

Whole Life Carbon Guide for Building Systems

ASHRAE

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This publication was prepared under the auspices of ASHRAE's Center of Excellence for Building Decarbonization (CEBD).

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Contents

1 INTRODUCTION 1

1.1 Background 1
1.2 Purpose 2
1.3 Scope of this Document 2
1.4 Specific Roles in Reducing Greenhouse Gas Emissions of Mechanical, Electrical, and Plumbing Systems 2

2 LIFE-CYCLE GREENHOUSE GAS ASSESSMENT 5

2.1 Global Warming Potential 5
2.2 Life-Cycle Assessment 5
2.3 Whole Building Life-Cycle Assessment 5
2.4 Environmental Product Declarations and Mechanical, Electrical, and Plumbing 8
2.5 Impacts of Electricity Grid Greenhouse Gas Emissions 9
2.6 Impacts of Transportation 11
2.7 Uncertainty Analysis 12

3 MECHANICAL, ELECTRICAL, AND PLUMBING CONTRIBUTIONS TO BUILDING WHOLE LIFE GREENHOUSE GAS EMISSIONS 15

3.1 Embodied Greenhouse Gas Emissions for Mechanical, Electrical, and Plumbing Systems 16
3.2 Operational Greenhouse Gas Emissions for Mechanical, Electrical, and Plumbing Systems 19
3.3 Balance Between Embodied and Operational Greenhouse Gas Emissions 19

4 DESIGN OF HIGH-PERFORMANCE, LOW GLOBAL WARMING POTENTIAL MECHANICAL, ELECTRICAL, AND PLUMBING SYSTEMS 21

4.1 Mechanical Systems 22
4.1.1 Building Enclosure and HVAC Optimization 22
4.1.2 HVAC System Selection 23
4.1.3 High-Efficiency and Right-Sized Equipment 23

4.1.4 Energy Recovery Systems 23
4.1.5 Relationship Between Supply Air Temperature and HVAC System Size 24
4.1.6 Ducts, Piping, and Conduits 25
4.1.7 Low-Global Warming Potential Refrigerants and Operational Impacts 27
4.2 Electrical Systems 30
4.2.1 Lighting 30
4.3 Plumbing Systems 31
4.4 On-Site Renewable Energy Systems 32
4.4.1 Electrical Energy Storage 32
4.4.2 Thermal Energy Storage 33

5 BEST CONSTRUCTION PRACTICES FOR LOW GREENHOUSE GAS EMISSIONS 35

5.1 Energy to Construct the Project 35
5.2 Transportation Energy 36
5.3 Temporary Facilities 36
5.4 Waste Materials 36

6 OPERATING MECHANICAL, ELECTRICAL, AND PLUMBING SYSTEMS TO REDUCE GREENHOUSE GAS EMISSIONS 39

6.1 Importance of Controls 40
6.1.1 Demand Control 40
6.1.2 Smart Controllers and Sensors 41
6.1.3 Artificial-Intelligence-Driven Equipment 41
6.2 In-Use Stage Carbon Audits 42
6.3 Maintenance Impacts on Greenhouse Gas Emissions 43
6.4 System Replacements 43

7 CIRCULARITY AND END OF LIFE 45

7.1 Design Considerations 45
7.2 Recovery, Reuse, and Recycling 46
7.3 Circular Economy Business Models 46

8 CONCLUSION 47

Appendix A: Additional Resources 49

ANSI/ASHRAE/IES Standard 90.1-2022, *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* 51
ANSI/ASHRAE/IES Standard 90.2-2024, *Energy-Efficient Design of Low-Rise Residential Buildings* 51
ANSI/ASHRAE Standard 105-2021, *Standard Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions* 52
ANSI/ASHRAE/ICC/USGBC/IES Standard 189.3-2021, *Standard for the Design, Construction, and Operation of Sustainable High-Performance Health Care Facilities* 52
ANSI/ASHRAE/ACCA Standard 211-2018 (RA2023), *Standard for Commercial Building Energy Audits* 52
ANSI/ASHRAE Standard 228-2023, *Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance* 53

BSR/ASHRAE/ICC Standard 240, *Quantification of Life Cycle Greenhouse Gas Emissions in Buildings* 53
ASHRAE Standard 242, *Standard Method for Calculation of Building Operational Greenhouse Gas Emissions* 53
ASHRAE Standard 244, *Sustainability Assessment for Mechanical, Electrical, and Plumbing Products* 54
IgCC/189.1, International Green Construction Code® powered by ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings* 54
A.1 Summary of Life-Cycle Assessment Standards 54

Appendix B: Environmental Product Declarations and Life-Cycle Data Sources 55

Appendix C: Embodied Carbon and Life-Cycle Assessment Tools 57

Glossary 63

References 65

1

Introduction

1.1 Background

According to the *ASHRAE Position Document on Building Decarbonization*, by 2030, the global built environment must halve its 2015 greenhouse gas (GHG) emissions (ASHRAE 2024). This requires that all new buildings must have net-zero GHG operational emissions, widespread energy-efficiency retrofits of existing assets must be well underway, and embodied carbon in new construction must be reduced by at least 40% compared to 2015 levels. In addition, by 2050 at the latest, all new and existing assets must have net-zero GHG emissions across the entire building life cycle.

Meeting these targets requires accounting for the whole life GHG emissions of buildings and building systems rather than only the operational carbon emissions. *Whole Life Carbon Guide for Building Systems* examines the impacts of mechanical, electrical, and plumbing (MEP) systems and how their design, operation, maintenance, replacement, and end-of-life treatment contribute to GHG emissions. Properly functioning MEP systems are essential to ensure the comfort, health, and productivity of occupants as well as the efficient operation of buildings. MEP systems impact both the amount of energy consumed to operate the building and the embodied carbon emissions of buildings. Operational emissions include Scope 1 emissions from on-site fuel combustion and Scope 2 emissions from purchased energy. Embodied emissions include the total GHG emissions resulting from the manufacturing, transportation, installation, maintenance, and disposal of a material or product.

Carbon emissions and *GHG emissions* are often used interchangeably in publications. In this guide, the term *GHG emissions* is predominately used because it comprises all GHGs, not just carbon emissions (see the Glossary for the definition of *GHG emissions*). Carbon dioxide (CO_2) is the most abundant GHG, and all GHGs are accounted for by equating the global warming impact to CO_2 (see the Glossary for the definition of *global warming potential [GWP]*). *Carbon* is a convenient shortened version that is commonly used when referring to CO_2 and other GHGs.

The choice of MEP systems affects the embodied carbon emissions in building construction, the potential lifetime maintenance and replacement embodied emissions, and the long-term operational carbon emissions. Meeting current owner and occupant wants and needs and anticipating how future regulations—building performance standards, for example—could impact a building's operation requires careful consideration and planning.

The buildings industry is well-practiced at designing and constructing MEP systems that meet building performance requirements while also reducing operational energy consumption. However, limited data and little design guidance are available to quantify and reduce the GHG emissions associated with the entire life cycle of MEP systems. Whole life GHG emissions include the embodied carbon emissions

associated with the extraction, transportation, and manufacturing of building materials and products as well as building construction; operational carbon emissions associated with energy consumption, refrigerant and other relevant GHG leaks, and maintenance and repair; and end-of-life carbon emissions or credits from building demolition, recycling, and disposal. Recent studies have shown that the embodied GHG emissions from MEP systems can be between 10% and 39% of the total building embodied emissions and even higher if photovoltaic (PV) systems are included on the building (see Table 4.2, "Mechanical, Electrical, and Plumbing Embodied Carbon Emission Impacts by Study" in Chapter 4).

Reducing the whole life GHG emissions of MEP, architectural, and structural systems requires striking a balance between addressing those systems' embodied and operational GHG emissions. The lack of guidance, reliable and comparable data, and integrated design tools can make balancing emissions from embodied and operational activities challenging. This guide provides the definitions, concepts, and guidance needed to calculate, interpret, and integrate life-cycle data from multiple sources to design MEP systems with lower whole life GHG emissions. This guide assumes that all local regulations will be followed, and the recommendations apply only to projects for which the concepts are legally allowed.

1.2 Purpose

Whole Life Carbon Guide for Building Systems provides the relevant background and practical guidance for building engineers, designers, consultants, operators, and owners to understand and reduce the whole life GHG emissions and other environmental impacts of MEP systems. In this guide, readers will find clear definitions of relevant terms, an introduction to life-cycle assessment, and a description of the roles and responsibilities for designing, operating, and maintaining MEP systems to reduce whole life GHG emissions and environmental impacts. This guide applies to building types covered by ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* (ASHRAE 2022) and ANSI/ASHRAE/IES Standard 90.2, *High-Performance Energy Design of Residential Buildings* (ASHRAE 2024a). This document is not intended to replace code compliance with any authorities having jurisdiction (AHJ).

1.3 Scope of this Document

The definitions and information included in this guide can help guide the design, operation, and maintenance of building MEP systems, focusing on reducing energy consumption and the associated GHG emissions and embodied emissions during the systems' lives. It is not intended to provide calculation or estimation methods to determine these systems' energy consumption or GHG emissions. Additionally, it is not a performance standard, nor does it set performance targets.

In this guide, MEP systems include mechanical, electrical, and plumbing systems, as well as information technology (IT), security, fire alarm, building automation systems (BASs), and other extra-low-voltage systems. However, many of the results and references presented in this guide only apply to MEP systems because these systems have the largest impacts and have more industry references. Readers should be aware of the scope of the different references presented in this guide when comparing results.

1.4 Specific Roles in Reducing Greenhouse Gas Emissions of Mechanical, Electrical, and Plumbing Systems

All parties involved in building design, construction, and operation play a role in reducing GHG emissions over the life of a building's MEP systems. Owners, designers, contractors, opera-

tions teams, and occupants each have a unique set of responsibilities to minimize emissions from MEP systems.

An important first step is for owners and owner representatives to initiate the process of setting and committing to performance goals. The more specific these goals are, the easier it will be to communicate, track, and achieve them. Goals that state specific emissions and energy consumption levels are best, such as an operational energy target of 25 kBtu/ft^2/y (79 kWh/m^2/y) and zero annual GHG emissions. In addition to setting the goals, the owner or owner representative should communicate these goals to all parties involved with the project, establish a method to measure and track performance toward the goals, and hold all parties accountable to ensure the team achieves the goals.

The building design team is responsible for developing designs that meet, exceed, or find the best balance among the performance goals set by the owner. The design team should evaluate the performance goals and present the owner with a range of cost-effective solutions. Developing low-carbon-intensive buildings starts with considering how all aspects of the design will impact the embodied and operational GHG emissions. The design team must make design choices that balance whole life carbon, project budget, and other owner priorities. It is also crucial for the design team to balance system complexity with operational and maintenance requirements and the ability to maintain long-term performance.

Building contractors are responsible for constructing the building and its systems so that the end product meets or exceeds the performance requirements in the design specifications. The contractor must follow best practices for reducing, measuring, and reporting carbon emissions and waste associated with the construction process. The contractor should coordinate with the building owner and the design team when issues arise that could result in deviations from the owner's and/or designer's goals that might impact project performance. Refrigeration and heating, ventilating, and air-conditioning (HVAC) systems that require field-installed refrigerant lines and system charging should be carefully installed and tested to ensure system integrity and minimal refrigerant leakage.

Commissioning authorities, building operators, and maintenance workers inspect and interact with all building systems and ensure they are installed, set up, and operate as designed. High-performance systems may require nonstandard start-up procedures and sequences of operation that require additional time, expertise, and ongoing commissioning. Preventative and corrective maintenance of systems containing refrigerants must be performed to minimize refrigerant leaks, which are a potentially large source of GHG emissions.