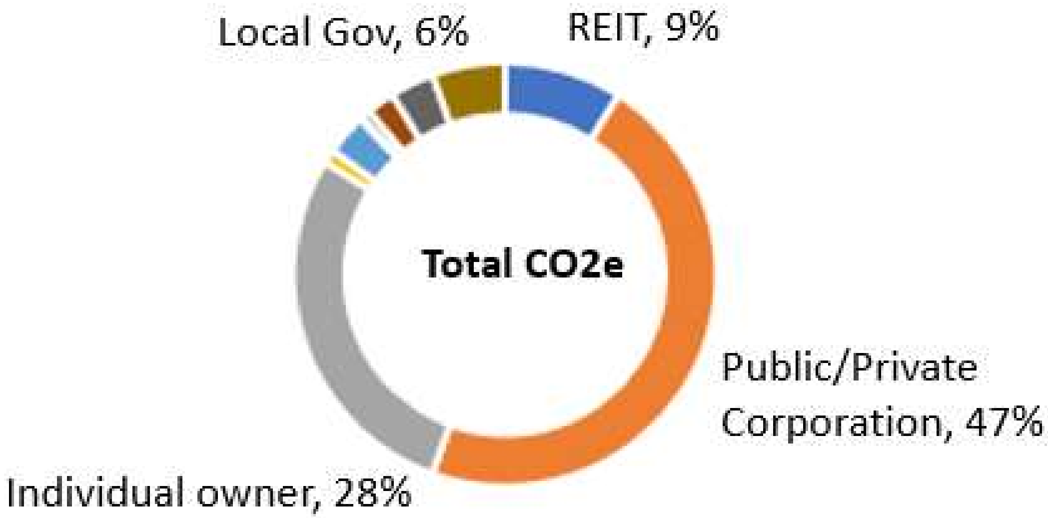

Figure 37. SME CO_2e by owner type.

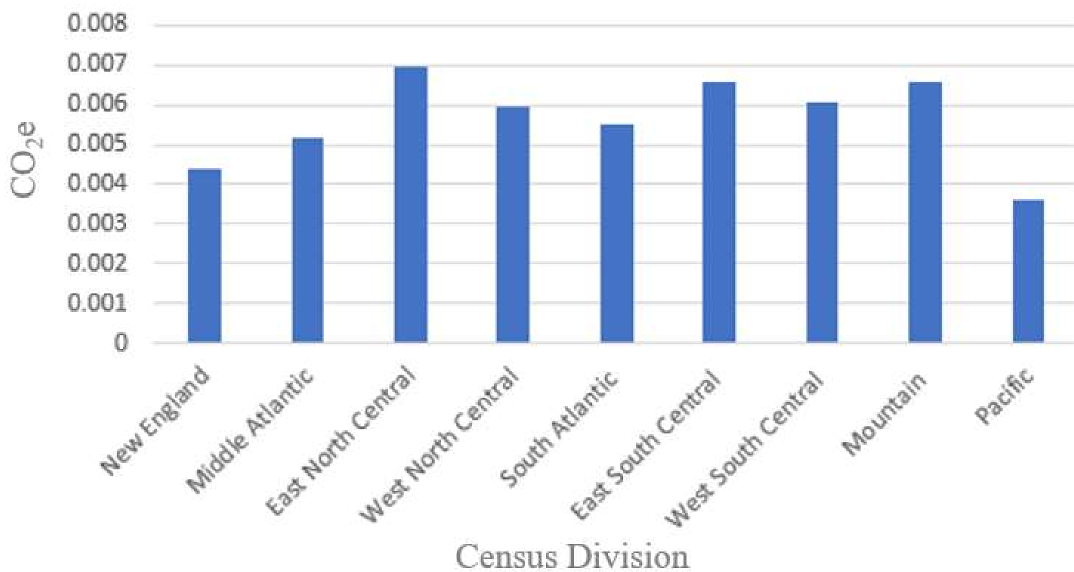

Figure 38. SME CO_2e per square feet by census division.

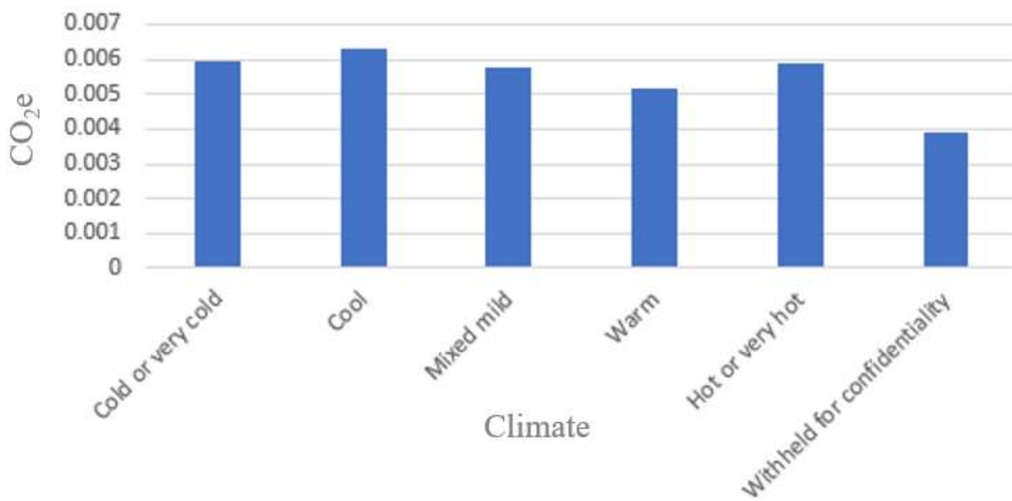

Figure 39. SME CO_2e per square foot by climate.

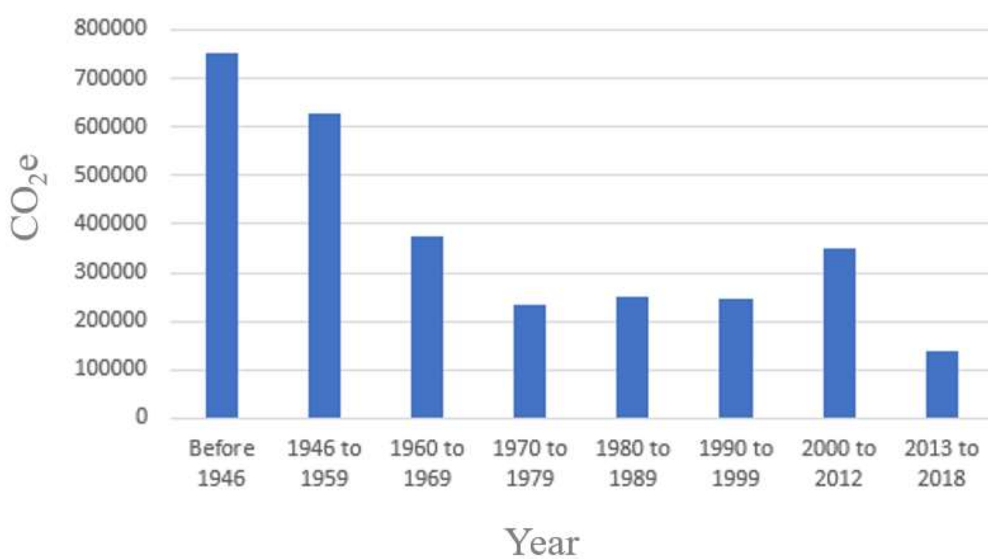

Figure 40. SME total fuel oil CO_2e by year constructed.

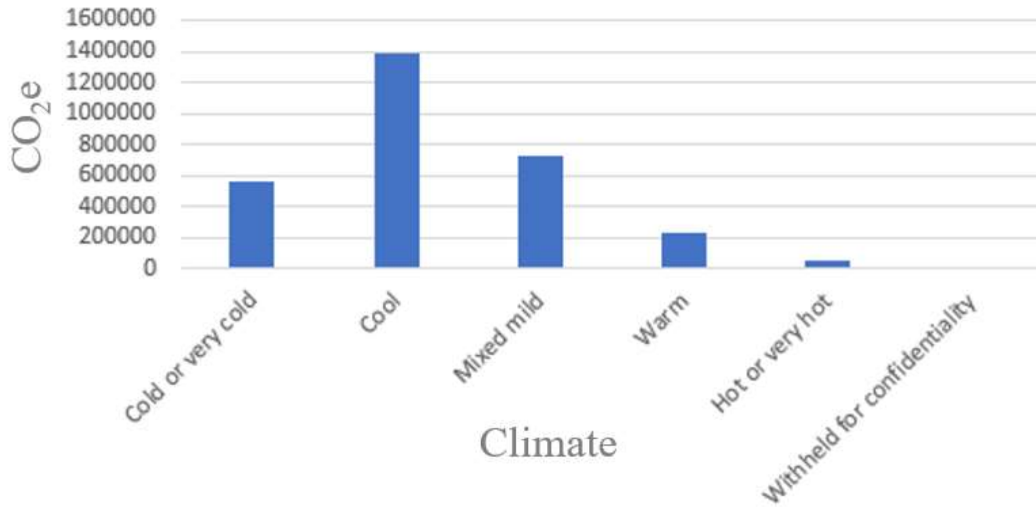

Figure 41. SME total fuel oil CO_2e by climate.

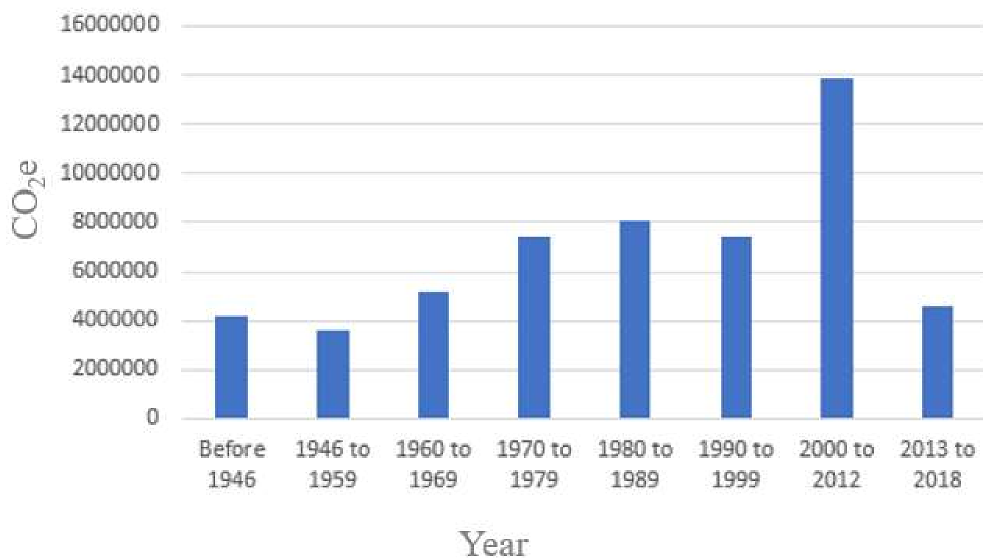

Figure 42. SME total natural gas CO_2e by year constructed.

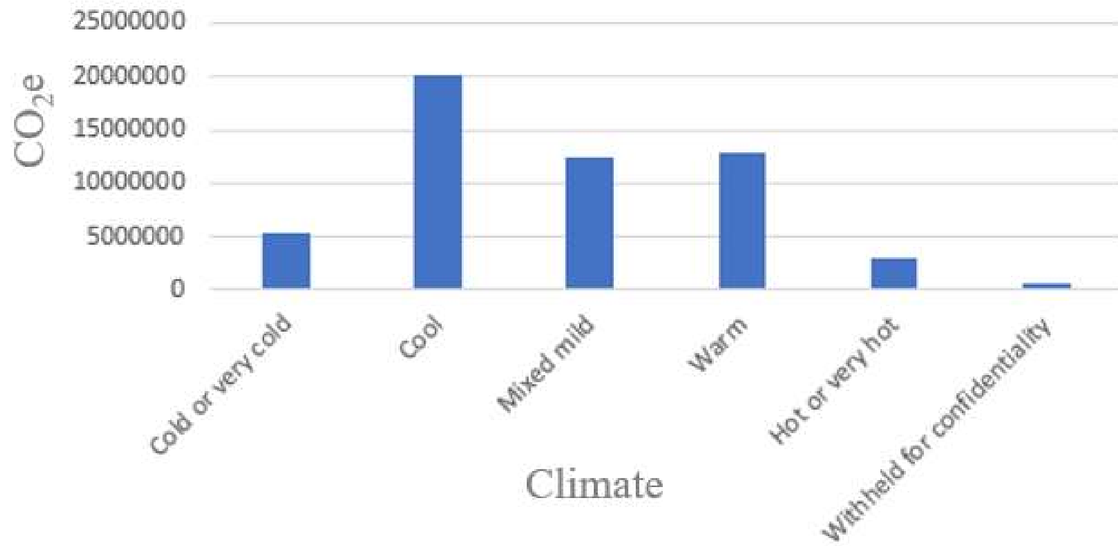

Figure 43. SME total natural gas CO_2e by climate.

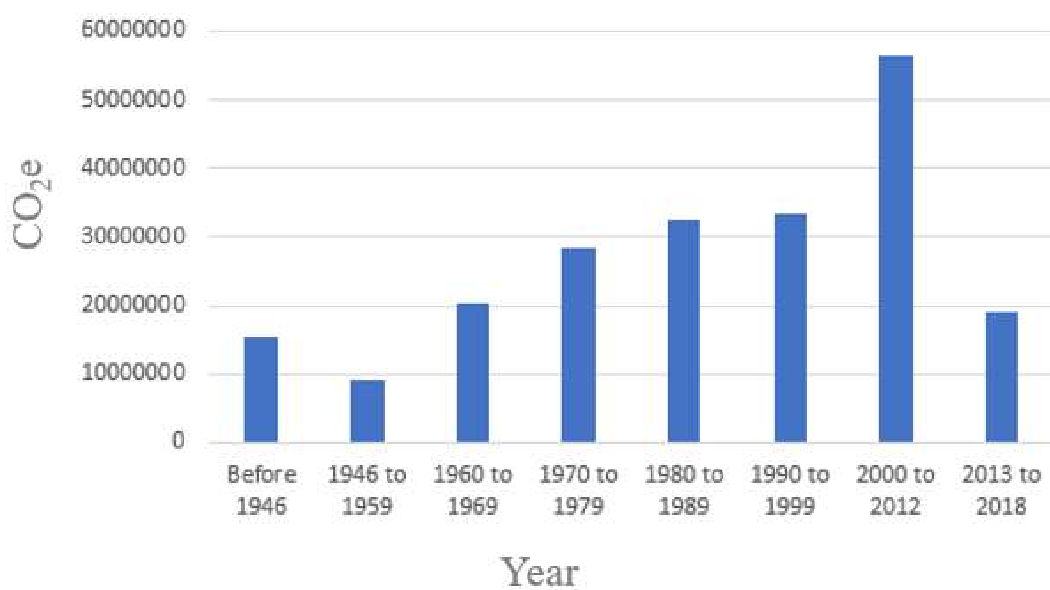

Figure 44. SME total electricity CO_2e by year constructed.

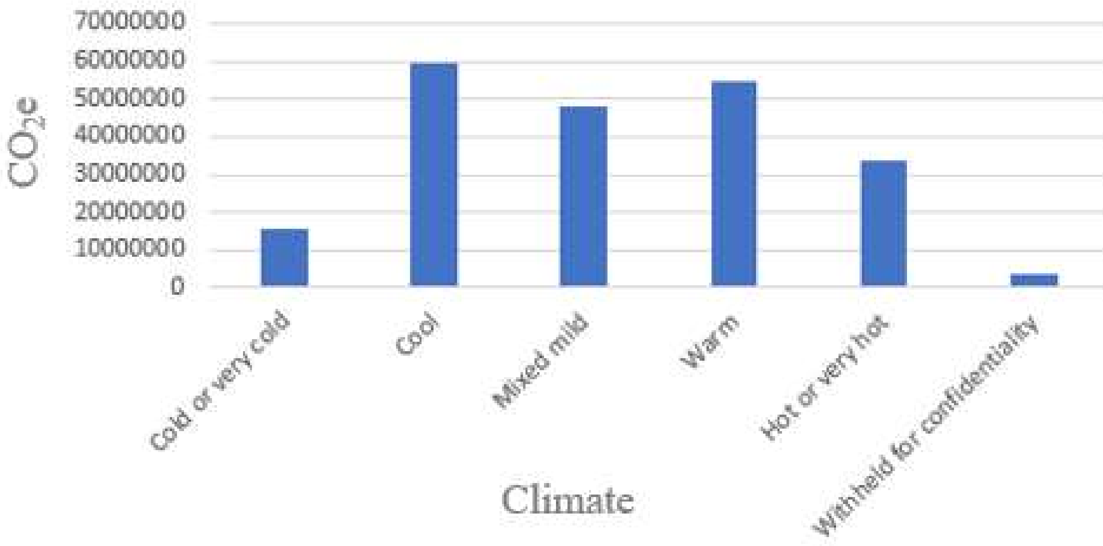

Figure 45. SME total electricity CO_2e by climate.

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