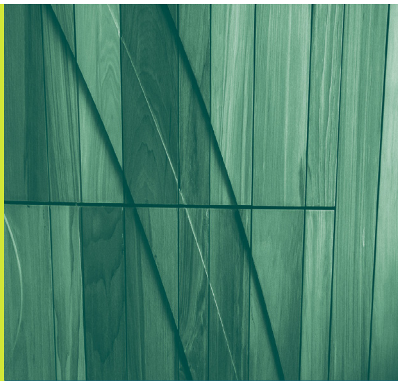
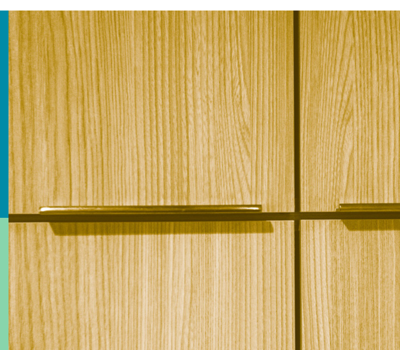
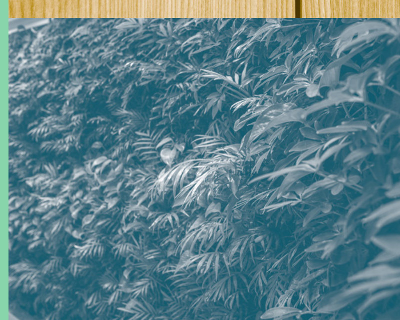



State of Decarbonization

Progress in U.S. Commercial Buildings 2023


U.S. GREEN BUILDING COUNCIL
USGBC

ARUP

Contents

Letter from the CEO

Thirty years ago, the U.S. Green Building Council was founded by a small group of individuals who believed in building a more sustainable world. Over the next several decades, USGBC grew that idea into a global community of leaders that transformed the design, construction, and operation of buildings and communities to better serve people, the planet and our climate.

The progress we have made together is remarkable. Today, USGBC represents thousands of organizations that have delivered nearly 110,000 LEED-certified projects representing the highest standard of sustainability in more than 180 countries and territories globally. In just the past year, the knowledge represented in these projects has been shared with more than 25,000 practitioners, empowering a workforce to scale best practice across the entire built environment.

Yet, as the world gathers in Dubai for the COP28 climate change conference, we find ourselves at an inflection point. Earlier this year, the United Nations issued the first global stocktake report measuring progress toward the goals of the 2015 Paris climate accord. It found that the rise in global emissions has slowed, but progress is not nearly enough to achieve the Paris targets and avoid the most catastrophic impacts of climate change. The implication is clear: the world must act with greater collective urgency, and leaders from the public and private sectors must do more to lead the way.

USGBC is embracing the challenge. In partnership with Arup, the award-winning sustainable design and engineering firm, we are proud to present the *State of Decarbonization: Progress in U.S. Commercial Buildings 2023* report, a deeply researched snapshot of U.S. commercial building decarbonization trendlines and opportunities to accelerate progress.

Among the report's findings are that absolute U.S. commercial building emissions have decreased to 1990 levels despite a 55% increase in U.S. commercial floor area over the same period, but that greater progress is needed for the United States to achieve its commitments under the Paris agreement even after accounting for the expected impacts of federal Inflation Reduction Act investments.

This report is a call to action and a reminder that there is no scenario in which the United States or the world achieves its decarbonization, climate resilience, public health, and social equity goals without improving the places we live, work, learn and play. USGBC will continue to play a leading role including through the forthcoming LEED v5, which aligns building decarbonization action with the urgency of the Paris climate targets while also addressing critical human health, resilience, and equity imperatives.

Given the tremendous progress we have made and the momentum we have built together over the past 30 years, I am confident these goals are within reach. Thank you for your interest in this report and joining us on this critical journey.

With deepest respect,

Peter Templeton
President and CEO, U.S. Green Building Council

Executive Summary

Achieving climate goals in the United States will require deep and rapid reductions across the building sector to keep limits on temperature increases within reach of 1.5°C in line with the Paris Agreement. Among U.S. commercial buildings, the focus of this report, there are notable signs of progress, and yet further action is needed to decarbonize over the next ten years to align with climate goals.

There are several reasons for hope. Commercial building efficiency has gone up and emissions intensity has gone down over the past 16 years. Unprecedented funding is currently available for building energy efficiency retrofits, made available through government programs such as the Inflation Reduction Act.

Challenges that need attention include the uneven distribution of decarbonization progress across the country, with decarbonization targets, building performance, and grid conditions lagging in less urbanized states. Decarbonization efforts also follow patterns of income inequality and racial discrimination, threatening to leave marginalized communities behind. The lack of comprehensive building benchmarking data also hinders decarbonization progress, preventing all levels of government from formulating effective building performance standards and other policies.

The signs of progress are encouraging and show that the sector's efforts are working to decarbonize commercial buildings in some areas of the country. However, more comprehensive action that addresses all corners of the United States will be required if the commercial real estate sector is to achieve its share of U.S. decarbonization goals.

State of Decarbonization: Progress in U.S. Commercial Buildings 2023, first released at COP28 in December 2023, is the first report to bring together, in one place, a discussion of the U.S. commercial real estate sector's progress, the current status of data availability, and an exploration of the mechanisms and levers available to reduce the carbon emissions of commercial buildings in the United States. With full citations, sources, and methodology provided, these analyses focus on energy and operational emissions where data are more robust and actions more mature. This report complements critical new resources for building decarbonization, including the RMI-USGBC report *Driving Action on Embodied Carbon in Buildings* released earlier this year, to help policymakers, advocates, and companies understand the landscape and develop strategies to achieve the urgent scale of action needed.

KEY TAKEAWAYS:

1. Absolute operational emissions from U.S. commercial buildings have stabilized.

Despite tremendous growth in the volume of square footage developed, absolute emissions from the commercial real estate sector have stabilized within the past 16 years. Commercial buildings in the U.S. have become 37% less carbon-intensive and 26% more energy-efficient since 1990 on a per-square-foot basis. This is one of the greatest success stories in the built environment in the past 30 years and speaks in large part to the green building movement's leadership in advancing operational building efficiency, advocacy for more stringent energy codes, as well as the broader growth in renewable energy at the building and utility-scale.

Between 1990 and the mid-2000s, total emissions from the commercial building sector rose in concert with rising square footage. Total emissions peaked in 2007 when efficiency improvements began to significantly offset growth from new construction. Total emissions now are back at 1990 levels, even though commercial building square footage has increased by 55% over that period. This drawdown in emissions intensity has flattened the curve of absolute emissions growth, but to sustain this downward trend further action is needed for both new construction and existing buildings.

Executive Summary

2. Decarbonization progress varies substantially across the United States, with more urbanized metro areas and states in the vanguard of systemic change.

The geographical variation in decarbonization efforts is characterized by several factors. First, differences in the regional energy grid mix mean there are variations in the carbon intensity of electricity and thus the emissions impact of electricity use from state to state. Second, there are disparities in requirements mandated by government agencies, with some states implementing stringent building energy codes and existing building standards in line with their climate action commitments, and others using standards over 10 years old, and leaving existing building retrofits to the market or local government to address. Third, the measurement of progress varies, depending on what data is collected or not collected, making geographic comparisons challenging.

States with larger urban cores are leading the way on decarbonization actions across the board: emissions targets, emissions intensity performance, building energy performance for new buildings (code), existing buildings (performance standards), and data collection. Across all U.S. states, California consistently emerges as the most advanced on the decarbonization curve across all these factors.

3. Commercial building decarbonization progress expands as corporations are increasingly making climate commitments and reporting on emissions and progress.

Several factors are driving increased engagement by corporations in climate commitment and action to reduce emissions. First, investors continue to have high interest in climate financial risk. Secondly, emission reporting regulations are going into effect in Europe, affecting an estimated 3,000 U.S. companies.[1] Based on our analysis of the top publicly traded real estate investment trusts (REITs) focused on commercial buildings, there is a trend towards broader commitment and disclosure.

4. Commercial buildings located in historically vulnerable communities see less investment and face higher barriers to decarbonization.

Building decarbonization efforts are not evenly distributed across communities, following other patterns of income inequality and historical discrimination in the United States. Buildings throughout low-income communities are under-resourced, making investments in decarbonization retrofits less accessible or inaccessible through market forces alone. While much is written about this pattern with respect to affordable housing, the same occurs in commercial buildings, affecting businesses, economic opportunity, and climate resilience in these communities.

Though there is insufficient existing data to fully assess the conditions of commercial buildings in low-income communities and communities of color, it is crucial to recognize that this sector faces analogous challenges to residential buildings in the same communities, including disinvestment and often discriminatory policies. The Joint Center for Housing Studies (JCHS) underscores that low-income households are more likely to inhabit sub-par housing due to factors such as backlogs of deferred maintenance and limited access to capital.[2] Low-income communities and communities of color also bear more significant energy burdens compared to higher-income and white-majority communities, according to the American Council for an Energy Efficient Economy (ACEEE).[3]

Executive Summary

Many U.S. regions and urban centers are contending with post-pandemic economies, which include unprecedented vacancy rates, reflecting a trend in workers remaining remote, as well as prolonged underemployment in regions such as the Rust Belt. While building vacancies have risen markedly, owners face escalating maintenance costs and plummeting property values. This represents a detrimental feedback loop creating challenges for reinvestment in not only vacant and deteriorating buildings but potentially surrounding properties as well.[4]

5. The Inflation Reduction Act is a generational investment in climate change with a substantial focus on decarbonizing buildings over the next 12 years.

The Inflation Reduction Act (IRA) of 2022 is an unprecedented investment in decarbonization. The resources provided by the IRA are projected to reduce U.S. greenhouse gas (GHG) emissions by 20% below a non-IRA scenario by 2035. Furthermore, if the IRA programs realize a high level of participation, the law could enable the building sector to meet its proportional share of the U.S. Paris target early, by 2029.

However, these historic investments in clean energy and climate action initiated by the IRA alone are not enough to achieve the U.S. commitment under the Paris Agreement of a 52% reduction in GHG emissions below 2005 levels by 2030. Based on EPA projections, the U.S. would have to reduce emissions by an additional 17% beyond the IRA's impact to achieve the U.S. commitment under the Paris Agreement.

6. There is an opportunity for the IRA incentives to dramatically expand the rate of renovation and retrofit of commercial buildings, a crucial lever for decarbonization.

In 2022, the IPCC called for developed countries to double the rate of building retrofit, pointing to low renovation rates and low ambition when existing buildings are renovated as a driver of emissions.[5] Deep energy retrofits in commercial buildings can draw down energy use intensity by 30% or more.[6] Over the past eight years, the market for commercial renovations and retrofits in the U.S. grew by 39%. Despite its potential as a force for decarbonization, historically only around 17% of total renovation spending has gone to energy efficiency-related retrofits. By incentivizing retrofits that target energy performance in the least efficient buildings, the IRA has the potential to increase spending on commercial building energy efficiency retrofits by up to 11% annually by 2027.

7. The absence of comprehensive benchmarking policies for commercial buildings in the United States is impeding decarbonization progress at scale.

Benchmarking policies serve as an important foundation for building performance standards, which empower governments to transform decarbonization priorities into enforceable policies. Despite this, current benchmarking policies apply to only <1% of commercial buildings nationwide. California buildings account for 39% of the total number of buildings benchmarked in the United States. In areas without benchmarking policies, data and the context for understanding building performance are lacking, which deter both private sector action as well as jurisdictions' policy development.

Executive Summary

8. The expansion and enforcement of rigorous energy codes across all states must be prioritized to meet current climate targets.

Advanced energy codes have proven to be one of the most impactful methods for optimizing commercial building performance. Accounting for current code progress and projections of new construction, buildings constructed in 2023 are expected to be 15% more energy-efficient than those built in 2017. More jurisdictions are adopting newer and more stringent codes. The percentage of new construction projects built to be less than or equal to the efficiency of standard ASHRAE 90.1-2010 (four update cycles ago) decreased by 78% from 2017 to 2023. However, more than half of all states are using energy codes from 2013 or earlier, and almost half of new commercial area built in the next four years will be no more energy efficient than 2013 standards.

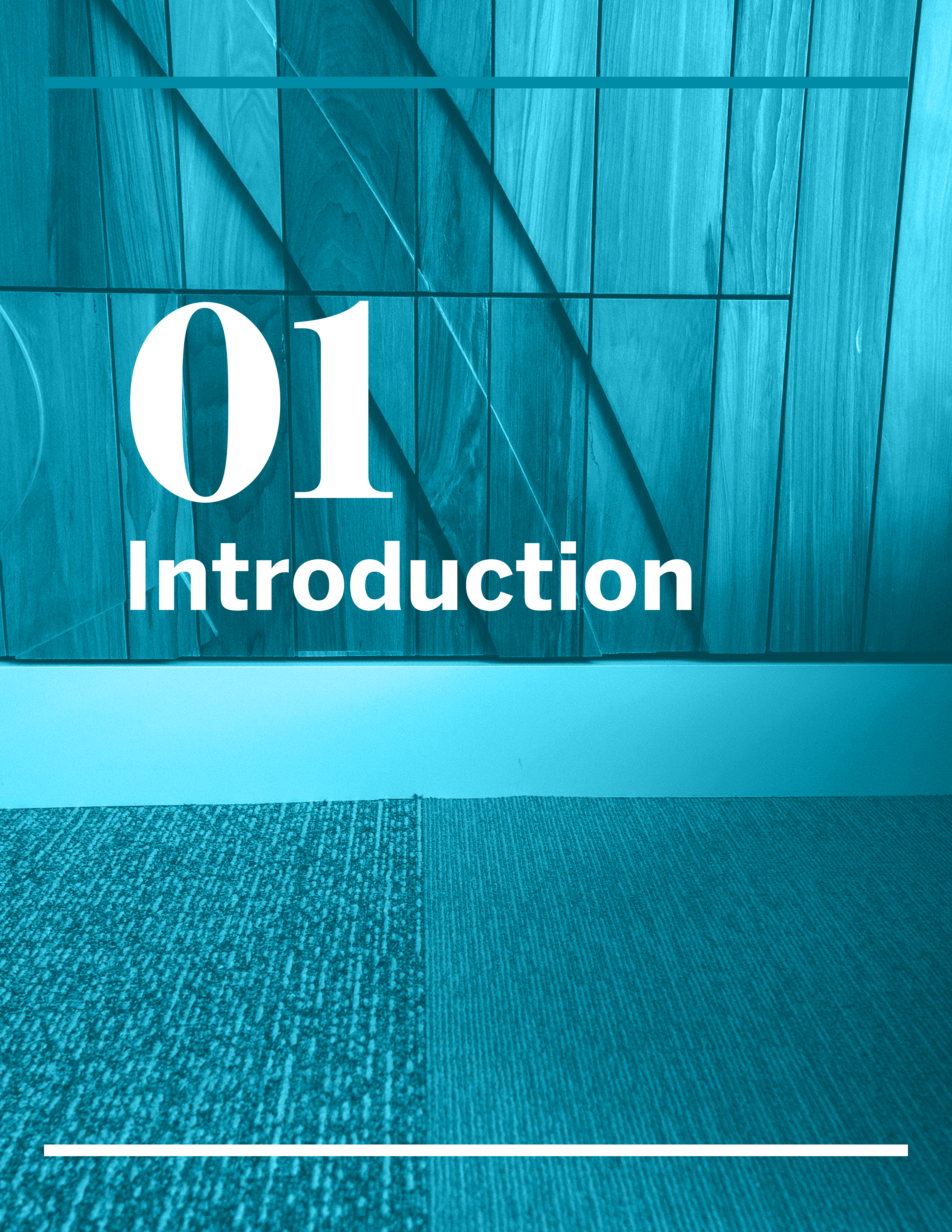
9. Embodied carbon emissions are significant and actionable through green building strategies.

Up-front emissions can include emissions embodied in the materials and products used in buildings as well as emissions related to energy use at the construction site. A building's embodied carbon emissions include the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials. The total of up-front emissions from all buildings is estimated at up to 370 million tons of CO_2e annually, or 6% of total U.S. GHG emissions per year; total emissions here are inclusive of both embodied carbon in materials and energy use at the construction site.[7] Although data regarding up-front GHG emissions from building construction in the U.S. have historically not been quantified or collected systematically, and therefore cannot be isolated in the data presented in this report, we know enough to say that the impact is significant and addressable through strategies such as those outlined in the RMI-USGBC report *Driving Action on Embodied Carbon in Buildings.*

In conjunction, these headlines indicate that the U.S. commercial real estate sector is improving rapidly, but progress is uneven and varies widely due to vast differences in state and local government regulations. As a result, the rate and scope of change will be neither fast nor broad enough to fulfill Paris Agreement commitments or 1.5 degree-aligned emissions budgets.

The *State of Decarbonization* report highlights where the sector is making progress and areas that continue to pose a challenge to decarbonization targets. Explore the full report to delve deeper into the key findings summarized in the Executive Summary as well as other statistical insights.

01 Introduction



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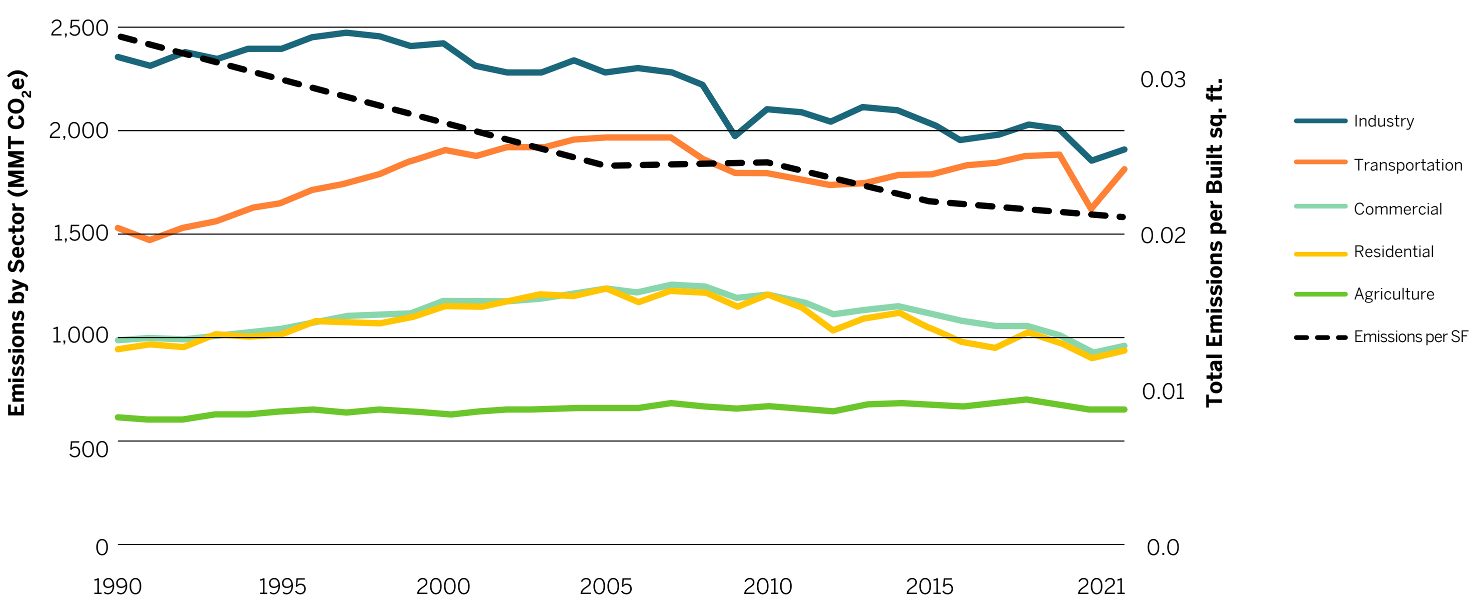
CONTEXT

The United States is one of the highest emitters of greenhouse gases (GHGs) globally, emitting 4.6 $GtCO_2e$ in 2021.[i] The commercial building sector is a major source of emissions in the U.S. and presents a key opportunity for decarbonization. Globally, the building sector contributes 40% of energy related emissions, but in the U.S., buildings accounted for 31% of total U.S. emissions in 2021. In part, this lower percentage can be attributed to transportation emissions, which are 10% higher in the U.S. than the global average.[ii] This difference also reflects the success of the building industry in keeping the absolute quantity of building sector emissions relatively flat over the past 30 years, even as the total amount of building space has increased significantly.

U.S. GHG Emissions: Sector vs Built Area Intensity (1990-2021)



Building energy codes, efficiency improvements, and growth in renewable energy at the building and utility scale have actively contributed to decarbonization results. Between 1990 and the mid-2000s, emissions from the commercial building sector rose by 26%, peaking in 2007. Emissions declined from 2007 on, and are now back to the level last seen in 1990. During this same 30-year period, commercial building square footage increased by 55%. Declining sector emissions over the last 16 years, while total square footage has increased, reflects the fact that commercial buildings are becoming more energy and carbon efficient. Since 1990, commercial building energy use per square foot has fallen by 26% and carbon emissions per square foot have decreased by 37%. Additionally, average U.S. grid emissions intensity decreased by 38% over this time period.[1]

It is important to recognize that this progress is not consistent across all 50 states. The United States represents a diverse landscape in terms of requirements and performance. While regulations and investments benefit some locations, others have fallen behind. Stark disparities in building performance exist between low-income communities and well-resourced communities, where the barriers to investing in more efficient systems, making improvements, or providing ongoing maintenance (including emissions reductions strategies discussed throughout this report) contribute to the uneven progress. Many of the federal dollars flowing to support decarbonization are in some way earmarked for low-income communities of color in recognition of chronic historic disparities. It is important to note that the way these disparities play out across the building sector are not well reflected in the data sets included in this report, but that does not mean they don't exist or are not important.

According to the Environmental Protection Agency (EPA) analysis of their ENERGY STAR Portfolio Manager Tool, which benchmarks hundreds of thousands of buildings across the U.S., buildings in low-income communities have scores that are 4% lower than those in moderate and high income communities. In cold and moderate climate communities with the highest proportion of residents of color (greater than 75%), the rate of building electrification is 50% lower compared to majority-white communities.[2] These disparities are potentially understated because these populations typically have lower levels of participation in voluntary reporting programs. While this equity-focused analysis was not possible across much of this report due to lack of data, it is important context that should be considered throughout.

The purpose of this report is to explore the state of commercial building decarbonization in the United States. Since the passage of major federal investment laws in 2021,[iii] building decarbonization efforts have seen a significant increase in public investment. Funds are now moving from the federal government to states and cities to implement levers for building decarbonization. While it is too early to determine the impacts of these investments, this report seeks to provide a national perspective on the overall state of commercial building energy and emissions today. This report provides analysis and insights into the complexities and opportunities of the sector and can serve as a benchmark for future evaluations.

Commercial Real Estate Challenges

Over $1.5 trillion in U.S. commercial real estate (CRE) debt will mature in 2025.[3] U.S. banks are currently overexposed to CRE lending, with 15% exceeding the recommended concentrations.[4] This heightened risk is causing concern that there will be a bank run that destabilizes the system in a manner reminiscent of the 2008 financial crisis. These tensions are exacerbated by the shift to remote work introduced during the pandemic, which has caused drops in office and retail valuations. The national vacancy rate for offices reached 17.8% in September 2023, and over 20% in some metro areas.[5] There is current debate on whether remote work will remain high for segments of the workforce and specific metros. Cities and CRE owners are considering how CRE assets might evolve to remain attractive.

Regional banks in particular hold 32% of CRE debt;[6] the rash of recent prominent regional bank closures, notably Silicon Valley Bank in the Spring of 2023, demonstrated what can happen when lending exceeds recommended concentration levels. With interest rates rising, refinancing is unattractive. CRE owners will face a choice between high-cost refinancing or selling at a loss, which could lead to market reshuffling. Pivoting CRE assets, through either office retrofits or conversions to new uses, could result in carbon savings.

i. Sources and explanations are provided for each section in the endnotes and methodology, respectively, which follow in the report text.
ii. The difference in transportation emissions between the U.S. and global average can likely be attributed to higher usage of individual vehicles and lower access to public transportation across the U.S., relative to many other countries.
iii. The referenced major federal investment laws refer, in particular, to the Bipartisan Infrastructure Investment and Jobs Act (known as IIJA) and the Inflation Reduction Act (IRA).

About the Data

Across the U.S., carbon emissions, data availability, and operational building performance varies regionally and by state. Energy code adoption and fuel sources of the electric grid must be considered at a state or regional level, as there is no unified national energy code standard and electricity generation is source dependent. These two factors — building efficiency and emissions intensity of the grid — are large determinants of the commercial sector's decarbonization performance, which therefore must be evaluated state by state.

Building performance data availability also varies by state and city, making it challenging to map out geographic trends. More urbanized states, particularly California, are farther ahead in collecting building benchmarking data than others, which will be evident throughout this report. California emerges as a leader across all evaluated metrics. The data challenges make relating social and racial equity to decarbonization progress difficult to analyze quantitatively. This does not mean inequities do not exist, rather it means that significant research is needed to characterize and address disparities.

Absent a national database with consistent building information, it is difficult to develop key metrics such as the commercial area of building stock by state or city, or typical energy performance of buildings per state. It is also important to note that the definition of commercial buildings varies by database. This report utilizes the best available datasets on commercial building performance through September 2023. Data sources and methodologies for all graphics are included and can be found in the Methodology section.

Note on Embodied Carbon Data

Reliable data sets quantifying the aggregate embodied carbon emissions for the U.S. commercial building sector are not available at this time. What is known about building materials' embodied carbon has led to an understanding by building industry stakeholders that immediate action to reduce these emissions is needed. For example, in the recent report *Driving Action on Embodied Carbon in Buildings,*[7] RMI and USGBC underscore that there are substantial embodied carbon reductions available today that are well within reach using available tools and guidance. At a macro scale, embodied carbon data is not yet systematic across the industry and is largely reliant on ongoing research, initiatives, and reporting efforts.

Building industry organizations are working to increase the availability of embodied carbon data at the material and product level, boosted by some government procurement policies as well as funding. While the lack of data hinders a comprehensive quantitative assessment in this report, there are signs of progress, which we present in the Embodied Carbon of Construction note.

Building Decarbonization Terminology

The following terms and strategies are key to understanding building decarbonization, and are used in many of the graphs and analyses presented throughout this report. Definitions are provided here to level set an understanding of report findings across a broad audience.

GHG Emissions

Greenhouse gases absorb infrared radiation in the atmosphere, leading to global warming. They include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), ozone (O_3), perfluorinated compounds (PFCs), and hydrofluorocarbons (HFCs).[8] GHG emissions are typically reported in carbon dioxide equivalents (CO_2e) for consistent reporting across gas types. Unless otherwise noted, GHG emissions in this report are in CO_2e. GHG emissions may be used with other data to report intensity, expressed as emissions per square foot or per unit of energy produced to compare normalized data.

Decarbonization

Decarbonization is the process by which a country or entity aims to reduce and eliminate GHG emissions. In this report, the term is used to refer to the measures that must be implemented in buildings to reduce and eliminate emissions; examples include efficiency and electrification.

To decarbonize, buildings must eliminate on-site combustion, become more efficient by reducing Energy Use Intensity (EUI), and connect to zero emissions energy sources. Building efficiency strategies include passive measures like improved envelope performance, daylighting and natural ventilation. Active efficiency measures include high efficiency mechanical systems and optimized building controls. Efficiency strategies are often referred to as demand-side decarbonization strategies. Supply-side decarbonization strategies for buildings include electrification of energy sources, developing on-site renewables such as solar or wind, or including battery storage to shift when renewable energy can be used by a building.

Net Zero

The term net zero is often used to refer to distinct but related concepts. In the case of this report, net zero refers to 'net zero energy,' meaning that a building consumes only as much energy as it produces.[9]

'Net zero carbon' or 'net zero emissions' are achieved when GHG emissions are balanced by removals over a specified period. This is also referred to as carbon neutrality.[10] The distinction between net zero energy and net zero carbon is important because the two can encourage different strategies, such as on-site generation or carbon offsets. Differences in definitions further complicate data analysis at a national scale.

The Biden administration is in the process of developing a national definition for a zero emissions building as part of its climate resilience and decarbonization efforts. The definition is expected to be published in early 2024.[11]

Energy Use Intensity (EUI)

Energy use intensity (EUI) is a metric that expresses a building's energy use as a function of its size, usually expressed as energy consumed in kBtu per square foot per year. Source EUI represents the amount of raw fuel required to operate the building, incorporating all transmission, delivery, and production losses. Site EUI represents the amount of heat and electricity consumed by a building, as reflected in utility bills.[12] Unless otherwise noted, this report uses site EUI, which enables direct comparison between building efficiencies in different locations.

Electrification

In addition to building efficiency measures that reduce a building's EUI, a building's source of energy is key to decarbonization. Electrification refers to the process of replacing technologies that use fossil fuels (coal, oil, and natural gas) with technologies that use electricity as a source of energy. As electric grid regions across the country switch from fossil fuel energy sources to renewable sources, buildings can reduce their emissions by utilizing electrification to access this increase in grid renewable energy generation.

Additional terminology is available in the glossary.

Greenhouse Gas Emissions in the U.S.

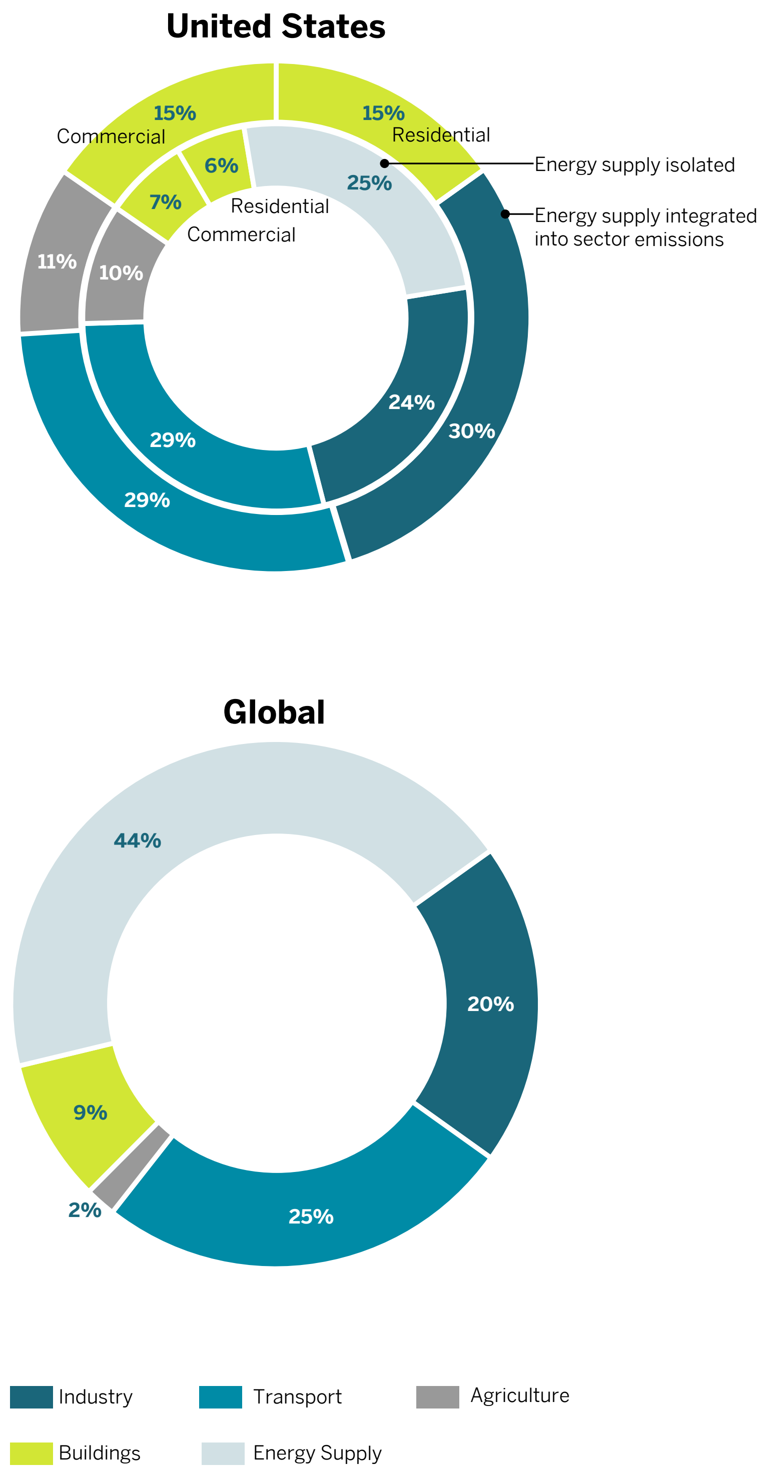
The United States commercial building sector is overdue for cost-effective energy efficiency improvements, which would also address GHG emissions and contribute to climate targets and decarbonization goals.

Globally, buildings account for 40% of energy-related GHG emissions.[13] Buildings in the U.S. are similarly significant. According to the EPA, buildings contributed to nearly a third (30%) of total GHG emissions in 2021. The portion of the country's GHG emissions attributable to commercial buildings are actually much greater, but inventories often do not account for building services such as potable water and wastewater, non-energy emissions from refrigerants, and the embodied carbon in materials used to construct and renovate commercial buildings. Global sources report embodied carbon within the Industry sector and account for 9-15% of these emissions.[14]

Data is most reliable, and most available historically, for the emissions from building energy use alone. Focusing on this data, aggregate U.S. commercial building emissions peaked in 2007 after a 26% increase from 1990 and have since declined, resulting in an only 3% reduction from 1990 to 2021. However, the total amount of commercial building space, measured in gross square footage (GSF), increased by 55%, resulting in a reduction of average energy use intensity by 26%. This points to improved efficiency in new construction, retrofits to existing buildings, and a reduction in emissions from changes to the fuel mix of electricity generation.

Emissions per capita in the U.S. have decreased by 33% since 1990, as the population has grown. Comparatively, commercial building sector emissions, if considered per capita, have decreased by 29%.[15] This is significant progress, but there is still room for energy efficiency improvements within the U.S. commercial building sector to continue to drive down GHG emissions.

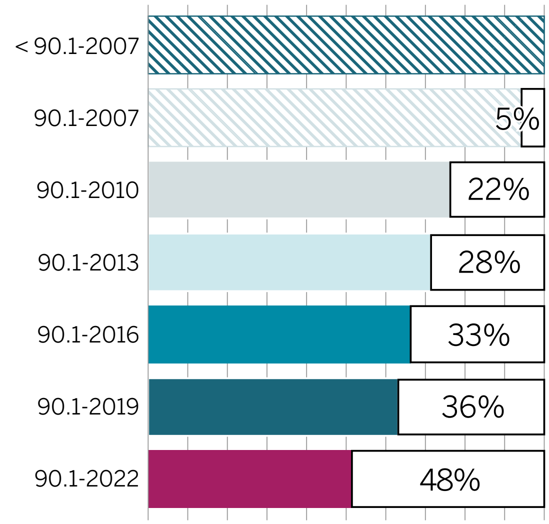
GHG Emissions by Sector (2021)



State of Current Codes Across the U.S.

Code requirements for building performance have become increasingly stringent in many places, but adoption is uneven across the United States. Overall, the most stringent energy codes are primarily concentrated in more urbanized states, while many other states are using standards that are at least 10 years out of date. As a result, almost half of new commercial area to be constructed in the next four years will be no more energy efficient than 2013 standards.

Commercial Energy Improvements by ASHRAE 90.1 Version

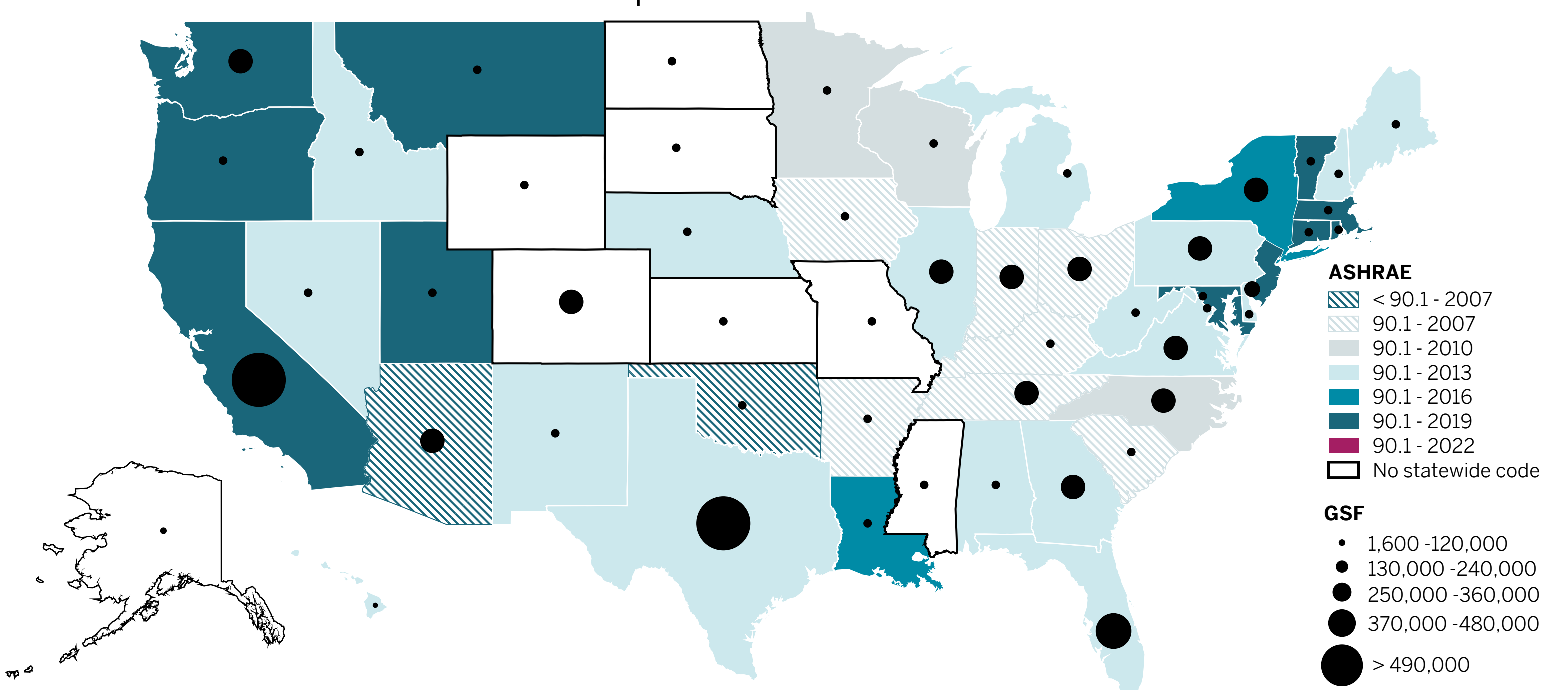


ASHRAE 90.1 is a global energy efficiency standard used to set minimum performance requirements for buildings. The bar graph at right describes efficiency improvements between newer versions of ASHRAE 90.1 relative to 2004. ASHRAE estimates that the newest 90.1 version (2022) will be ~48% more efficient than the 2004 version.

The map below shows the equivalent ASHRAE 90.1 version that is most aligned with each state's minimum energy code when factoring in amendments, as of October 2023. Future commercial GSF projections for each state between 2023–2027 depict where new commercial buildings will be built.

Equivalent State Minimum Energy Code Relative to ASHRAE 90.1 Version

Adopted as of October 2023



State of the U.S. Electric Grid

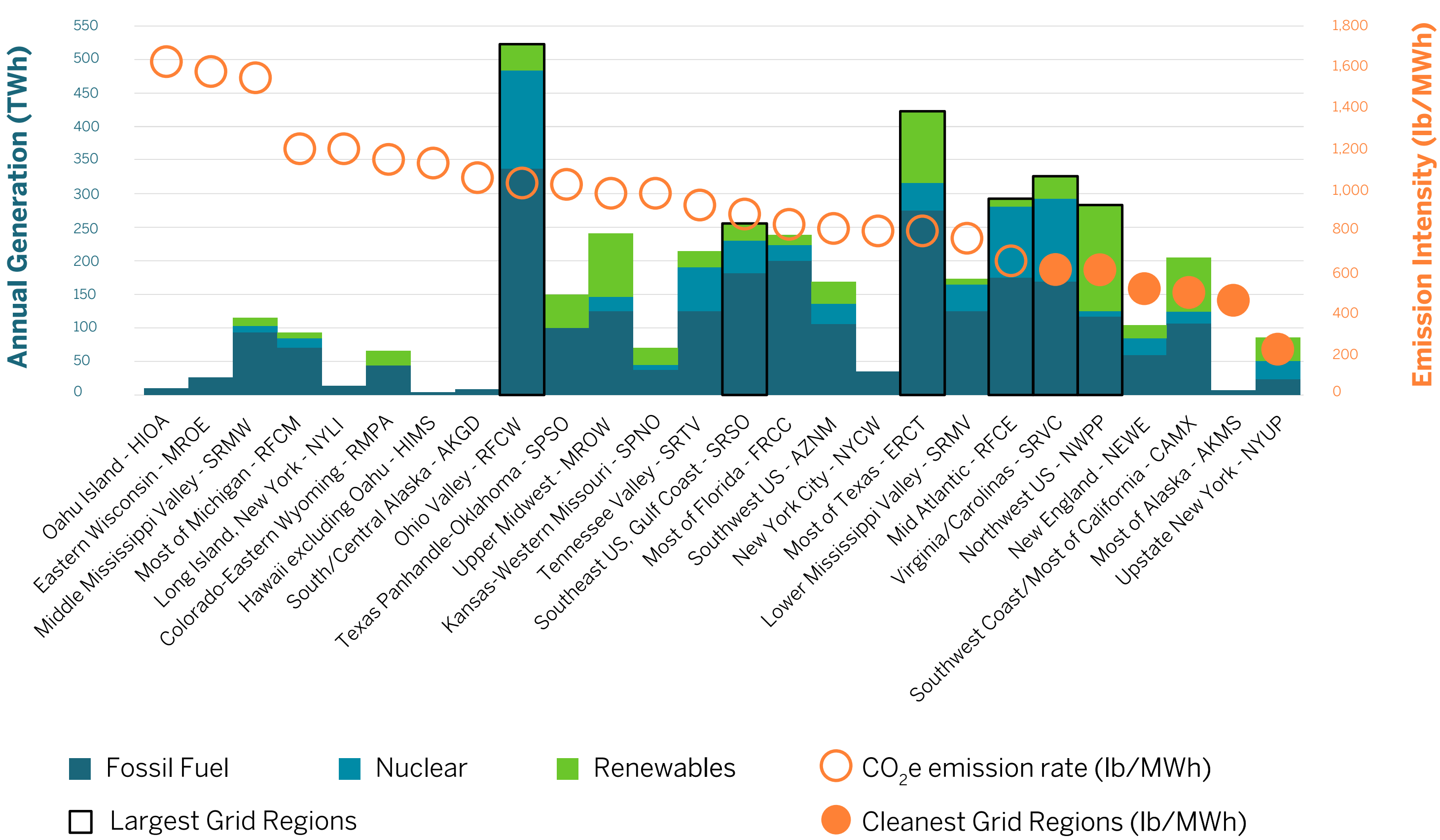
GHG emissions intensity of the average U.S. electric grid declined by 38% after peaking in 2000.[16] However, the GHG emissions associated with power generation varies widely across the U.S. Emissions are driven by a variety of factors, but generally states with the highest dependence on coal tend to also have the highest amount of GHGs generated per unit of energy.

Power generation and distribution in the U.S. is complex. It is not possible to track the origin of generated electricity to a single source and the environmental attributes of the electric power system in the U.S. vary significantly by region. Sources of energy, types of power plants, utility structures, and applicable regulations vary between cities, states, and regions.

The EPA established eGRID subregions to define characteristics of the country's electric grid. eGRID regions are based on North American Electric Reliability (NERC) region, power control areas, and utility service territories of transmission and distribution.

The graph below visualizes the 26 eGRID regions in the U.S. and their associated power generation and emissions intensity in 2021. There is no direct correlation between the largest capacity regions and GHG emissions intensity. The four eGRID regions with the highest emissions intensities make up only 4% of total U.S. electric generation.

eGrid Region Generation vs Emissions (2021)



State of the U.S. Electric Grid

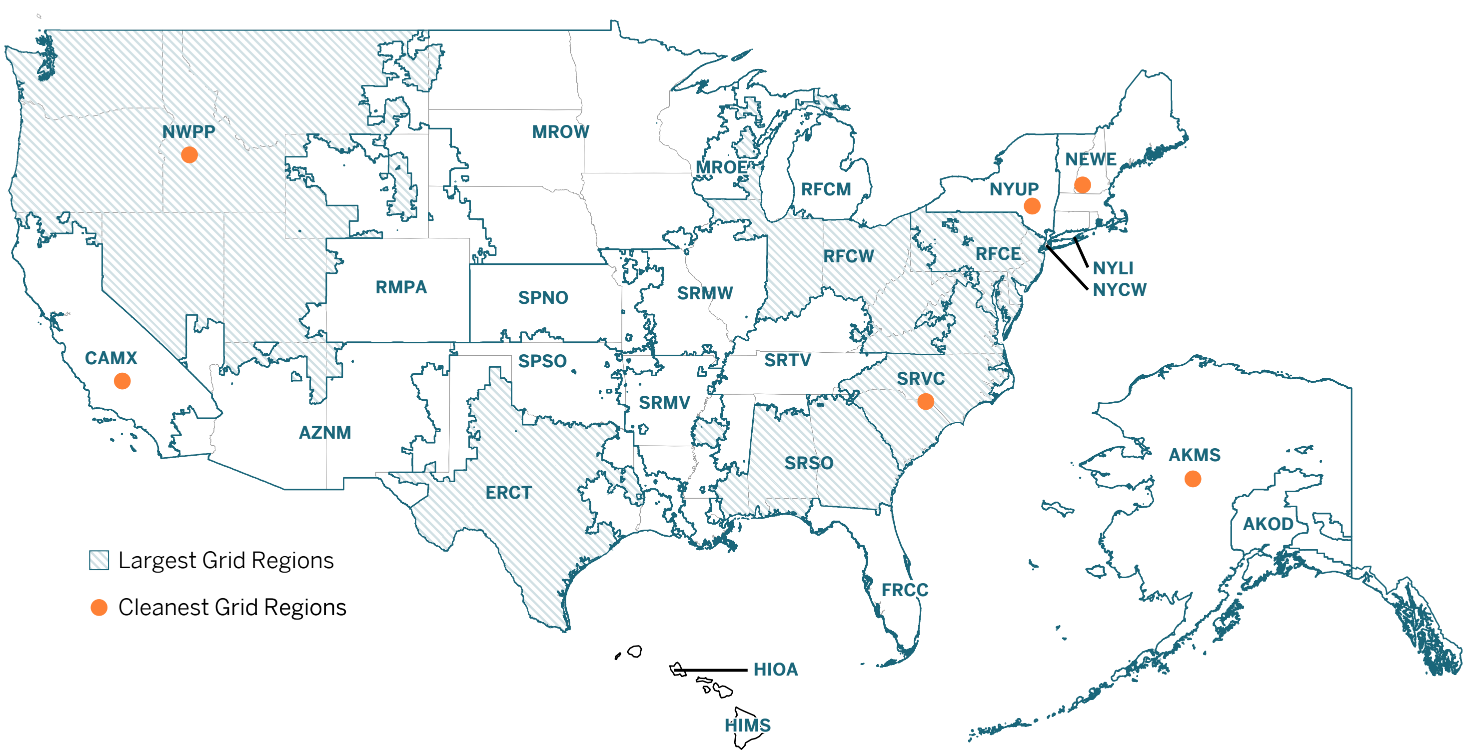
The lowest emitting eGRID regions are located on the East and West coasts of the U.S. This is primarily driven by the higher amounts of hydropower, nuclear, and renewable power on these grids, compared to more inland grids that rely more heavily on coal and other fossil fuels.

Even the cleanest eGRID regions have low percentages of renewable energy in their fuel mix, with the exception of CAMX (Southwest Coast and most of California) and NWPP (Northwest U.S.). Based on 2020 EPA data, the six cleanest eGRID regions are dominated by different sources of renewables and nuclear power. Renewable sources of power include hydropwer, biomass, wind, solar, and geothermal energy. CAMX has the largest solar power percentage of all grid regions, at 18%, and NWPP's fuel mix is 40% hydropower. Upstate New York (NYUP) and Virginia/Carolinas (SRVC) have fuel mixes dominated by nuclear power, with nuclear at 33.2% and 38.8% respectively. The fuel mix of Alaska (AKMS) is 67.1% hydropower.

The average CO_2 emission intensity for the entire U.S. electric grid was 852.3 lb/MWh in 2021. The 2018 rate was 947.18 lb/MWh, amounting to a 10% reduction over this three year period. Progress has not been evenly distributed, with some eGRID regions increasing in emissions intensity over this time.[17]

Corporate power purchase agreements (PPAs) across the U.S. increased by 35% in the past year, from 15.0 GW in 2020 to 20.3 GW in 2021. Building owners and corporations with assets in high emitting eGRID regions are increasingly turning to Power Purchase Agreements (PPAs) to achieve decarbonization targets.[18]

Largest Generating and Cleanest eGrid Regions (2021)



02 Trends and Commitments to Decarbonization in the U.S. Commercial Sector

2.1

U.S., STATE, AND CORPORATE COMMITMENTS TO DECARBONIZATION

The resources provided by the Inflation Reduction Act (IRA) of 2022 will reduce U.S. GHG emissions by 20% below a business-as-usual (non-IRA) scenario by 2035.[1] However, the U.S. EPA's projections of the law's impact indicate that the U.S. as a whole would have to reduce emissions by an additional 17% to meet the Paris Agreement target in 2030. It is possible that the direct investments made by the IRA could have spillover effects, increasing private sector demand for decarbonization to achieve greater reductions than the IRA alone. While the investments in clean energy and climate action initiated by the law could enable the building sector to meet its proportional share of the Paris target early, by 2029, adoption and participation in IRA programs remains an essential variable. Urgent action is needed to drive the commercial building sector's emissions down sharply enough to achieve Paris targets. California, Washington, New York, and Massachusetts stand out in their decarbonization efforts.

Corporate decarbonization commitments increased more than ten fold since 2016. While this indicates more awareness and urgency around decarbonization, standardized reporting is needed to track real performance. Comprehensive national leadership, beyond the incentives provided in the IRA, will be essential to drive progress across the United States towards decarbonization goals.

U.S. Commitments to Decarbonization

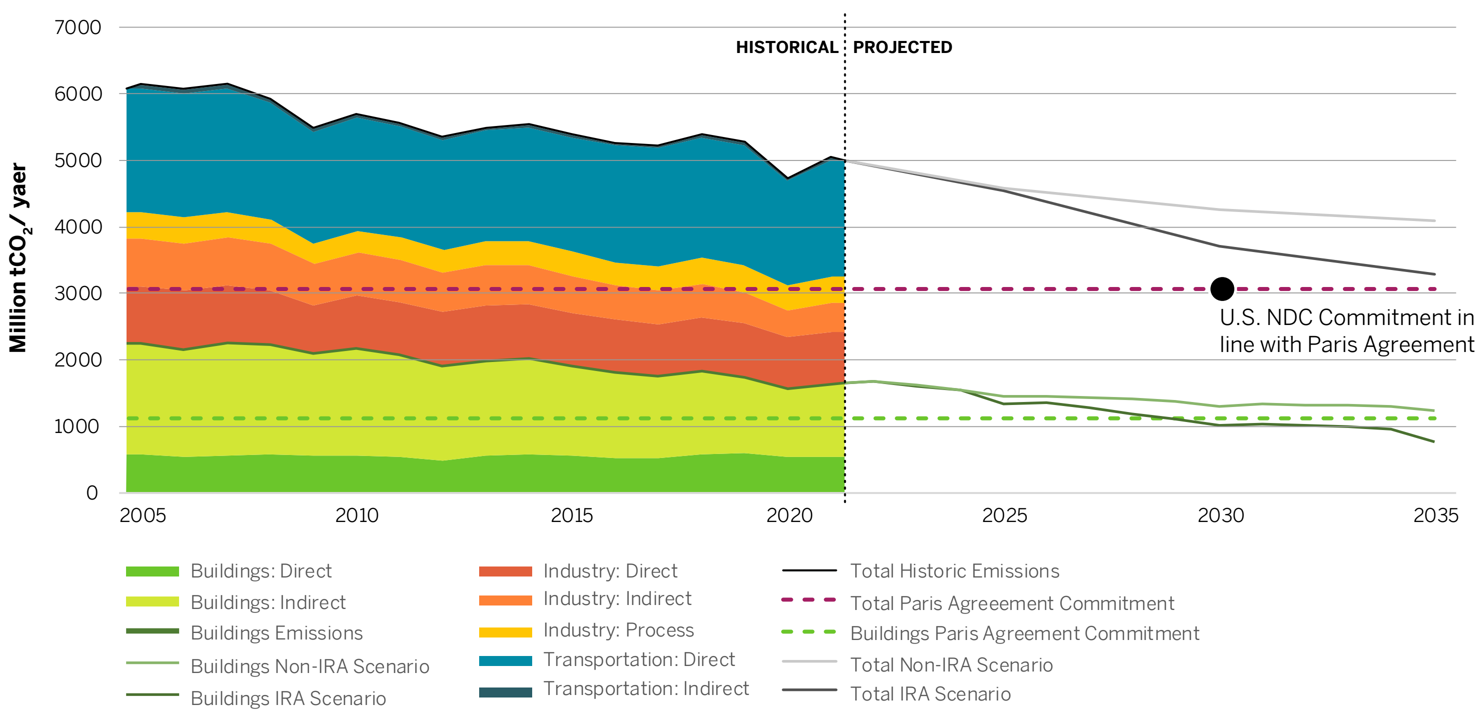
The financial resources provided by the Inflation Reduction Act of 2022 are projected to reduce U.S. GHG emissions by 20% below a business-as-usual scenario by 2035. Provisions in the law that incentivize a cleaner electric grid and high-efficiency building equipment could enable the building sector to meet its proportional share of the U.S. goal under the Paris Agreement early, by 2029.

The Inflation Reduction Act (IRA) is a landmark piece of climate legislation that the U.S. EPA predicts will significantly curb the United States' carbon emissions. The EPA study modeled multiple CO_2 reduction pathways that could result from the clean electricity and climate solutions in the IRA.[2] The median output resulted in a 39% reduction by 2030 compared to a 2005 baseline — a significant impact but not enough to meet the targets that align with the United States' nationally determined contribution (NDC) in line with Article 4 of the Paris Agreement.

The building industry is on-track to meet its proportionate share of the commitment. A predicted increase in renewables in electricity generation and high efficiency all-electric systems in buildings are key factors in the industry's projected emissions reductions. Reaching the proportionate share of the target is dependent on successful adoption and participation in IRA programs, so urgent action is still required of the commercial building sector.

In the graph below, note the downward trend of indirect emissions, which reflect both efficiency and cleaner electricity. The direct emissions line below that is a result of the use of natural gas and other fossil fuels for space and water heating. These emissions can be reduced through electrification.

U.S. Decarbonization Pathways by Sector

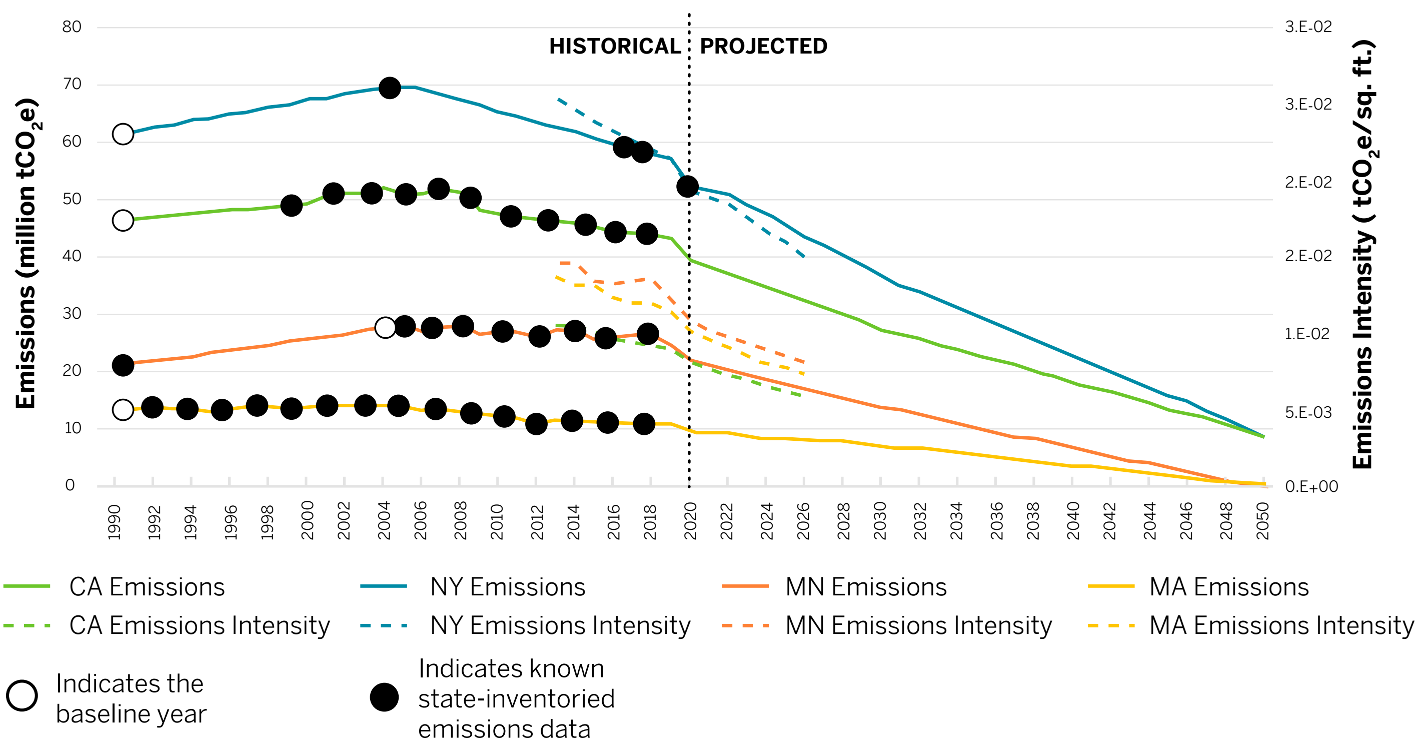


State Decarbonization Leadership

Four states have similar goals to reduce building emissions by between 80 and 100% by 2050, however their current emissions intensities differ. California commercial buildings have lower GHG emissions per square foot on average than New York, Minnesota, and Massachusetts.

The graph below compares the percent of total emissions attributed to commercial buildings for four representative states with net zero goals. California is targeting a 40% state-wide emissions reduction below 1990 levels by 2030 and an 80% reduction by 2050.[3,4,5] Massachusetts aims for a 50% emissions reduction below 1990 levels by 2030 and 100% reduction by 2050. [3,9] New York State aims to achieve a 40% emissions reduction by 2030 and an 85% reduction by 2050 compared to 1990 levels.[3,11] Minnesota is targeting a 50% emission reduction by 2030 and net zero carbon by 2050, compared to a 2005 baseline.

Commercial Building Emissions and Intensities for Selected States



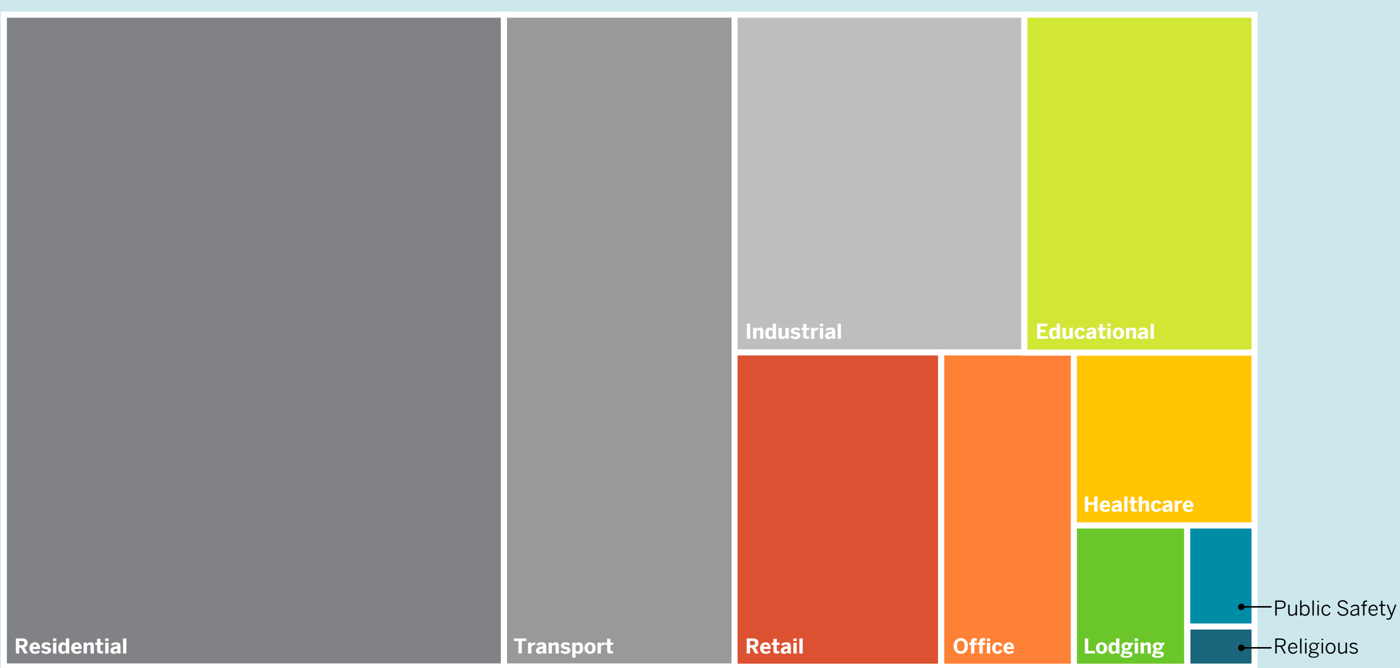
Commercial building square footage is only known from 2013 to 2027, so emissions intensity can only be projected for this time period. California, a signatory of the National Building Performance Standards Coalition and a member of the U.S. Climate Alliance, is targeting 40% state-wide emissions reductions below 1990 levels by 2030 and 80% reductions by 2050. [3,4,5] California's more temperate climate and cleaner electric grid contribute to its lower emissions intensity. The California Energy Commission adopted the 2022 Energy Code, which set efficiency requirements for new and existing buildings that are expected to save approximately 33 million therms of natural gas and 1.3 billion kWh of electricity across all residential and commercial buildings, relative to the 2019 Code.[6] An evaluated scenario to electrify 100% of new construction, replace 90% of fossil fuel end uses upon burnout, and retire 70% of equipment before the end of useful life is expected to result in about 50% emissions savings in 2030 compared to a system-wide 1990 baseline.[7] As of July 2024, California will be the first state in the nation to set code standards requiring the reduction of embodied carbon emissions in the construction or reuse of commercial buildings larger than 100,000 square feet and schools exceeding 50,000 square feet.[8] Massachusetts, a member of the U.S. Climate Alliance, aims for 50% emissions reductions below 1990 levels by 2030 and 100% reduction by 2050.[3,9] New York State, a member of the U.S. Climate Alliance, aims to achieve 40% emissions reductions by 2030 and 85% by 2050 compared to 1990 levels.[3,11] As per the Climate Leadership and Community Protection Act, New York State is targeting 1 million homes to be all-electric and 1 million homes to be electrification-ready by 2030.[12] The Carbon Neutral Buildings Roadmap developed by NYSERDA provides a vision of 2050 on policies and actions that would enable deep emission reductions of the State's building stock.[11] The City of Ithaca aims to be carbon neutral by 2030. In pursuit of this goal, the Ithaca Energy Code Supplement mandates all new buildings meet net zero energy requirements by 2026.[13] Minnesota's Climate Action Framework in 2022 set the state's climate goals to 50% emission reductions by 2030 and net zero by 2050, compared to a 2005 baseline. GHG emission reduction reports are published to the legislature on a biennial basis, which collates progress towards these goals. The Clean Energy and Efficient Buildings goal of the Framework proposes solutions including building code improvements that would enable all new commercial and large multi-family buildings to be net zero by 2036.[14] Minnesota is a member of the U.S. Climate Alliance.[3]

Embodied Carbon of Construction

GHG emissions from building material production and building construction in the U.S. are significant. At a project scale, these emissions historically have not been widely quantified and therefore cannot be evaluated by building sector in the same manner as building energy use and operational emissions. Up-front emissions include emissions related to energy use at the construction site as well as the emissions from building material production and transportation to site. Collectively, emissions from maintenance and disposal of building materials, these emissions are commonly referred to as "embodied carbon." The total of the up-front emissions from materials and construction from all buildings are estimated at up to 370 million tons of CO_2e annually, or 6% of total U.S. GHG emissions per year.[15] The State of Oregon Consumption Based GHG Inventory reports 8% of total emissions are from embodied carbon of construction.[16] The proportion of these up-front emissions associated with the commercial real estate sector is roughly aligned with development and renovation rates, as they fluctuate annually.

For over a decade, green building programs and sustainable building advocates have encouraged practitioners to consider embodied carbon when selecting materials and products, and in building design. These efforts have increased the availability of material scale data from embodied carbon declarations and building scale data from whole building life-cycle assessment. Along with the increased availability of data and an emerging market, leading jurisdictions are leveraging policy to capture the purchasing power of the building sector. Over a ten year period from 2008-2018, embodied carbon of construction in the U.S. resulted in approximately 4.7 billion metric tons of CO_2e in emissions. CRE typologies account for nearly 30% of these emissions, as shown in the graph below. Additionally, the opportunity for impact and leadership from the private sector is double that of the public sector, as private sector projects account for 66% of total emissions and public projects only 33%.

Relative Embodied Carbon Impact from U.S. Construction (2008-2018)



Policy leadership on embodied carbon has been driven at a state level, complimented by federal buy clean programs. These policies can be distinguished between those targeted at the public sector and those applicable to the private sector. Some jurisdictions are using their public sector purchasing power to help develop a market for lower embodied carbon materials and products. For example, the Buy Clean California Act (enacted in 2017) was the first statewide policy addressing embodied carbon of building materials. The act requires contractors who bid on state infrastructure projects to disclose emissions data for certain materials, such as steel and glass.[17] Similar policies have since proliferated across several more states, cities, and federal agencies.

A few policies impacting private sector development are also enacted. For example, the California statewide building code, CALGreen, will include embodied carbon provisions starting in 2024. These provisions introduce prescriptive paths for reusing buildings or demonstrating materials in compliance with established GWP limits and a performance path using whole building life-cycle assessment to demonstrate an embodied carbon reduction at the building scale.[18]

Seattle and Denver are additional jurisdictions where embodied carbon provisions are adopted in their code change proposals. Amongst the model codes, the next version of ASHRAE 189.1 (the International Green Construction Code), which is voluntarily adopted by jurisdictions, includes two new prescriptive embodied carbon provisions. The provisions require a percentage of products by cost to have EPDs and another percentage of products to meet GWP limits.[19] The New Buildings Institute proposed the Embodied Carbon Building Code overlay to the International Building Code (IBC), which includes prescriptive GWP limits for almost 40 product types. The selected product categories are both widely used and typically high carbon-emitting building materials.[20]

Policies covering embodied carbon are passed as mandates, but intentional design decisions in buildings also hold substantial weight in driving down embodied carbon emissions. Notable for commercial buildings, retrofits and renovations can drive significant reductions in embodied carbon.

Reuse of existing buildings and/or materials will reduce emissions, often by as much as 75% compared with demolishing and building new.

Driving Action on Embodied Carbon in Buildings, RMI and USGBC, 2023

Other approaches to reducing embodied carbon include deconstruction policies and voluntary commitments such as the C40 Clean Construction Declaration. Policies, available data, and tools focusing on embodied carbon are nascent but rapidly emerging and considerable progress is anticipated over the next decade. The Carbon Leadership Forum, a non-profit organization focused on eliminating embodied carbon, tracks both proposed and adopted policies.[21]

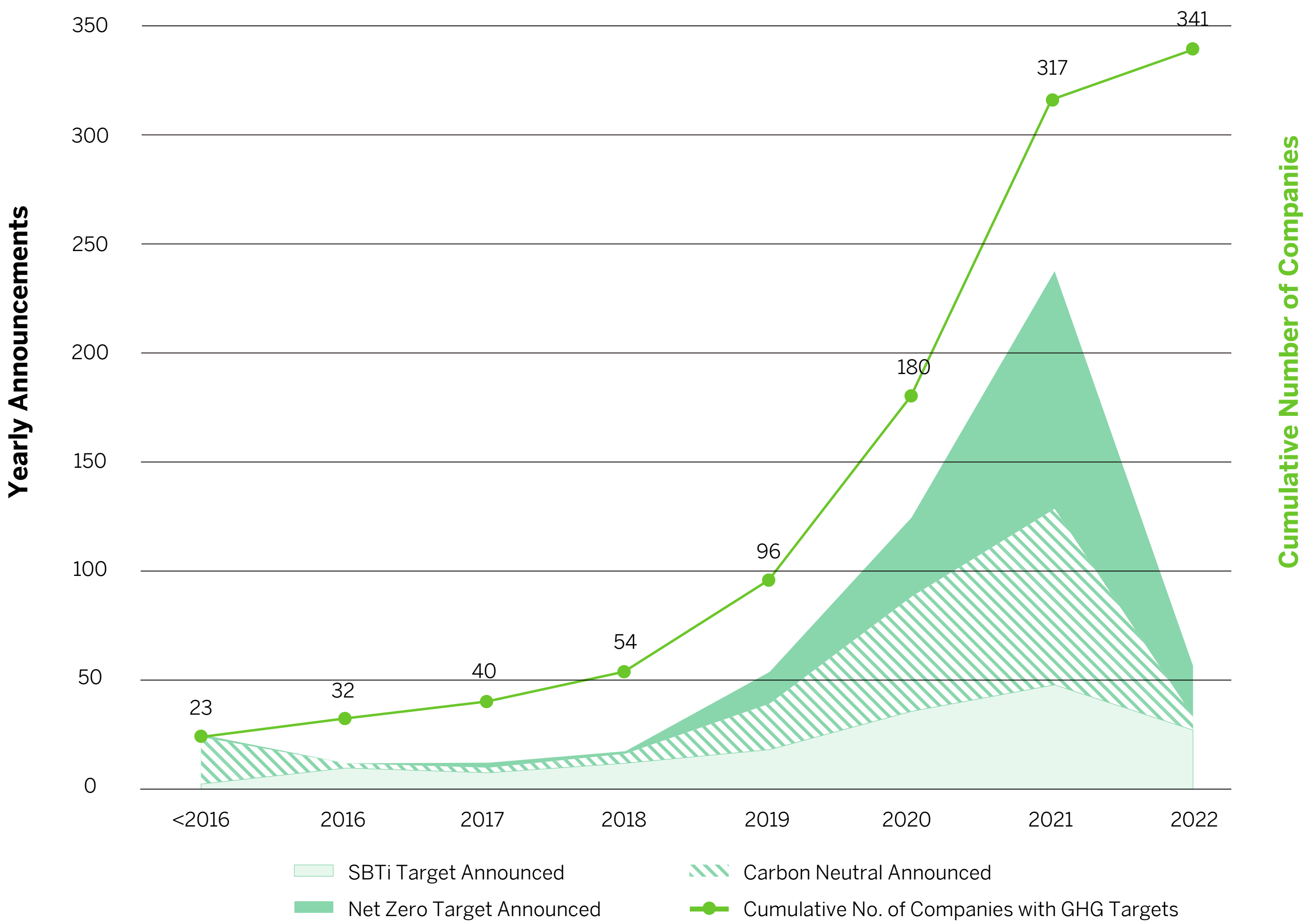
Corporate Decarbonization Targets

68% of Fortune Global 500 companies published a GHG reduction target as of 2022, up from 6% in 2016.[22] This increase demonstrates greater corporate awareness of the urgent need for commercial real estate decarbonization, as SBTi targets will trickle down to real estate holding performance. Corporate goals will provide accountability for progress through consistent measurement, but standardized ESG reporting will be essential to verify claims and track real progress.

From 2016 on, there has been an upwards trend in the number of corporations announcing pledges that commit to carbon neutrality, net zero operations, or a Science-Based Targets Initiative (SBTi) approved decarbonization target. While there is some variation in the definition of these terms, these commitments indicate that more businesses are taking steps to mitigate their climate impacts and to be transparent about their targets.

Corporations may be motivated to do so by investor pressure, engagement from stakeholders such as customers and employees, internal risk management, and/or corporate purpose. Environmental, Social, and Governance (ESG) factors are now considered by many investors.

Fortune Global 500's GHG Reduction Targets



REITs and Decarbonization Targets

About one quarter of the largest commercial REITs are making serious, science-based commitments to decarbonize their buildings. Over time, these commitments will translate into implementation of decarbonization strategies across their portfolios, and may influence additional REITs and portfolios.

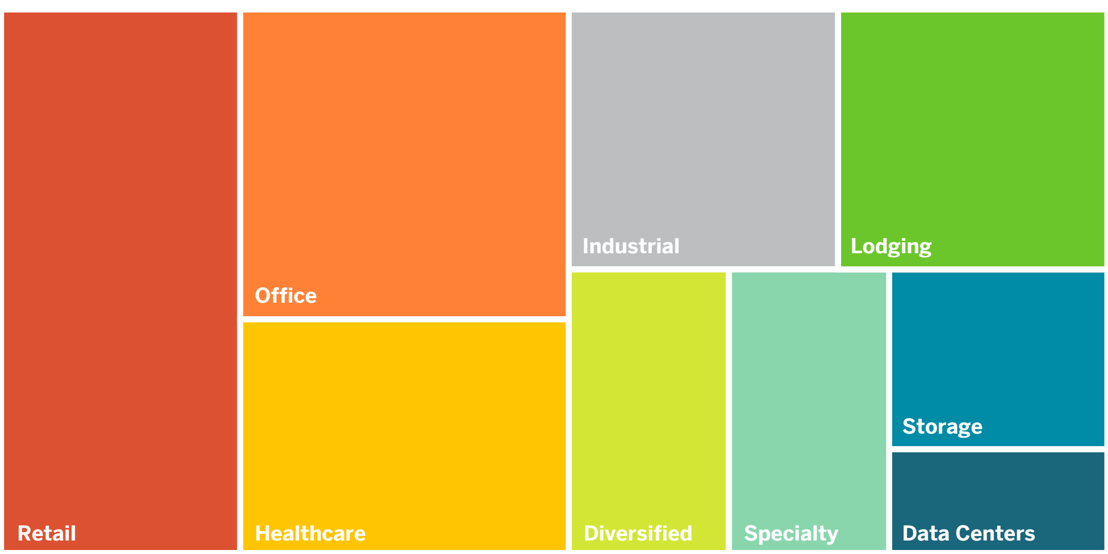
Real estate investment trusts (REITS) are real estate companies that own, operate, and finance income-producing real estate. Many REITs are publicly traded, meaning they are subject to reporting, which provides insight into their climate related goals, emissions, and priorities and allows them to serve as a valuable indicator for broader CRE market trends.[i]

The largest 100 listed REITs represent 93% of listed equity REIT market capitalization.[23] Of these, 78 REITs are predominantly commercial real estate and their U.S. assets represent over $700 Billion in market capitalization. These commercial REITs include retail, office, healthcare, logistics, and other building types.

Of these 78 commercial REITs, 47 (60%) publicly report a GHG reduction goal or energy reduction goal. Significantly, 20 of the commercial REITs have an SBTi approved or aligned target.[ii] REITs with these SBTi targets have U.S. assets representing over 50% of floor area and an estimated $226 billion in market capitalization. Additionally, 20 of the commercial REITs have been determined by the rating firm MSCI as having "Implied Temperature Rise" of less than 2°C of warming.[24]

These indicators – emissions and energy goals, SBTi targets, and MSCI temperature rise ratings – show that about one quarter of leading commercial REITs are making serious, science-based commitment to decarbonize their buildings. Over time, we can expect to see these REITs take action, and for their investments in efficiency and renewable energy to play out in their assets across the U.S. Moreover, we expect to see more REITs join in such efforts as they compete for investment as well as contend with new reporting requirements.

Commercial REITs Typology Breakdown



i. REITs make up an estimated 9.4% of the total CRE market.[25] While representing a fraction of the broader private asset class, the climate activities of REITs can serve as a valuable indicator. Because they are publicly traded, or listed, REITs compete for investors and may be more likely to commit to and invest in emissions reduction in their building portfolios. Moreover, their climate-related activities may have spillover effects within their markets, building typologies, and supply chains.

ii. SBTi, the Science Based Target Initiative, is a leading standard for climate targets; according to SBTi, "Targets are considered 'science-based' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to 1.5°C above pre-industrial levels." SBTi approved targets mean that SBTi has verified the target is science-based and meets their criteria.

Decarbonized and Net Zero Energy Buildings in the U.S.

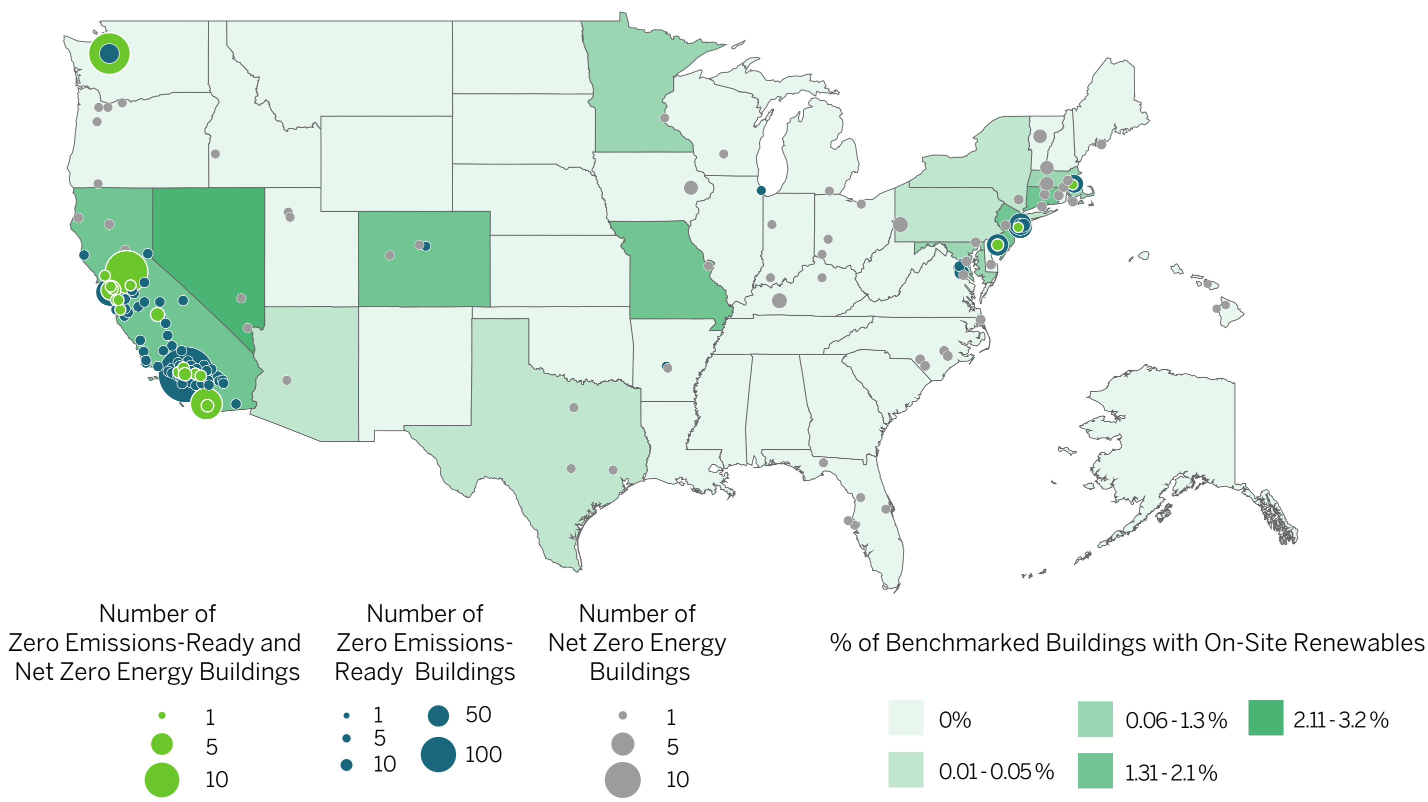
Zero emissions-ready buildings are emerging as a prioritized tactic for taller and urban commercial buildings. These efficient and all-electric buildings overcome the space limitations of on-site renewable energy sources and will be zero emissions when they connect to or procure clean electricity.

The movement towards decarbonizing individual buildings began with the concept of net zero energy buildings and has evolved to focus on energy-related emissions. Zero emissions-ready buildings are defined here as all-electric buildings with a site EUI that is 35% below the baseline by building typology per ENERGY STAR.[26] These buildings will be net zero carbon when the electric grid in their region fully decarbonizes.

Hot spots of commercial zero emissions-ready buildings are located predominantly in Los Angeles, Seattle, and San Diego. States with the greatest number of net zero energy buildings as of 2020 are California, Florida, Massachusetts, and Washington.[27]

Cities with both zero emissions-ready and net zero energy buildings are mostly located in California and Washington, with a few scattered in the Northeast United States.

Location of Selected Buildings with Characteristics Indicating Decarbonization



2.2

COMMERCIAL TYPOLOGY TRENDS

Scope 1 and 2 GHG emissions of the commercial building sector are projected to decrease due to electrification and reductions in both carbon emissions of the electric grid and building EUI. However, more aggressive action is needed to reach the U.S. commitment under the Paris Agreement of 52% reduction in GHG emissions from 2005 levels by 2030.

Progress varies across the commercial sector depending on building typology. We use typology to refer to different building uses within the commercial real estate sector. Tailoring decarbonization efforts to typologies with a large footprint can help the commercial building sector accelerate decarbonization to meet Paris targets.

While the EUI of commercial buildings has trended downward over the past 9 years, the EUI of refrigerated warehouses has increased by 32%. Refrigerated warehouses are a notable building type to watch as the commercial sector seeks to decarbonize, due to this increase in EUI and an expanding footprint. Additionally, refrigerated warehouses pose GHG emissions concerns from potential refrigerant leakage.

Average GHG intensity of commercial buildings is lower in rural areas than in urban areas. Urban areas include a large portion of building typologies with high EUI, such as retail stores, while suburban and rural areas have higher rates of typologies like non-refrigerated warehouses, with lower EUI. Considering geography and typology type in future policies and decarbonization efforts will support effective and targeted progress.

Trajectory of Commercial Building Emissions Toward 2030 Goals

Separate from IRA-specific projections, anticipated reductions in carbon emissions of the electric grid, expanding building electrification, and reductions in building EUI are sufficient for the commercial building sector to reach the IPCC determined reductions required to keep warming to 1.5°C. However, additional reductions will be needed to meet the U.S. target under the Paris Agreement of a 52% reduction from 2005 levels by 2030.

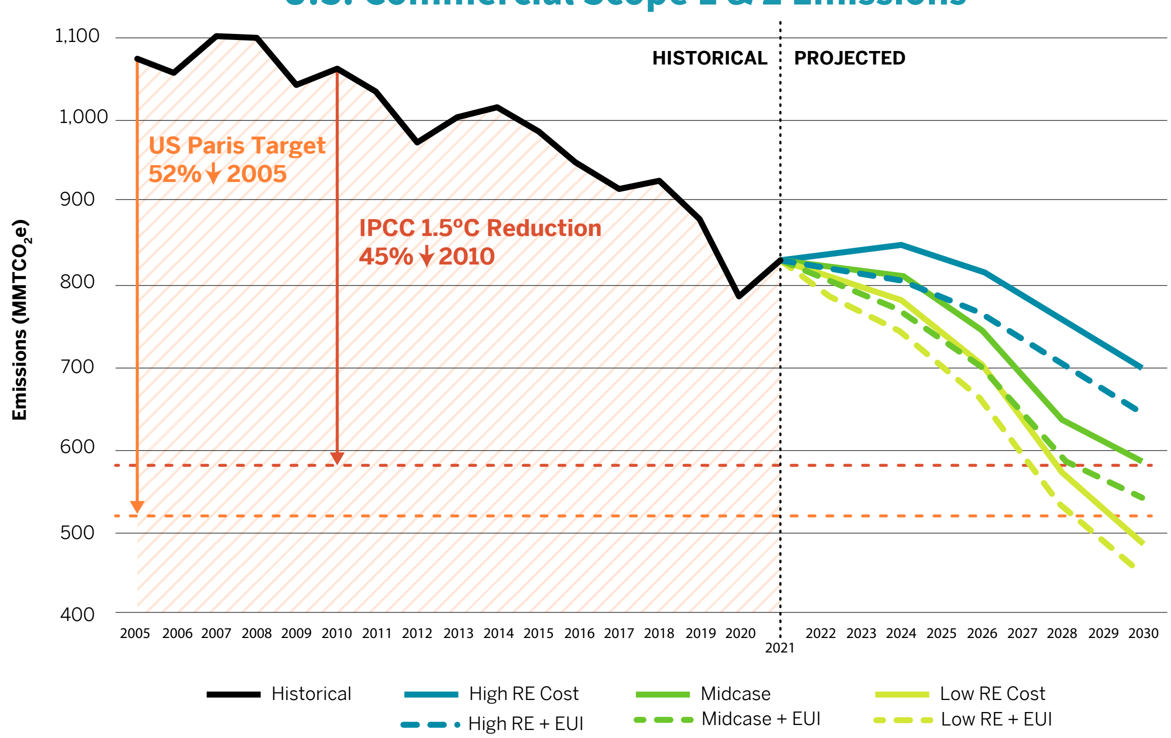
The IPCC has determined that greenhouse gas emissions must peak before 2025 and reduce 45% by 2030 relative to 2010 levels to limit global warming to 1.5°C.[28] The U.S. committed to a 52% reduction by 2030 relative to 2005 levels under the Paris Agreement.[29] To understand the rate at which the U.S. commercial sector is decarbonizing, projected EUI and gross square footage for commercial buildings are combined with forward looking grid decarbonization scenarios from NREL's Cambium Tool, reflecting low, mid, and high cost of utility-scale renewables (RE). Note that these projections are not directly tied to the EPA's IRA projections, providing an alternate look at the status of the commercial sector.

Under the midcase cost scenario, the commercial sector reaches the UN reduction goal through grid decarbonization alone but falls short in reaching the U.S. target under the Paris Agreement, even when factoring in the additional 5% reduction from EUI improvements.

Under the high renewable cost scenario, commercial emissions continue to increase until 2025 and do not reach a 45% reduction until after 2030, even when considering EUI improvements.

Only under the low renewable cost scenario are all the goals achieved, emphasizing the importance of continued federal, state, local, and private financial support for decarbonization projects and continued, urgent action within the commercial sector.

U.S. Commercial Scope 1 & 2 Emissions



Typology Trends

Existing Commercial Buildings by the Numbers

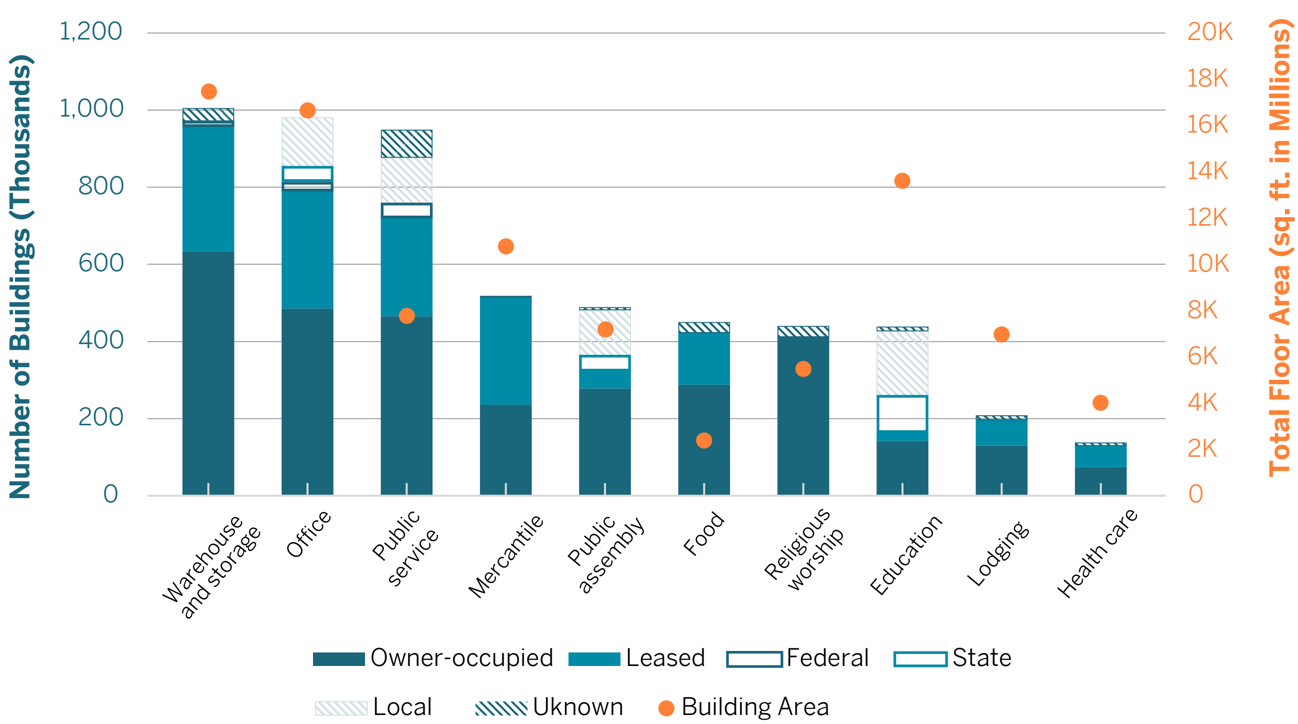
Office, warehouse, and education are the three largest typologies by existing building square footage. Tailoring decarbonization efforts to those typologies with a large footprint can help the commercial building sector decarbonize most quickly.

The composition of existing building typologies in the market impacts the potential pace, technical feasibility, and cost of decarbonization.

In the United States, commercial office space, warehouses, and education buildings make up the majority of the built area.[30] However, warehouses, offices, and public service buildings have the largest number of buildings.[31] As companies and municipalities adopt targets and develop transition plans, focusing on large buildings with high energy demand is one strategy to achieve greater reductions more quickly.

Warehouse and storage typologies have grown the fastest over the last decade. This is likely due to an increase in e-commerce and the logistics industry. Addressing warehouse typologies is critical to decarbonization efforts as its representative total floor area is expected to continue increasing.

Buildings Quantity vs Total Floor Area by Typology and Ownership Type



Typology Trends

Historical Typology Intensity Trends

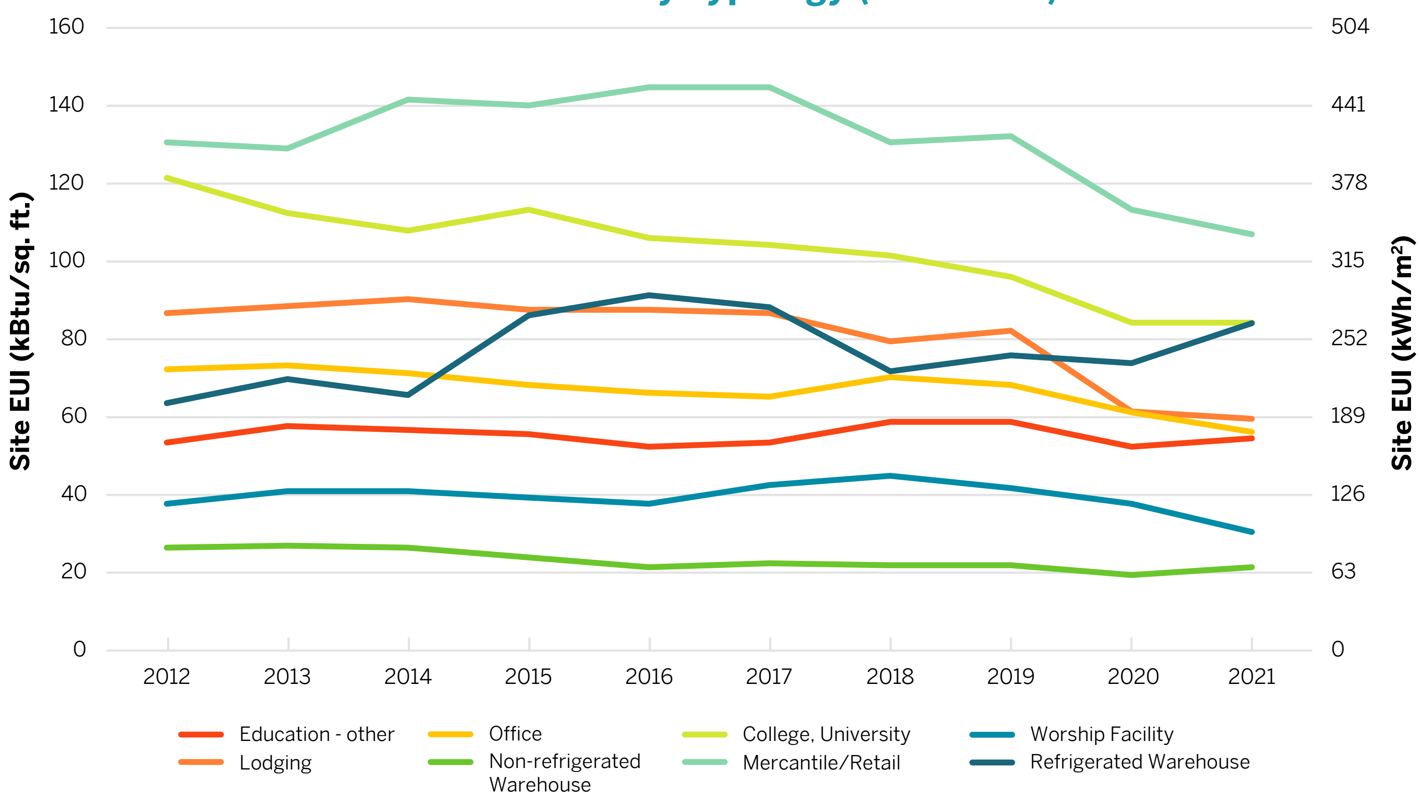
Total energy use in the commercial sector decreased by 12% over the last decade despite a significant increase in the area of total building stock. All commercial typologies increased in square footage between 2012-2021. EUI fluctuated over this time period and generally trends downward, with significant reductions of >30% in only university and lodging building types. A notable exception is the refrigerated warehouse typology, which has increased in EUI by 32% in this time period.

Comparing site EUIs between typologies provides insight into the energy intensity of a given commercial type. The average site EUI of commercial typologies below decreased by 13% from 2012-2021, while total square footage increased by 20%. The result is that total energy use in the commercial sector reduced by 12% over this time period, despite growth in area.

This graph indicates the range in energy use between typologies. The overall reduction in EUI is not spread evenly across typologies. Non-refrigerated warehouses have the lowest EUI, at 21.5 kBtu/sq.ft., while the highest is the mercantile/retail type at 107 kBtu/sq.ft. The office building typology is roughly the median typology for energy use, at 56.2 kBtu/s.ft. As noted, refrigerated warehouses[i] are the only typology with a significant increase in EUI over this time period, at 84.1 kBtu/sq.ft.[32]

It is critical that building owners planning on portfolio growth ensure that newly constructed, retrofit, or acquired buildings target increasingly lower EUI values over time.

Median Site EUI by Typology (2012-2021)



i. Per ENERGY STAR, Refrigerated Warehouse refers to refrigerated buildings that are used to store or redistribute perishable goods or merchandise under refrigeration at temperatures below 50 degrees Fahrenheit (10 degrees Celsius).

Typology Trends

Notable EUI Differences within Typologies

Commercial real estate typologies present different opportunities and challenges to decarbonization. Refrigerated warehouses increased in both EUI and gross square footage over the past decade and contain additional GHG emissions concerns through risk of refrigerant leakage.

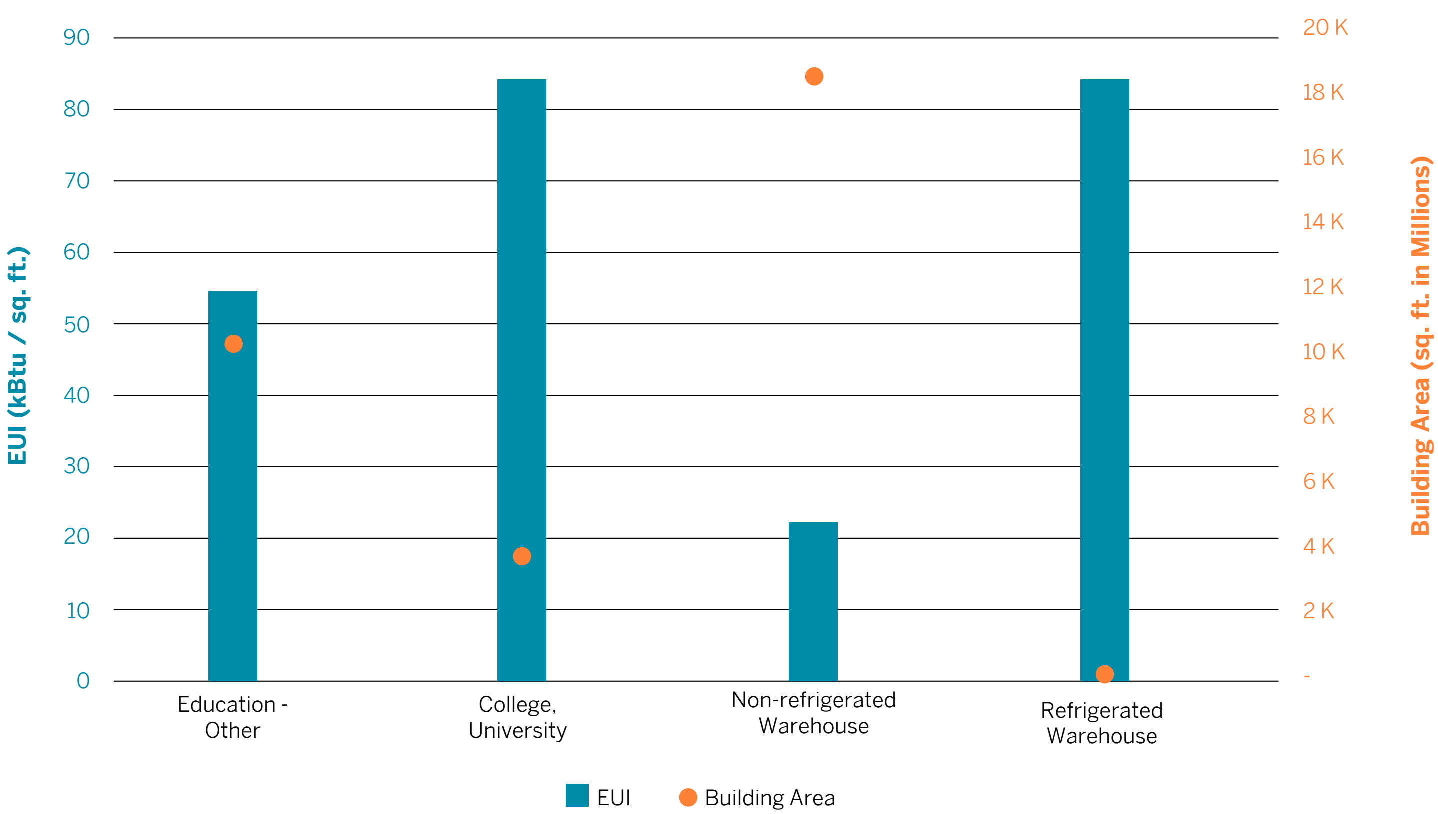
As noted on the previous page, there is a significant difference in EUI between sub-categories in the education and warehouse typologies. Datasets should distinguish between these subcategories.

University buildings have the second highest EUI of all typologies, although they decreased by 31% between 2012 and 2021. The EUI of other education buildings has remained stagnant, increasing by 2% over the evaluated time period. University buildings are 55% more energy use intensive than other educational buildings. This is likely due to higher energy use from ventilation demand in laboratories and longer or more irregular occupancy schedules than other educational buildings.

Refrigerated warehouses are the only typology to show a considerable increase in EUI between 2012 and 2021 (32%) and are almost 4 times as energy intensive as non-refrigerated warehouses. The total area of refrigerated warehouses increased by 44% during this time period, although the warehouse typology is dominated by non-refrigerated area.[33]

In 2021, approximately 1.3% of commercial building emissions came from refrigerated warehouses alone.[34] Refrigeration is both energy intensive and contributes to GHG emissions through the global warming potential (GWP) associated with refrigerant leakage, which comes in addition to the impacts of EUI, making the technology and sector critical to address.

Notable Differences Between Median Site EUI vs Building Area (2021)



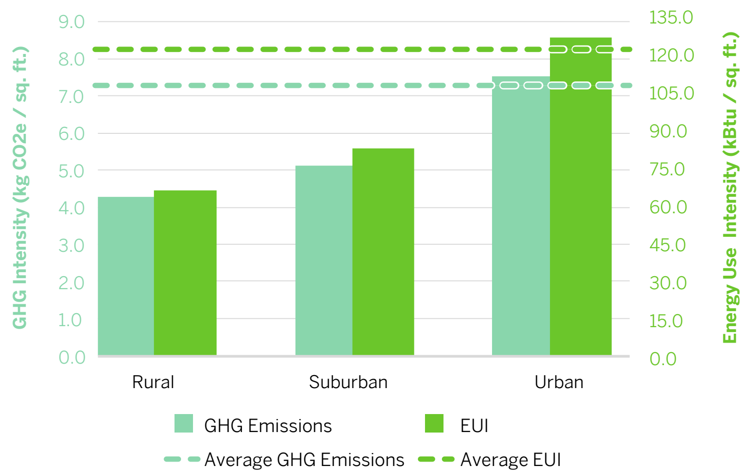
Geographic Distribution of GHG Emissions in California

California's dataset enables evaluating GHG emissions in addition to EUI. This provides insight into the carbon impact of different building typologies, and reveals notable GHG intensity and building typology differences between rural, suburban, and urban areas

Most states in the U.S. do not have comprehensive historical benchmarking data, with data collection concentrated in urban areas only. California's benchmarking dataset is the most comprehensive in the nation. Here, to illustrate the value of such data and to gain insights, its 2019 data has been used to compare building GHG emissions based on geographic location in relation to rural, suburban, and urban areas.

California GHG Intensity & EUI By Location

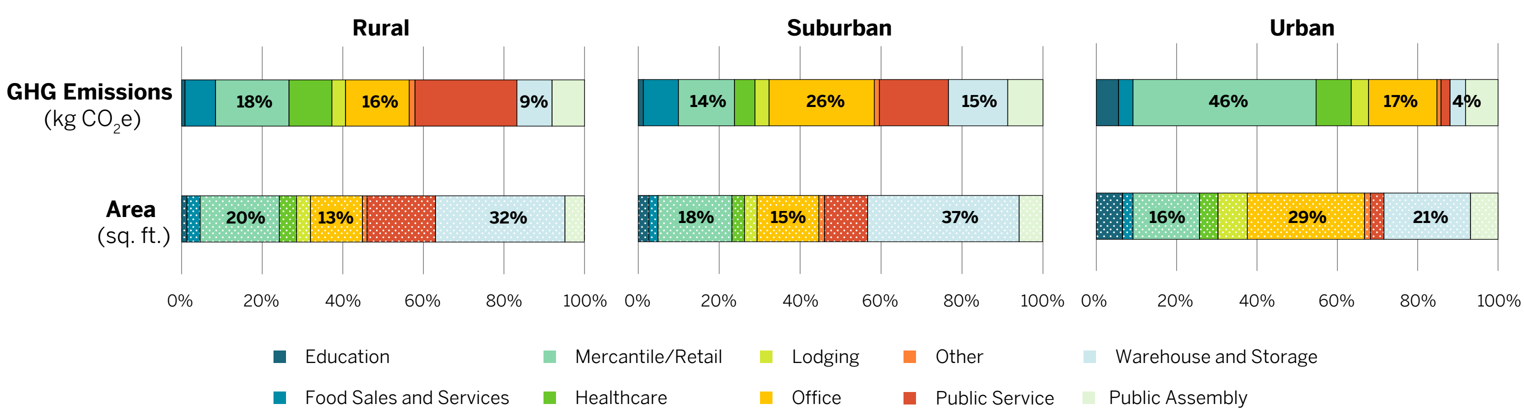
In 2019, average GHG intensity of buildings was lowest in rural areas at 4.27 kgCO_2e/sf and highest in urban areas at 7.53 kgCO_2e/sf. It is important to note that buildings and transportation work in a system. While urban buildings have higher EUI and emissions intensity, the greater density of these areas lowers per capita transportation emissions.

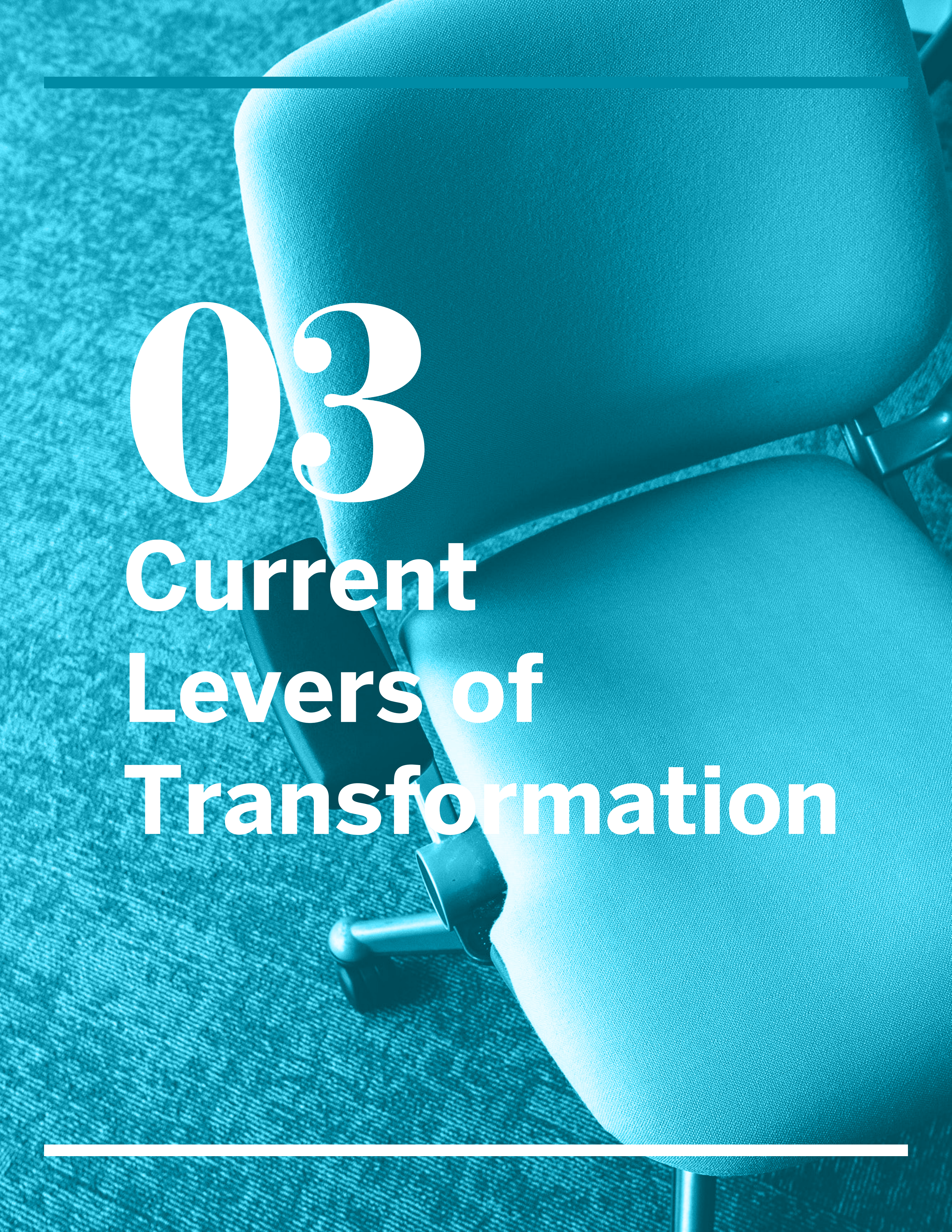


California GHG Emissions and Building GSF by Typology

Urban buildings include typologies, particularly retail, that are more GHG intensive than dominant typologies in rural areas. Retail Stores make up 46% of GHG emissions in urban areas, despite being only 16% of building area. Suburban emissions are distributed across the range of types, with no dominant typology.

Warehouse and storage typologies (primarily non-refrigerated) are dominant in rural and suburban areas, but the low energy use of this typology results in minor sources of GHG emissions in these regions. Public service and assembly space produce about 30% of rural emissions, underscoring the opportunity for government leadership by example.





03

Current Levers of Transformation

3.1

ENERGY CODE, GRID DECARBONIZATION, AND ELECTRIFICATION

Improved building efficiency, electrification of heating and cooling, and clean power are all necessary to decarbonize the commercial real estate sector. Only half of the six most populous power grid regions per the EPA have achievable forecasts to fully decarbonize electricity generation by 2050. In some regions, electrifying building systems will be insufficient to achieve zero emissions, and a combination of efficiency and on-site renewable sources will still be needed into the future.

New commercial buildings constructed in jurisdictions with more advanced energy codes will continue to be more energy efficient and have lower carbon intensities. Focusing on existing buildings remains critical for successful decarbonization of the whole sector.

Regardless of grid region, the transition to electrified space heating from continued use of natural gas will yield significant operational carbon savings. Over a 25-year lifespan, both heat pump and efficient electric resistance heating systems will have lower cumulative emissions when compared to their natural gas counterparts.

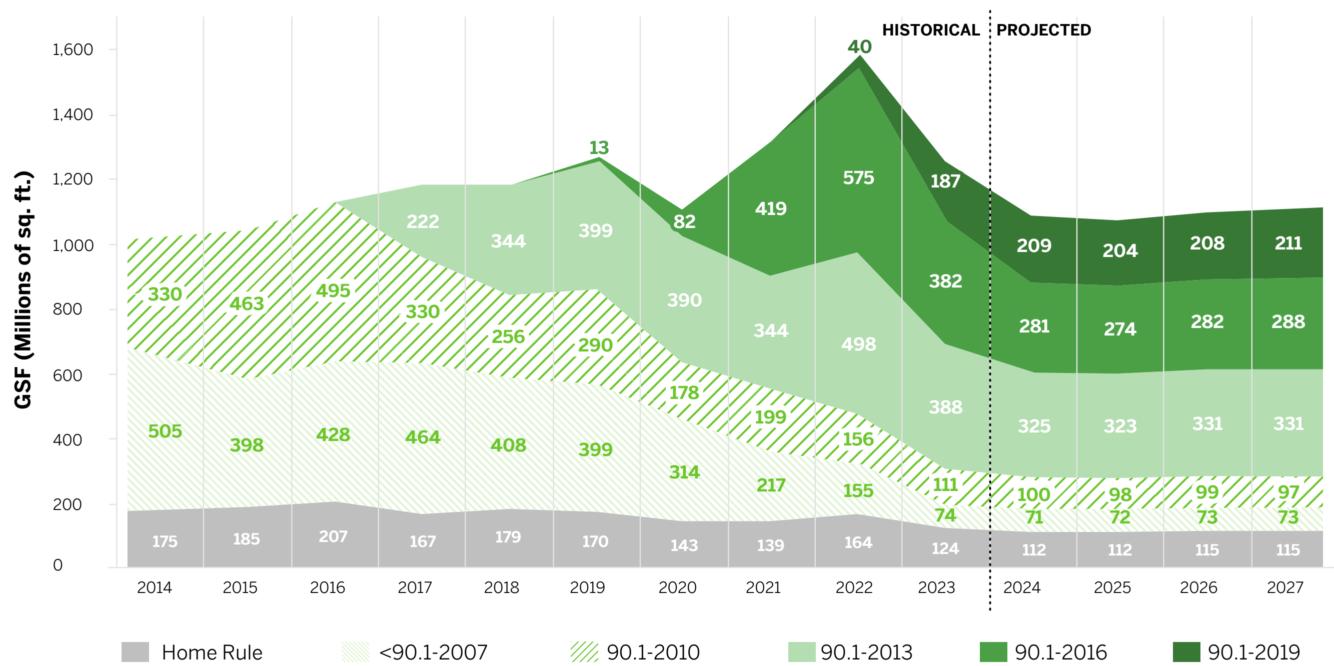
Energy Code Progress Across the U.S.

States are starting to adopt advanced energy codes, more frequently. Buildings constructed in 2023 are projected to be 15% more efficient than those from 2017. These advanced building codes are driving new commercial building decarbonization primarily in more urbanized states and cities. Despite this advancement in new construction, it will be necessary to also make progress on existing buildings for the commercial sector to decarbonize as a whole.

ASHRAE releases a new version of Standard 90.1 every three years to evolve the requirements for energy efficient design of new construction and major renovations. ASHRAE 90.1 is a standard for minimum energy efficiency in commercial buildings and is included as a compliance path within the International Energy Conservation Code (IECC). The graphic below shows historical and projected commercial GSF compared to the minimum energy code that was in effect in each state when the asset was built. The percentage of new construction projects built to ASHRAE 90.1-2010 and older decreased by 78% from 2017 to 2023. When factoring in improvements between 90.1 versions,[i] on average buildings constructed in 2023 are expected to be 15% more efficient than those constructed in 2017.

Cities and states can act to decarbonize their new buildings by adopting the most current model energy codes. For example, Texas requires a minimum performance of 90.1-2013, yet cities like Austin, Dallas, and San Antonio require new construction to meet 90.1-2019. Such regulations provide an improved minimum required efficiency for buildings built in the next few years, which is essential given that these assets are likely to operate for the next 40+ years. The IRA includes substantial incentives to help cities adopt the latest 90.1-2019 code, which may further accelerate adoption.

Commercial New Construction by State Energy Code[ii]



i. For further discussion of ASHRAE 90.1 versions, refer to the introduction of this report. ii. Addendums made to ASHRAE 90.1 versions by States were omitted in analysis. Addendums can derate or improve original performance values. The Home Rule category references GSF built in states where a state minimum energy code is not implemented and is left up to local jurisdictions to decide. Projected GSF uses the same energy codes in place in 2023.

Projected Electric Grid Decarbonization

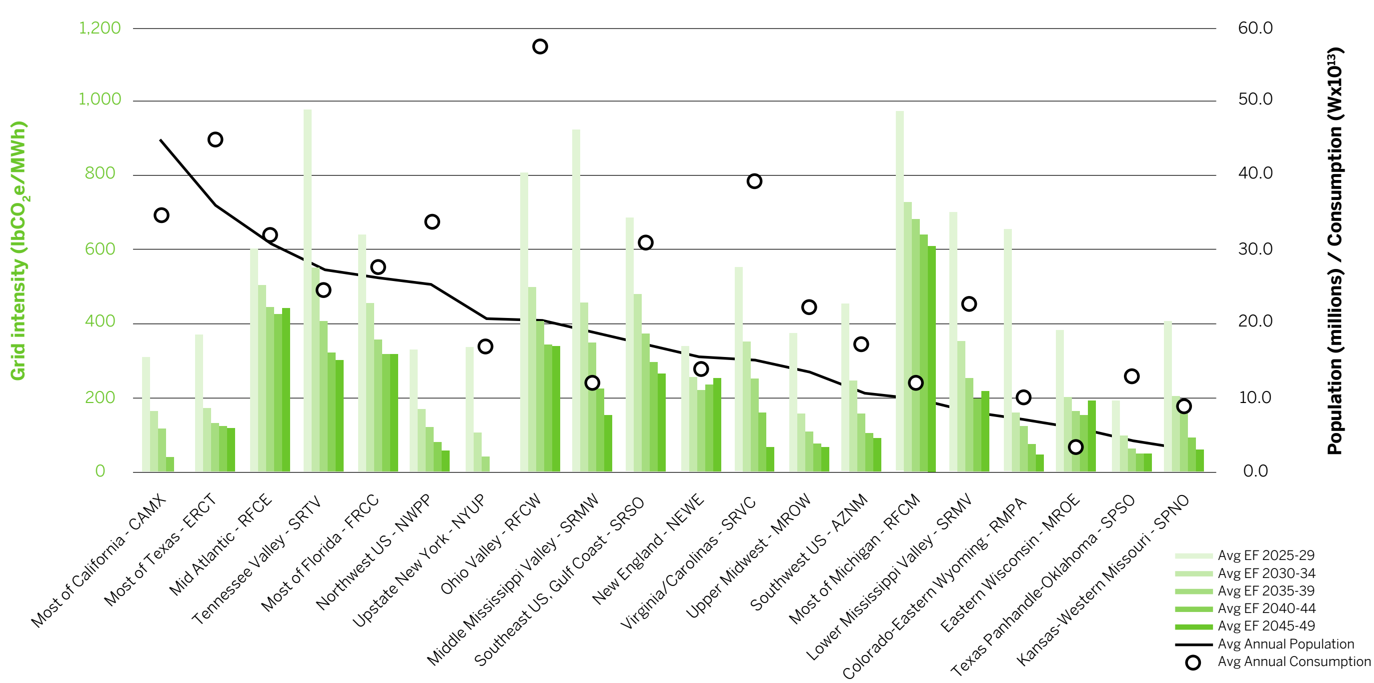
Relying on grid decarbonization and electrification of buildings will only be sufficient in about half of the U.S. Forecasts indicate that three out of the six most populous eGRID regions are on track to attain near-zero emissions intensity by the year 2050. This trajectory means that all-electric buildings will have zero emissions in California, Texas, and the Northwest regions. In the remaining three highly populous regions, including the Mid-Atlantic, Tennessee Valley, and most of Florida, buildings will not be able to achieve zero emissions by 2050 without stringent efficiency measures and on-site renewable energy integration per current grid decarbonization projections.

The U.S. electric grid is projected to decarbonize rapidly over the next 25 years. Projected decarbonization rates based on NREL's mid-case scenario for each grid region are overlaid with population and average annual consumption below. Consumption of each grid region is not proportional to the population served within a region.

Regions in California (CAMX), the Upper Midwest (MROW) and Upstate New York (NYUP) are all projected to decarbonize quickly, with emission intensities at or near zero in 2050. However, regions in the Ohio Valley (RFCW), Mid-Atlantic (RFCE) and Michigan (RFCM) have projected 2050 grid emission intensities significantly higher than those of other regions in 2020.

High emission intensity regions with larger populations are correlated with more commercial buildings. Buildings in these regions must pair efficiency measures with on-site renewable generation to achieve future net zero emission goals. Relying on the grid to decarbonize the electricity supply will not enable commercial buildings in these regions to achieve net zero emissions.

Projected Grid Emission Intensity by 2050



Electrification of Heating and Grid Decarbonization

Shifting from natural gas to electrified heating will yield significant operational carbon savings, regardless of grid region.[i] Over a 25-year lifespan, both electric resistance and heat pump heating systems will yield lower cumulative emissions than natural-gas counterparts, based on NREL's future grid intensity projections.

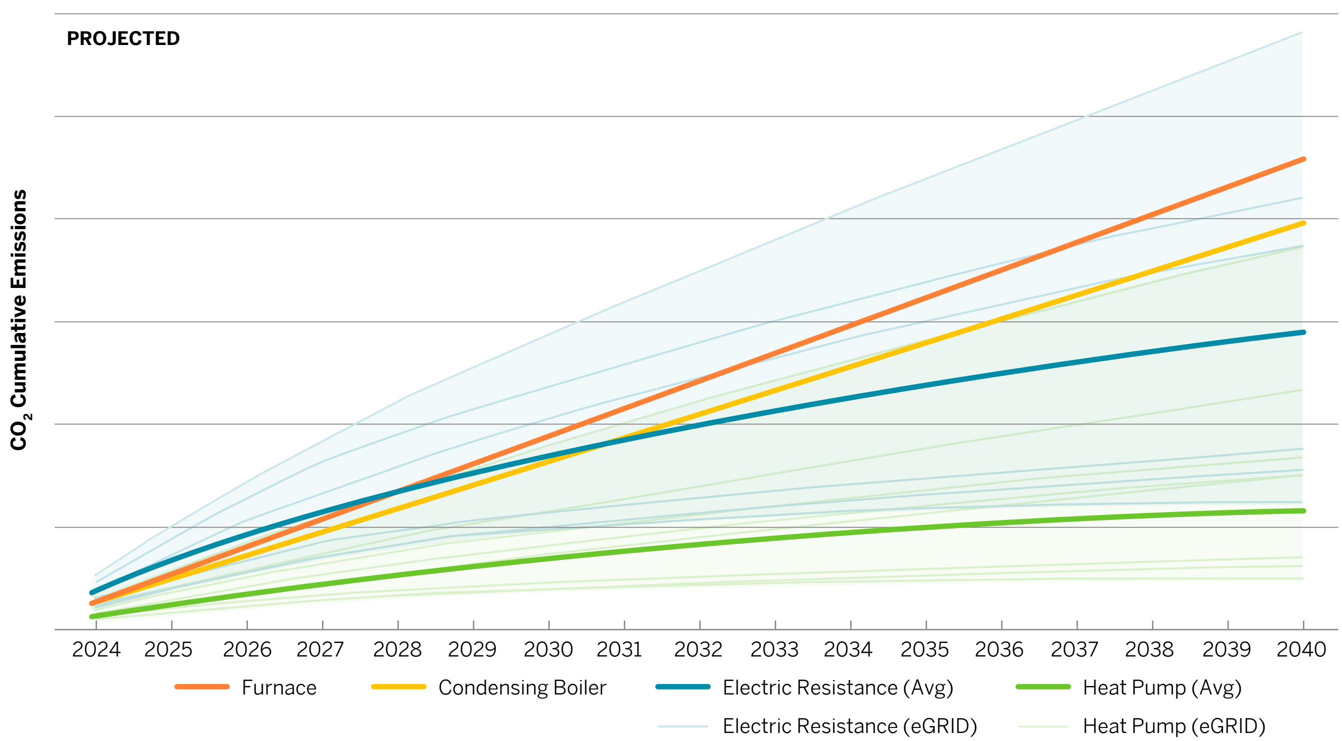
Space heating systems are the largest source of direct GHG emissions by end use in commercial buildings, comprising 37% of annual energy use in the sector. NREL's Cambium 2022 baseline projections were used to calculate the cumulative emissions from four different heating systems over a typical 25-year lifespan to understand how emissions from heating can vary depending on heating source and grid region.

Emission factors from a gas furnace and condensing boiler will be the same regardless of eGRID region. Emission factors from electric resistance heaters and heat pumps vary depending on eGRID region because of variation in grid emissions intensities, with the solid blue and green line representing the U.S. average in the graph below.

Heat pumps have the lowest cumulative emissions: the 25-year average across regions is 75% less than a furnace, 71% less than a condensing boiler and 60% less than electric resistance heaters.

Electric resistance heaters on average produce 37% less cumulative emission than a gas furnace and 27% less than a condensing boiler. Regardless of grid region and electric heating technology, electrification will result in lower heating emissions.

Heating Source CO_2e Emissions by eGRID Region



i. Only 1 of 26 eGRID regions (RFCM – most of Michigan) fails to outperform natural gas systems for its electric resistance heating option under the NREL Midcase scenario. For this reason, heat pumps should be the only recommended electric heating system for this region. Values are not included on the graphic's y-axis as the characteristics of the lines remain the same regardless of building properties (GSF, Heating EUI, etc.) as it is assumed that the heating load will be identical across all four heating systems.

3.2

KEY TECHNOLOGIES: DEMAND RESPONSE, PV, HEAT PUMPS, EV

Demand response is the practice of adjusting electricity consumption in response to grid conditions, which helps maintain grid reliability and optimize energy usage during peak demand periods. However, the availability and rate of participation in demand response programs throughout the United States remains low. Furthermore, the technology underpinning these programs has become obsolete. Industry focus has shifted towards more advanced smart building integrations that extend beyond regulating energy in individual buildings to an emphasis on interactive building and grid systems.

Real-time grid emissions data for 24/7 generation is available and can now inform decisions that were formerly made based on annual averages. Buildings can implement rapid response systems to shift demand when the grid is dirtiest, especially in grid regions with a high percentage of renewable energy as part of the generation mix.

With the emergence of more sophisticated and integrated technologies, commercial buildings are poised to have more control over their energy demand and associated emissions. These advanced technologies include solar PV, all-electric heating and cooling equipment, bidirectional EV charging, and grid-interactive building control systems. Such technologies have experienced exponential growth, driven by policy incentives and shifting market dynamics.

Storage and Demand Response

Grid Interactive Buildings

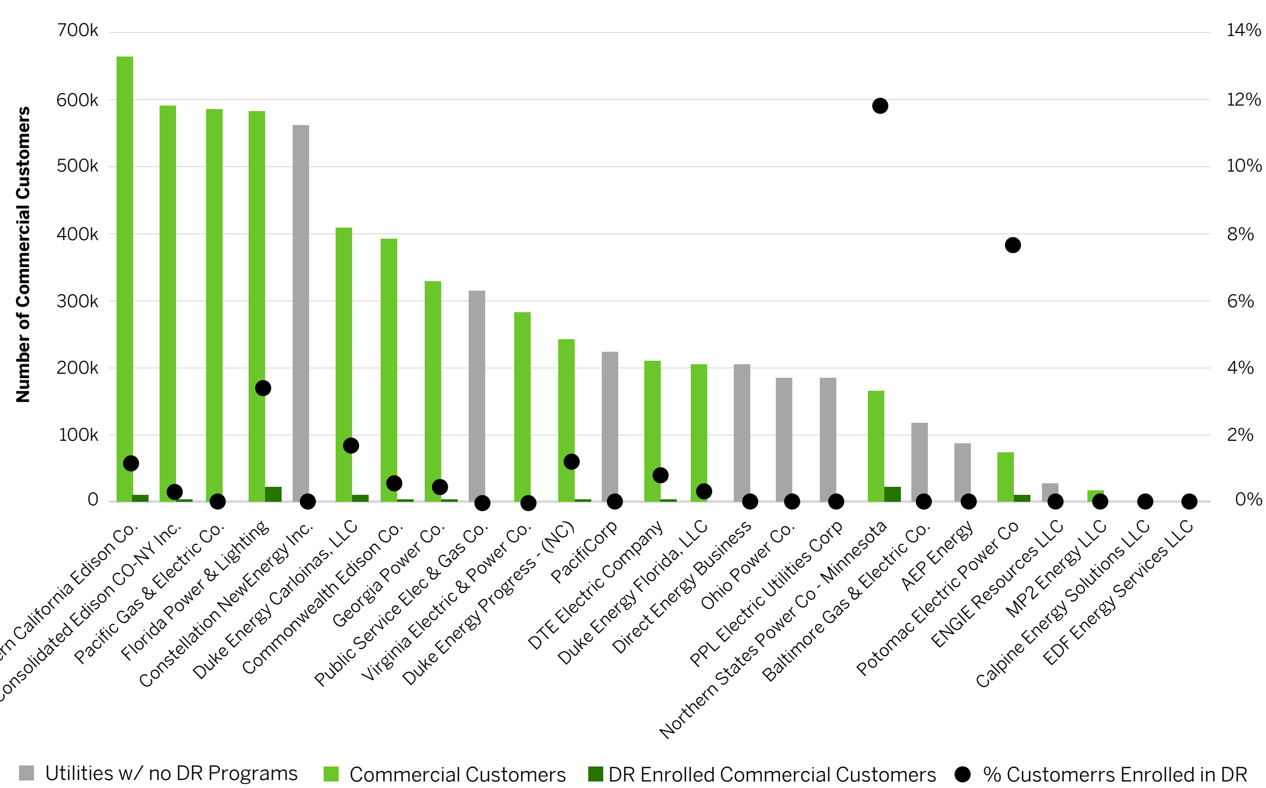
The availability and participation in demand response programs throughout the U.S. remains low and the technology underpinning these programs has become obsolete. Among the top 25 utilities, only 52% currently offer demand response programs. Of these utilities none have participation rates exceeding 12%. Industry focus shifted towards more advanced smart building integrations that extend beyond regulating energy in individual buildings to an emphasis on interactive building and grid systems.

Demand response programs are currently the most common form of grid interaction, with varying levels of complexity. The top 25 utilities in the U.S. generated 748 million MWh of electricity resulting in 291 million tons of CO_2e in 2021.[1] The largest providers are offering 50% more dynamic pricing programs than they were five years ago.

'Critical Peak Pricing' and 'Critical Peak Rebate' programs saw the highest growth in offerings and are expected to become more common as grid interactive building technologies are adopted in the market.

While demand response program offerings are becoming more prevalent across the largest utilities, commercial customer enrollment in these programs remains low. Of the top 25 utilities that offer demand response, 85% have a participation rate of 3% or less with none exceeding 12%.

Commercial Demand Response Program Enrollment



Storage and Demand Response

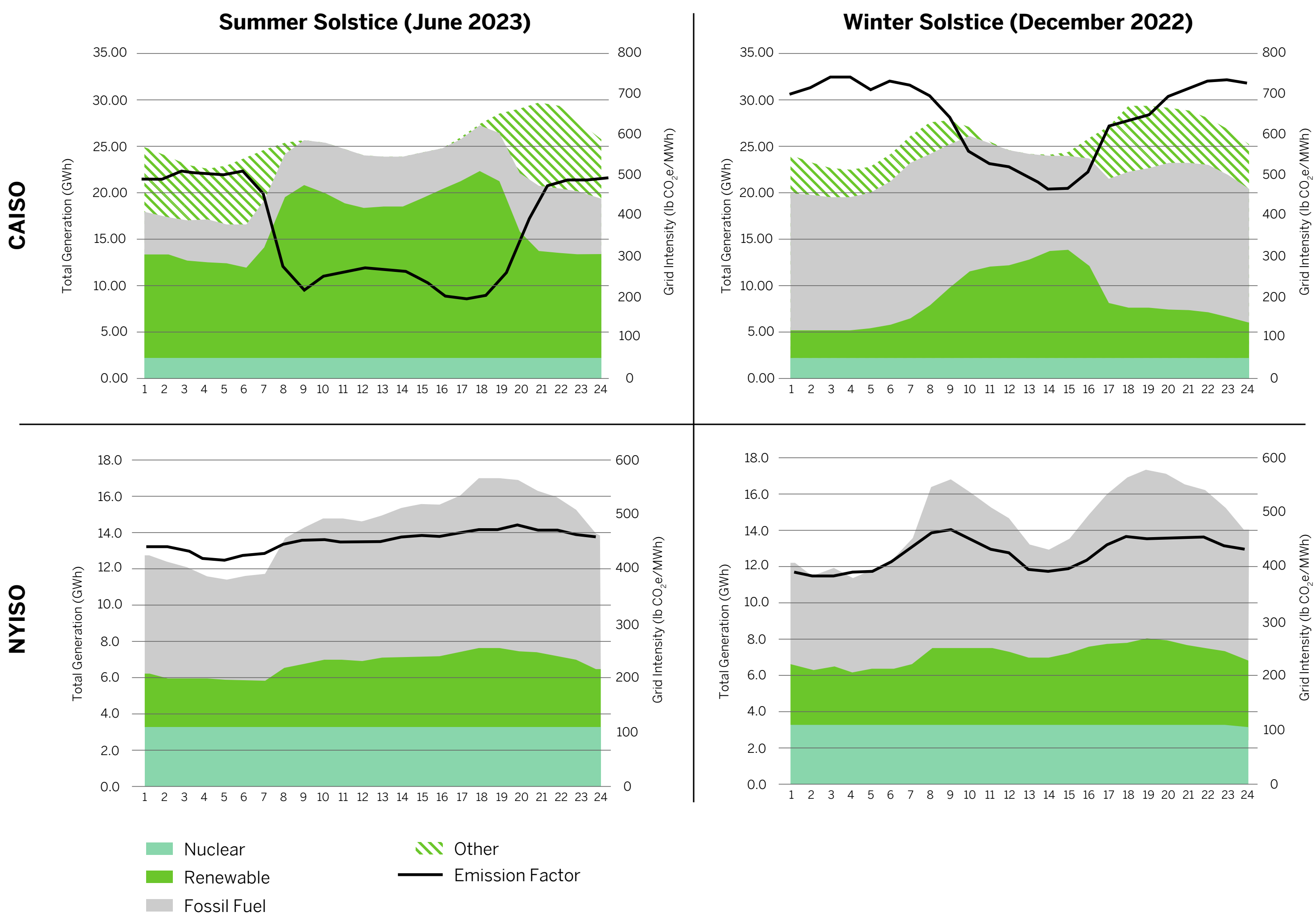
Hourly Emissions and Demand Response

Demand response must move beyond a focus on peak demand, to considerations of peak carbon. Buildings can implement real-time response systems to shift demand when the grid is dirtiest, especially in grid regions with a high percentage of renewable energy as part of the generation mix.

This strategy may be counter to traditional demand response goals, which aim to shift energy demand away from peak demand depending on location and renewable energy mix.

Grid emissions for commercial buildings are time dependent and based on generation happening in real-time. To demonstrate this variability across the U.S., data from New York[2] and California's Independent System Operators (ISO)[3] were extracted during the summer and winter solstice on an hourly basis to demonstrate how generation changes and affects the intensity of carbon emissions.

Nuclear generation remains constant in both locations, while CAISO renewable energy generation tracks with daylight hours from solar generation and NYISO remains more consistent from hydroelectric power.[4] Carbon intensity is more variable in states that have larger concentrations of wind and solar generation.



Building, Transportation, and Grid Connectivity

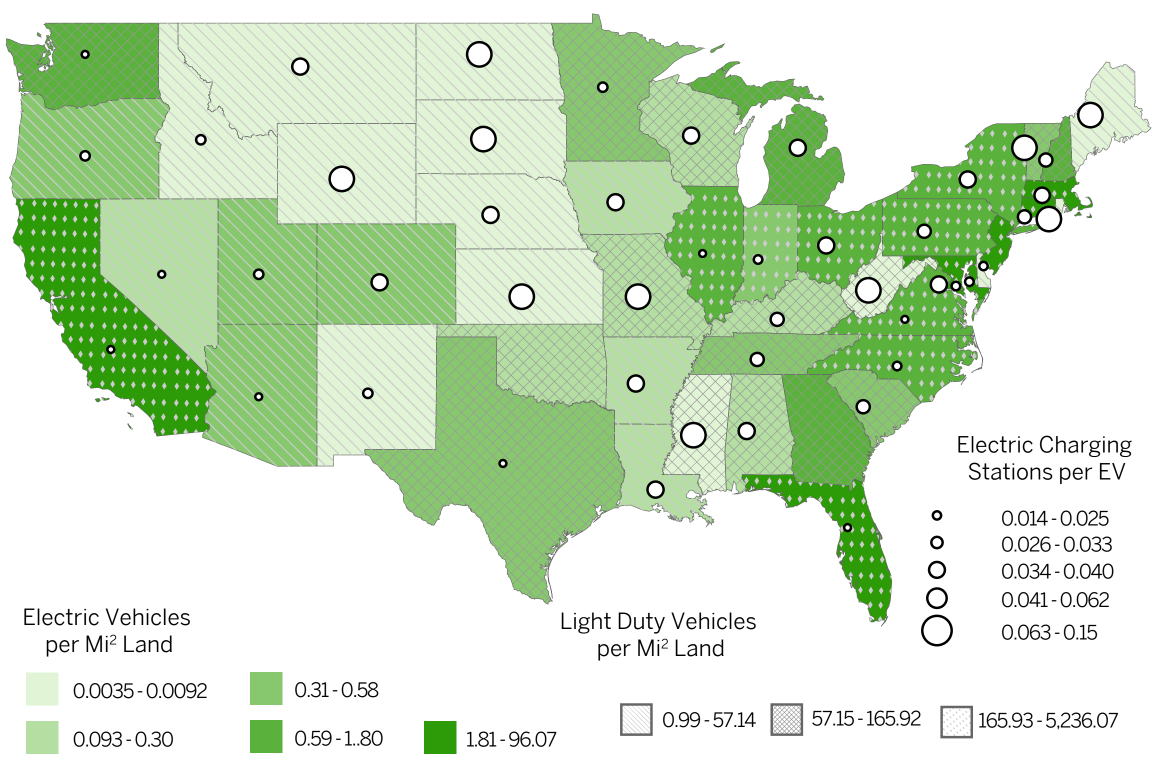
Electric vehicle (EV) charging is a convergence point for transportation systems, the electric grid, and building energy storage systems. Both transportation and building emissions can be mitigated through increased EV use, and bidirectional charging adoption offers the potential for buildings to become an asset to a decarbonized and resilient electric grid. In key markets, the development of EV charging infrastructure has failed to keep pace with growing EV demand.

Buildings are indirectly linked to transportation sector emissions. EV batteries have the potential to provide backup power for peak demand or critical loads. Newer EV supply equipment is built with bidirectional charging capabilities, allowing the EV battery to discharge stored battery energy to an external source in a commercial building.[i]

In California and Florida, demand for EV charging stations currently outpaces the level of charging infrastructure available for users.

According to the Electric Power Research Institute and NRDC, when emissions reductions from vehicle electrification, a decarbonized grid, and existing vehicle efficiency programs are modeled, a 48% reduction in GHG emissions is achieved by 2050.[5]

EV Registrations and Charging Stations vs Total Vehicles



i EV models with bidirectional charging capability comprise about 10% of the EV market share and about 11% of all EVs sold in 2022. As electric vehicle registrations continue to increase over time, reductions in transportation emissions and in building emissions through bidirectional charging are expected to increase accordingly. In a new project between the City of Boulder and Fermata Energy, a bidirectional charging station has been installed to allow vehicle batteries to transfer energy from the battery back to the North Boulder Recreation Center to support the building's electric loads and reduce peak demand. Vehicle-to-building / vehicle-to-load charging increases a building's energy resilience by serving as emergency backup power. This solution can pair with solar photovoltaic systems and other distributed energy resources, or supplement diesel generators to round out a resilient backup power solution.

Essential Decarbonization Technologies

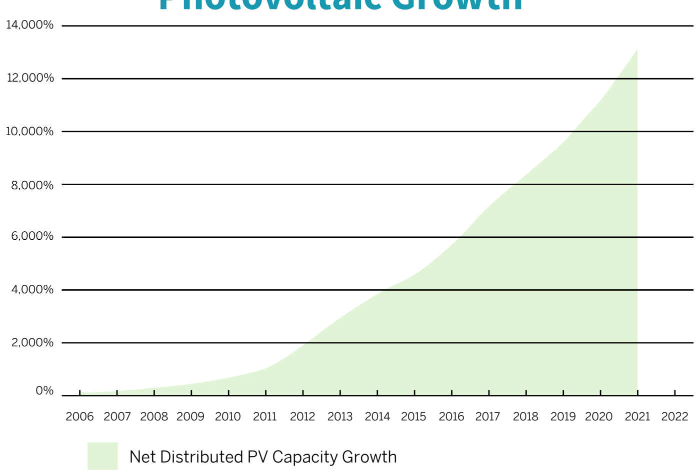
Over the past decade, the market for 'green' technologies such as solar PV and LED lighting has experienced exponential growth, driven by policy incentives and shifting market dynamics. New financial incentives in the IRA and Bipartisan Infrastructure Law (BIL) are expected to further accelerate adoption of these and newer technologies.

The adoption of on-site renewable energy generating technologies and high-efficiency systems in existing and new buildings are two key elements needed for decarbonization. The Energy Policy Act of 2005 established the Solar Investment Tax Credit (ITC), creating a 30% credit for solar energy systems. This catalyzed the adoption of solar in U.S. commercial buildings,[i] as the capital cost of installation has decreased significantly over the last decade. As new incentives and financing opportunities targeting electrification and EUI reductions emerge, it is important to consider how they can help facilitate the adoption of other high-performance systems, including heat pumps.

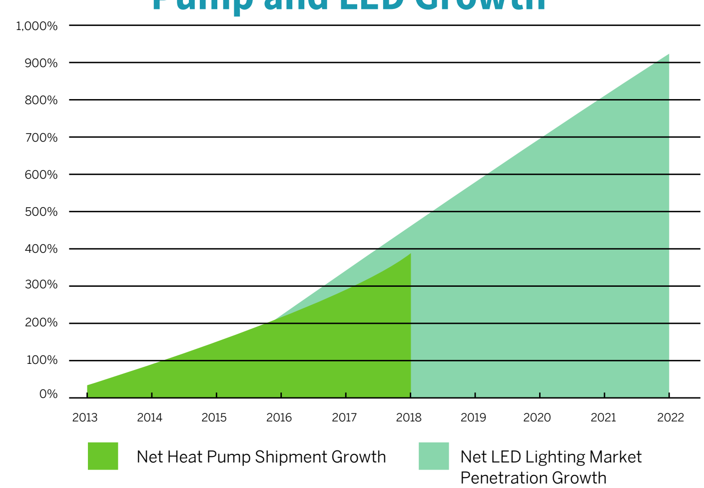
Although heat pumps are highly efficient and low-carbon in operation, they often require a complete system overhaul in existing buildings to replace fossil-fuel equipment with electric. Retrofitting buildings is a major undertaking which has slowed heat pump adoption and growth to-date as compared to solar installations.[ii] Conversely, LED lighting grew from a 9% adoption rate to a 44% rate in commercial buildings from 2012 to 2018. Key drivers are ease of installation and low upfront costs.[iii]

One potential barrier to adoption of decarbonization technologies is the significant labor gap in the construction industry. Per the Associated Builders and Contractors (ABC), the U.S. construction industry needs to close a 546,000-person workforce gap to meet the current demand. The 4% workforce growth projected in the next ten years will not add enough jobs to meet this demand. To facilitate the adoption of energy efficient technology, this gap needs to be addressed to ensure new technologies can be implemented.

Commercial Sector Distributed Photovoltaic Growth



Commercial Sector Heat Pump and LED Growth



i. The ITC has since been renewed several times, most notably as part of the Inflation Reduction Act (IRA), which renewed the 30% ITC until at least 2031.
ii. Section 48 of the IRA promises to catalyze geothermal heat pump adoption through an ITC with a 6% base credit rate and a 30% bonus rate between 2023 and 2035. An additional 10% bonus rate can be achieved if owners prove the project was made in the U.S. and meets prevailing wage and apprenticeship requirements.
iii. IRA amendments to 179D offers a deduction of up to $5 per square foot for projects meeting prevailing wage and apprenticeship labor requirements, with the amount depending on reduction of total annual energy and power costs for the building. This can incentivize other high-performance systems like LED lighting.

04

Future Mechanisms for Transformation

4.1

BENCHMARKING AND PERFORMANCE STANDARDS

Key policies have emerged in U.S. state and city governments to tackle emissions in existing buildings. The first steps for jurisdictions are enacting benchmarking and disclosure policies, whereby building owners report annual building energy use and other information to enable buildings to be benchmarked against peers.

Current benchmarking policies cover only <1% of commercial buildings in the country. California alone disproportionately accounts for 39% of the total number of buildings benchmarked in the United States. In addition, standards and data collection vary significantly by state. Expansion of benchmarking policies across the United States will help develop a detailed understanding of building performance to support policy development.

Benchmarking policies have been shown to slightly reduce energy use by covered building owners. More significantly to decarbonization, these benchmarking policies are the basis for Building Performance Standards (BPS). Following or in conjunction with establishment of benchmarking, BPS set limits on building energy or emissions intensity, often with a series of enforceable standards that become more stringent over time. While benchmarking policies enable improvement, BPS require it.

In free market-oriented states, incentives and private sector initiatives will be required for the commercial real estate sector to meet decarbonization goals set out in the U.S. commitments under the Paris Agreement.

Benchmarking Data Availability

Buildings in California disproportionately make up 39% of the total number of buildings reporting under mandatory benchmarking policies in the United States. Current reported buildings under mandatory benchmarking cover <1% of commercial buildings in the United States. Continued implementation and expansion of benchmarking policies across the U.S. is needed to develop a detailed understanding of building performance and to develop policy.

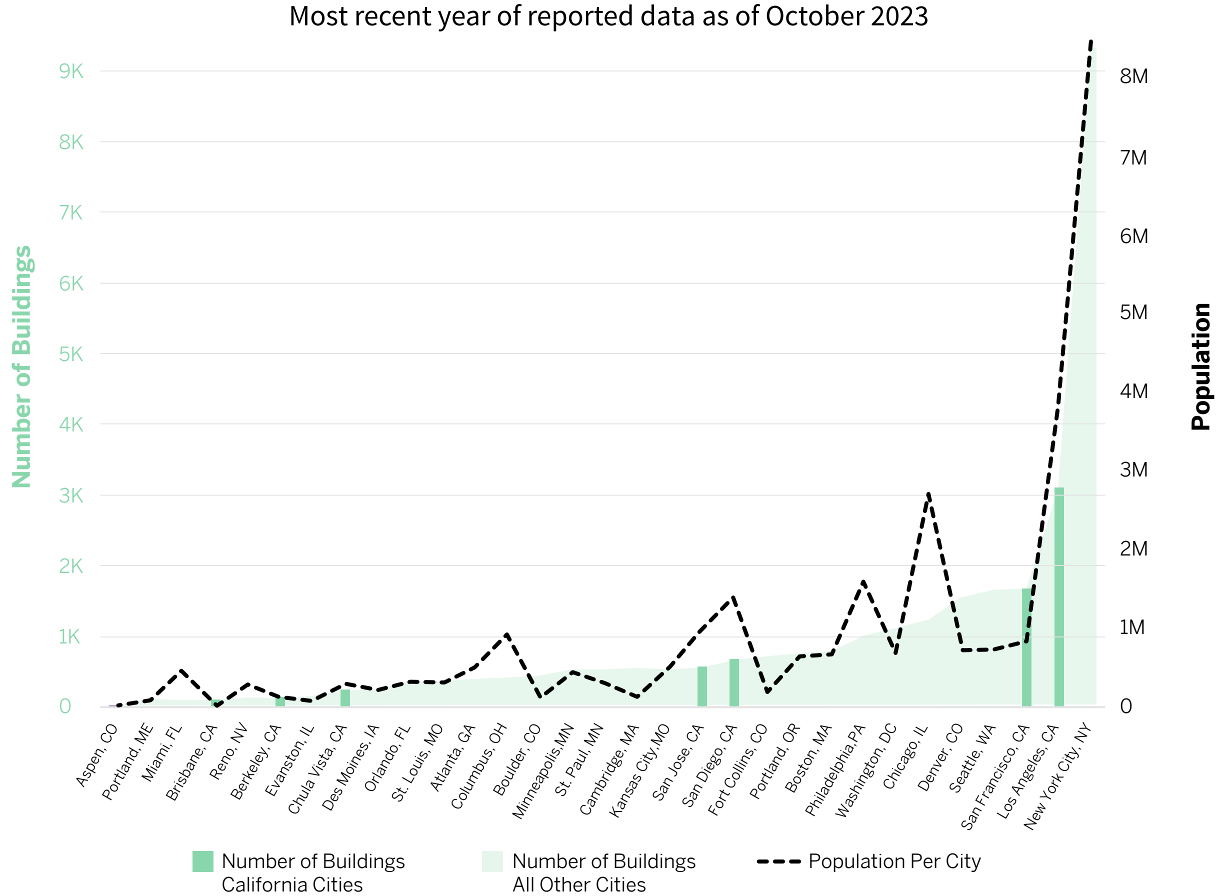
Mandatory building energy benchmarking policies currently used in cities and states are often a first step before establishing building performance standards (BPS). This creates awareness and can lead building owners to improve the efficiency of their buildings, decreasing overall energy use and cost.

Buildings publicly reporting energy use data under mandatory benchmarking have increased to include more than 37,000 commercial buildings annually. However, this number only represents <1% of commercial buildings in the country. There are over 130,000 buildings covered by mandatory benchmarking laws,[1] but not all covered buildings report energy use data each year.

California has accessible, benchmarked energy data from 2021 for 14,551 commercial buildings, which make up 39% of the total U.S. commercial buildings with public benchmarking data. New York City, the only city in New York State with mandatory benchmarking, collected energy data from 2021 for 9,297 buildings, comprising 25% of the total.

Buildings Reporting Under Mandatory Benchmarking Policies by U.S. City

Most recent year of reported data as of October 2023



Benchmarking Policies Across the U.S.

Benchmarking policies have been shown to reduce energy use by 2.4% annually.[2] While this is a slight decrease, Building Performance Standards build on the data collected through benchmarking policies to further decarbonization goals. Benchmarking policies began over a decade ago and remain limited, but are increasing.

More widespread adoption of mandatory benchmarking is needed to both understand current building performance and develop policies to decarbonize existing buildings. Increased data availability would aid policy development. Even in cities and states with mandatory benchmarking, data is often not publicly available, is inaccessible, or publicly available data may not include the full range of years since the ordinance was passed.

It should be noted that many of these policies are targeting medium to large commercial building sizes, aiming to driving impact at scale.

The survey of benchmarking policies summarized in this matrix note a historic shift to operational carbon as the metric to evaluate building performance. Of the 51 cities and states with benchmarking policies, 32 specifically outline GHG emissions as one of the required metrics to report.

This trend indicates a growing adoption of decarbonization targets among policy makers, in addition to an established focus on energy efficiency. Developing BPS policies with GHG emissions intensity metrics would further advance existing building decarbonization strategies such as electrification of energy sources as grids decarbonize. Cities including Boston, Cambridge, and New York have enacted BPS policies within the past four years that target maximum annual GHG emissions of public and commercial buildings, with enforcement by fine for non-compliance.

Divergent state and city policies suggest that the commercial real estate sector may follow different paths towards achieving zero emission buildings. States have different orientations towards regulation, and some have preemption laws that restrict the potential use of city and county ordinances for building decarbonization. In these states, BPS ordinances at a local level are unlikely, and free market solutions will be required for the commercial real estate sector to decarbonize.

Location	Ordinance First Year in Effect	Minimum Building Size (SF)	Ordinance CRE Impact	EUI or GHG Reporting Specified	Required Performance Threshold
Alabama					
Alaska					
Arizona					
Arkansas					
California*	2018	50,000		Both	
Berkeley*	2018	15,000		EUI	
Brisbane	2019	10,000		EUI	
Chula Vista	2017	20,000		Both	✓
Los Angeles*	2016	20,000		Both	
San Diego*	2018	15,000		Both	
San Francisco*	2019	10,000		EUI	
San Jose	2023	20,000		Both	

* Indicates that data is publicly available

More comprehensive policy

Location	Ordinance First Year in Effect	Minimum Building Size (SF)	Ordinance CRE Impact	EUI of GHG Reporting Specified	Required Performance Threshold
Colorado	2022	15,000		Both	✓
Aspen	2023	15,000		Both	
Boulder	2016	1		EUI	✓
Denver*	2016	25,000		Both	✓
Fort Collins	2020	5,000		EUI	
Connecticut					
Delaware					
District of Columbia*	2012	25,000		Both	✓
Florida					
Miami	2023	20,000		Both	
Orlando*	2019	10,000		Both	
Georgia					
Atlanta	2019	25,000		Both	
Hawaii					
Honolulu	2023	100,000		Both	
Idaho					
Illinois					
Chicago*	2014	50,000		Both	
Evanston*	2018	1		Both	
Indiana					
Indianapolis	2023	100,000		Both	
Iowa					
Des Moines	2019	25,000		EUI	
Kansas					
Kentucky					
Louisiana					
Maine					
Portland*	2018	20,000		Both	
South Portland*	2021	20,000		Both	
Maryland	2024	35,000		GHG	✓
Montgomery County*	2015	25,000		EUI	✓
Massachusetts	2013	20,000		Both	
Boston*	2017	35,000		EUI	✓
Cambridge*	2015	25,000		Both	✓
Michigan					
Ann Arbor	2021	20,000		Both	
Minnesota	2014	50,000		EUI	
Bloomington	2023	100,000		Both	
Edina	2020	25,000		Both	
Minneapolis*	2014	50,000		Both	
St. Louis Park	2020	25,000		EUI	
St. Paul	2020	50,000		EUI	

* Indicates that data is publicly available

More comprehensive policy

Location	Ordinance First Year in Effect	Minimum Building Size (SF)	Ordinance CRE Impact	EUI or GHG Reporting Specified	Required Performance Threshold
Mississippi					
Missouri					
Kansas City*	2017	50,000		Both	
St. Louis*	2017	50,000		Both	✓
Montana					
Nebraska					
Nevada					
Reno*	2020	30,000		Both	✓
New Hampshire					
New Jersey	2023	25,000		Both	
New Mexico					
New York					
New York City*	2010	50,000		Both	✓
Syracuse*	2017	1		Both	
North Carolina					
North Dakota					
Ohio					
Columbus	2021	50,000		Both	
Oklahoma					
Oregon					✓
Portland*	2016	20,000		Both	
Pennsylvania					
Philadelphia*	2013	70,000		Both	
Pittsburgh	2018	50,000		EUI	
Rhode Island					
South Carolina					
South Dakota					
Tennessee					
Texas					
Austin*	2013	10,000		Both	
Utah					
Salt Lake City	2016	25,000		EUI	
Vermont					
Virginia					
Washington*	2019	10,000		Both	✓
Seattle*	2015	20,000		Both	✓
West Virginia					
Wisconsin					
Madison	2024	25,000		Both	
Wyoming					

* Indicates that data is publicly available

More comprehensive policy

4.2

RETROFIT AND RENOVATION

Growth in commercial sector renovations and retrofits increased significantly within the last decade. Looking forward, this trend is expected to continue, with renovation spend projected to increase up to 11% annually by 2027 with additional funding from the IRA. IRA amendments to the commercial building incentive known as Section 179D update the financial benefits for energy efficiency retrofits to existing buildings. The most significant potential for energy efficiency savings lies in buildings constructed before 1980 that have not been renovated since 2000, which represent 37% of the national gross commercial floor area. Nearly half (47%) of the tax deductions provided under §179D are linked to this subset of buildings.

Retro-commissioning (RCx) is a valuable tool for identifying and maximizing potential energy savings. For example, every 1% of retro-commissioning market penetration results in energy savings of almost four billion kBtu, the equivalent of over 830,000 metric tons of CO_2e per year — more than the average of two U.S. natural gas-fired power plants operating for an entire year. Retro-commissioning in 2021 hovered above 0.6% penetration per year, so there exists considerable untapped opportunity for RCx to expand and contribute to decarbonization goals.

Several other factors could impact retrofit and renovation rates. Building performance standards are projected to induce investment in efficiency and electrification, to achieve compliance. Corporate climate commitments could lead to portfolio-wide building improvements to make progress towards targets. Office and retail vacancy rates in urban downtowns will likely affect investment in existing buildings. These factors could be significant, however there is not sufficient data to quantify their impact today.

Growth of Building Renovation Market in the U.S.

The commercial market for renovations and retrofits increased by 39% across the U.S. over the past 8 years. It is estimated that 17% of this spending has historically been on energy efficiency related retrofits. With the impact of the IRA, the future amount spent on renovations is projected to increase by up to 11% annually by 2027.

Renovation spending has increased 7% year over year (YOY) since 2014 and is projected to continue at this historical growth rate as a baseline. The six U.S. states with the largest renovation spend are highlighted in the graph below.

Four scenarios modeling potential impact on renovation spending from IRA amendments to the commercial building incentive known as Section 179D are shown below. The projections assume a federal income tax rate of 21% but do not incorporate state income taxes. Therefore, the projections slightly undervalue spending if offset state income taxes were also reinvested into additional retrofit spend.

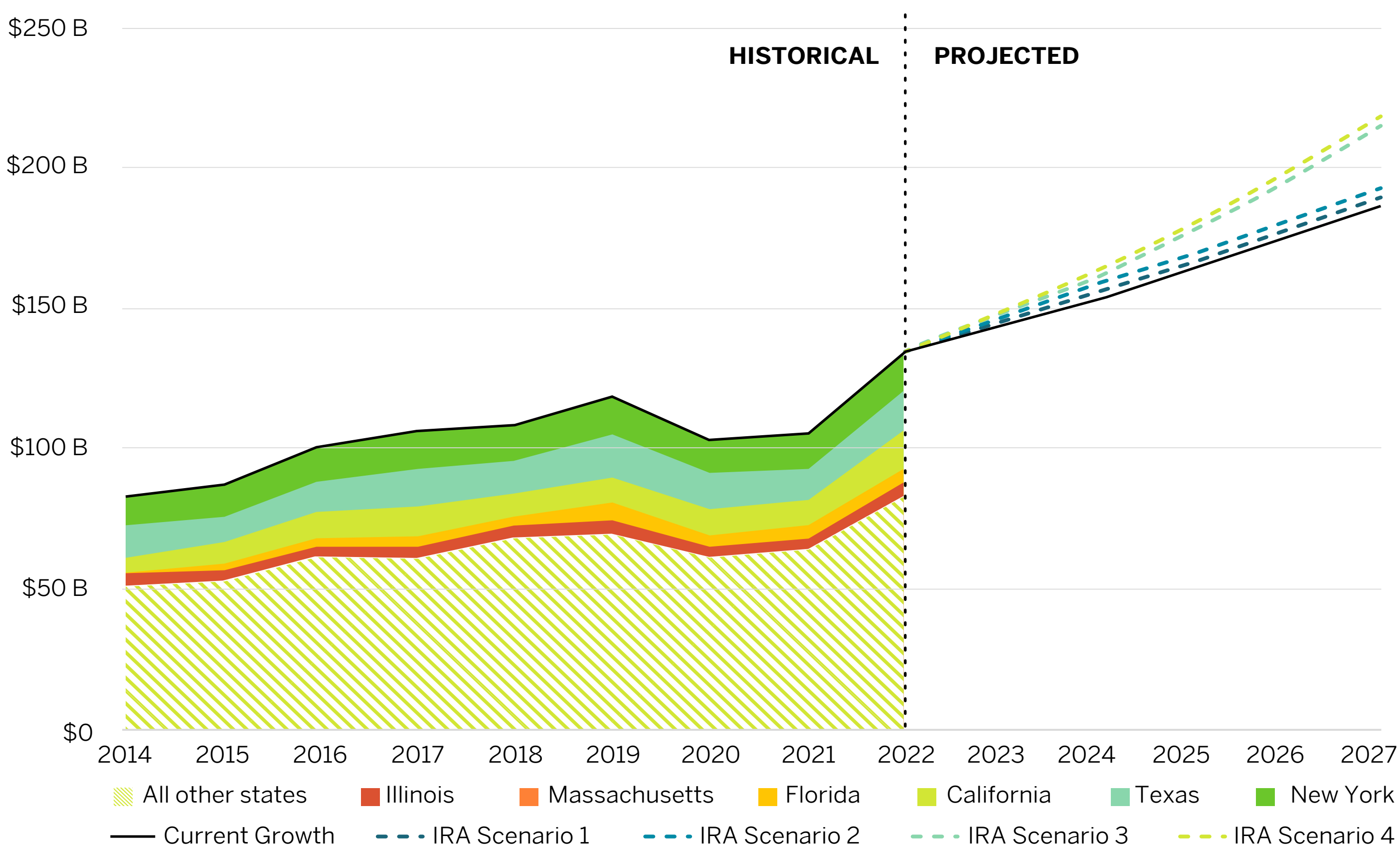
Scenario 1: Retrofit spend grows 7% and 8.5% of received tax deductions is reinvested into additional retrofit spend YOY

Scenario 2: Retrofit spend grows at 7% and 17% of received tax deductions is reinvested into additional retrofit spend YOY

Scenario 3: 50% of the retrofit spend offset by tax deductions is reinvested into additional spend. Total growth rate of 9% YOY

Scenario 4: 100% of the retrofit spend offset by tax deductions is reinvested into additional spend. Total growth rate of 11% YOY

Building Renovation Spend with IRA Projections



Federal IRA Funding and Incentives

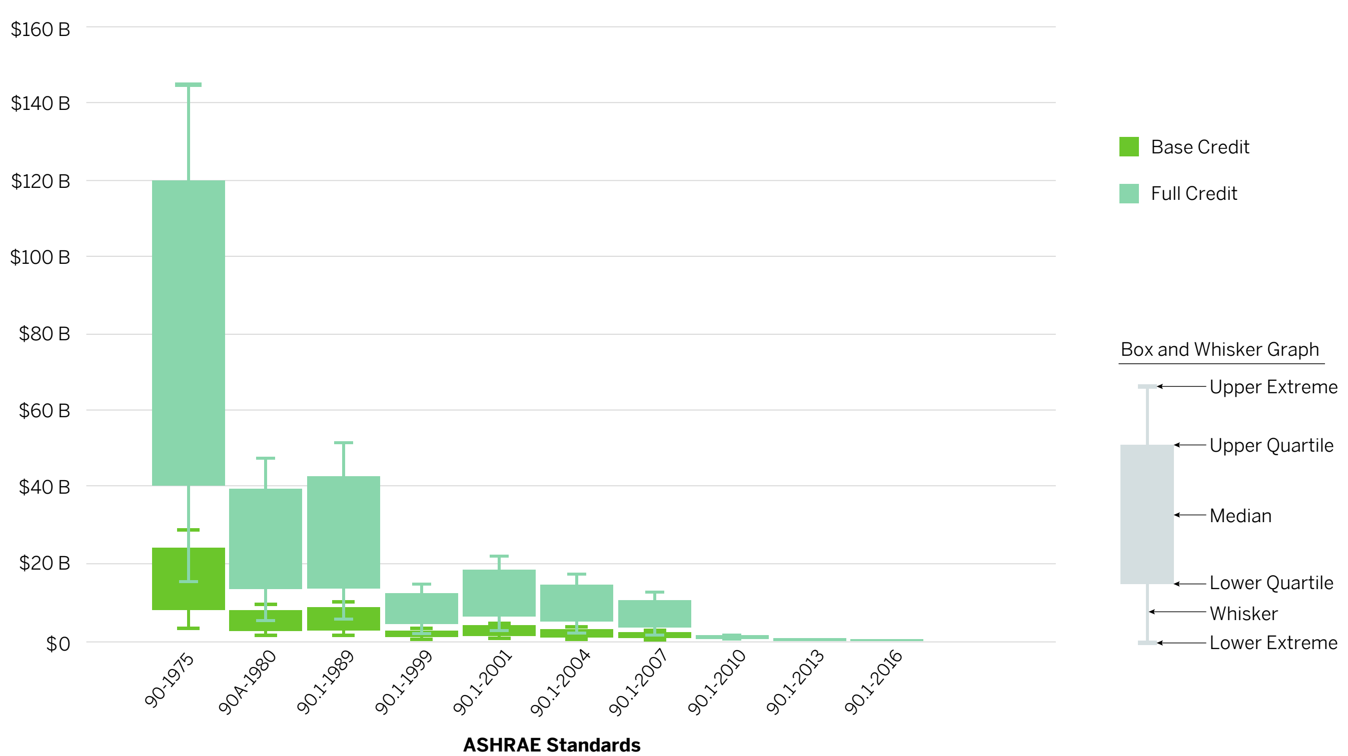
IRA amendments to the commercial building incentive known as Section 179D are projected to provide a net total tax savings of $66B for energy efficiency retrofits to existing buildings, equivalent to 35% of the 2022 U.S. spend on renovations. Retrofitting commercial buildings constructed before 1980 presents the largest opportunity for receiving tax deductions based on assumed potential improvement.

IRA amendments to Section 179D, Energy Efficient Commercial Building Deduction (§179D), provides incentives to building owners for existing building retrofits. The law allows tax deductions on energy efficiency upgrades that result in energy savings greater than 25%, and up to 50%, based on the existing building's certified EUI. Section §179D provides five times the deduction if taxpayers and contractors comply with local prevailing wage and apprenticeship (PW&A) requirements.[3]

Commercial buildings built before 1980 that have not been renovated since 2000 represent 37% of the national gross floor area. These buildings offer the greatest opportunity for energy savings given their age and assumed condition. This subset of pre-1980s buildings results in 47% of the tax deductions available through §179D.

If all existing commercial buildings in the United States were retrofitted with energy efficiency upgrades in compliance with their respective states' current energy code, $314B of tax deductions could be recognized, resulting in $66B in net total tax savings.[i] These provided tax savings are 35% of the 2022 U.S. spend on renovations, highlighting the scale of incentives offered by the IRA.

Estimated Building Retrofit Tax Deductions by ASHRAE 90.1 Standards



i. In the chart above, the 'Base Credit' represents the amount of available tax deductions if PW&A requirements are not met, while the 'Full Credit' represents the amount if PW&A requirements are met. Net total tax savings assume a federal income tax rate of 21%, and do not incorporate state income taxes.

Commissioning and Retro-Commissioning Market Penetration

Estimates show that every 1% of retro-commissioning market penetration in the commercial sector results in an energy savings of almost 4 billion kBtu, the equivalent of over 830,000 metric tons of CO_2e per year. Retro-commissioning (RCx) in 2021 hovered above 0.6% penetration per year, so there exists considerable untapped opportunity for RCx to expand and contribute to decarbonization.

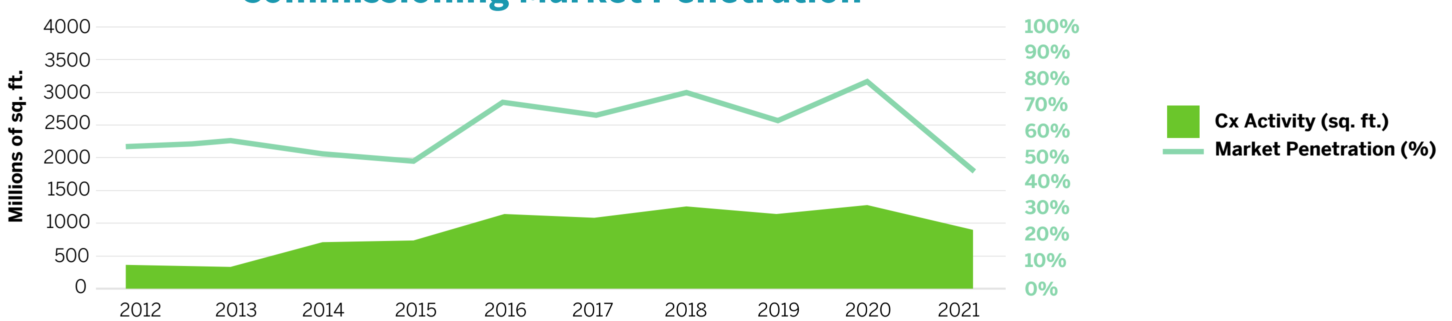
The process of commissioning (Cx) and retro-commissioning (RCx) aligns building operations with design, making buildings more energy efficient in the process. Cx involves a multi-day review of the building's systems to ensure they perform according to the design intent for new construction or major retrofits. RCx is analogous to a car tune-up to make sure systems are operating effectively after a building has been in operation for a period of time. RCx has been shown to reduce energy demand by 6% on average in existing buildings, but energy savings can be significantly higher in poor performing buildings.[4]

The Northwest Energy Efficiency Alliance (NEEA) has published data on market penetration[i] of Cx and RCx for the Pacific Northwest.[5] The following data was extrapolated to the entire commercial building stock of the United States to evaluate trends and estimate potential energy savings.

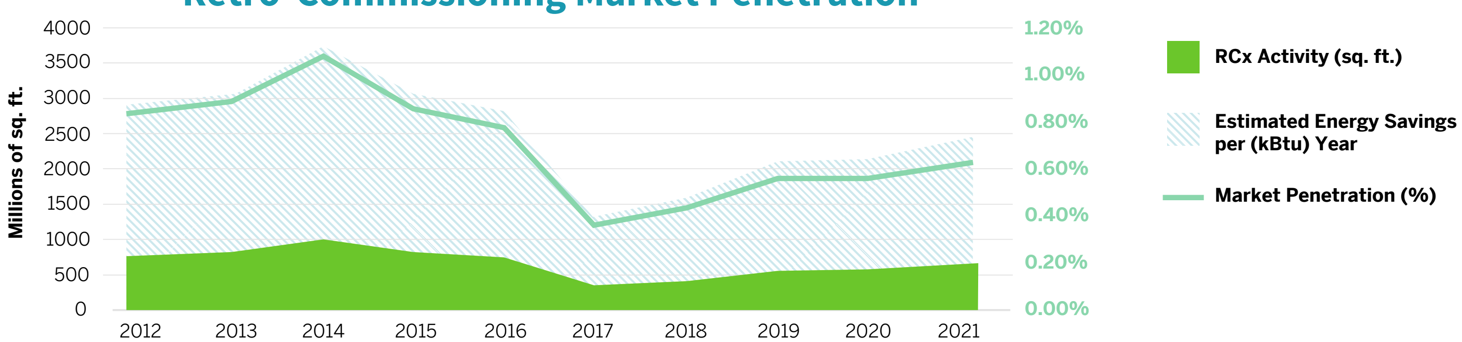
While in the most recent year data was available (2021) Cx activity and market penetration dipped, between 2012 and 2020 Cx activity increased by 269% and market penetration increased by 25%.

After a significant drop in 2017, RCx activity and market penetration are recovering and are estimated to grow in the coming years. However, market penetration of RCx is 70 times lower than Cx, so there is significant room for growth of RCx to contribute to decarbonization targets.

Commissioning Market Penetration



Retro-Commissioning Market Penetration



i. Annual market penetration is the floor area covered by the Cx activity in a year divided by the total floor area.

Building Ownership and Occupancy

Owner-occupied buildings make up 55% of the commercial building stock.[6] Decarbonization of privately-owned existing buildings can be influenced by public policies, voluntary corporate commitments, sustainable financing alternatives and government tax incentives, among other strategies.

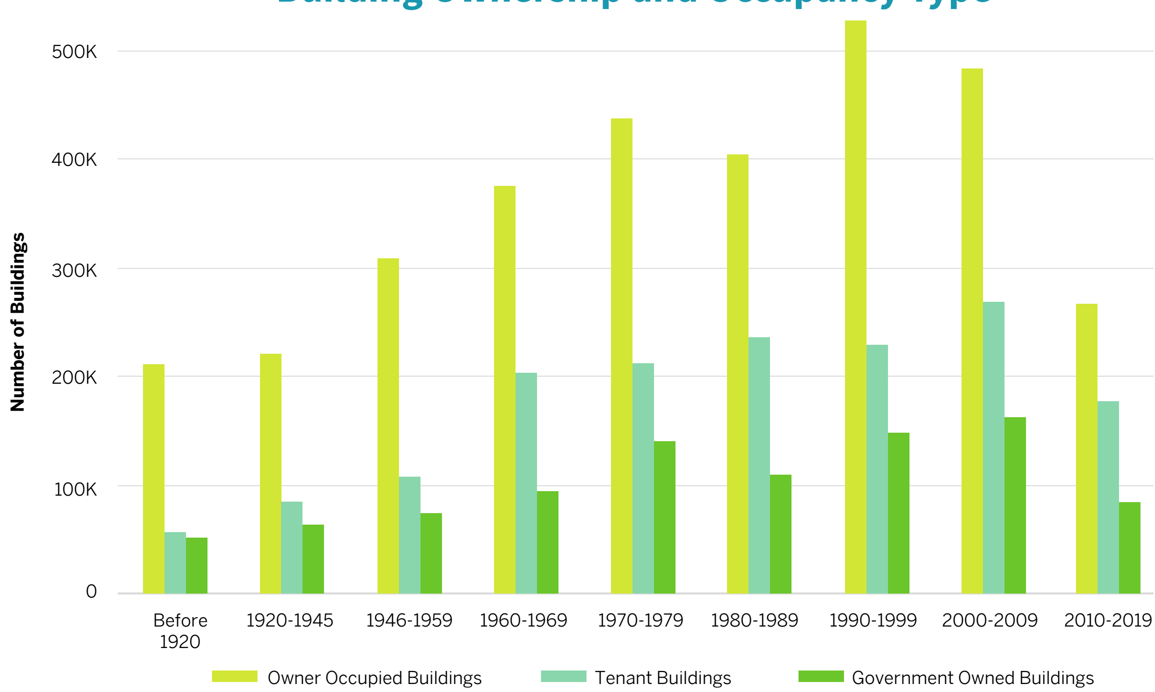
59% of commercial buildings built before 1980 are owner occupied. This group of buildings presents the largest opportunity for impactful decarbonization strategies, because of the potential for efficiency retrofits and because owner-occupied buildings can be influenced by the largest range of strategy types, from policy to market forces. Over one quarter of all commercial buildings are tenant-occupied, which create more challenges for decarbonization.

Buildings across all levels of government jurisdictions comprise 16% of the commercial building stock.[7] The government is the single largest building owner in the United States. This fact makes government buildings prime targets for decarbonization through policy action. The federal government has undertaken efforts to advance energy efficiency in buildings for over 25 years, through laws, executive orders, and other policies. In recent years, the government has committed to a 50% reduction in emissions from its building portfolio by 2032 and net zero emissions by 2045.[8]

Tenant-occupied buildings represent 27% of commercial buildings. These buildings pose a challenge to decarbonization, because both landlords and tenants are traditionally discouraged from investing in building energy efficiency measures through lease structures. Green Leases are a valuable mechanism to decarbonize tenant-occupied commercial building space. While traditional leases suffer from principle-agent contractual structures, green leasing takes a step to mitigate this challenge by realigning the financial incentives of sustainability or energy measures in lease documents.

Given disparities in energy burden, which can reach 36% in Black and Native American households,[9] policies that require decarbonization measures have the potential to decrease energy costs. However, many low-income owners and tenants do not have access to capital to cover upfront costs that are either incurred directly or passed along through rent increases. Therefore, subsidies or protections may be needed for small businesses and services in low-income communities.

Building Ownership and Occupancy Type



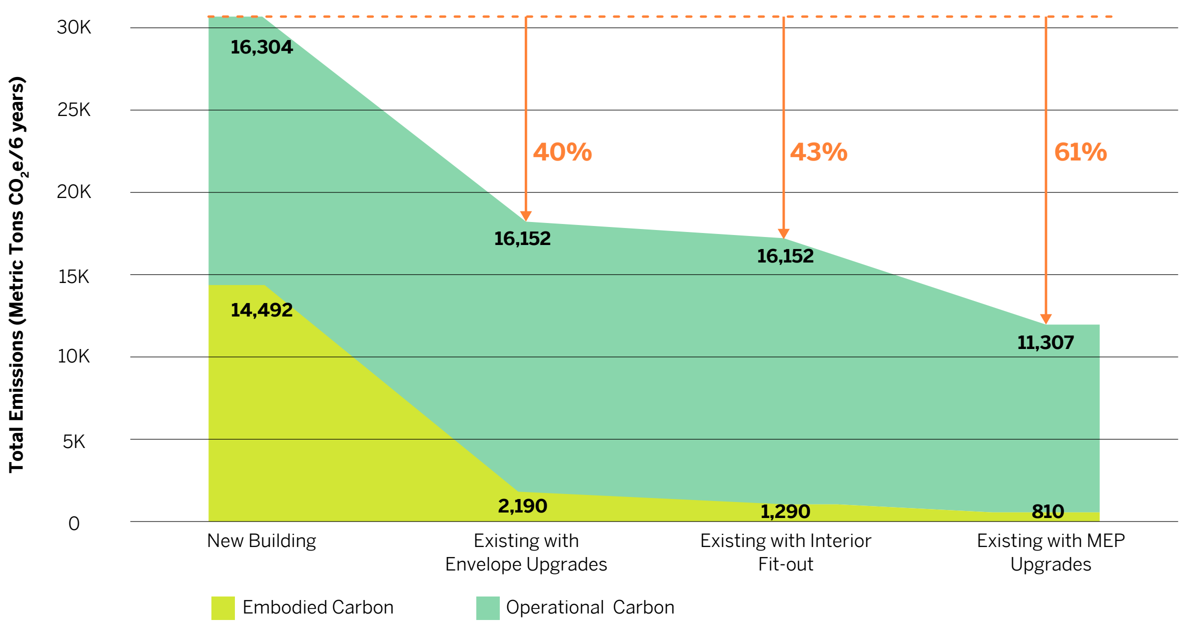
Whole Life Carbon Savings

A whole life carbon savings lens provides additional argument for retrofit, especially when considering the time value of carbon. Retrofitting existing buildings with envelope, interior, and MEP upgrades can be up to 60% less carbon intensive than building a new high performance building.

This chart shows the reduction in whole life carbon by 2030 if upgrades are made to an existing distribution center (warehouse typology) in 2023. Renovation and reuse scenarios are shown in comparison to the baseline of new construction.

Upgrading an MEP system, rather than building new, will save both 94% embodied emissions and 31% operational emissions due to increased system efficiency for a total of 61% reduction in emissions. It is important to consider the balance between operational improvements, types of refrigerants, and risk of refrigerant leakage, which has significant associated global warming potential. As buildings electrify, additional focus is needed on the impact of refrigerants on whole life carbon emissions.

Distribution Center Renovation Emissions Reduction Scenario



Embodied carbon emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings throughout their whole life cycle.

Operational carbon emissions are generated from the energy used to heat, cool, ventilate, and power the building.

Whole life carbon emissions (WLC) encompasses both embodied and operational emissions of a building or project across its entire life cycle.

Achievable reductions in embodied carbon below the footprint of standard building materials are shown below. These percent reductions apply to materials going into a new construction building.

Concrete - up to 33% reduction with no to low-cost premium

Insulation - up to 16% reduction with no to low-cost premium

Rebar - up to 10% reduction with no to low-cost premium

Finishes - up to 5% reduction with no to low-cost premium

05 Conclusion

5.1 CONCLUSION

This report provides a snapshot of the state of decarbonization in the U.S. commercial building sector. It explores the historical context of decarbonization in the United States, current trends and commitments to decarbonization, levers of transformation currently in progress, and mechanisms for transformation of the sector.

While progress has been made over the past 30 years, with a 37% reduction in commercial building carbon intensity per square foot since 1990, there is still significant work to be done. Decarbonization strategies that have proven effective in more urbanized states, such as grid decarbonization, adoption of more aggressive energy codes, and benchmarking mandates, still have significant room for growth across the remainder of the U.S. The IRA is an unprecedented investment in decarbonization. While it does not go far enough for the country as a whole to achieve the Paris Agreement target of 52% reduction in GHG emissions below 2005 levels by 2035, it could enable the commercial building sector to achieve its proportional share of the target by 2029. However, broad adoption and participation in IRA programs remains an essential variable, so urgent action is still needed to drive the commercial building sector's emissions down sharply enough to achieve Paris targets.

Potential Future Trajectories for Decarbonization

A 62% reduction in U.S. commercial building industry emissions compared to the 2005 baseline can be achieved through a combination of factors: grid decarbonization by 2030, growth of heat pump installations modeled to the trajectory of solar in the past decade, a 1% annual expansion of the retro-commissioning market, and net zero carbon government buildings by 2045.

Five different emissions reduction scenarios were modeled on top of the baseline scenario defined by the NREL Cambium Tool, which adjusts for the decarbonizing grid. The graph on the following page illustrates the potential impacts of heat pump growth, retro-commissioning market expansion, and the achievement of net zero carbon federal buildings by 2045 as per the Federal Sustainability Plan.[1] Further reductions that could be realized with the inclusion of all state and local government buildings in this net zero carbon goal are included as well.

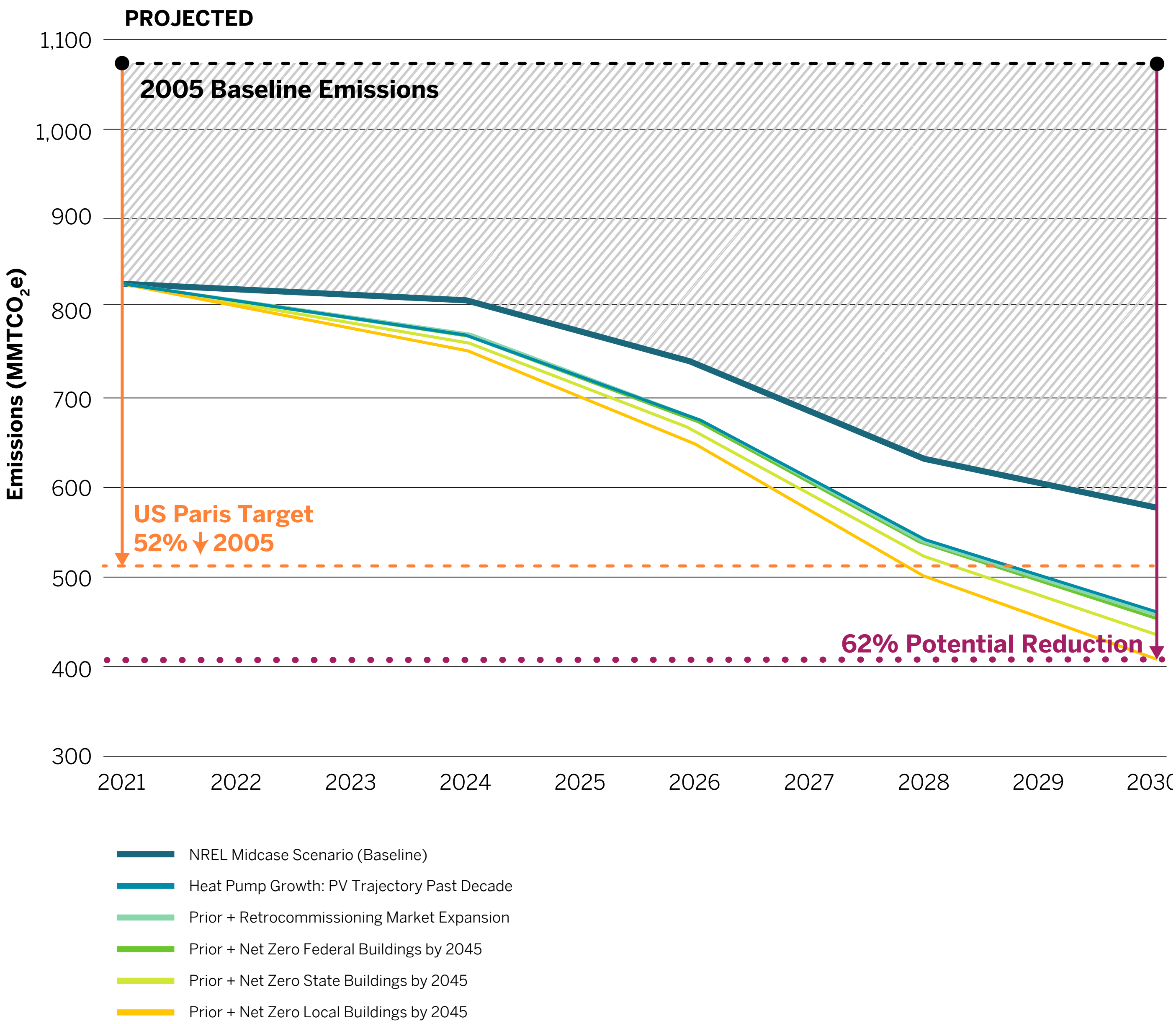
Grid decarbonization alone is projected to achieve 46% emissions reductions by 2030 compared to a 2005 baseline. Adding impacts from heat pump growth modeled after the growth trajectory of solar PV, retro-commissioning market expansion, and the achievement of net zero carbon across all federal buildings by 2045 results in 58% cumulative emissions reductions.

Adding the hypothetical emissions reduction impacts of achieving net zero carbon in state and local government buildings by 2045 achieves an additional 4% emissions savings, for a total of 62% savings.

The greatest emissions savings lie in the rapid adoption of commercial heat pumps until all commercial buildings use the technology and the decarbonization of state and local government buildings by 2045. While there are no anticipated regulations that would mandate decarbonization of government buildings beyond federal buildings, there is a large potential for impact, as about 17% of total commercial sector emissions are attributed to government buildings across all levels.

The U.S. has committed to a 52% reduction in carbon emissions relative to 2005 levels under the Paris Agreement, to limit global warming to 1.5°C. As prior analysis in this report showed, the country as a whole is not on track to achieve this reduction. Additional decarbonization levers in the commercial building sector, as explored here, could meet and possibly exceed this critical reduction goal.

U.S. Commercial Scope 1 & 2 Emissions Projections



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Methodology

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Glossary

ASHRAE 90.1 - 2019	The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 is a benchmark for commercial building energy codes in the United States, providing the minimum requirements for energy efficient design of most sites and buildings, except low-rise residential buildings (ASHRAE).
Battery Storage	Battery storage, or battery energy storage systems, are devices that enable energy from renewables, like solar and wind, to be stored and released when the power demand is highest. Currently lithium-ion batteries are the dominant storage technology for large scale plants to help electric grids ensure a reliable supply of renewable energy (National Grid). Battery storage, thermal energy storage and mechanical energy storage are ways we can continue to build out renewable energy infrastructure (World Economic Forum).
Building Decarbonization	The process by which countries, individuals or other entities aim to achieve zero fossil carbon emissions in buildings, typically referring to a reduction of the emissions associated with electricity, industry and transport. For buildings, decarbonization typically relates to electrification of buildings (IPCC).
Building Performance Standards (BPS)	Adopting a BPS enables states to set an energy use intensity cap for a specific category of existing buildings, and they can progressively tighten the limit to achieve more ambitious goals. Buildings that exceed the set limit may face fines.
Building Retrofit	Retrofitting is the process of modifying existing commercial buildings and structure to keep pace with modern equipment and technology. Energy-efficiency retrofits can decrease energy demand and reduce the operational costs, particularly in older buildings (Office of Energy Efficiency & Renewable Energy).
C40 Cities Clean Construction Declaration	The C40 Clean Construction Declaration is a pledge created by cities to promote collaboration with the construction industry, with the goal of cutting emissions in half by 2030. Through this initiative, city mayors have pledged to work to shift the construction industry towards a more sustainable future (C40 Cities).
Carbon Neutral	Carbon neutrality refers to a net zero carbon emission release. This means that any emissions would be accompanied by other actions that confidently reduce or offset emissions (Yale).
Commercial Building	The term commercial building means any building other than a residential building, including any building developed for industrial or public purposes (Cornell Law). For this study commercial buildings include Stores and Restaurants, Warehouses, Office and Bank Buildings, Manufacturing and Processing, Laboratories, Schools and Colleges, Libraries and Museums, Hospitals and Other Health Treatment, Capitols/Court Houses/City Hall, Other Government Service Building, Houses of Worship, Other Religious Buildings, Amusement/Social and Recreation, Miscellaneous Nonresidential Buildings, Hotels and Motels, and Dorms. Multifamily housing and Parking structures were not included in this study.
Commissioning	Commissioning is the process of verifying and documenting that a building and all of its systems are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements (USGBC).
Critical Peak Pricing (CPP)	A rate and/or price structure that is designed to encourage reduced consumption during periods of high wholesale market prices or system contingencies, by imposing a pre-specified high rate or price for a limited number of days or hours. Very high "critical peak" prices are assessed for certain hours on event days (often limited to 10-15 per year). Prices can be 3-10 times as much during these few hours (Form EIA-861 Instructions).
Critical Peak Rebate (CPR)	A rate and/or price structure that is designed to encourage reduced consumption during periods of high wholesale market prices or system contingencies, by providing a rebate to the customer on a limited number of days and for a limited number of hours, at the request of the energy provider. The energy provider can call event days (often limited to 10-15 per year) and provide a rebate typically several times the average price for certain hours in the day. The rebate is based on the actual customer usage compared to its baseline to determine the amount of the demand reduction each hour (Form EIA-861 Instructions).

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Demand Response	A change in electricity use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized (USGBC).
Direct Emissions	Emissions from sources that are owned or controlled by the reporting company (GHG Protocol).
Electricity Generation	Electricity generation occurs when a device converts a form of energy into electricity. This typically occurs on power plants that often use fossil fuels or non-renewable energy sources, such as natural gas, coal, and sometimes petroleum. About a fifth of U.S. electricity is generated using nuclear energy, and almost a quarter of U.S. electricity was generated from renewable energy sources such as solar panels and wind turbines in 2022 (US EIA).
Electrification	Electrification refers to the process of replacing technologies that use fossil fuels (coal, oil, and natural gas) with technologies that use electricity as a source of energy (Resources for the Future).
Embodied Carbon	Embodied carbon refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials (Carbon Leadership Forum).
Energy Efficiency	Energy efficiency is the use of less energy to perform the same task or produce the same result as prior to implemented measures. Energy efficient homes and buildings use less energy to heat, cool, and run appliances and electronics (Department of Energy).
Energy Grid	A complex network of asset owners, manufacturers, service providers, and government officials at the federal, state, and local levels including power plants, transmission lines designed to transport energy over long distances, and distribution systems that carry electricity to the individual customer (Department of Energy).
ENERGY STAR	ENERGY STAR is the government-backed symbol for energy efficiency, administered by the Environmental Protection Agency (EPA) that awards certification for successful energy efficient products (ENERGY STAR).
Environmental, Social, Governance (EGS)	ESG is a means by which companies can be evaluated with respect to a broad range of social and environmental criteria. ESG describes a set of factors used to measure the non-financial impacts of particular investments and companies (Harvard Law).
Energy Use Intensity (EUI)	EUI is a metric that expresses a building's energy use as a function of its size or other characteristics, usually expressed as energy per square foot per year (ENERGY STAR).
Electric Vehicle (EV) Infrastructure	Electric vehicles (EVs) have a battery instead of a gasoline tank, and an electric motor instead of an internal combustion engine. Creating EV infrastructure is the process of integrating EV charging stations into land use and transportation plans (EPA, Department of Transportation).
Flexible Loads	Loads or energy usage that can be adjusted to match the supply of electricity. This can be applied to water heaters, air conditioning, electric vehicles, and photovoltaics to use less energy when the grid is under stress and more energy when electricity is cheaper and clean (California Energy Commission).
Greenhouse Gas Emissions (GHG)	Gases that trap heat in the atmosphere, such as carbon dioxide, methane, nitrous oxide, and fluorinated gases (EPA).

Glossary

Green Leases	A green lease is one which includes commitments from both parties (landlord and tenant) to collaborate on environmental issues. These environmental clauses are enforceable under the lease and can cover a range of topics from energy usage and water efficiency to waste reduction (Lambert Smith Hampton).
Grid-Interactive Energy Efficient Buildings (GEBs)	Buildings that respond to the energy grid by increasing or decreasing energy use depending on the cost or carbon intensity of the generation source. This helps decarbonize the electricity system and optimize renewable energy sources (RMI).
Grid Harmonization	Strategies that synchronize customer owned distributed energy resources (DER) with the grid to maximize the use of renewable energy and limit grid exports during times of high cost. For example, photovoltaics store energy in batteries when electrical building loads are low and inexpensive (usually midday) and then release energy when the demand and cost of electricity is high (usually afternoon and evening) (Energy Code ACE).
Grid Optimization	Grid optimization consists of managing distributed energy assets to minimize energy consumption of a building (US Energy Solutions).
Heat Pumps (HP)	Heat pumps use electricity to transfer heat from a cool space to a warm space. Because they transfer heat rather than generate heat, heat pumps can efficiently provide comfortable temperatures for homes. Geothermal heat pumps, sometimes referred to as ground-source, or water-source heat pumps use the relatively constant temperature of the earth as the exchange medium, whereas Air-Source heat pumps use the outside air temperature (Department of Energy).
Indirect Emissions	Indirect emissions are those that result from an organization's activities, emitted from sources owned by other entities (EPA).
Inflation Reduction Act (IRA)	The Inflation Reduction Act is a legislative package passed by Congress aimed at fighting inflation, investing in domestic energy production and manufacturing, reducing carbon emissions, and lowering prescription drug and health care costs (White House, Senate Democrats).
LED Fixtures	Light-emitting diode (LED) is a highly energy efficient lighting technology, using at least 75% less energy, and last up to 25 times longer, than incandescent lighting (Energy.gov).
LEED	LEED (Leadership in Energy and Environmental Design) is the most widely used green building rating system in the world. Available for virtually all building types, LEED provides a framework for healthy, efficient, and cost-saving green buildings (USGBC).
Major Renovation	Major renovation refers to any renovation that has a cost equal to or exceeding $250,000 (Cornell Law).
Mandatory Benchmarking	ESG benchmarks provide a way to systematically evaluate the performance of certifications, voluntary standards, companies, or other entities (Measurabl, SEC).
National Climate Task Force (NCTF)	The National Climate Task Force is a group of Cabinet-level leaders from more than 25 federal agencies and senior White House officials created with the goal of tackling climate change, create good-paying, union jobs, and achieve environmental justice (White House).
Net Zero Carbon	Net zero carbon is achieved when anthropogenic CO2 emissions are balanced globally by anthropogenic CO2 removals over a specified period. Net zero CO2 emissions are also referred to as carbon neutrality (IPCC).

Glossary

Net Zero Energy	Net Zero Energy means consuming only as much energy as produced (EPA). A net zero energy building is one that consumes a net of zero energy by balancing the total amount of energy used by the building annually with renewable energy produced on site. For the purpose of this report, net zero buildings in the U.S. were defined by the New Buildings Institute's Getting to Zero Buildings Database (New Buildings Institute).
Operational Carbon	The greenhouse gas emissions associated with building energy consumption, such as HVAC systems, lighting, plug loads, hot water, etc. (CLF).
Paris Agreement	The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, with an overarching goal to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" (UNCC).
Passive Design	Passive building is a design methodology defined by a set of principles that prioritize energy conservation and best practices. Passive building is associated with lower energy use, specifically lower space-conditioning loads. However, the methodology produces other benefits: comfort, improved indoor air quality, durability, and resilience. Passive building principles can be applied to all building typologies-"from single-family homes to multifamily apartment buildings, offices, and skyscrapers " (ASHRAE).
Peak Demand	Peak demand is the largest instance of power usage in a given time frame. (Setra, NREL)
Photovoltaic (PV) / Solar Energy	Photovoltaic (PV) technologies, or solar panels, generate power using devices that absorb energy from sunlight and convert it into electrical energy through semiconducting materials (Department of Energy).
Retro-commissioning (Rx)	Retro-commissioning means a process - (i) of commissioning a facility or system beyond the project development and warranty phases of the facility or system; and (ii) the primary goal of which is to ensure optimum performance of a facility, in accordance with design or current operating needs, over the useful life of the facility, while meeting building occupancy requirements (Federal Energy Management Program).
Smart Buildings	A smart building uses advanced and integrated technology systems to optimize building and operational automation, intelligent space management, user experience, productivity, energy efficiency, and security (Deloitte).
Solar Investment Tax Credit (ITC)	The solar investment tax credit is for individuals installing solar systems on residential property (under Section 25D of the tax code). The Section 48 commercial credit can be applied to both customer-sited commercial solar systems and large-scale utility solar farms (SEIA).
Whole Life Carbon	Whole life carbon emissions (WLC) are the entire amount of carbon produced by any particular built asset, from a house to an office block to an airport (Arup).

Methodology

Note from the Authors

Future iterations of this report would benefit from an expected increase in available data. Between increased building benchmarking and performance policies, it is anticipated that the availability of data on commercial building performance in the U.S. will increase in the next few years.

Additional data and analysis is needed in particular to address disparities in energy burden, and distribution of the benefits of decarbonization to address economic and racial inequities.

The methodology section that follows indicates the specific data sources used for each graphic included in this report. How discreet data was combined to produce each graphic is also noted.

Absent a national dataset that includes energy use, typology, area, and GHG emissions for every commercial building in the U.S., this report relied on a combination of a few national resources to illustrate the state of decarbonization in the commercial building sector. The main datasets used were: Lawrence Berkeley Lab's (LBL) Building Performance Database (BPD), ENERGY STAR Portfolio Manager, 2018 Commercial Buildings Energy Consumption Survey (CBECS) data, and Dodge Construction Network.

The Building Performance Database was used for present day building performance data, while ENERGY STAR was used for historical performance data. Because the Building Performance Database is not nationally representative, although it is the most detailed dataset, it was used in conjunction with CBECS 2018 data to scale performance nationally where required. Dodge Construction Network data was used for forecasting commercial square footage and construction spend data. Many additional data sources were used for each graph, as noted in the following pages.

The anticipated increase in building performance data will make national trend conclusions more accurate. This type of data is sorely needed by the industry to truly understand how buildings perform across the country, how far we have come, and how far we still have to go to achieve our decarbonization goals.

Methodology

1.1 Introduction

Greenhouse Gas Emissions in the U.S.

Sources:

1. Inventory of U.S. Greenhouse gas emissions and sinks: 1990-2021 [Reports and Assessments]. (Feb. 2023). U.S. EPA. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021
2. Global CO2 emissions by sector, 2019. (Aug. 2021). International Energy Agency. https://www.iea.org/data-and-statistics/charts/global-co2-emissions-by-sector-2019
3. Global Energy Review: CO2 Emissions in 2021. (March 2022). International Energy Agency. https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2
4. U.S. Population 1950-2023. (2023). Macrotrends. https://www.macrotrends.net/countries/USA/united-states/population
5. 1989 CBECS Survey Data: Commercial Buildings Characteristics. (June 1991). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/archive/cbecs/archive/arch_hist_pubs/cbecs_pdf/DOE%20EIA-0246(89).pdf
6. 1992 CBECS Survey Data: Table A1. Summary table of square feet, hours of operation, age of building, 1992. (n.d.). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/1992/pdf/24692ii.pdf
7. 2018 CBECS Survey Data: Table B20. Energy sources, floorspace, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
8. Dodge Construction Network. (2023). Historical Construction Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
9. 1989 CBECS Survey Data: Commercial Buildings Energy Consumption and Expenditures. (Apr. 1992). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/archive/cbecs/archive/arch_hist_pubs/cbecs_pdf/DOE%20EIA-0318(89).pdf
10. 1992 CBECS Survey Data: Table 3.2. Total energy consumption by major fuel, 1992. (n.d.). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/1992/pdf/cbcetb02.pdf
11. 2018 CBECS Survey Data: Table C1. Total energy consumption by major fuel. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/

Methodology

GHG Emissions by Sector (2019)

1. Use EPA (2023) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 "Executive Summary" Table ES-6: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed by Economic Sector. Use emission totals in the year 2019 and include both United States data absorbing energy emissions into the economic sectors, and break out energy emissions as its own sector.
2. Compare the above to the 2021 global GHG emissions by adding the CO2 emissions by sector in 2019 from IEA to the net 2019-2021 change in emissions published by the EIA.
3. Note: Global GHG emissions are represented in CO2, rather than CO2-equivalent. CO2-equivalent emissions data is not publicly available for 2021, but the representative share per sector is expected to be consistent.

U.S. GHG Emissions (from 1990-2021)

1. Use EPA (2023) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 "Executive Summary" Table ES-6: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed by Economic Sector. Use all economic sector emissions per year to create a line graph of emissions by sector.
2. Overlay population data from source below to determine Total Emissions per Capita by dividing total emissions by U.S. population per year. Similarly, calculate the total commercial emissions per capital by dividing the total commercial emissions by the U.S. population per year and find the rate of change from 1990 to 2021.

Commercial Building GSF and EUI (from 1990-2021)

1. Use CBECS 1989 and 1992 data to identify the commercial building area of those years and interpolate in between to calculate an estimated area for 1990.
2. Calculate the total commercial floor area in 2021 by adding the Dodge new construction square footage for 2019, 2020, and 2021 to the 2018 CBECS baseline.
3. Use CBECS 1989 and 1992 consumption data to divide the total energy usage for each year by the total commercial square footage. Similar to the GSF, interpolate in between to estimate an EUI for 1990.
4. Estimate the average EUI of commercial buildings in 2018 using 2018 CBECS data. As 2019-2021 commercial energy usage is unknown, apply the growth rate of commercial building square footage from 2018 to 2019, 2019 to 2020, and 2020 to 2021 to the 2018 EUI to create an estimation for the average EUI in 2021.

Methodology

1.1 Introduction

State of Current Codes Across the U.S.

Sources:

1. Building Energy Codes Program. (2022, March 29). Estimated Improvement in Commercial Energy Code (1975-2021). Tableau.com. https://public.tableau.com/app/profile/doebecp/viz/HistoricalModelEnergyCodeImprovement/CombinedHistoricalCodeImprovement_1
2. Building Energy Codes Program. (2021, April 7). Status of State Energy Code Adoption: Commercial Buildings. Tableau.com. https://public.tableau.com/app/profile/doebecp/viz/BECPStatusofStateEnergyCodeAdoption/ResidentialDashboard
3. Dodge Construction Network. (2023). Forecast Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338

Methodology:

1. Improvements between ASHRAE 90.1 versions are based on work conducted by the Pacific Northwest National Laboratory (PNNL) for the Department of Energy Building Energy Codes Program
2. Current statewide minimum energy codes are pulled from the BECP Status of State Energy Code Adoption report by Building Energy Codes Program, last updated October 2023.
3. Projections for new commercial GSF by state was obtained from Dodge´s Forecast Dashboard between the years 2023 – 2027.

State of the U.S. Electric Grid

Sources:

1. U.S. EPA, O. (2020, July 27). Emissions & Generation Resource Integrated Database (eGRID). U.S. EPA. https://www.epa.gov/egrid

Methodology:

1. Total generation and CO_2e intensities by eGRID region were pulled from the EPA´s Emissions & Generation Resource Integrated Database.

2.1 U.S., State, and Corporate Commitments to Decarbonization

U.S. Commitments to Decarbonization

Sources:

1. Electricity Sector Emissions Impacts of the Inflation Reduction Act: Assessment of projected CO2 emission reductions from changes in electricity generation and use. (2023). U.S. Environmental Protection Agency. https://www.epa.gov/inflation-reduction-act/electric-sector-emissions-impacts-inflation-reduction-act

Methodology:

1. Data from the EPA's report on the impact of the Inflation Reduction report was referenced in the creation of the graphic.
2. Data on Economy-wide CO2 emissions from fossil fuel combustion and industrial processes was referenced to understand the U.S.'s emissions since 2005. These datapoints are plotted over their respective year.
3. Projections of economy-wide CO2 emissions were also referenced. The EPA used several models to predict future emissions, split into two categories The data was separated into the scenarios of IRA impact and a hypothetical no-IRA scenario.
4. Multiple models fell under each category. The average was taken of their outputs and plotted over each year.

Methodology

2.1 U.S., State, and Corporate Commitments to Decarbonization

State Decarbonization Leadership

Sources:

1. The State Energy Efficiency Scorecard. (2022). American Council for an Energy-Efficiency Economy. https://www.aceee.org/state-policy/scorecard
2. Massachusetts Clean Energy and Climate Plan for 2025 and 2030. (June 2022). Executive Office of Energy and Environmental Affairs. https://www.mass.gov/doc/clean-energy-and-climate-plan-for-2025-and-2030/download
3. New York's Carbon Neutral Buildings Roadmap. (Dec. 2022). New York State Energy Research and Development Authority https://www.nyserda.ny.gov/all-programs/carbon-neutral-buildings
4. California plans to reduce greenhouse gas emissions 40% by 2030. (2018). U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=34792#:~:text=The%20initial%20target%20was%20to,largest%20percentage%20decline%20among%20sectors.
5. Massachusetts Clean Energy and Climate Plan for 2050. (2023). Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs. https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2050#:~:text=Also%20on%20December%2021%2C%202022,greenhouse%20gas%20emissions%20in%202050.
6. Current California GHG Emission Inventory Data. (2022). California Air Resources Board. https://ww2.arb.ca.gov/ghg-inventory-data
7. 2022 Statewide GHG Emissions Report. (2022). New York State Department of Environmental Conservation. https://www.dec.ny.gov/docs/administration_pdf/ghgsumrpt22.pdf
8. Greenhouse Gas Emissions: 1990-2014. (Jan. 2017). Minnesota Pollution Control Agency. https://www.leg.mn.gov/docs/2017/mandated/170156.pdf
9. Minnesota's GHG emissions 2005-2020 and goals from the Next Generation Energy Act and Climate Action Framework. (Jan. 2023). Tableau. https://public.tableau.com/app/profile/mpca.data.services/viz/GHGemissioninventory/GHGsummarystory
10. Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2020, with Partial 2021 & 2022 Data. (2023). Massachusetts Department of Environmental Protection. https://www.mass.gov/lists/massdep-emissions-inventories
11. 2018 CBECS Survey Data: Table B5. Census region and division, floorspace, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
12. Dodge Construction Network. (2023). Historical Construction Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
13. Dodge Construction Network. (2023). Forecast Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
14. Population Density of the 50 States, the District of Columbia, and Puerto Rico: 1910 to 2020. (2020). U.S. Census Bureau. https://www2.census.gov/programs-surveys/decennial/2020/data/apportionment/population-density-data-table.pdf

Methodology:

1. Search the ACEEE 2022 State Energy Efficiency Scorecard for states with the most ambitious decarbonization goals, as well as jurisdictions with marked improvements that demonstrate progress towards meeting these goals.
2. Identify decarbonization plans or studies for these states to understand the steps being taken to evaluate the feasibility of achieving targeted emission reduction goals.
3. Find the total building sector emissions per studied state by finding the total state-wide emissions per year of interest and applying the percentage of commercial building emissions out of total state-wide emissions. State-specific percentages were used where available, but Minnesota did not publish sector-specific percentages of state-wide emissions and thus, the national average was used instead from Greenhouse Gas Emissions in the U.S.
4. Enter emissions data where it has been publicly inventoried by state governments for years from 1990-2022. Interpolate commercial building emissions per state where data is not available by using the government-inventoried values that are known.
5. Retrieve the total commercial building floor area in 2018 from CBECS and the commercial building floor area projections from Dodge for 2023-2027 by state.
6. The 2018 CBECS total floor area is by census region, rather than by state. Find the state-specific 2018 square footage by identifying the census region in which each state lies and scale the total commercial building floor area of that census region to the state level by using proportions of population density of the entire census region and by state.
7. Find the total 2013-2017 and 2019-2027 commercial building floor area by state of interest by subtracting (for pre-2018 years) the new commercial square footage added in the following year based on Dodge data from the total square footage calculated for that following year, or adding (for post-2018 years) the new square footage of that year based on Dodge data to the total square footage calculated in the previous year.
   - Note: The commercial building typologies in Dodge to identify new annual square footage additions are consistent with those used in Energy Code Progress Across the U.S. Calculate the emissions intensity of commercial buildings per state of interest for years where total commercial building square footage is known from Dodge (2014-2027). The emissions intensities are only calculated for years where building square footage is known because the square footages preceding 2013 and post-2027 are not able to be accurately extrapolated with confidence.
   - Note: Although Dodge's new construction data only dates to 2014, square footage in 2013 was able to be calculated by subtracting the newly added commercial building square footage in 2014 (Dodge) from the total commercial building square footage calculated for 2014.
8. The known and projected emissions were plotted on a line graph as the primary y-axis, with the emissions intensity as the secondary y-axis. Years for which data is known is manually denoted on the graph with black circles and is shown more explicitly in the supporting calculations spreadsheet. Baseline years based on state emission reduction targets and reduction goals are denoted in the graph as well.

Methodology

2.1 U.S., State, and Corporate Commitments to Decarbonization

Embodied Carbon of Construction

***Data and analysis provided by Carbon Leadership Forum**

Sources:

1. Construction Spending. (2023).U.S. Census Bureau. https://www.census.gov/construction/c30/historical_data.html
2. US Environmentally-Extended Input-Output model v1.1. (2020). EPA. https://catalog.data.gov/dataset/useeio-v1-1-matrices

Methodology:

1. Retrieved construction spending data fromU.S. Census Bureau and Impact factors from USEPA EEIO model with updated factors found here.
2. Formatted, transposed and organized data for analysis.
3. Manually matched the USEEIO categories to theU.S. census public and private construction spending categories.
4. Aligned Census categories with commercial property types from CBECS. Retail category also includes warehouses, service and food service.
5. Calculate percentage of impact for commercial, industrial, transport and residential; and public vs private breakdown of total US$.

Corporate Decarbonization Targets

Source:

1. If Not Now, When? How are companies stepping up with the urgency required to deliver climate impact. (2022). Climate Impact Partners.https://www.climateimpact.com/news-insights/fortune-global-500-climate-commitments/

Methodology:

1. Climate Impact Partners' report was referenced to assess how many companies have to-date adopted pledges to decarbonize their operations.
2. Climate Impact Partners' report contains information for the Global 500, which represents the 500 highest revenue companies in the world.
3. Data was collected from the report on what percentage of the Global 500 had adopted what kind of pledge by what year, with these percentages plotted over the year as a stacked column chart.
4. The percentage of companies with targets in 2022 exceeds 100%. This is the result of multiple targets being set by one company (e.g. carbon neutral now, then net zero by 2050).

Methodology

2.1 U.S., State, and Corporate Commitments to Decarbonization

REITs and Decarbonization Targets

***Data and analysis provided by U.S. Green Building Council**

Sources:

1. ESG Ratings & Climate Search Tool. Retrieved November 29, 2023, from https://www.msci.com/our-solutions/esg-investing/esg-ratings-climate-search-tool
2. REIT Directory. Retrieved November 29, 2023, from https://www.reit.com/investing/investor-resources/reit-directory
3. REIT ESG Dashboard. Retrieved November 29, 2023, from https://www.reit.com/investing/reits-sustainability/reit-esg-dashboard

Methodology:

1. Compile the largest 100 REITs in the U.S. by market cap for 2021, referencing Nareit's Top 100 REITs list.
2. Search each individual REIT through Nareit's directory.
3. Record each REIT's type, description of assets, ticker, weblink and corresponding ESG report.
4. Referencing REIT type, exclude all REITs that are not predominantly commercial.
5. With the remaining 78 predominantly commercial REITs, review publicly available information such as ESG reports, company website, or 10-k filings.
6. Reference publicly available data for each REIT, note the following attributes of the REIT: number of assets, asset type, floor area of each asset type, and geographic location of the asset.
7. Compile REIT information and exclude REIT assets which are not commercial buildings or that are outside of the United States.
8. Note each REIT's climate and energy goals as stated in its ESG reports or website. Goals are defined as based on metrics tracking shifts in the following areas: GHG emissions, net zero operations, energy consumption or energy-use-intensity (EUI). If a company has a GHG emissions target, note whether it is associated with the Science-based Targets Initiative (SBTi) Exclude renewable energy generation or PV installation goals.
9. Note whether the REIT has an MSCI scope and an MSC temperature rise rating. MSCI information was obtained from either the company ESG, or the MSCI online searchable ratings
10. Use the collected data to determine the number, percentage, market cap, asset count and floor area for each REIT with climate and energy goals, SBTi aligned goals or other approved targets.

Methodology

2.1 U.S., State, and Corporate Commitments to Decarbonization

Decarbonized and Net Zero Energy Buildings in the U.S.

Sources:

1. Building Performance Database. (n.d.). https://bpd.lbl.gov/explore
2. U.S. Energy Use Intensity by Property Type. (2021). Energy Star Portfolio Manager. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf
3. How to Use the Zero Tool. (n.d.). Zero Tool. https://zerotool.org/user-guide/#toggle-id-3
4. 2020 Getting to Zero Buildings List: Growth and trends for zero energy and zero carbon buildings. (2020). New Buildings Institute. https://newbuildings.org/wp-content/uploads/2020/09/NBI_GTZ-_List_2020.pdf
5. Commercial Buildings and On-site Renewable Energy. (2020). Energy Star Portfolio Manager. https://www.energystar.gov/buildings/about_us/datatrends_research/renewable_report

Methodology:

1. Compile data from BPD for all available cities with energy benchmarking data.
2. Filter for buildings with fuel EUI of 0 (all-electric buildings) and filter out commercial building typologies that are excluded from the scope of this study (parking garages and uncategorized/other lodging uses).
3. Filter only for building data entries of 2019 to avoid duplicates and to have the most representative pre-Covid data. (2021/2022 data was not available for all cities.)
4. List the baseline site EUI of each building by using the Energy Star / CBECS 2012 median site EUI, matching with the appropriate building typology.
5. According to the Zero tool, the 2030 Challenge energy reduction target for existing buildings is 35% by 2025 (and 50% by 2030). Criteria to determine if a building is on a path to decarbonization is if it is all-electric and if the site EUI is at least 35% below that of the determined baseline for that typology. These criteria determine a list of buildings that are assumed to be decarbonization-ready.
6. Geocode the cities/states of these buildings and add to a base map. Use a proportional circle symbology on ArcGIS to correlate cities with a greater number of decarbonization-ready buildings to larger circles on the map.
7. Overlay the cities where net zero buildings as defined by the New Buildings Institute (Zero Energy Certified and Zero Energy Verified) onto this map. Use a proportional circle symbology on ArcGIS to correlate cities with a greater number of net zero buildings to larger circles on the map.
8. Intersect the two layers of decarbonization-ready and net zero buildings.
9. Color-code the states of the USA shapefile by using the percentage of buildings with on-site renewable energy that submit benchmarking in the state.

Methodology

2.2 Commercial Typology Trends

Trajectory of Commercial Building Emissions Toward 2030 Goals

Source:

1. US EPA, O. (2023, February 1). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021, Table 2-12. Www.epa.gov. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021
2. U.S. Energy Information Administration (2023): Annual Energy Outlook 2023. https://www.eia.gov/outlooks/aeo/
3. Gagnon, Pieter; Cowiestoll, Brady; Schwarz, Marty (2023): Cambium 2022 Data. National Renewable Energy Laboratory. https://scenarioviewer.nrel.gov
4. International Code Council, INC. (2018). 2018 International Green Construction Code.
5. US EPA, O. (2020, July 27). Emissions & Generation Resource Integrated Database (eGRID). U.S. EPA. https://www.epa.gov/egrid
6. 2018 CBECS Survey Data: Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
7. U.S. Buildings Sector Decarbonization Scenarios to 2050. (Aug. 2023). Lawrence Berkeley National Laboratory. https://emp.lbl.gov/us-buildings-sector-decarbonization-scenarios-2050

Methodology:

1. Historical commercial emissions were extracted from Table 2-12 from EPA´s Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021:
2. EIA Annual Energy Outlook 2023 was referenced to extract the following between the years 2023 - 2030:
    - Commercial gross square footage (GSF) from the Commercial sector's Total Floorspace: Surviving (billion sq ft) in Table 5. Commercial Sector Key Indicators and Consumption
    - Projected electricity EUI from the Commercial sector's Purchased Electricity (quads) in Table 2. Energy Consumption by Sector and Source
    - Projected natural gas EUI from the Commercial sector's Purchased Electricity (quads) in Table 2. Energy Consumption by Sector and Source
    - Projected Petroleum and Other Liquid EUI from Purchased Electricity (quads) in Table 2. Energy Consumption by Sector and Source
3. EUIs were calculated by dividing the respective energy use types by the total commercial GSF.
4. Grid emissions factors reference NREL's Cambium 2022 tool and uses the metric 'aer_load_co2e' to calculate the emissions resulting from interregional energy use. The following three scenarios were used to calculate grid emissions:
    - Mid-case (considered the baseline scenario)
    - Low Renewable Energy and Battery Costs (considered best case scenario)
    - High Renewable Energy and Battery Costs (considered worst case scenario)
5. Due to the NREL's Cambium 2022 tool only having data available starting 2024, the EPA eGRID data was used to populate the emission intensity for 2021. The emission intensity for 2022 and 2023 were extrapolated using the data from eGRID 2021and the Cambium 2024 5.
    - It was acknowledged that Cambium's grid subregions, referred to as GEA, are not a perfect match to EPA eGRID regions, but was deemed similar enough to complete the analysis for only 2021 – 2023 calculations.
6. To determine the emissions resulting from fossil fuels (natural gas and petroleum and other liquids), ASHRAE 189.1 was used to obtain emission factors and references the total emission (lb/MWH of input) metric:
    - Natural Gas (at the building): 681 lbCO2e/MWh
    - LPG (Liquid Petroleum Gas) or Propane: 651 lbCO2e/MWh
7. To estimate the commercial GSF in each state, the total commercial GSF from CBECS 2018 was distributed amongst each U.S. state based on population.
8. To ensure the proper electricity emission factor is used, each state was assigned to a GEA region that they most aligned with.
9. To determine the emissions resulting from electricity usage, each states GSF was by multiplied by the electricity EUI to get the total energy use by state and then multiplied by the respective GEA regions' carbon intensity.
10. Once emissions per fuel source were calculated for the time 2021 – 2030, they were summed up and graphed.
    - To estimate the impact of grid decarbonization, EUI per fuel source was fixed using 2021 EUI values for the time 2021-2030. After, the appropriate emission factors from each of the three Cambium 2022 tool scenarios were multiplied to calculate GHG emissions and graphed.
    - To estimate the impacts of grid decarbonization and EUI improvements, the projected EUI from EIA were used and multiplied by the appropriate emission factors from each of the three Cambium Tool scenarios were multiplied to calculate GHG emissions and graphed.

Methodology
2.2 Commercial Typology Trends
Typology Trends - Existing Commercial Buildings by the Numbers

Sources:

1. 2018 CBECS Survey Data: Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
2. 2018 CBECS Survey Data: Table B17. Occupancy of nongovernment-owned and government-owned buildings, number of buildings, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/

Methodology:

1. Using CBECS 2018 data, estimate the total commercial building floorspace for Owner Occupied, Tenant, and Government Owned occupancy types by determining the average building floorspace per building within each floorspace range, then multiplying by the number of buildings in each floor space range for each occupancy type.
2. Using CBECS 2018 data, calculate the % of total buildings that was constructed in each provided time frame for Owner Occupied, Tenant, and Government Owned occupancy types.
3. Calculate the building floorspace per time frame period for each occupancy type by multiplying the estimated floor space calculated in Step 1 by the percentage calculated in Step 2.
4. Determine the percentage of buildings in each occupancy type per construction year by dividing the number of buildings constructed in each timeframe for each occupancy type by the total number of buildings for each respective occupancy type.

Typology Trends - Historical Typology Intensity Trends

Sources:

1. U.S. Energy Use Intensity by Property Type. (2021). Energy Star Portfolio Manager. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf
2. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for Office Properties. (2019). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_office_properties
3. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for Retail Properties. (2019). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_retail_properties
4. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for K-12 School Properties. (2019). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_k_12_school
5. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for Hotel Properties. (2021). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_hotel_properties
6. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for Warehouse Properties. (2019). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_warehouse
7. Analysis and Key Findings from EPA's Review of the ENERGY STAR Score Model for Worship Properties. (2019). Energy Star. https://www.energystar.gov/buildings/tools-and-resources/analysis_and_key_findings_epas_review_energy_star_score_model_worship_facilities l
8. Building Performance Database. (2023). https://bpd.lbl.gov/explore
9. How Many Schools are in the U.S.? (And More Interesting School Statistics). (Jan. 2023). We are Teachers. https://www.weareteachers.com/how-many-schools-are-in-the-us/
10. School Costs: Did You Know… (July 2015). Spaces4learning. https://spaces4learning.com/articles/2015/07/01/school-costs.aspx
11. Construction Cost Estimates for a Vocational School in National, US. (n.d.). https://www.rsmeans.com/model-pages/vocational-school
12. Higher education construction costs for 2023. (Apr. 2023). Building Design + Construction Network. https://www.bdcnetwork.com/higher-education-construction-costs-2023

Methodology:

1. Use Energy Star to identify typologies with published historical EUI, which are: Education, Lodging, Mercantile, Office, Religious worship, Warehouse and storage.
2. Retrieve the historical EUI data from each technical document as listed in the Sources and compare with the 2021 Energy Star EUI by property type.
3. Although the Energy Star EUI report data source remains uneven across different typologies, it was taken as the baseline for comparison because it was published in 2021 as the most updated version.
4. Use the BPD dataset to extract annual EUI data for the 6 typologies for 2012-2021.
5. Based on the 2021 Energy Star data, scale the EUI numbers in BPD so that the values match. Then, cross-check with 2012 data to ensure alignment.

Methodology
2.2 Commercial Typology Trends

Typology Trends - Historical Typology Intensity Trends (cont.)

Methodology (cont.):

6. Identify the total square footage by typology in 2018 using CBECS data. To find the square footage of that typology for pre-2018 years, subtract the new commercial square footage added in the following year based on Dodge data from the total square footage calculated for that following year. For post-2018 years, add the new square footage of that year for the given typology based on Dodge data to the total square footage calculated in the previous year.
   - As the “Education – Other” and “College, University” typologies are together considered as “Education” under CBECS, a split was calculated by calculating the total square footage of elementary, middle and junior high, senior high, K-12 combined, and other schools. The number of schools in each category type reported as of 2022 was multiplied by the median square footage characteristic of each school type. This data was not available for K-12 combined schools, so the median square footage of a senior high school was applied, and for schools in the “other” category. The total square footage of college and university buildings was reported as over 6 billion square feet nation-wide, but a 75% factor was applied as this includes dormitories and other non-educational spaces. As a result, non-university educational buildings comprise about three times more floor area than university and college educational buildings nation-wide. This breakout was used to split the total CBECS “Education” square footage into the two appropriate categories.
   - As the “Non-refrigerated Warehouse” and “Refrigerated Warehouse” typologies are together considered as “Warehouse and Storage” under CBECS, the share of refrigerated warehouse area from the total warehouse area is calculated by dividing the total volume of gross refrigerated storage capacity in the US and dividing by the typical clear height of warehouses. This area was subtracted from the total area of warehouses as reported from CBECS to determine the total area of non-refrigerated warehouses.
   - As “Mercantile/Retail” is not a typology within Dodge (Dodge represents this under “Stores and Restaurants”), the total area of non-mall retail properties in the U.S. in 2022 was identified. This 2022 value and 2018 figure from CBECS were used to interpolate between these two years. For pre-2018 years, 2012 CBECS data was used to interpolate between 2012 and 2018.
7. Overlay the total square footage per typology from 2012 to 2021 as a secondary axis.

Typology Trends - Notable EUI Differences within Typologies

Sources:

1. Dodge Construction Network. (2023). Historical Construction Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
2. Building Performance Database. (2023). https://bpd.lbl.gov/explore
3. 2018 CBECS Survey Data: Table B11. Selected principal building activity: part 1, number of buildings, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
4. U.S. Energy Use Intensity by Property Type. (2021). Energy Star Portfolio Manager. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf
5. Dodge Construction Network. (2023). Forecast Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
6. 2018 CBECS Survey Data: Table B12. Selected principal building activity: part 1, floorspace, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
7. 2018 CBECS Survey Data: Table B13. Selected principal building activity: part 2, number of buildings, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
8. 2018 CBECS Survey Data: Table B14. Selected principal building activity: part 2, floorspace, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
9. How Many Schools are in the U.S.? (And More Interesting School Statistics). (Jan. 2023). We are Teachers. https://www.weareteachers.com/how-many-schools-are-in-the-us/
10. School Costs: Did You Know… (July 2015). Spaces4learning. https://spaces4learning.com/articles/2015/07/01/school-costs.aspx
11. Construction Cost Estimates for a Vocational School in National, US. (n.d.). https://www.rsmeans.com/model-pages/vocational-school
12. Higher education construction costs for 2023. (Apr. 2023). Building Design + Construction Network. https://www.bdcnetwork.com/higher-education-construction-costs-2023

Methodology:

1. Determine typologies: Compare CBECS, Dodge, and BPD datasets to find a common breakdown for commercial building typologies. Since the CBECS typologies are aligned with Energy Star’s EUI reports, this study refers to the CBECS typologies.1,2,3
2. Modify typologies: For CBECS typology breakdown, combine food services and food sales into one category. This doesn’t count sub-categories under healthcare and mercantile. This narrows our typology down to 10: Warehouse and storage, Office, Mercantile, Public assembly, Food, Religious worship, Education, Lodging, Healthcare, and Public Service.
3. To find leading typologies, aggregate Dodge and BPD datasets to the 10 typologies mentioned in the step above. CBECS returns the three leading typologies to be Warehouse and storage, Office, and Public Service when measured in building numbers; Warehouse and storage, Office, and Education when measured in building areas. Leading typologies as reported by BPD building counts are Office, Education, and Mercantile. Using building areas from Dodge causes the leading typologies to be Warehouse and storage, Office, and Education. With these findings, Warehouse and storage, Office, and Education were designated as the leading typologies.

Methodology

2.2 Commercial Typology Trends

Typology Trends - Notable EUI Differences within Typologies (cont.)

Methodology (cont.):

4. Use CBECS building floor area and building numbers in relation to building ownership type for final representation. Data was extracted from CBECS tables B11-B14
5. For the three selected leading typologies, investigate Energy Star EUI and determine if further breakdown is required. Since the EUI of college vs. non-college and refrigerated warehouse vs. non-refrigerated warehouse are very different from each other, the EUI of each was disaggregated from each other.
6. For floor area, as the "Non-refrigerated Warehouse" and "Refrigerated Warehouse" typologies are together considered as "Warehouse and Storage" under CBECS, the share of refrigerated warehouse area from the total warehouse area is calculated by dividing the total volume of gross refrigerated storage capacity in the U.S. and dividing by the typical clear height of warehouses. This area was subtracted from the total area of warehouses as reported from CBECS to determine the total area of non-refrigerated warehouses.
7. As the "Education – Other" and "College, University" typologies are together considered as "Education" under CBECS, a split was calculated by calculating the total square footage of elementary, middle and junior high, senior high, K-12 combined, and other schools. The number of schools in each category type reported as of 2022 was multiplied by the median square footage characteristic of each school type. This data was not available for K-12 combined schools, so the median square footage of a senior high school was applied, and for schools in the "other" category. The total square footage of college and university buildings was reported as over 6 billion square feet nation-wide, but a 75% factor was applied as this includes dormitories and other non-educational spaces. As a result, non-university educational buildings comprise about three times more floor area than university and college educational buildings nation-wide. This breakout was used to split the total CBECS "Education" square footage into the two appropriate categories.
8. To identify the number of buildings reporting data and location mapping, follow the results from Benchmarking Data Availability and find the number of buildings per city/state reporting benchmarking data.

Geographic Distribution of GHG Emissions in California

Sources:

1. Commission, California Energy. "Download Submitted 2019 Benchmarking Information." California Energy Commission, https://www.energy.ca.gov/media/4639. Accessed 13 Sept. 2023.
2. US EPA, OAR. "GHG Emission Factors Hub." Www.epa.gov, 27 July 2015, www.epa.gov/climateleadership/ghg-emission-factors-hub.
3. Bureau, U.S. Census. "2020 Census Demographic Data Map Viewer." The United States Census Bureau, 2020, www.census.gov/library/visualizations/2021/geo/demographicmapviewer.html .
4. US Census Bureau. "Urban and Rural." The United States Census Bureau, 30 Aug. 2018, www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html .
5. Bureau, U.S. Census. "Redefining Urban Areas Following the 2020 Census." The United States Census Bureau, www.census.gov/newsroom/blogs/random-samplings/2022/12/redefining-urban-areas-following-2020-census.html .

Methodology:

1. The United States Census Bureau defines Rural as less than 1000 persons per square mile, Suburban as 1000 to 2000 persons per square mile, and Urban as more than 2000 persons per square mile.
2. Using the United States Census Bureau's 2020 Census Demographic Data Map Viewer, population density (persons per square mile) data was obtained per zip code.
3. The state of California was the focus of this question. Therefore, the 2019 data published by the California Building Energy Benchmarking Program (BEBP) was used for this question.
   - Note that all Residential, Multifamily, and Parking buildings were eliminated.
4. Using the EPA Emission Factor Hub of 2023, GHG emissions were calculated by multiplying energy use (kBtu) by GHG emissions factors for electricity and natural gas respectively in California. Then add the GHG emissions from electricity and natural gas to get total GHG emissions for each building
   - Electricity purchased from the grid – *0.070945804 kgCO2e/kBtu
   - Natural gas – *0.0531148 kgCO2e/kBtu
5. Calculate GHG Intensity by dividing total GHG emissions by total area (ft2).
6. Calculate Site EUI by dividing total energy use (kBtu) and by total area (ft2).
7. Remove outliers (2 in this dataset) and buildings with negative EUI from electricity, assuming that renewable energy use is larger than electricity use, and therefore there are negative GHG emissions. Also remove any buildings with "0" GHG Intensity, assuming missing information.
8. Classify each building as rural, suburban, or urban based on population density of the zip code it belongs in.
9. Graph EUI and GHG Intensity by location (rural, suburban or urban) as well as average in California for comparison. Total building area and GHG emissions was also calculated by building function to find the largest GHG emitters.

Methodology

3.1 Energy Code, Grid Decarbonization, & Electrification

Energy Code Progress Across the U.S.

Source:

1. Dodge Construction Network. (2023). Historical Construction Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
2. Dodge Construction Network. (2023). Forecast Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338
3. Office of Energy Efficiency and Renewable Energy. (n.d.). Building Energy Codes Program. Www.energycodes.gov. https://www.energycodes.gov/

Methodology:

1. Historical GSF was pulled from Dodge´s Historical Construction Dashboard for commercial typology for the years 2014 – 2022 by state
2. Projected GSF was pulled from Dodge´s Forecast Dashboard for the commercial typology for the years 2023-2027 by state.
3. Due to different names used to filter the data in the Historical Construction Dashboard and the Forecast Dashboard, the following table was used to align categories:

***Historical Construction Dashboard* Commercial Categories**	**Forecast Dashboard Commercial Dashboard**
Schools and Colleges	Education
Stores and Restaurants	Retail
Hospitals and Other Health Treatment	Health Care
Hotels and Motels	Hotel
Dormitories	Dormitories
Office and Bank Buildings	Office
Libraries and Museums	
Amusement, Social and Recreation Buildings	Recreation Buildings
Other Governmnet Service Buildings	Government Buildings
Capitols/Court Houses/City Halls	
House of Worship	
Other Religious Buildings	Religious Buildings
Warehouses (Manufacturer Owned)	
Warehouses (excl. Manufacturer Owned)	Warehouse (Non-Manufacturing)
Manufacturing and Processing Plants	Manufacturing
Miscellaneous Nonresidential Buildings	Transport Buildings
Laboratories (Manufacturer Owned)	
Laboratories (excl. Manufacturer Owned)	

4. Once commercial GSF by obtained by state, historical code cycles were researched for each state and documented to understand what version of ASHRAE 90.1 (or equivalent) was in effect when the new construction was built.
5. It was assumed that the energy impacts from the new codes would be seen one year after it was signed into effect. For example, if a state updated its code in 2018, new construction would start reflecting the new code in 2019.
6. For states that operated under home rule, the new GSF was placed under the Home Rule category.
7. For assigning ASHRAE 90.1 versions to projected new construction, the code cycle in effect in 2023 for each state was used for the years 2024 – 2027.

Projected Electric Grid Decarbonization

Source:

1. Gagnon, Pieter; Cowiestoll, Brady; Schwarz, Marty (2023): Cambium 2022 Data. National Renewable Energy Laboratory. https://scenarioviewer.nrel.gov

Methodology:

1. Grid emission intensity (aer_load_co2e) and generation (endues_use_load) were extracted from NREL's Cambium 2022 tool between 2024 – 2050 for the various grid regions. Due to the outputs from the Cambium 2022 tool only providing data for the years 2024, 2026, 2028, 2030, 2035, 2040, 2045 and 2050, a straight-line interpolation was used to populate the data for the years in between. The Mid-case scenario was used for the analysis as it is recommended by NREL when simulating baseline cases.
2. The average emission intensity was calculated in 5-year intervals between 2025 – 2050 and plotted while the average generation was calculated using the total generation between 2025 – 2050.

Methodology

3.1 Energy Code, Grid Decarbonization, & Electrification

Electrification of Heating and Grid Decarbonization

Source:

1. Gagnon, Pieter; Cowiestoll, Brady; Schwarz, Marty (2023): Cambium 2022 Data. National Renewable Energy Laboratory. https://scenarioviewer.nrel.gov
2. International Code Council, INC. (2018). 2018 International Green Construction Code.

Methodology:

1. NREL's Cambium 2022 tool was used to model future grid emission between 2024 – 2050 for the various grid regions. Due to the outputs from the Cambium 2022 tool only providing data for the years 2024, 2026, 2028, 2030, 2035, 2040, 2045 and 2050, a straight-line interpolation was used to populate the data for the years in between. The Mid-case scenario was used for the analysis as it is recommended by NREL when simulating baseline cases.
2. The Cambium 2022 data was used to calculate the emissions resulting from electric heating systems (heat pumps and electric resistance heaters).
3. The ASHRAE 189.1-2017 standard was used to calculate the emissions resulting from natural gas heating systems (furnace and condensing boiler). The natural gas emission factor was set at 231 kgCO2/MWh) and accounts for both direct and indirect emissions.
4. The following efficiencies were assumed for calculating the energy usage of each heating system: furnace: 80%, condensing boiler: 93%, electric resistance heater: 100%, heat pump: 2.5 COP
5. By using the same heating load for each heating system, the cumulative CO2e emissions were calculated by multiplying it against respective efficiency values and emission.

3.2 Key Technologies: Demand Response, PV, Heat Pumps, EV

Storage and Demand Response - Grid Interactive Buildings

Source:

1. Annual Electric Power Industry Report, Form EIA-861 detailed data files. (2021). U.S. Energy Information Administration. https://www.eia.gov/electricity/data/eia861/zip/f8612021.zip

Methodology:

1. Determined the 25 largest utilities by commercial customer sales (MWh) using the "Sales_Ult_Cust_2021.xslx" file within the EIA 2021 detailed data files.
2. Determined the number of commercial customers for each of the 25 identified utilities from Step 1 using the "Sales_Ult_Cust_2021.xslx" file within the EIA 2021 detailed data files.
3. Determined the number of commercial customers enrolled in demand response for each of the 25 identified utilities from Step 1 using the "Demand_Response_2021.xslx" file within the EIA 2021 detailed data files.
4. Calculated the percentage of commercial customers enrolled in demand response for each of the 15 largest utilities by dividing the number of commercial customed enrolled in demand response from Step 3 by the number of commercial customers from Step 2

Storage and Demand Response - Hourly Emissions and Demand Response

Source:

1. California ISO. (n.d.). California ISO. www.caiso.com. http://www.caiso.com/Pages/default.aspx
2. New York ISO. (n.d.). LBMP Results Index. Mis.nyiso.com. http://mis.nyiso.com/public/
3. US EPA, O. (2020, July 27). Emissions & Generation Resource Integrated Database (eGRID). U.S. EPA. https://www.epa.gov/egrid

Methodology:

1. For CAISO graphics, generation and carbon emission data were extracted for the winter solstice (December 20, 2022) and the summer solstice (June 20, 2023).
2. For NYISO graphics, generation data was extracted for the winter solstice (December 20, 2022) and the summer solstice (June 20, 2023).
3. The NYISO dataset did not contain data regarding emissions produced from the respective power generation, so EPA eGRID data was used to set the emission factor for fossil fuel power generation. This metric was set at a fixed value of 851.54 lbCO2e/MWh which is based on the eGRID region NYUP's 2021 All Fossil Fuel output emission rate for CO2e.

Methodology

3.2 Key Technologies: Demand Response, PV, Heat Pumps, EV

Top 25 Utilities by 2021 Customer Sales (MWh)		Demand Response Dynamic Pricing Programs				
Rank	Utility Company	Time of Use Pricing	Real Time Pricing	Variable Peak Pricing	Critical Peak Pricing	Critical Peak Rebate
1	Constellation NewEnergy, Inc		New Program in Last 5 Years			
2	Direct Energy Business					
3	Virginia Electric & Power Co	Existing Program	New Program in Last 5 Years	Existing Program	Existing Program	
4	Florida Power & Light Co					
5	Southern California Edison Co	Existing Program	Existing Program		Existing Program	New Program in Last 5 Years
6	Calpine Energy Solutions, LLC					
7	Consolidated Edison Co-NY Inc					
8	ENGIE Resources LLC					
9	Georgia Power Co	Existing Program	Existing Program			
10	Commonwealth Edison Co		Existing Program			
11	Duke Energy Carolinas, LLC	Existing Program	Existing Program			
12	Pacific Gas & Electric Co.	New Program in Last 5 Years			New Program in Last 5 Years	
13	Public Service Elec & Gas Co					
14	AEP Energy					
15	DTE Electric Company	New Program in Last 5 Years			New Program in Last 5 Years	
16	PacifiCorp	Existing Program				
17	EDF Energy Services, LLC		New Program in Last 5 Years			
18	Ohio Power Co	Existing Program				
19	Duke Energy Florida, LLC	Existing Program				
20	Duke Energy Progress - (NC)	Existing Program	Existing Program			
21	Baltimore Gas & Electric Co					
22	Northern States Power Co - Minnesota	Existing Program	New Program in Last 5 Years			
23	Potomac Electric Power Co					New Program in Last 5 Years
24	MP2 Energy LLC		Existing Program			
25	PPL Electric Utilities Corp	Existing Program	Existing Program			

Legend

- Existing Program
- New Program in Last 5 Years
- No Program

- The largest utility providers are offering 50% more demand response programs than they were 5-years ago.
- CPP and CPR programs saw the highest growth in offerings and are expected to become more common as grid-interactive building technologies are adopted in the market.
- Some CPR programs offer monthly incentives, regardless of peak demand events occurring.

Time-of-Use Pricing (TOU): Customers pay different prices at different times of the day. On-peak prices are higher and off-peak prices are lower than a "standard" rate. Price schedule is fixed and predefined, based on season, day of week, and time of day.

Real-time Pricing (RTP): A rate and price structure in which the retail price for electricity typically fluctuates hourly or more often, to reflect changes in the wholesale price of electricity on either a day-ahead or hour-ahead basis.

Variable Peak Pricing (VPP): A form of TOU pricing that allows customers to purchase their generation supply at prices set on a daily basis with varying on-peak and constant off-peak rates. The on-peak price for each weekday becomes available the previous day and the customer is billed for actual consumption during the billing cycle at these prices.

Critical Peak Pricing (CPP): A rate and/or price structure that is designed to encourage reduced consumption during periods of high wholesale market prices or system contingencies, by imposing a pre-specified high rate or price for a limited number of days or hours. Very high "critical peak" prices are assessed for certain hours on event days (often limited to 10-15 per year). Prices can be 3-10 times as much during these few hours.

Critical Peak Rebate (CPR): A rate and/or price structure that is designed to encourage reduced consumption during periods of high wholesale market prices or system contingencies, by providing a rebate to the customer on a limited number of days and for a limited number of hours, at the request of the energy provider. The energy provider can call event days (often limited to 10-15 per year) and provide a rebate typically several times the average price for certain hours in the day. The rebate is based on the actual customer usage compared to its baseline to determine the amount of the demand reduction each hour.

Source:

1. Annual Electric Power Industry Report, Form EIA-861 detailed data files. (2021). U.S. Energy Information Administration. https://www.eia.gov/electricity/data/eia861/zip/f8612021.zip
2. Annual Electric Power Industry Report, Form EIA-861 detailed data files. (2016). U.S. Energy Information Administration. https://www.eia.gov/electricity/data/eia861/archive/zip/f8612016.zip

Methodology:

1. Determined the 25 largest utilities by commercial customer sales (MWh) using the "Sales_Ult_Cust_2021.xslx" file within the EIA 2021 detailed data files.
   - Combined Part, Service Type, and State, and BA Code for each utility to determine the aggregated commercial customer sales.
   - Then, determined the 25 largest utility companies by commercial sales using the aggregated data.
2. Determined the types of demand response financial incentives being offered using the "Dynamic_Pricing_2021.xslx" file within the EIA 2021 detailed data files.
3. Determined the demand response financial incentive programs offered by the 25 largest utilities in 2021 by referencing the data in Step 2 against the 25 largest utilities determined in Step 1.
4. Determined the demand response financial incentive programs being offered by utility companies five years prior using the "Dynamic_Pricing_2016.xslx" file within the EIA 2016 detailed data files. 2
5. Determined the demand response financial incentive programs offered by the 25 largest utilities in 2016 by referencing the data in Step 4 against the 25 largest utilities determined in Step 1.
6. Compared the programs being offered in 2021 by the 25 largest utilities against the programs being offered in 2016 to determine programs that were new offerings in the last 5 years and programs that have been offered for more than 5 years.

Methodology

3.2 Key Technologies: Demand Response, PV, Heat Pumps, EV

Building, Transportation, and Grid Connectivity

Source:

1. Developer Network: All Stations. (2023). National Renewable Energy Laboratory. https://developer.nrel.gov/docs/transportation/alt-fuel-stations-v1/all/
2. Electric Vehicle Registrations by State. (2022). U.S. Department of Energy. https://afdc.energy.gov/data/10962
3. 10 Electric Vehicles Available With Bidirectional Charging Capabilities. (June 2023). Make Use Of. https://www.makeuseof.com/electric-vehicles-bidirectional-charging/
4. What's Bidirectional Charging and Which EVs Offer It? (Sept. 2022). Cars.com https://www.cars.com/articles/whats-bidirectional-charging-and-which-evs-offer-it-457608/
5. Here's how U.S. electric vehicle sales by maker and EV model through Q3 2022 compare. (Oct. 2022). Electrek. https://electrek.co/2022/10/18/us-electric-vehicle-sales-by-maker-and-ev-model-through-q3-2022/
6. Bidirectional Charging and Electric Vehicles for Mobile Storage. (n.d.). Federal Energy Management Program. https://www.energy.gov/femp/bidirectional-charging-and-electric-vehicles-mobile-storage
7. State Area Measurements and Internal Point Coordinates. (2010). United States Census Bureau. https://www.census.gov/geographies/reference-files/2010/geo/state-area.html
8. Vehicle Registration Counts by State. (2022). U.S. Department of Energy. https://afdc.energy.gov/vehicle-registration

Methodology:

1. Retrieve data from the NREL API for all alternative fuel stations (updated as of August 2023) using the Postman platform.
2. Filter the alternative fuel stations data for all-electric-only charging stations and sum the total number of stations available by state.
3. From the U.S. Department of Energy, download the number of electric vehicle registrations by state and match with the charging stations data.
4. Identify which electric vehicles currently on the U.S. market offer bidirectional charging capabilities and calculate their relative market share, as well as the total number of all cars sold in 2022.
5. Identify the number of electric vehicles and light-duty vehicles per square mile of land, per state. Shade states according to the quantile approach for electric vehicles/area, and hatch states based on three groupings of classes for light-duty vehicles/area using the quantile approach.
6. Calculate the number of electric charging stations per electric vehicle by state and overlay on the map, with classes categorized using the quantile approach.

Essential Decarbonization Technologies

Source:

1. 2018 Commercial Buildings Energy Consumption Survey: Building Characteristics Highlights (p. 32). (2022). U.S. Energy Information Administration.
2. BloombergNEF. (n.d.). BloombergNEF. Retrieved August 23, 2023, from https://about.bnef.com/
3. Historical Data | AHRI. (n.d.). Retrieved August 23, 2023, from https://www.ahrinet.org/analytics/statistics/historical-data

Methodology:

Three different data-sources were processed to track the adoption and growth of the three explored technologies: commercial building distributed PV, commercial building heat pumps and commercial building LED lighting.

1. Commercial, Distributed PV Capacity was collected from Bloomberg NEF. Units were recorded in Gigawatts. The percentage increase from the first year to the most recent year data was calculated and plotted over its respective year
2. Data on the number of heat pumps and commercial AC Units shipped was collected from AHRI. The December monthly reports of each year were referenced, as those reports also listed Yearly data on the amount of equipment shipped.
3. Units with a BTU greater than 65 were considered as commercial units following guidance from AHRI. To separate heat pumps from central AC units, the yearly breakdown of heat pumps vs AC units sold was used and assumed consistent across Heat Pumps of different BTUs.
4. To separate heat pumps from central AC units, the yearly breakdown of heat pumps vs AC units sold was used and assumed consistent across Heat Pumps of different BTUs.
5. To reflect the adoption of the technology overtime and to be consistent with how the other technologies' data is reported, the net number of heat pumps shipped since 2014 is calculated from the yearly numbers.
6. Then the percent increase over the first year reported (2014) is calculated and plotted over each respective year.
7. Commercial LED lighting was collected from EIA's 2018 Commercial Buildings Energy Consumption Survey. The data communicates the market penetration rate in percentage format.
8. The survey reported data on LED lighting adoption in 2012 and 2018, but not for any year in between. For the report, it was assumed LED lighting market penetration was consistent between the years reported, and interim years were calculated as a linear increase in market penetration.
9. The percent increase from the first year's market penetration (2012) is then calculated and plotted over each respective year.

Methodology

4.1 Benchmarking and BPS

Benchmarking Data Availability

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Methodology
4.1 Benchmarking and BPS
Benchmarking Data Availability (cont.)

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Methodology:

1. Using the International Market Transformation's Map of the U.S. City, County, and State Policies for Existing Buildings: Benchmarking, Transparency, and Beyond, a list was created to note the existence of benchmarking and BPS policies.
2. For cities with downloadable benchmarking data in the form a .CSV file, the following steps were taken to calculate total number of buildings benchmarked in 2021.
    - For Portland, ME, Orlando, FL, and Columbus, OH, 2022 data was used, since 2021 data was not available
    - For Evanston, IL, 2019 data was used, since 2021 data was not available
    - For St. Louis, MO, 2018 data was used, since 2021 data was not available
    - For San Jose and San Diego, the California BEBP was filtered by these two cities to get total number of buildings benchmarked, since city-specific data was not available, but they both have benchmarking policies
    - For all datasets, first "Parking" and "Multifamily" primary building uses were eliminated
    - For all datasets, "Blanks" or "Not Available" data under Energy Use (kBtu) or Site EUI (kBtu/sf) were eliminated
    - The remaining number of rows after this filtration indicates commercial buildings benchmarked in that year, in that city
3. For cities with web-based interactive maps and charts, the available filters were used to calculate number of commercial buildings benchmarked
    - These cities are: Miami, FL, Brisbane, CA, Chula Vista, CA, Des Moines, IA, Atlanta, GA, Columbus, OH, Boulder, CO, Minneapolis, MN, Fort Collins, CO
        - For Des Moines, IA, "multifamily" and "parking" was not able to be excluded from total benchmarked buildings count.
    - For maps based in "touchstoneiq.com" "multifamily" and "parking" buildings were subtracted from the total number of reporting commercial buildings to get the year's total benchmarked buildings
4. For cities with a .PDF benchmarking report, the total number of reporting commercial buildings was used.
    - These cities are: Aspen, CO, and St. Paul, MN
    - For St. Paul, MN, "multifamily" and "parking" was not able to be excluded from total benchmarked buildings count.
5. For California, the California Building Energy Benchmarking Program (BEBP) dataset from Open Data was used.
    - Data values from Berkeley, Brisbane, Chula Vista, Los Angeles, and San Francisco were eliminated.
    - To avoid double counting, the number of buildings from the California BEBP Open Data set was added with the number of buildings from Berkeley, Brisbane, Chula Vista, Los Angeles, and San Francisco city-specific datasets, to get a total of 14,551 buildings in 2021.
6. According to EIA CBECS dataset, there are 5,900,000 total commercial buildings in the US in 2018, and after adding CA and the 24 other cities buildings benchmarked, there is a total of 37,571 buildings benchmarked in the US, which is 0.64% of all buildings.

Methodology

4.1 Benchmarking and BPS

Benchmarking Policies Across the U.S.

Source:

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Methodology
4.1 Benchmarking and BPS
Benchmarking Policies Across the U.S. (cont.)

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Methodology

4.1 Benchmarking and BPS

Benchmarking Policies Across the U.S. (cont.)

Methodology:

1. Using the International Market Transformation's 2023 Map of the U.S. City, County, and State Policies for Existing Buildings: Benchmarking, Transparency, and Beyond and U.S. City and State Policies for Existing Buildings: Building Performance Standards, a list was created to note the existence of benchmarking and BPS policies.
2. For each benchmarking policy, government websites and publicly available data was used to find the following information
   - First Year of Benchmarking Ordinance in Effect
   - Current Commercial Building Area Minimum (sf)
   - EUI and/or GHG Reported
   - Publicly Available and Accessible Data Noted
3. Ordinance comprehensiveness was ranked color coding from least to most as follows:
   - Public building benchmarking required - lightest color
   - Public and commercial building benchmarking required
   - Public and commercial building benchmarking, and additonal actions required (such as BPS standards/performance thresholds, required lighting upgrades, water usage reporting, etc.)
   - Public, commercial and multifamily building benchmarking, and additonal actions required (such as BPS standards/performance thresholds, required lighting upgrades, water usage reporting, etc.) - darkest color

Methodology

4.2 Retrofit and Renovation

Growth of Building Renovation Market in the U.S.

Source:

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Methodology:

1. Dodge Historical Stats Report gives values for building renovation at the state level between 2014 and 2022 in yearly intervals.
2. On the left bar, select commercial real estate building types to include: Stores and Restaurants, Warehouses (exclude manufacturer owned), Office and Bank Buildings, Manufacturing and Processing, Warehouses (Manufacturer owned), Laboratories (Manufacturer owned), Schools and Colleges, Laboratories (excl. manufacturer owned), Libraries and Museums, Hospitals and Other Health Treatment, Capitols/Court Houses/City Hall, Other Government Service Building, Houses of Worship, Other Religious Buildings, Amusement/Social and Recreation, Miscellaneous Nonresidential Buildings, Hotels and Motels, and Dormitories.
3. On right bar, show advanced filter and deselect New Construction to get building renovations.
4. On right bar, select State and download the dataset.
5. Multiply raw dataset by 1000 to get the value in Gross, $
6. Calculate total money spent from 2014 – 2022 for each state to find the top six states with the largest amount of Gross, $ spent for Renovations.
7. Add the rest of the states to show a cumulative amount and create a stacked area chart to show change in money spent towards renovations each year from 2014 to 2022.
8. Repeat Steps 1-7 except for square footage data in place of Gross, $.
9. Divide the total money spent for each year by the total square footage for each year to get dollar spent per square foot per year.
10. Calculate the average $/sf from 2014-2022.
11. Rocky Mountain Institute performed a study finding the dollar spent per square foot for deep energy retrofit measures is $150/sf.
12. Divide the average total money spent per square foot determined in Step 10 by the deep energy retrofit spend per square foot from Step 11 to determine the percentage of total retrofit spend that is for deep energy efficiency measures. This resulted in 17% of total spend.
13. Determine the historical average retrofit spend growth rate from 2014-2022, which equaled 7% Use this rate to project retrofit spend through 2027 to determine a 'Current State' projection.
14. Determine which IRA / BIL sections provide incentives for commercial energy efficiency upgrades.
    - The study assumed IRA Section 179D to be the most applicable as it relates to energy efficient commercial property tax deductions for private and public entities. While other programs also provided incentives, these programs were targeted at specific groups (e.g., low-income housing, schools, etc.) so these were not considered in the results.
15. Determine the impact IRA Section 179D will have on future retrofit spend by considering the below four scenarios.
    - **Current State:** Retrofit spend increased by 7% year over year based on the historical average growth rate determined in Step 13.
    - **Scenario 1:** Retrofit spend grew by 24% (7% historical growth rate + 4% additional spend) year over year based on the below assumptions.
        - Assumed all energy efficiency spend for the year applied for and received tax deductions.
        - Assumed a federal income tax rate of 21%, which resulted in net annual tax savings of 4% (17% of retrofit total spend from Step 12 multiplied by 21%)
        - Assumed 100% of net annual tax savings were reinvested into additional retrofit spend that year.
    - **Scenario 2:** Retrofit spend grew by 15.5% (7% historical growth rate + 8.5.% additional spend) year over year based on the below assumptions.
        - Assumed all energy efficiency spend for the year applied for and received tax deductions.
        - Assumed a federal income tax rate of 21%, which resulted in net annual tax savings of 4% (17% of retrofit total spend from Step 12 multiplied by 21%)
        - Assumed 50% of net annual tax savings were reinvested into additional retrofit spend that year.
    - **Scenario 3:** Retrofit spend grew by 7% year over year based on the historical average growth rate. An additional 17% spend was then applied to the total of each projected year to account for tax deductions reinvested that year for additional retrofit spend. The scenario made the following assumptions.
        - Assumed all energy efficiency spend for the year applied for and received tax deductions.
        - Assumed a federal income tax rate of 21%, which resulted in net annual tax savings of 4% (17% of retrofit total spend from Step 12 multiplied by 21%)
        - Assumed 100% of net annual tax savings were reinvested into additional retrofit spend that year.
    - **Scenario 4:** Retrofit spend grew by 7% year over year based on the historical average growth rate. An additional 17% spend was then applied to the total of each projected year to account for tax deductions reinvested that year for additional retrofit spend. The scenario made the following assumptions.
        - Assumed all energy efficiency spend for the year applied for and received tax deductions.
        - Assumed a federal income tax rate of 21%, which resulted in net annual tax savings of 4% (17% of retrofit total spend from Step 12 multiplied by 21%)
        - Assumed 50% of net annual tax savings were reinvested into additional retrofit spend that year.

Methodology

4.2 Retrofit and Renovation

Federal IRA Funding and Incentives

Sources:

1. 2018 CBECS Survey Data: Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
2. 2018 CBECS Survey Data: Table B17. Occupancy of nongovernment-owned and government-owned buildings, number of buildings, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
3. California Energy Commission Letter. (2020). Office of Energy Efficiency & Renewable Energy. https://www.energycodes.gov/sites/default/files/2020-06/California_Certification_of_Com_Codes_Standard90.1-2016.pdf
4. Energy efficient commercial buildings deduction. (2023). Internal Revenue Service. https://www.irs.gov/credits-deductions/energy efficient-commercial-building-deduction
5. Estimated Improvement in Commercial Energy Code (1975-2021). (2022). DOE Building Energy Codes Program https://public.tableau.com/app/profile/doebecp/viz/HistoricalModelEnergyCodeImprovement/CombinedHistoricalCodeImprovement_1
6. State Level Commercial Codes Energy Use Index FY2022Q3. (2022). DOE Building Energy Codes Program. https://public.tableau.com/app/profile/doebecp/viz/BECPStatusofStateEnergyCodeAdoption/ResidentialStateEnergyIndex_1
7. US States - Ranked by Population 2023. (2023). World Population Review. https://worldpopulationreview.com/states

Methodology:

1. Using CBECS 2018 data, determined the total amount of commercial building floorspace.
2. Using CBECS 2018 data, calculated the % of total buildings that was constructed in each provided time frame but dividing the number of buildings constructed in each time frame by the total number of commercial buildings.
3. Calculated the building floorspace per time frame period by multiplying the total commercial floorspace calculated in Step 1 by the percentage calculated in Step 2.
4. Estimated the amount of floor space constructed to each ASHRAE 90.1 standard version.
    - Assumed all buildings constructed 1980 and before were built to ASHRAE 90.1-1975 (conservative estimate since most were not required to comply by ASHRAE 90.1)
    - Assumed all buildings were constructed to the most recent ASHRAE 90.1 standard after the year of release (e.g., buildings constructed in 2007 would be constructed to ASHRAE 90.1-2004 while buildings constructed in 2008 would be constructed to ASHRAE 90.1-2007)
    - For multiple ASHRAE 90.1 versions released within a 10-year period, assumed pro-rata share of building floor space for the 10-year range calculated in Step 2 based on the logic in Step 4(b).
5. Adjusted the estimated floor space constructed to each ASHRAE 90.1 standard version based on CBECS 2018 Commercial renovation data.
    - CBECS 2018 data provided the number of buildings that received renovations since 2000.
    - Calculated the % of buildings that received renovations against all buildings constructed before 2000, since it is assumed most buildings renovated between 2000-2013 would be older than 13-years.
    - Reduced the amount of gross floorspace for buildings constructed to ASHRAE 90.1-75 from Step 4 by the percentage calculated in Step 5(b).
        - Assumed the oldest buildings received renovations.
    - Distributed the amount of gross floorspace renovated calculated in Step 5(c) across each ASHRAE 90.1 version released from 2000 through 2012 using the logic from Step 4(b).
6. Calculated the percentage of % of total building floorspace for each ASHRAE 90.1 standard version.
7. Calculated the percentage of the U.S. population by state using World Population Review data for 2023.
    - Added District of Columbia as a separate territory (“state”).
8. Calculated the total building floorspace per ASHRAE 90.1 version by state by multiplying the ASHRAE 90.1 standard floorspace calculated in Step 5 by the percentage of population for each state calculated in Step 7.

Methodology
4.2 Retrofit and Renovation

Federal IRA Funding and Incentives (cont.)

9. Using DOE BECP data, calculated the energy efficiency ratio for each ASHRAE 90.1 version by comparing the Energy Rating Index of the ASHRAE 90.1 standard against the Current State ASHRAE Code.
    - Assumed a flat ratio across all states for ASHRAE 90.1 2001 and before using DOE Building Energy Codes Program: Estimated Improvement in Commercial Energy Code (1975-2021), since DOE Building Energy Codes Program: State Level Commercial Codes Energy Use Index FY2022Q3 only provided state ERI ratios starting with ASHRAE 90.1-2004.
    - Based on an analysis by the California Energy Commission, the 2016 California State Energy Code is 13% more efficient than ASHRAE 90.1-2013, and the 2019 California State Energy Code is 10.7% more efficient than the 2016 CA State Energy Code. Therefore, the 2016 California State Energy Code replaced ASHRAE 90.1-2016, and the 2019 CA State Energy Code replaced ASHRAE 90.1-2019 using these ratios to determine the ERI ratios for California.
    - The analysis excludes states with a home rule or no state energy code since an ERI against ASHRAE 90.1 does not exist. This includes the following states: Alaska, Arizona, Colorado, Hawaii, Kansas, Mississippi, Missouri, North Dakota, South Dakota, and Wyoming. These states account for 9% of the national GSF estimates. Excluding these states results in a conservative estimate of available tax deductions.
10. Calculated the estimated available tax deductions by multiplying the total building floorspace per ASHRAE 90.1 version by state calculated in Step 8 by the IRA tax deduction amount ($/sqft) respective to the estimated energy efficiency savings calculated in Step 8.
11. Calculated the total available tax deductions available by retrofitting buildings constructed to each ASHRAE 90.1 version by summing the dollar value calculated across all states in Step 10.

Commissioning and Retro-Commissioning Market Penetration

Source:

1. 2018 CBECS Survey Data: Table B5. Census region and division, floorspace. (2022). [dataset]. https://www.eia.gov/consumption/commercial/data/2018/
2. 2018 Commercial Buildings Energy Consumption Survey: Building Characteristics Highlights. (2022). U.S. Energy Information Administration.
3. Crowe, E., Granderson, J., & Mills, E. (2018). 2018 Commissioning Cost/Benefit Study Findings. Lawrence Berkeley National Laboratory and the Building Commissioning Association.
4. Dodge Construction Network Dataset. (2023). [dataset]. https://www.construction.com/
5. U.S. Energy Use Intensity by Property Type. (2021). Energy Star Portfolio Manager. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf
6. US EPA, OAR. (2015, August 10). Greenhouse Gases Equivalencies Calculator—Calculations and References [Data and Tools]. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Methodology

4.2 Retrofit and Renovation

Commissioning and Retro-Commissioning Market Penetration (cont.)

Methodology:

1. The Northwest Energy Efficiency Alliance's (NEEA's) report on building commissioning was referenced for metrics on commercial building commissioning (Cx) and retro-commissioning (RCx).
2. NEEA frames Cx's market penetration as the percentage of newly constructed buildings which undergo Cx each year.
3. NEEA frames RCx's market penetration as the percentage of all existing buildings which undergo RCx in that year.
4. The NEEA dataset is limited to buildings within the Northwestern US. For the study, the rates of Cx and RCx were taken from NEEA's report and applied to national statistics on new and existing commercial building square footage.
5. The square footage of newly constructed commercial buildings in the U.S. was taken from the Dodge Construction Network Dataset and covers 2014-2022. The square footage of existing commercial buildings in the U.S. was taken from the CBECS 2018 survey. Given that CBECS data was limited to 2018, to calculate the total square footage for each year, the "square footage added" from Dodge was added to or subtracted from the CBECS data given the year (e.g. to calculate the total commercial square footage of 2016, the Dodge commercial square footage added from 2018 and 2017 was subtracted from the CBECS 2018 total commercial square footage). Given a lack of data, commercial demolition was not factored into the total stock estimates.
6. The market penetration percentage for Cx from NEEA was multiplied by the corresponding total commercial floorspace added yearly and plotted over its corresponding year.
7. The market penetration percentage for RCx from NEEA was multiplied by the corresponding existing commercial floorspace and plotted over its corresponding year.
8. Crowe et al (2018) found a median 6% energy savings when buildings undergo RCx.
9. The average EUI for different commercial building typologies is taken from Energy Star's 2018 report. Using data on the prevalence of each typology from CBECS 2018 survey data, a weighted average EUI for commercial buildings in the U.S. is calculated.
10. The total square footage of commercial buildings in the U.S. is multiplied by the EUI to return an estimate of the U.S. commercial building stock's energy demand, in kBTU.
11. The total energy demand is then multiplied by 6%, showing the estimated national energy savings from RCx. The savings varies based on the market penetration of that year, so in addition to plotting the per-year savings, the energy savings per 1% of RCx market penetration was reported.
12. The 2022 and 2023 projections for RCx market penetration, square footage, and energy savings are taken from a linear extension of growth from the prior two years.
13. To calculate the carbon savings per 1% of RCx market penetration, the total energy savings was converted from energy demand in kBTU to the unit appropriate for each respective fuel type (kwh for electric, thermes for natural gas, mmbtu for Fuel Oil, and kwh for district heat). GWP factors were sources from the U.S. for all except district heating, which was sourced from VDA's Emissions Factors for Electricity, District Heating and Fuels (2023).

Building Ownership and Occupancy

Source:

1. 2018 CBECS Survey Data: Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
2. 2018 CBECS Survey Data: Table B17. Occupancy of nongovernment-owned and government-owned buildings, number of buildings, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/

Methodology:

1. Using CBECS 2018 data, estimated the total commercial building floorspace for Owner Occupied, Tenant, and Government Owned occupancy types by determining the average building floorspace per building within each floorspace range, then multiplying by the number of buildings in each floor space range for each occupancy type.
2. Using CBECS 2018 data, calculated the % of total buildings that was constructed in each provided time frame for Owner Occupied, Tenant, and Government Owned occupancy types.
3. Calculated the building floorspace per time frame period for each occupancy type by multiplying the estimated floor space calculated in Step 1 by the percentage calculated in Step 2.
4. Determined the percentage of buildings in each occupancy type per construction year by dividing the number of buildings constructed in each timeframe for each occupancy type by the total number of buildings for each respective occupancy type.

Methodology

4.2 Retrofit and Renovation

Whole Life Carbon Savings

Source:

1. 2018 CBECS Survey Data: Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
2. Care tool | carbon avoided: Retrofit estimator. (n.d.). Retrieved September 21, 2023, from https://caretool.org/

Methodology:

1. CBECS Data gives values for new construction by building typology for 2000-2018. It also gives values for building renovations by renovation type for 2000-2018.
2. Using the Care Tool, map out different scenarios to gather the various emissions intensity per square foot values and apply to CBECS Data square footage.
    - The Case Study Scenario square footage has the following assumptions applied in Care Tool:
        - New Building: 300,000 sf distribution center in St. Louis, MO. One story above grade with steel and/or concrete structure. Assume a 30% reduction in energy use with high-performance mechanical, electrical, and plumbing equipment.
        - Envelope Upgrades: Total roof replacement, 50% of exterior wall assembly replacement including insulation, 35% window to wall ratio with total window replacement, and lateral structural upgrade.
        - Interior Fit-out: 90% interior wall reconfiguration.
        - MEP Upgrades: Replace equipment with high-performance and reuse distribution. 30% reduction in EUI. Repair/refurbish lighting, plumbing, and electrical systems.
3. CBECS Data gives values for new construction by building typology for 2000-2018. It also gives values for building renovations by renovation type for 2000-2018, as well as vacant and demolished buildings in number of buildings and square footage.
4. CBECS Data gives values for vacant and demolished buildings in number of buildings and square footage.
    - Since CBECS Data does not break down vacant and demolished square footages by building typology, apply new construction percentages to the vacant and demolished square footages to estimate the typologies.
    - Use Care Tool to model scenario using the following assumptions and apply the different building typologies to the new construction and renovation tab. Gather the emissions intensities and break out by percentage in embodied and operational.
        - Vacant and demolished buildings square footage in the U.S. is assumed to have undergone "worst case" renovations including: plumbing and electrical upgrades, replacement of HVAC systems with new high-performance systems, roof and window replacement, 90% interior wall reconfiguration, and a lateral upgrade to the structural system. This is an ideal scenario where all buildings could be reused.
5. Determine the % savings by finding the difference between whole life carbon for renovations and whole life carbon for new construction, and comparing this number to the new construction.

Methodology
5.1 Conclusion

Potential Future Trajectories for Decarbonization

Source:

1. 2018 CBECS Survey Data: Table B11. Selected principal building activity: part 1, number of buildings (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
2. The Future of Heat Pumps: Executive Summary. (n.d.). International Energy Agency. https://www.iea.org/reports/the-future-of-heat-pumps/executive-summary
3. 2018 CBECS Survey Data: Table B20. Energy sources, floorspace, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
4. 2018 CBECS Survey Data: Table C1. Total energy consumption by major fuel, 2018. (2022). U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/
5. Dodge Construction Network. (2023). Historical Construction Dashboard. Dodge Construction Central. https://apps.construction.com/analytics/report/R338

Methodology:

1. Reference source data from Trajectory of Commercial Building Emissions Toward 2030 Goals for historical commercial emissions from 2010 to 2021.
2. Reference source data from Trajectory of Commercial Building Emissions Toward 2030 Goals for the NREL mid-case scenario, which calculates GHG emissions by applying the same energy use intensity (EUI) from 2021 through 2030, but with decarbonizing grid emission factors by region. This will serve as the baseline scenario from 2021-2030 by which emissions reduction measures can be compared.
3. Identify emissions savings from growth in heat pump shipments at the trajectory in which solar PV has grown in the last decade by finding the average growth rate of distributed PV as per Essential Decarbonization Technologies from 2012-2021, which is about 30%. Applying an annual 30% increase in the number of heat pumps from 2022 to 2030 results in more heat pumps than number of buildings as reported in CBECS Table B11 (2018). The difference between the number of projected heat pumps in 2030 with a growth similar to the trajectory of PV and the total number of commercial buildings is greater than the difference between the increase in commercial buildings from 2012 to 2018 as reported by CBECS. Thus, it is assumed that the number of heat pumps in 2030 according to this growth scenario will still outweigh the total number of commercial buildings to be projected in 2030, especially with declining office construction.
4. 20% emissions reductions should be achieved through heat pumps which would be fully realized in 2030, once there are as many commercial heat pumps as commercial buildings. Subtract what 20% emissions savings would be in 2030 from the 2030 baseline and interpolate the emissions savings between 2021 and 2030 evenly.
    - The emissions reductions achieved through heat pumps is from the IEA statistic in the Sources. This is a minimum percentage of emissions reductions that considers the impacts of refrigerant leakage. Savings would increase with grid decarbonization.
5. Calculate the emissions reductions achieved from an annual increase of 1% in the market penetration rate of retrocommissioning from 2024 by multiplying this penetration rate by the estimated market size (through projections from Dodge as retrieved from Essential Decarbonization Technologies and average rate of change for years that have not been forecasted) by an energy savings rate of 6%, for each year from 2022 to 2030. Convert these calculated energy savings into metric tons of CO2-equivalent by calculating the breakout of energy by fuel source (from CBECS Table B20) and applying the appropriate emission factors. Subtract the annual emissions savings from the annual emissions calculated in Step 3.3.
    - Grid emission factors for 2022 and 2023 were calculated by interpolating between the EPA eGrid grid emission factor for 2021 and the NREL Cambium Tool's 2024 grid emission factor, as used in Trajectory of Commercial Building Emissions Toward 2030 Goals. The NREL Cambium Tool's nation-wide grid emission factors were used for 2026, 2028, and 2030, and all odd years in between were interpolated between these known factors.
    - The natural gas emission factor is sourced from the same emission factor as used in Trajectory of Commercial Building Emissions Toward 2030 Goals.
    - The fuel oil emission factor is sourced from the same emission factor as used in Essential Decarbonization Technologies.
    - The district heat emission factor is sourced from the same emission factor as used in Essential Decarbonization Technologies.
6. Calculate the impact of decarbonizing all federal buildings by 2045 by retrieving the total energy by source from Table C1 of CBECS 2018. Scale the energy use up to what would be expected in 2021 by applying the total growth of federal building square footage from 2018 to 2021. This can be found by summing the total new government building square footage reported by Dodge for 2019, 2020, and 2021 and applying the percentage of federal buildings square footage of total government building square footage, as per CBECS Table B20. Convert the total calculated 2021 energy use to emissions by applying the appropriate emission factors for site electricity, natural gas, district heat, and fuel oil, as defined above. As these emissions savings will be realized in 2045, interpolate what interim savings would be from 2022-2044 and apply emissions savings to what was calculated in Step 4.
7. Repeat the step above, but for state buildings and local buildings in two separate step down reductions from the previously calculated cumulative annual emissions.

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