

Building Decarbonization Retrofits for Commercial and Multifamily Buildings

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Building Decarbonization Retrofits for Commercial and Multifamily Buildings

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Decarbonization of our existing building stock is one of the most important challenges of our time. We hope that this book provides practical and timely guidance for a wide range of interested parties. The solutions in this space are evolving rapidly, and no guide of this breadth can cover each topic exhaustively; thus, the authors have highlighted many other excellent references on specific topics throughout the book. While specific technological solutions will change over time, the key insights and planning framework presented in this guide will long be relevant.

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Acronyms

ASHP	air source heat pump
BESS	battery energy storage system
BPS	building performance standards
CO_2	carbon dioxide
CHW	chilled water
CUI	carbon use intensity
Cx	commissioning
DCV	demand-controlled ventilation
DWHR	drain water heat recovery
EIFS	exterior insulation and finish system
EPC	energy performance contract
EPD	Environmental Product Declaration
ERV	energy recovery ventilation
ESPC	energy savings performance contract
EUI	energy usage intensity
EUL	effective useful life
GHG	greenhouse gas
GWP	global warming potential
GSHP	ground-source heat pump
HFC	hydrofluorocarbon
HPWH	heat pump water heater
IAQ	indoor air quality
ITC	investment tax credit
LCCA	life-cycle cost analysis
LFG	landfill gas
LHS	latent heat storage
LTHW	low-temperature hot water
MBCx	monitoring-based commissioning
$MTCO_2$	metric tons of carbon dioxide
NPV	net present value
OPR	owner's project requirements
PCM	phase-change material
PPA	power purchase agreement

RCx	retrocommissioning
ReCx	recommissioning
ROI	return on investment
SHGC	solar heat gain coefficient
SHS	sensible heat storage
SPB	simple payback
VAV	variable air volume
VRF	variable refrigerant flow

1

Introduction

1.1 Background

In response to the rising awareness of decarbonization's vital role in confronting climate change, the *ASHRAE Position Document on Building Decarbonization* was published stating ASHRAE's commitment to pursuing efforts related to building decarbonization. Applied to existing buildings, decarbonization is the reduction of carbon emissions through converting existing equipment and systems powered by fossil fuel combustion processes to highly efficient equipment and systems that use low-carbon or carbon-free fuels. It is the intent of this building decarbonization retrofit guide for existing commercial and multifamily buildings to serve as an educational resource on the processes of planning and implementing decarbonization efforts and to provide high-level technical guidance on available decarbonization technologies and strategies.

ASHRAE Position Document on Building Decarbonization


ASHRAE Shaping Tomorrow's Built Environment Today

ASHRAE Position Document on

Building Decarbonization

Approved by the ASHRAE Board of Directors June 26, 2022

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ASHRAE is a global professional society of over 50,000 members, committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields (HVACAR). ASHRAE position documents are approved by the Board of Directors and express the views of the society on specific issues. These documents provide objective, authoritative background information to persons interested in issues within ASHRAE's expertise, particularly in areas where such information will be helpful in drafting sound public policy. The documents also clarify ASHRAE's position for its members and building professionals.

Building Decarbonization is a Public Interest Issue

Building decarbonization is imperative for global climate stability, energy security, and the general well-being of communities. As the building sector accounts for significant global greenhouse gas (GHG) emissions, prioritizing decarbonization action directly serves the public interest. Addressing this issue has the potential not only to help mitigate climate change in the short term but also to provide a stable environment for future generations. The benefits of building decarbonization include improved indoor air quality, energy efficiency, community health, and social equity.

For building decarbonization to be successful, it requires robust research and development, industry standardization, effective government policies, and workforce development. R&D programs must focus on strategies that reduce GHG emissions without compromising occupant safety and indoor environmental quality. Collaboration between energy, transportation, and building sectors is essential to cost-effectively optimize GHG reductions. Moreover, equipping the future workforce with the skills to support building decarbonization is crucial.

Building decarbonization is a public interest issue because it directly impacts climate stability, public health, economic well-being, and the broader societal goal of sustainability. Addressing this issue is pivotal for current and future generations, making it a collective responsibility. Embracing it is not just an industry priority, but a move in the best interest of the public at large.

Why ASHRAE Takes Positions on Building Decarbonization

ASHRAE underscores the urgency of decarbonizing buildings due to their contribution to global GHG emissions. With the global building stock projected to double by 2060, ASHRAE commits to a holistic approach encompassing research, design, technical guidance, regulations, and education.

This position document emphasizes the necessity of decarbonization, addresses key carbon-reduction principles and decarbonization strategies, and poses challenges that need to be addressed (ASHRAE 2022h). As society faces the challenge of mitigating climate change, ASHRAE's position is that the decarbonization of buildings and their systems must be based on a holistic analysis that includes healthy, safe, and comfortable environments; energy efficiency; environmental impacts; sustainability; operational security; and economics.

1.1.1 Why Decarbonization?

In 2020, existing buildings were responsible for nearly 40% of energy-related greenhouse gas (GHG) emissions, quantified as carbon dioxide equivalent (CO_2-eq), as shown in Figure 1.1. In *ASHRAE Position Document on Building Decarbonization*, ASHRAE established that the global built environment must halve its 2015 GHG emissions levels by 2030. It lists three main pillars of this plan:

- all new buildings are net-zero GHG emissions in operation,
- widespread energy-efficiency retrofits of existing assets are well underway, and
- embodied carbon of new construction is reduced by at least 40% (ASHRAE 2022h).

With the global building stock expected to double by 2060, strategic efforts must be made within the scope of these pillars to move from energy efficiency to decarbonization (ASHRAE 2022h). Though energy efficiency and decarbonization are related, once carbon emissions levels become the metric, the approach to high-performance building design changes in unexpected ways—namely, it becomes imperative to transition away from fossil-fuel-burning appliances in concert with a greening grid. Efficiency is still important, as discussed further in Chapter 3, because peak load and other grid impacts become important as buildings transition to decarbonized systems along with the increasing adoption of electric vehicles (EVs).

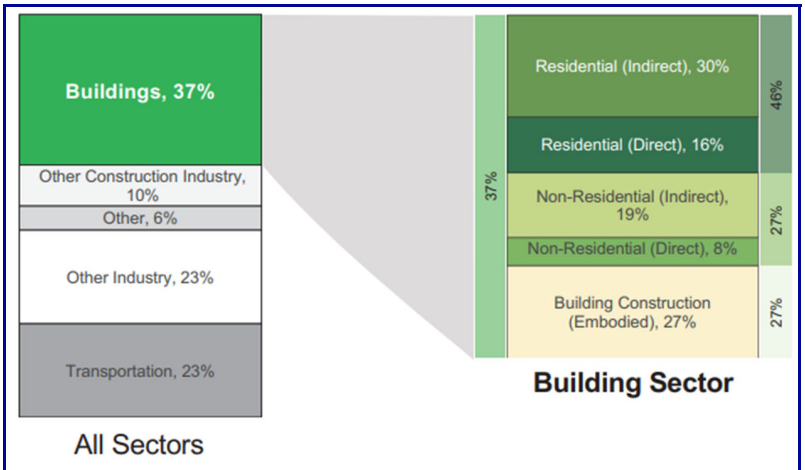
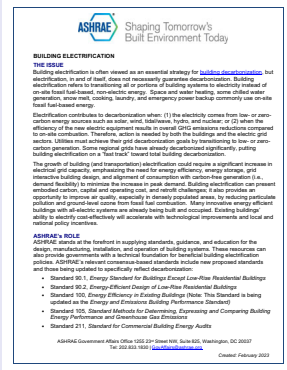


Figure 1.1 Energy-related CO_2 emissions in 2020. (Image credit: ASHRAE 2022a)

1.1.2 What Does Decarbonizing Existing Buildings Mean?

ASHRAE Public Policy Information Brief on Building Electrification


ASHRAE Shaping Tomorrow's Built Environment Today

BUILDING ELECTRIFICATION

THE ISSUE

Building electrification is often viewed as an essential strategy for building decarbonization, but electrification, in and of itself, does not necessarily guarantee decarbonization. Building electrification refers to transitioning all or portions of building systems to electricity instead of on-site fossil fuel-based, non-electric energy. Space and water heating, some chilled water generation, snow melt, cooking, laundry, and emergency power backup commonly use on-site fossil fuel-based energy.

Electrification contributes to decarbonization when: (1) the electricity comes from low- or zero-carbon energy sources such as solar, wind, tide/wave, hydro, and nuclear; or (2) when the efficiency of the new electric equipment results in overall GHG emissions reductions compared to on-site combustion. Therefore, action is needed by both the buildings and the electric grid sectors. Utilities must achieve their grid decarbonization goals by transitioning to low- or zero-carbon generation. Some regional grids have already decarbonized significantly, putting building electrification on a "fast track" toward total building decarbonization.

The growth of building (and transportation) electrification could require a significant increase in electrical grid capacity, emphasizing the need for energy efficiency, energy storage, grid interactive building design, and alignment of consumption with carbon-free generation (i.e., demand flexibility) to minimize the increase in peak demand. Building electrification can present embodied carbon, capital and operating cost, and retrofit challenges; it also provides an opportunity to improve air quality, especially in densely populated areas, by reducing particulate pollution and ground-level ozone from fossil fuel combustion. Many innovative energy efficient buildings with all-electric systems are already being built and occupied. Existing buildings' ability to electrify cost-effectively will accelerate with technological improvements and local and national policy incentives.

ASHRAE's ROLE

ASHRAE stands at the forefront in supplying standards, guidance, and education for the design, manufacturing, installation, and operation of building systems. These resources can also provide governments with a technical foundation for beneficial building electrification policies. ASHRAE's relevant consensus-based standards include new proposed standards and those being updated to specifically reflect decarbonization:

- Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- Standard 90.2, *Energy-Efficient Design of Low-Rise Residential Buildings*
- Standard 100, *Energy Efficiency in Existing Buildings* (Note: This Standard is being updated as the *Energy and Emissions Building Performance Standard*)
- Standard 105, *Standard Methods for Determining, Expressing and Comparing Building Energy Performance and Greenhouse Gas Emissions*
- Standard 211, *Standard for Commercial Building Energy Audits*

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Building electrification is often viewed as an essential strategy for building decarbonization, but electrification, in and of itself, does not necessarily guarantee decarbonization. Existing buildings' ability to electrify cost effectively will accelerate with technological improvements and local and national policy incentives. ASHRAE supports the global need to reduce emissions from buildings, including through beneficial electrification. This public policy information brief (PPIB) outlines the issues and considerations for policy makers regarding building electrification (ASHRAE 2023d).

Decarbonizing an existing building is the process of reducing its carbon emissions through the building's life cycle. Generally, building construction, energy use, methane leakage, and refrigerants are the primary sources of GHG emissions (ASHRAE 2022h). This guide offers mitigation approaches such as building electrification, energy efficiency and demand management, embodied carbon considerations, and more for the various sources of building carbon emissions. Chapter 2 describes what can be found in each chapter and how to use this guide.

1.1.2.1 Types of Carbon in Existing Buildings

There are two types of carbon in existing buildings: operational carbon and embodied carbon. Embodied carbon comes from material extraction, manufacturing processes, transport, refrigerant leakage, and waste processing, while operational carbon is generated as the building uses energy and water during its operations.

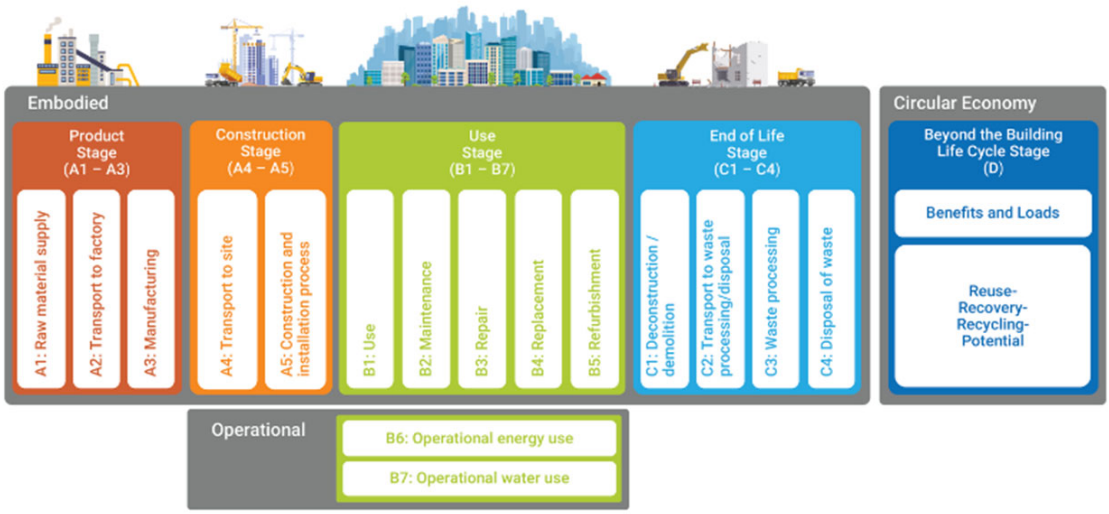


Figure 1.2 Building whole-life carbon stages. (Image credit: P2S Inc., figure based on CEN [2011])

1.1.2.1.1 Embodied Carbon

Significant amounts of a building's emissions occur as embodied carbon during the construction phase, especially for new construction because foundation materials such as steel and concrete have high embodied carbon. For existing buildings, embodied carbon must be accounted for when considering the "in-use" stage of embodied carbon—including refrigerant leakage, equipment, or building systems replacements (such as windows)—because the deconstruction, waste processing, and materials replacement still occur during renovation. Because this guide targets decarbonization of existing buildings, the strategies presented for embodied carbon reduction will focus on use stages B1–B5, including refrigerant leakage, retrofits, and replacements. Tools for calculating a project's embodied carbon and assessing low-emissions materials are outlined in Section 3.3.2 in Chapter 3.

1.1.2.1.2 Operational Carbon

Operational carbon reductions are accomplished through upgrades to the building envelope, lighting, and building systems and through electrification of HVAC, water heating, and appliances. These types of upgrades reduce fossil fuel consumption during building operations, thereby reducing emissions. This emissions reduction can be monitored through regular benchmarking for energy use and energy audits to compare the building's operational carbon over time. Chapter 3 lays out the steps to decarbonizing through renovation and outlines procedures to assess and monitor carbon consumption related to building operations.

1.1.3 Building Decarbonization Strategies and Benefits

There are many ways to decarbonize buildings, from passive envelope retrofits to implementing demand response controls. These different decarbonization approaches fit into six strategies that contribute to emissions reduction in various ways. The six strategies are shown in Figure 1.3. Strategies that are appropriate for a given existing building depend on that building's specific char-

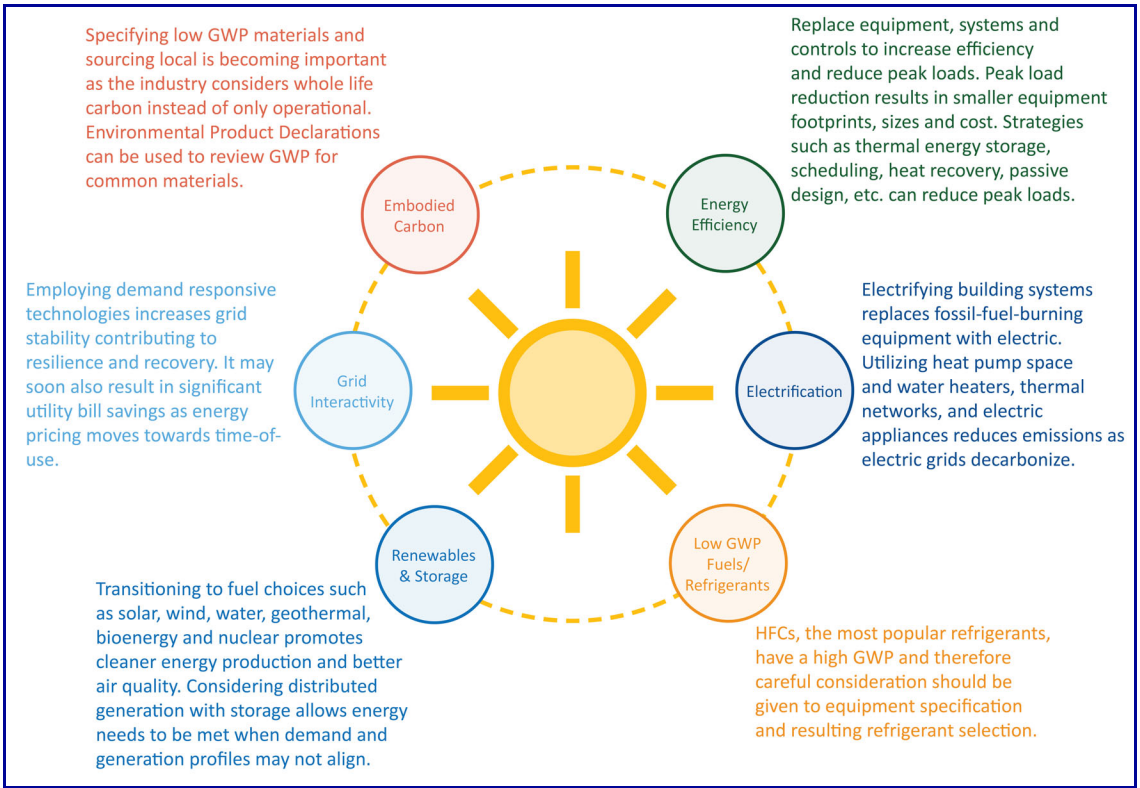


Figure 1.3 Decarbonization strategies. (Image credit: NORESCO)

acteristics. Chapter 3 offers a pathway to identify energy-efficiency measures (EEMs) and emission-reduction measures (ERMs) that employ the strategies summarized here.

Four primary benefits of implementing decarbonization in existing buildings are reduced operating costs, mitigation of climate change impacts, improved occupant health and well-being, and economic benefits for communities.

- **Reduced Operating Costs.** Building operating costs may decrease due to more efficient equipment replacing older equipment, rightsizing building systems, on-site renewable generation, and other conservation measures. Depending on pricing structure, utility costs may also be reduced by limiting consumption during peak hours through peak load-reduction strategies such as passive design, controls, energy storage, and demand response.
- **Mitigation of Climate Change Impacts.** ASHRAE recognizes the need to reduce GHG emissions from existing buildings to mitigate the impacts of climate change including climate-caused disasters and displacements. Extreme heat for prolonged periods, intensifying storms, and unhealthy air quality are some of the impacts we are experiencing; these have outsized consequences for front-line community members.
- **Improved Occupant Health and Well-Being.** Well-designed decarbonized building systems promote increased indoor air quality (IAQ) through weatherization, proper ventilation, and the elimination of nitrogen dioxide, carbon monoxide, and other chemical emissions generated on-site. Existing building upgrades are also an

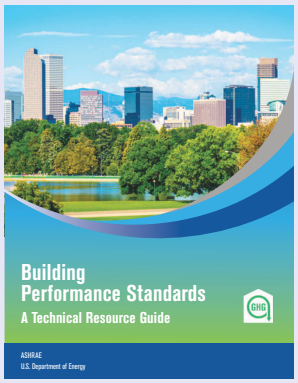
opportunity to increase occupant comfort through HVAC control strategies, daylighting and glare mitigation, etc.

- **Community Economic Benefits.** Significant investments are being made to grow a workforce skilled in building decarbonization. Design consultants, contractors, building officials, and facility managers are just a few of the roles that will require new skills and increased numbers to meet the demands of emerging decarbonization policy. The need for an upskilled and increased workforce may result in a greater number of higher-quality jobs. Climate-related disasters and mitigation are also a significant cost to communities. Disaster-related recovery costs often result in the displacement of community members.

1.2 Existing Building Decarbonization in Building Codes and Ordinances

Building energy codes have focused primarily on reducing energy consumption for new construction buildings and major renovations and on addressing alterations when equipment or building components are replaced by the building owner. However, a growing number of jurisdictions, such as Denver, New York City, Vancouver, and the State of Washington, have realized that existing building decarbonization must be part of the strategy to meet their emissions reduction goals. As a result, ordinances have become increasingly popular requiring existing building owners to report their consumption through building benchmarking and, in some instances, reduce it through building performance standards (BPS). ASHRAE has created a companion guide on building performance standards to address the policy aspect of achieving existing building decarbonization.

Building Performance Standards: A Technical Resource Guide



This guide is intended to provide a technical basis and resources to policy makers, building owners, facility managers, design professionals, and ASHRAE members when developing and implementing building performance standards (BPS) (ASHRAE 2023g). The guide focuses on larger building types and scope of BPS as developed by leading U.S. cities and states. The guide covers BPS aimed at reducing building operating energy use and resulting emissions and does not cover embodied energy or carbon, which are addressed by the *Whole-Life Carbon Guide for Building Systems*.