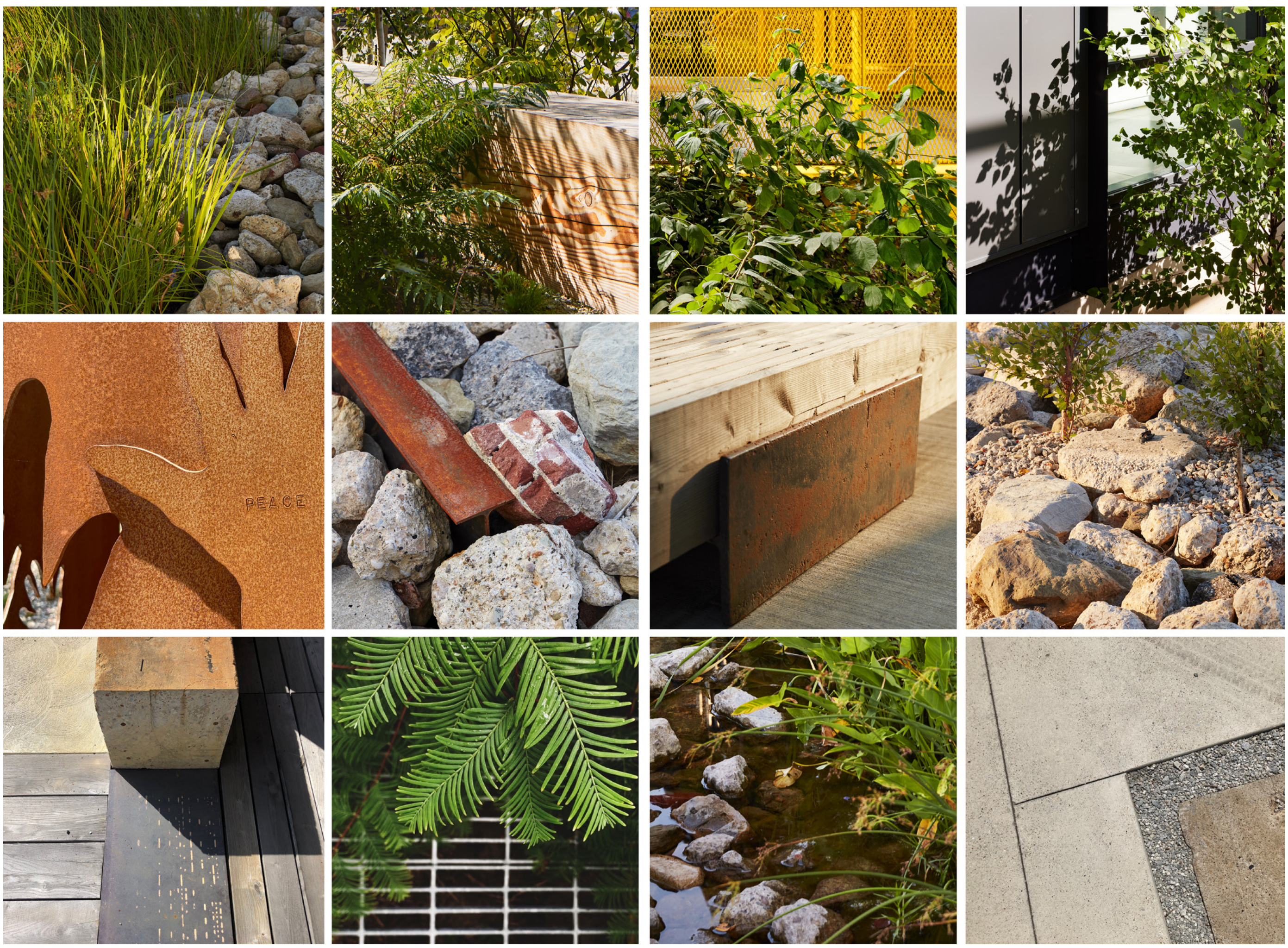
LANDSCAPE ARCHITECTURE 2040

Guide to Site Carbon Assessment v1



ASLA 2025 Professional General Design Honor Award. Mill 19: A Catalytic Postindustrial Landscape. Pittsburgh, Pennsylvania
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American Society of Landscape Architects

ASLA Fund

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Content Disclaimer

The subjects addressed in this guide are evolving. This document was developed by experts, practitioners, and researchers with the intention of providing the best recommendations available at the time of publication. We refer to existing research and standards for Life Cycle Assessments (LCA), site carbon assessment (SCA), biogenic product and landscape carbon storage modeling when applicable.

Estimation and reporting of biogenic product and landscape carbon storage are not well-quantified or standardized across the industry. As such, portions of this guidance document propose novel methods for measuring and reporting aspects of site-related carbon burdens and benefits that are not standardized across the industry.

To address this, this document is intended to be updated periodically as methods evolve and emerging research and refreshed standards incorporate the complexities of measuring and tracking site scope for whole life carbon.

EXECUTIVE SUMMARY

Landscape Architecture 2040: ASLA Climate & Biodiversity Action Plan, released in 2025, advances ambitious goals for site design professionals to reduce emissions 50-65 percent by 2030 and achieve zero emissions and double carbon sequestration by 2040. Progress toward these goals can be tracked, but only if project site emissions and landscape carbon storage are measured with similar methods.

Landscape Architecture 2040: Guide to Site Carbon Assessment, v1 was developed to standardize an industry approach to site carbon assessments (SCA).

This guide does not address any other environmental impact categories outside of GWP, which is why it is entitled site carbon assessment (SCA), not site Life Cycle Assessment (sLCA). The quantification of whole life site carbon measures embodied emissions, operational emissions, and landscape carbon storage of sites across a standardized system boundary. This boundary represents the physical, process, temporal, and geographical limits of what is included and not included in an assessment. (ISO 21931-2:2019[en]).

This guide is intended to be used by practitioners to gather, document, and quantify information about the total emissions and carbon storage of site projects in a unified way. This carbon assessment guidance for sites was also created with the intention of aligning with similar decarbonization efforts and commitments in our allied professions of planning, architecture, civil, mechanical, electrical, plumbing, and structural engineering.

Whole Life Carbon & Life Cycle Stages

According to leading whole life cycle carbon assessment standards, such as RICS Whole Life Carbon Assessment 2nd Edition and draft standard ASHRAE/ICC 240P, a whole life carbon assessments should, at a minimum, include:

- *Product Stage and Construction Stage* emissions from the manufacturing and transport of materials, and construction processes (life cycle phases A1-A5).
- *In-Use Stage* emissions from operating the energy and water needs of the site as well as site maintenance and refurbishment activities and products (B1-B7).
- *End-of-Life Stage* emissions from deconstructing the site and transporting materials to waste or recycling facilities (C1-C4).

Additionally, this guide proposes a **new** site-related whole life carbon assessment phase:

- (B9) Landscape Carbon Storage, which captures the landscape carbon storage from existing and proposed vegetation and soils in the In-Use Stage (B) to better represent the active carbon storage throughout the life of the project.

Methods and Pathways of Site Carbon Assessment

The guide offers methods for site carbon assessment (SCA) and provides three carbon assessment pathways. The pathways include different life cycle stages and assess different scopes of site elements (See Table 2.3):

Pathway 1: Carbon Assessment Lite is a simplified approach to a site carbon assessment. It includes only priority site scope elements indicated in Table 2.2 and requirements to measure impacts from the Product stage (A1-A3) and Construction stage (A4-A5). (See Chapter 3 and 5 for more detail).

Pathway 2: Simple Carbon Assessment expands past the priority elements and includes all site elements in Table 2.1, measuring impacts across the Product stage (A1-A3), Construction stage (A4-A5), Maintenance (B2), Replacement (B4) and Landscape Carbon Storage (B9). (See Chapters 3-5 for more detail).

Pathway 3: Whole Life Carbon Assessment includes all site elements and life cycle stages in the Simple Carbon Assessment in addition to the End of Life Stage (C1-C4).

Measuring Embodied Carbon Emissions

Embodied carbon emissions appear throughout the life cycle of the project. Estimating upfront embodied carbon emissions involves tracking materials required for design and construction in order to assess the emissions from their production and transport. This includes emissions from the raw material extraction needed, manufacturing, and the transport between these points and the site.

Embodied carbon emissions also result from the Use Stage and the End of Life Stage of the project. It is important to note that estimating Use Stage and End of Life Stage carbon emissions during the design phase requires assumptions about maintenance techniques, frequency and equipment, as well as service life of materials (Appendix III), and eventual demolition and waste processing.

Site elements such as pavements, walls, and drainage structures, are organized by layering ISO 12006.2-compliant classifications with practice knowledge about how these elements are typically documented and detailed for construction. Typical assembly components are listed for each element to aid full and consistent assessment of the element's embodied carbon emissions. Measuring the quantity, volume, area, and/or mass of each component and documenting assumptions for each element in a well-organized manner is critical to carbon assessment. A Material Quantities and Takeoffs template is provided for this purpose in Appendix II.

Estimating Operational Carbon Emissions

Operational carbon emissions occur across the service life of the site to power lighting and site equipment such as fountain pumps, transformers, and controllers. They also occur from the energy used to clean and convey water for site functions, such as water features, irrigation, and site maintenance water.

To estimate operational carbon emissions during the design phase, assumptions are made about the types of fixtures and equipment for a site, the amount of time they will be used, and the fuel sources of the power used for each type. Quantities and sources of water are also estimated as the basis for quantifying the emissions associated with that water supply.

Estimating Landscape Carbon Storage

Estimating landscape carbon storage over time from existing and proposed vegetation and soils on a site in the context of project design and construction has not been standardized or developed in previous documentation in the same capacity that measuring embodied or operational emissions has been.

Sequestration and storage rates of living plants are projected and depend on plant health and environmental conditions. Plant mortality, disease, disturbance, or removal can occur throughout the project's service life, impacting estimated landscape carbon storage while stocks of soil organic carbon (SOC) can be impacted during site construction.

This document only provides estimated average carbon storage values (kgCO2e/m2) for mature ecosystems, inclusive of SOC. This data comes from the Carbon Conscience dataset which was developed through aggregated literature review, mostly based on FAO global ecological zones (FAO 2001) and urban coverage studies by (Nowak et al., 2013).

All other projected values for new vegetation will need to be calculated directly in tools such as iTree, Pathfinder, Carbon Conscience, or C.Scale or derived from peer-reviewed research. Landscape carbon storage (B9) can be estimated through two approaches:

- Via individual plants through Net Primary Productivity (NPP), which is the total carbon stored after probable respiration and decay
- Via land cover, which often combines both carbon storage and soil organic carbon (SOC).

It is important to note that different tools can take a different approach to these estimations and don't always include carbon storage captured in SOC which should be considered when reviewing projected values.

Currently, embodied and operational emissions far outweigh the landscape carbon storage potential of vegetation and soils. But as lower carbon materials are increasingly used and site maintenance activities move away from the "mow and blow" paradigm, it is possible that landscape carbon storage could equal or surpass emissions after a few decades of the site vegetation's carbon storage.

Biobased Materials and Products

Carbon is also stored in biobased construction materials, such as lumber and decking. This biogenic carbon is referenced as Product Carbon Storage in this document and should be accounted for and reported separately from embodied and operational carbon as well as landscape carbon storage.

Tools and Certifications for Carbon Assessment

Conducting a site carbon assessment can be performed using tools such as Pathfinder, Carbon Conscience, C Scale, or One Click LCA Infrastructure. These tools are evolving as new data and standards emerge. More information about them can be found in Chapter 6. Carbon assessment can also be done "manually" using carbon factors found in Environmental Product Declarations (EPDs), or using data sourced from resources such as the Carbon Leadership Forum Material Baselines or Building Transparency's EC3 tool.

Sustainability certification programs such as SITES, LEED, Living Future Zero Carbon Certification, and Envision are increasingly addressing carbon impacts in the built environment. Most encourage emissions reduction practices and site carbon assessment, while only SITES addresses landscape carbon storage. As of September 2026, none currently require reporting of site operational emissions.

Looking Ahead to 2040

The climate goal of Landscape Architecture 2040: ASLA Climate & Biodiversity Action Plan asks the landscape architecture community to reduce greenhouse gas emissions from projects by 50–65 percent by 2030 and double carbon sequestration and achieve zero emissions by 2040.

To achieve these ambitious goals, landscape architects will need to commit to reducing greenhouse gas emissions and increasing landscape carbon storage of their built landscapes. They must also commit to assessing the biodiversity of their projects.

The American Society of Landscape Architects (ASLA) is developing a program that will enable landscape architects and allied professionals to commit to reduced emissions, increased landscape carbon storage, and improved biodiversity. Landscape Architecture 2040: Guide to Site Carbon Assessment, v1 along with a forthcoming guide on assessing site biodiversity to support the development of this commitment program.

The first step in the program is a national carbon benchmark pilot and then full benchmarking study to gather and compare carbon data across multiple sites. The benchmarking efforts will use this guide as a foundation along with parameters set by forthcoming benchmark study methods. The study will aim to reveal data trends about the climate impacts of sites and provide practitioners with an initial set of reference numbers from which to decarbonize from.

Appendices

This document contains three appendices that provide additional information not included in the main body of the document. Appendix I provides resources for more information. Appendix II is a material quantities and take off template for tracking the quantities and embodied, operational and sequestered carbon of site materials and activities. Appendix III provides replacement factors for common site materials to supplement assumptions being made for life cycle phase B4.

HOW TO NAVIGATE THIS GUIDE

This document is organized into eight chapters within four major sections; *Introduction, Methods, Guidance, and Reference*. These sections contextualize how chapters are framed, and are intended to provide the reader greater clarity when navigating this document.

Introduction

- Executive Summary summarizes the guide and contextualizes the progression of climate & biodiversity action within ASLA. It outlines the steps that led to the creation of this guide and queues the next steps.
- How To Navigate This Guide orients the user and expands on the organization of the sections, chapters, and appendices.

Methods

- Chapter 1: Introduction to Whole Life Carbon defines key terms and concepts, places site design impacts in their respective life cycle stages, and layers recommendations to address and track them, depending on the method of carbon calculation pursued.
- Chapter 2: Defining & Managing a Site Carbon Assessment defines the scope and standard criteria for a site carbon assessment, providing methods for setting an assessment boundary, conducting quantity takeoffs, and sourcing carbon data. Multiple assessment pathways are offered based on project data resolution.

Guidance

- Chapter 3: Measuring Embodied Carbon Emissions provides methods for measuring the embodied carbon emissions of site materials and products, along with embodied carbon from construction and maintenance activities.
- Chapter 4: Estimating Operational Carbon Emissions provides guidance for measuring the estimated operational carbon emissions of a site, such as lighting, equipment, energy use, and emissions from water treatment for irrigation and water features.
- Chapter 5: Estimating Landscape Carbon Storage and Product Carbon Storage provides guidance for measuring the estimated landscape carbon storage potential of living plant material, and product carbon storage of biobased products.

Reference

- Chapter 6: State of the Tools reviews the current state of carbon assessment tools available to site designers.
- Chapter 7: Sustainability Certification Programs discusses sustainability certifications and how they incorporate site-focused carbon metrics.
- Chapter 8: Looking Ahead to LA 2040 discusses future efforts under the LA2040: ASLA Climate & Biodiversity Action Plan, including the planned LA2040 Commitment Program and an upcoming carbon assessment benchmarking effort.

Step-by-Step: How to Use This Guide

This guide is a framework for assessing and estimating whole life carbon for sites. It includes guidance for tracking both hardscape and softscape, as well as site prep and earthwork. It is very important to keep track of assumptions made about materials, processes, exclusions, and operations.

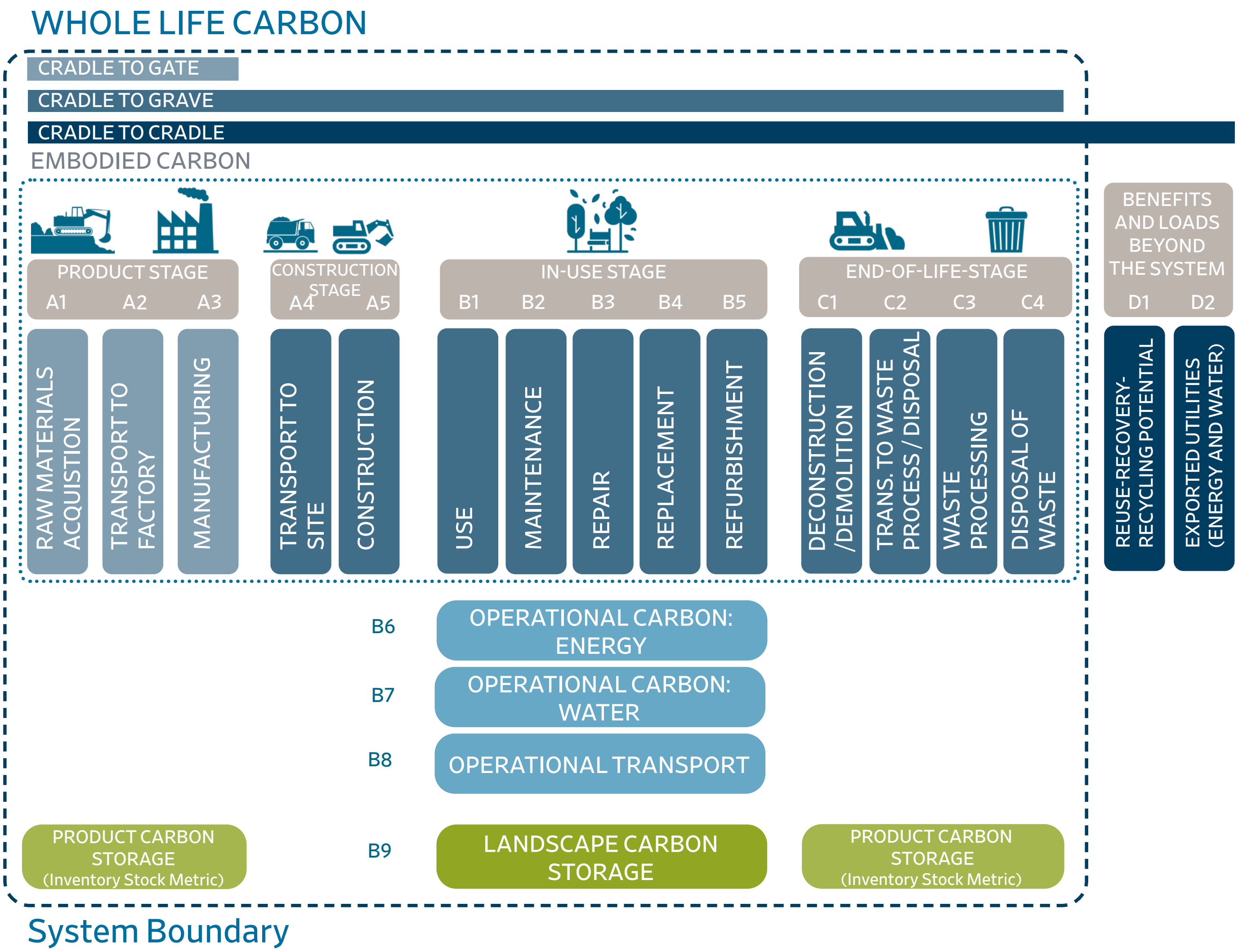
1. Review this guide in full
2. Use Table 2.3 to establish a Site Carbon Assessment Pathway to pursue
3. Identify and measure applicable site elements to assess their embodied carbon (See Chapter 3: Measuring Embodied Carbon Emissions.)
4. Identify and measure applicable site elements to assess their operational carbon (See Chapter 4: Measuring Operational Carbon Emissions.)
5. Identify and measure applicable vegetation, soils, and biobased products to assess their landscape and product carbon storage (See Chapter 5: Estimating Landscape Carbon Storage and Product Carbon Storage.)
6. Input measurements of Site Elements, Vegetation, and Soils into a carbon assessment tool (See Chapter 6: State of the Tools). Or reference the carbon data hierarchy discussed in Chapter 2 to identify carbon factors for project materials and products in order to conduct manual calculations.
7. Determine the carbon impact of a site project. Track total embodied and operational carbon emissions together, and landscape carbon storage and product carbon storage separately.

CHAPTER 1

Introduction to Whole Life Carbon

ASLA 2026 Professional
General Design Honor Award.
Gathering Place. Tulsa, Oklahoma.
Michael Van Valkenburgh
Associates / Elizabeth Felicella

A site's whole life carbon includes the embodied and operational greenhouse gas (GHG) emissions and removals over its entire life cycle (Figure 1.1). Carbon assessments apply the principles of a Life Cycle Assessment (LCA) with a sole focus on greenhouse gas (GHG) emissions. LCAs can be used to assess a variety of impact categories, including global warming potential (GWP), as defined by ISO 21930, EN 15804, and EN 15978.



Embodied Carbon Emissions are the greenhouse gas (GHG) emissions generated by the raw material extraction, manufacturing, transportation, installation, maintenance, and disposal of construction materials and equipment (CLF). In the context of this guide, this refers to emissions from materials, processes for constructing and maintaining sites, and end of life scenarios.

Emissions are expressed in **carbon dioxide equivalents (CO_2e)**, a standardized metric used to convert the global warming potential of all greenhouse gases, such as methane or nitrous oxide, into a single unit based on the equivalent global warming potential of carbon dioxide.

Operational Carbon Emissions are the greenhouse gas emissions generated by the day-to-day energy and water used to operate an asset over its lifecycle (CLF). For sites and landscapes, these may include emissions from powering site equipment, such as lights and controllers, and electricity used to clean and convey water. Operational carbon emissions result from electricity produced offsite and equipment on the site (See Chapter 4 for more).

Biological Carbon Sequestration is the process of atmospheric CO_2 being taken up by trees, grasses, and other plants through photosynthesis. It is stored carbon once it is permanently fixed in the cells of biomass (trunks, branches, foliage, and roots) and soils (USDA). About one third of carbon is stored above ground in plants and two-thirds is stored in the soil, plant roots, decaying material, and fossil fuels (NASA).

Sequestered carbon becomes **stored carbon** the moment the captured carbon is locked away in a stable biological, geological, or technological sink. Stored carbon contributes to the mitigation of climate change by reducing the amount of greenhouse gases in the atmosphere (USDA).

Landscape Carbon Storage represents the stored biogenic carbon in both existing and new plants and soil (USDA). This scope is to be tracked and reported in the newly proposed phase B9 Landscape Carbon Storage (See Chapter 5 for more).

Product Carbon Storage refers to the stored biogenic carbon in construction materials produced from biological materials (OneClick LCA). This biogenic carbon is stored until the product decays or burns.

Life Cycle Stages

Life Cycle Assessment frameworks, stages, and requirements are defined by ISO 14040: 2006 Life Cycle Assessment and ISO 14044: 2006 Environmental Management.

Life Cycle Assessment (LCA) is a systematic set of procedures for compiling and evaluating the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a product or process throughout its life cycle. LCA can measure a wide variety of environmental impacts — from greenhouse gas emissions to acidification and eutrophication. This guide is focused on greenhouse gas (GHG) emissions and carbon storage only, but follows LCA life cycle stages and phases.

The forthcoming ASHRAE/ICC240p will offer methods for calculating the carbon impacts of each life cycle stage, and data gaps around the Construction Stage (A4-A5), Use Stage (B1-B5), and End of Life Stages (C1-C4). This ASHRAE publication will provide the architecture, engineering, and construction (AEC) industry with a primary measurement standard for evaluating and reporting greenhouse gas (GHG) emissions for building construction in North America.

Life Cycle Stages are grouped into the five categories below, and Table 1.1 provides common site-related CO2e emissions (+) and carbon sinks (-) according to each stage and phase. Readers can refer to this table to verify they are measuring the appropriate emissions and removals, and locating them in the correct life cycle phase.

- The Product Stage (A1-A3)
- The Construction Stage (A4-A5)
- The In-Use Stage (B1-B8)
- The End-of-Life Stage (C1-C4)
- Benefits and Loads Beyond the System Boundary (D1-D2). These emissions and sinks are beyond the system boundary and if calculated, must always be reported separately from A-C results.

Due to a lack of standards for placing landscape carbon storage estimations of on-site vegetation in a specific life cycle stage, this guide tracks them in the Use Stage, phase B9, which is a new life cycle stage outside of ISO standards, being proposed by this guide.

Table 1.1 Common CO_2e Emissions and Removals by Life Cycle Stages

STAGES AND PHASES	COMMON EXAMPLES OF CO_2e EMISSIONS (+) OR CARBON SINKS (-)	NOTES
Product Stage		
A1 Raw Materials Acquisition	(+) Emissions from raw material extraction (+) Biogenic carbon released from removal of soil and vegetative cover from extraction of raw materials (-) Product carbon storage	Referred to as "Cradle to Gate." Required in ISO 21930:2017 Refer to Chapter 3: Measuring Embodied Carbon Emissions
A2 Transport	(+) Emissions from transporting raw materials to the manufacturing site	
A3 Manufacturing	(+) Process emissions from chemical conversion of fossil-based materials during manufacturing	
Construction Stage		
A4 Transport to Site	(+) Emissions from transportation to construction site	Phases A1-A5 are referred to as "Upfront Carbon." Refer to Table 3.13 for carbon factors of transportation
A5 Construction A5.1 Pre-Construction Activities A5.2 Construction A5.3 Waste Management	(+) Emissions from pre-construction demolition or staging (A5.1) (+) Biogenic carbon released during site demolition, prep, or construction activities, including clearing existing site vegetation and soil disturbance from grubbing and grading (A5.1) (+) Emissions from use of construction equipment and activities on site (A5.2) (+) Emissions from construction waste offhaul and processing (A5.3)	

STAGES AND PHASES	COMMON EXAMPLES OF CO_2e EMISSIONS (+) OR CARBON SINKS (-)	NOTES
Use Stage		
B1 Use		Emissions from operating the site are included in phases B6 and B7
B2 Maintenance	(+) Emissions from powering equipment to maintain the site (+) Emissions from cleaning and conveying water used to maintain the site (+) Emissions from maintenance products such as fertilizers, pesticides, herbicides, and cleaners (+) Emissions from nitrogen fertilizer breakdown that is not absorbed by plants (+) Emissions from methane released from landfilled trimmings and green waste (+) Emissions from composted trimmings and green waste	Refer to Chapter 3: Measuring Embodied Carbon Emissions
B3 Repairs	(+) Emissions from materials to repair and refurbish site elements	
B4 Replacement	(+) Emissions from the production and transportation of replacement materials and components	
B5 Refurbishment	(+) Emissions from materials to refurbish site elements	
B6 Operational Energy Use	(+) Emissions from operating light fixtures, transformers, pumps, sensors, controllers and other equipment (B6)	Refer to Chapter 4: Measuring Operational Carbon Emissions
B7 Operational Water Use	(+) Emissions from treating and conveying operational water use for irrigation, water features, and maintenance (B7)	
B8 Users Activities		
B9 Landscape Carbon Storage	(-) Landscape carbon storage in vegetation and soils on site (B9)	Refer to Chapter 5: Estimating Landscape Carbon Storage and Product Carbon Storage
End-of-Life Stage		
C1 Deconstruction/ Demolition	(+) Emissions from machinery and and equipment used to demolish or deconstruct the site	
C2 Transportation to Waste Processing	(+) Emissions from transportation of waste materials to processing	
C3 Waste Processing	(+) Emissions from waste processing machinery	
C4 Disposal of Waste	(+) Product carbon storage released from biobased products at disposal, incineration, or decay (on-site or off site) (+) Emissions from pretreating waste and managing the landfill site.	Product carbon stored in biobased construction products is released in phase C4, per EN 15804+A2 (2019), even if the biobased product is salvaged for use on another site of building

Benefits and Loads Beyond the System Boundary		
D1 Reuse, Recovery, and Recycling Potential Stage	(-) *Reuse, recovery and recycling*	Carbon impacts in this stage are considered supplementary information because the reuse, recovery, and recycling benefits are part of another site or building and its system boundary. Refer to Table 3.12: Measuring Material and Asset Reuse
D2 Exported Utilities (Energy and Water)	(-) *Onsite energy production from solar, wind, heat pumps or geothermal sources*	

Benefits and Loads Beyond the System Boundary (D Stage)
This methodology does not include Module D Potential Benefits and Loads Beyond the System Boundary, such as material reuse, recycling, energy recovery (D1) or benefits of exported utilities, such as on site renewable energy generation or on-site water treatment (D2).

New to Carbon Assessment? Here's where to start!

Understanding and offsetting the carbon impacts of our built landscapes is key to meeting the goals of the Landscape Architecture 2040: ASLA Climate & Biodiversity Action Plan. If you are new to this practice, these resources will help you get started:

- AIA CLF Embodied Carbon Toolkit for Architects provides an overview and steps to reduce embodied carbon in the built environment.
- CLF Embodied Carbon Toolkit for Roadway Infrastructure provides an overview and steps to reduce embodied carbon in infrastructure projects.
- Decarbonizing the Design Process: A Phase by Phase Approach for Landscape Architects offers big ideas, strategies, and best practices that can be implemented regardless of project type, scope, and scale.
- Decarbonizing Specifications: Guidelines for Landscape Architects, Specifiers, and Contractors provides seven key design principles and eighteen areas of specification to reduce the carbon impacts of landscapes.
- Details and Materials for Resilient Sites: A Climate Positive Approach offers information for reducing the carbon impacts of site construction materials and details.
- Climate Positive Design offers tools, guidance, and resources for assessing carbon impacts and climate positive design.
- Carbon Conscience is a tool for assessing carbon impacts early in the design or planning process.

CHAPTER 2

Defining & Managing a Site Carbon Assessment

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Peak House. Dali, Yunnan, China. Z'scape /
Holi Photography

Site Carbon Assessment (SCA) Defined
For a product or building, ISO standard 14040 sets clear definitions, requirements, scope, and methods for how to conduct a Life Cycle Assessment (LCA). However, this standard does not apply to a whole "project" or a "site." Per ISO, an LCA reports the impacts of greenhouse gases (GHGs) through Global Warming Potential (GWP), calculated in carbon equivalents ($kgCO_2e$). This is just one of the environmental impact categories of an LCA. The others include acidification, eutrophication, ozone depletion, etc. This guide does not address any other environmental impact categories outside of GWP, which is why it is entitled site carbon assessment, not site Life Cycle Assessment.

A site carbon assessment tracks embodied carbon emissions, operational carbon emissions, and estimated landscape carbon storage potential of a project's "site scope."

"Site Scope" Defined
The "site scope" of a project has not been well-defined or previously assigned a standardized boundary in the fast-evolving world of carbon assessments. There is also a shared scope and responsibility for shaping the site between landscape architects, civil engineers, and others. This guide encourages open collaboration and communication among project partners to capture the impacts of the collective site, not those of individual disciplines.

This will require coordination between landscape architects, civil engineers, and geotechnical, structural, and MEP engineers. Tracking the associated scope of earthwork, footings, wiring, piping, etc. will be necessary to accurately complete the site's whole-life carbon assessment. Managing scope and boundaries may also require coordination with project owners, architects, and planners.

This guide defines "site scope" as an assessment boundary inclusive of multidisciplinary project scope. Therefore, the site carbon assessment should use the Limit of Work (LOW) or Limit of Construction (LOC) as the physical assessment boundary, also referred to as the project site boundary. Once established, the site elements within the project site area can be tracked for assessment

Site Element Categories for SCA

After finalizing the site boundary, the project team should evaluate project requirements and the proposed design to track the site elements for inclusion in the site carbon assessment. Tables 2.1, 2.2, and 2.3 and the subsequent chapters should be used to verify that site elements, their respective assemblies, and site construction activities are tracked and measured in alignment with the requirements of the Site Carbon Assessment scope being pursued by the project team.

The main and sub-categorization of site elements outlined in Table 2.1 were created and organized by layering ISO 12006.2-compliant classifications with practice knowledge about how these elements are typically documented and detailed for construction. Additionally, the site element categories correspond to the respective life cycle stages and phases in which they should be measured and ultimately reported.

The goal of this approach is to provide clarity and simplicity in tracking and measuring the site scope, structuring a standardized classification system with the nuance of practice realities.

Table 2.1 Site Element Scope for Site Carbon Assessment

SITE ELEMENT SCOPE FOR SITE CARBON ASSESSMENT		
EMBODIED CARBON EMISSIONS		
LIFE CYCLE STAGES AND PHASES	**SCA SCOPE CATEGORY**	**SITE ELEMENT CATEGORY**
Product Stage **A1-A3** (required)	Site Improvements	Roadways and Parking Lots Pedestrian Plazas and Walkways Athletic and Playfield Areas Retaining and Site Walls Fences, Gates, and Rails Furnishings and Lighting Site Structures and Features Planting, Soils, Accessories Site Irrigation System Utilities and Distribution Systems
Transport to Site **A4** (required)	Material & Product Transportation	
Construction Stage **A5** (required)	Site Preparation and Construction Activities	Site Clearing and Demolition Construction Activities and Site Earthwork Construction Waste
In-Use Stage **B2-B5**	Site Use	Site Maintenance Equipment Use Replacements
End-of-Life Stage **C1-C4**	Site End of Life	Transportation Disposal Impacts

Table 2.1 (continued)

SITE ELEMENT SCOPE FOR SITE CARBON ASSESSMENT		
OPERATIONAL CARBON EMISSIONS		
LIFE CYCLE STAGES AND PHASES	**SCA SCOPE CATEGORY**	**SITE ELEMENT CATEGORY**
Operational Energy **B6**	Site Energy Use	Fixtures Equipment
Operational Water **B7**	Site Water Use	Site Irrigation Water Features Site Maintenance Water
LANDSCAPE CARBON STORAGE and PRODUCT CARBON STORAGE		
LIFE CYCLE STAGES AND PHASES	**SCA SCOPE CATEGORY**	**SITE ELEMENT CATEGORY**
Landscape Carbon Storage **B9.1**	Site Vegetation	Existing Vegetation to Remain Restored Vegetation New Planting
Landscape Carbon Storage **B9.2**	Site Soils	Existing Soils
A1 (Carbon Stored) **C4 (Carbon Released)**	Biobased Construction Materials and Products	Decks and Boardwalks Fences and Gates Site Furnishings Overhead Structures Retaining Walls Play Structures Curbing and Edging

Table 2.2 Carbon Assessment Lite: Priority Site Elements

PRIORITY SITE ELEMENTS			
LIFE CYCLE STAGES AND PHASES	**SCA SCOPE CATEGORY**	**SITE ELEMENT CATEGORY**	**SITE ELEMENT SUB-CATEGORY**
Product Stage A1-A3 (Required)	**Site Improvements**	Roadways and Parking Lots Pedestrian Plazas and Walkways Retaining and Site Walls Site Structures and Features Planting, Soils, Accessories For this sub-category please refer to Table 3.12 for more detail, including the notes connecting elements and assembly components to MEP2040 scope: Utilities and Distribution Systems	Roadway and Parking Lot Pavement (Rigid/Flexible) Pedestrian Pavement (Rigid/Flexible) Pedestrian Pavement (On Structure) Athletic and Play Surfacing Cast In Place Walls Stack and Block Walls Panel and Modular Walls Covers, Shelters and Screens Site Bridges Decks and Boardwalks Turf, Grasses, and Herbaceous Plants Trees and Shrubs
	Site Preparation and Construction Activities	Site Clearing and Demolition Construction Activities and Site Earthwork Construction Waste	Vegetation Removal and Trimming (Existing Trees, Shrubs, and Groundcover) Earthwork
LIFE CYCLE STAGES AND PHASES	**SCA SCOPE CATEGORY**	**SITE ELEMENT CATEGORY**	**SITE ELEMENT SUB-CATEGORY**
Landscape Carbon Stroage B9.1	**Site Vegetation**	Existing Vegetation to Remain Restored Vegetation New Planting	Protected plant communities and vegetation Protected Individual Trees Restored plant communities and vegetation Restored Individual Trees Newly Planted Individual Trees
Landscape Carbon Stroage B9.2	**Site Soils**	Existing Soils	Existing protected SOC

Site Carbon Assessment (SCA) Pathways

This guide outlines three pathways to complete a Site Carbon Assessment (SCA). Project teams should pursue the assessment pathway that they can complete based on the outlined requirements in Table 2.3.

Table 2.2 lists priority items that must be accounted for in any type of site carbon assessment. These priority items were determined through published industry research, discussion with practitioners, and review of completed carbon assessments for site projects

Pathway 1: Carbon Assessment Lite is a simplified approach to a site carbon assessment. It includes only priority site scope elements indicated in Table 2.2 and requirements to measure impacts from the Product stage (A1-A3) and Construction stage (A4-A5). (See Chapter 3 and 5 for more detail).

Pathway 2: Simple Carbon Assessment expands past the priority elements and includes all site elements in Table 2.1, measuring impacts across the Product stage (A1-A3), Construction stage (A4-A5), Maintenance (B2), Replacement (B4) and Landscape Carbon Storage (B9). (See Chapters 3-5 for more detail).

Pathway 3: Whole Life Carbon Assessment includes all site elements and life cycle stages in the Simple Carbon Assessment in addition to the End of Life Stage (C1-C4).

Table 2.3 Site Carbon Assessment Pathways

PATH 1 CARBON ASSESSMENT LITE	PATH 2 SIMPLE CARBON ASSESSMENT	PATH 3 WHOLE LIFE CARBON ASSESSMENT
Only priority site elements in Table 2.3 Life Cycle Stages: A1-A5, B9.	Life Cycle Stages: A1-A5, B2, B4, B9 All site elements in Ch 3-5	All Life Cycle Stages (A-C) All site elements in Ch 3-5

As-Built Whole Life Carbon Assessment is not represented in the table above, but is a target assessment level the landscape architecture industry is ultimately aiming for. It requires an added layer of due diligence to validate that the materials a project team designed, specified, and approved via submittal were installed along with purchase quantities made by the General Contractor or Subcontractor.

Quantity Takeoffs and Project Data Resolution

Accurate material and vegetation quantities are essential to documenting a whole life carbon assessment as precisely as possible. With the progression of each design phase, materials specification becomes clearer and more accurate. The carbon assessment being conducted should take this into consideration and allow for the carbon data resolution to develop over time, typically in line with the project's Level of Development (LOD).

The carbon assessment completed in Schematic Design will differ in overall resolution from the one completed in Construction Documentation, which will have an effect on material quantity and material specificity. Both are important to update and verify throughout the assessment process.

Site-focused disciplines most often operate in documentation softwares that require greater manual engagement than other disciplines for tracking the material and vegetation quantity data needed for a site carbon assessment. Recommendations for collecting quantity takeoffs by project phase are:

Project Design:

- Planning & Concept: Measure based on land uses.
- Schematic Design: Area takeoff quantities from preliminary designs.
- Design Development: Material schedules and associated quantities, preliminary area takeoffs, and quantity analysis reported in cost estimates.
- Construction Documents: Cross-reference project drawings, details, and specifications during or after the final CD set.

Post-Project Completion: Though this data collection process might be predominantly in the scope of the General Contractor, a collaborative process between designers and contractors can allow for the exchange of material quantity data through purchase order receipts and eventually, a contractor carbon register delivered upon project completion.

To avoid exponential increases in emissions totals, it is recommended to track the placeholder carbon values or assumptions being made at the beginning of the project with the intention of refining or updating them as the project progresses. This process will also give a more accurate understanding of why total carbon emissions may be changing throughout the design process.

Takeoff Tips for Materials & Planting

- **PDF Document Readers:** Use measurement tools in programs like Adobe and Bluebeam to run quick area takeoffs of exported PDFs.

- **Cost Estimates:** Refer to cost estimating standards to group and quantify site elements for quantity analysis that serves a dual function. Use existing estimates for easy takeoffs.

- **CAD:** Leverage plugins and commands to gather area and total length quicker than standard methods for both hardscape elements and planting areas.

- **BIM:** Create custom material schedules to live track material quantities and modeled site elements. Create custom planting schedules to track plant quantities. For more guidance please refer to the ASLA Guide: Evaluating the Climate Impacts of Projects Through BIM and Related Platforms

Sourcing and Collecting Carbon Data

In recent years, there has been a significant increase in research, data collection, and database development related to the carbon emissions of products and construction materials. This data is typically sourced through manufacturer or industry publications of Environmental Product Declarations (EPDs).

According to ISO, EPDs are standardized, third-party-verified documents that report the environmental impacts of a product based on a product's life cycle assessment (LCA). One of the environmental impacts reported on every EPD is the Global Warming Potential (GWP) of that product, represented in units of $kgCO_2e$. This is what we use to track and assess embodied carbon.

The GWP ($kgCO_2e$) in a product EPD can represent multiple stages and phases across the life cycle (A-D), but the minimum requirements per ISO 21930 are for A1-A3 to be documented. Manufacturers have the Product Stage (A1-A3) in their control before the product is sent to the construction site. If there are life cycle phases being represented in the EPD after A1-A3, they are assumptions. This is why a careful review of the GWP ($kgCO_2e$) scope is advised when pulling from an EPD, database, or tool, especially when comparing products against one another for selection. Using the GWP (A1-A3) scope is the most reliable way to assess product impact and evaluate alternatives.

Different products in the same material category can vary widely in GWP depending on the A1-A3 conditions which include the raw materials extracted (A1), transportation to the manufacturing site(s) (A2), and manufacturing processes (A3). This makes it important to find the exact – or closest possible – GWP value available for the materials called out in the project design and specifications.

These are some of the most reliable sources of carbon data for construction materials and building products, along with the recommended hierarchy of use:

1. **Product Specific (PS) Type III Environmental Product Declaration (EPD)** – This type of EPD collects LCA data for a specific product from an individual manufacturer and reports GWP along with other environmental impact categories. Product Specific EPDs are accessible through manufacturer websites, product reps, or public EPD databases such as Building Transparency's EC3 and the ASLA Product Manufacturer EPD List.

   When there is no available Product Specific Type III EPD for the product or material you're using, use one of the next available data sources in the order listed:

2. **Material Category GWP Baseline** – The Carbon Leadership Forum (CLF) publishes a North American Material Baselines Report, which "provides a snapshot of the state of environmental product declarations (EPDs) for North American-produced building materials." The report collects both Industry Average and Product Specific EPDs on the market for respective material categories and averages the reported values to provide GWP baselines. Materials such as cement and concrete, asphalt, masonry, wood, and steel. This report is available online and published every two years.

3. **Individual Industry Average Type III EPD** – This type of EPD aggregates LCA data from multiple manufacturers representing a majority of production for a material or material type. These manufacturers combine their data to provide average values and report on embodied carbon amongst other environmental impact categories. Industry Average EPDs are accessible through manufacturer websites, product reps, or public EPD databases, such as Building Transparency's EC3

4. **Generic GWP Values** – These could be from a carbon assessment tool's dataset or other background datasets. Different tools offer different options for sourcing and managing material and project carbon data (See Chapter 6: State of the Tools). Some allow you to pull in your own EPDs, some use industry average or product specific EPD averages as defaults, some pull from existing or shared industry databases, and some allow you to do all three. It is important to be aware of the sources of background data and the assumptions being applied at various life cycle stages that are not coming directly from product-specific EPDs.

5. **Proxy GWP Data/Proxy EPD** – A proxy substitute is the selection of another, similar product, ideally made by the same manufacturer, to use in lieu of the EPD for the material being used on the project without any data.

Site Carbon Assessment Overview

Below are the criteria and definitions for a standard site carbon assessment (SCA). When this information is consistently applied, a carbon assessment can be comparable to other assessments and baselines.

These definitions are aligned with ECHO's new publication, Project LCA Baseline Guidance:

- Project Area: The entire area of the site that is impacted by the project, including the building, sitework, and infrastructure
- Project Site Boundary: The Limit of Work (LOW) or Limit of Construction (LOC)
- Project Site Area: The total area based on the project's limit of work (LOW) or limit of construction (LOC), excluding the total building footprint (if applicable), beginning from the outside of the building facade.
  - The project site area can include the full property boundary beyond the LOW/LOC for the site carbon assessment if the project scope intends to protect and/or restore existing natural habitat areas to account for the benefits of site preservation.
  - If no conservation agreement is included, and/or no soil and vegetation protection zones are established or documented, then it is recommended these areas be excluded from the carbon assessment.
- Project Site Area Normalization Unit: m2
- SCA Embodied Carbon Intensity (ECI) Normalization Unit: $kgCO_2e/m2$
- Reference Study Period (RSP): 60 years

CHAPTER 3

Measuring Embodied Carbon Emissions

ASLA 2022 Professional General Design Honor Award.
From Brownfield to Green Anchor in the Assembly Square District. Somerville, Massachusetts. OJB / Kyle Caldwell

Site embodied carbon emissions result from site disturbance, material selection, sourcing and transportation, construction activities, ongoing maintenance, repairs, and replacements during the use of the site, and end of life deconstruction or demolition.

Table 3.1 Chapter 3 Embodied Carbon Emissions Sections

LIFE CYCLE STAGE AND PHASE	EMISSIONS CATEGORY	SCA SCOPE CATEGORY	SITE ELEMENT CATEGORY
Product Stage **A1-A3 (required)**	Embodied Carbon	Site Improvements	Roadways and Parking Lots Pedestrian Plazas and Walkways Athletic and Playfield Areas Retaining and Site Walls Fences, Gates, and Rails Furnishings and Lighting Site Structures and Features Planting, Soils, Accessories Site Irrigation System Utilities and Distribution Systems
Transport to Site **A4 (required)**	Embodied Carbon	Material & Product Transportation	No Sub-Categories
Construction **A5 (required)**	Embodied Carbon	Site Preparation and Construction Activities	Site Clearing and Demolition Construction Activities and Site Earthwork Construction Waste
In-Use Stage **B2-B5**	Embodied Carbon	Site Use	Site Maintenance Equipment Use Replacements
End-of-Life Stage **C1-C4**	Embodied Carbon	Site End of Life	Transportation Disposal Impacts

Within each category, standardized site elements are broken out and described with their typical construction assemblies through a series of detailed tables. This offers a standardized approach for the site elements and assembly components that should be included in a site carbon assessment.

These site element categories are inclusive of multidisciplinary scope items. The responsibility is on the project team to make sure required elements and their assembly components are accounted for, no matter the discipline lead. This guidance is to ensure that site carbon assessments are as consistent as possible for the purposes of data comparison.

Refer to Appendix II for an excel version of the tables in this chapter.

Measuring Product Stage (A1-A3) Embodied Carbon Emissions

The process for quantifying Product Stage A1-A3 emissions for a site carbon assessment is:

1. Develop a material inventory for all site elements included in the site project scope.
   a. Refer to the Site Element Category tables in this chapter for typical material assemblies and components that must be accounted for in each site element.
   b. Conduct takeoffs for the component material quantities. Depending on the component, these takeoffs could be for volume, area, length, mass, etc.

2. Quantifying the emissions of the component materials can then rely on an a carbon assessment tool, manual calculations, or a combination of both:

   Carbon Assessment Tool:

   a. Input the component material quantities into a carbon assessment tool to calculate A1-A3 emissions. *Placeholder A1-A3 carbon factors vary across different tools, as does the ability to manually enter product-specific carbon data. Carbon assessment tools are addressed in Chapter 6.*

   Manual Calculations:

   a. The individual component material quantities can then be multiplied by their respective carbon factors. *The primary carbon data sources for A1-A3 are discussed in Sourcing & Collecting Carbon Data in Chapter 2 to identify the appropriate data source within the recommended sourcing hierarchy.*

   Combined approach:

   a. Site assessment tools often lack the ability to comprehensively quantify everything addressed in this guide, and a combined approach may be required for certain materials, processes, or life cycle stages.

A1-A3 | Site Improvements

The Site Improvements category captures the majority of site design elements, both hardscape and softscape. Material selection, specification, layout, and detailing all contribute to the emissions from site improvements. This section is organized based on typical site designation and material schedules to facilitate tracking and measurement.

Each of these categories include a detailed table of site elements and assembly components to quantify. Use these tables to identify all scope items to be measured for site carbon assessment.

Use industry standard assumptions or project-specific detail documentation to ensure that each component of an assembly is accounted for. There may be several options within the tables, not all of which will occur in every application of a given material.

Guidance for estimating embodied carbon emissions of reused materials and structures is given at the end of this section.

Table 3.2 Site Improvements - Roadways and Parking Lots

While the design scope of roadways and parking lots may be distributed between site partners, for the purposes of measurement, these improvements generally share the same options for assemblies as outlined in this table. Specify whether the application is a Roadway or Parking Lot in assessment documentation.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Roadway and Parking Lot Pavement (Rigid)	x	m^3	Surface material	
	x	m^2	Reinforcing	Area of reinforced pavement and size or spacing of reinforcing
	x	m^3	Setting Bed	
	x	m^3	Mortar	
	x	m^3	Subslab	
	x	m^3	Aggregate Base	
Roadway and Parking Lot Pavement (Flexible)	x	m^3	Surface material	
	x	m^3	Aggregate Base	
	x	m	Edge Restraint	
Roadway and Parking Lot Curbs and Gutters		m^3	Surface material	
		m	Reinforcing	
		m^3	Aggregate Base	

Table 3.3 Site Improvements - Pedestrian Plazas and Walkways

Pedestrian plazas, walkways, curbs, steps, and ramps are assemblies made up of multiple components. This table outlines typical components to include in an assessment. However, these will depend on specific material specification and detailing.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Pedestrian Pavement (Rigid)	x	m^3	Surface material	
	x	m^2	Reinforcing	Area of reinforced pavement and size or spacing of reinforcing
	x	m^3	Setting Bed	
	x	m^3	Mortar	
	x	m^3	Subslab	
	x	m^3	Aggregate Base	
Pedestrian Pavement (Flexible)	x	m^3	Surface material	
	x	m^3	Bedding course	
	x	m^3	Sub drainage	
	x	m^2	Geotextile	
	x	m^3	Aggregate Base	
	x	m	Edge Restraint	

Table 3.3 (continued)

Pedestrian Pavement (On Structure)	x	m^3	Surface material	
	x	qty	Pedestal system	
	x	m^3	Fill Material (incl. geofoam)	
	x	m^2	Filter Fabric and Drainage Layer	
Pedestrian Pavement Curbs and Gutters		m^3	Surface material	
		m^2	Reinforcing	
		m^3	Aggregate Base	
Exterior Steps		m^3	Riser and tread surface material	
		m^3	Structural material	
		m^2	Reinforcing	
		m^3	Mortar	
		m^3	Aggregate Base	
Exterior Ramps		m^3	Ramp surface	
		m^3	Structural material	
		m^3	Reinforcing	Area of reinforced ramp and size or spacing of reinforcing
		m^3	Ramp Edge	
		m^3	Aggregate Base	

Table 3.4 Site Improvements - Athletic and Playfield Areas

Site improvements for areas that support athletic and play uses may have specific criteria and considerations. This table outlines typical assembly components for surfacing and equipment. For natural turf fields, refer to Table 2.8.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Athletic and Play Surfacing	x	m^2	Surface coating	
	x	m^2	Surface material	
	x	m^3	Subslab	
	x	m^2	Reinforcing	Area of reinforced subslab and size or spacing of reinforcing
	x	m^3	Bedding course	
	x	varies	Sub drainage	
	x	m^2	Geotextile	
	x	m^3	Aggregate Base	
	x	varies	Edge Restraint	
Athletic and Play Equipment		varies	Structures	
		m^3	Footings	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured

Table 3.5 Site Improvements - Retaining and Site Walls

These options for assemblies should be used for all site walls — planter walls, retaining walls, and seat walls. Coordinate as needed with project structural engineers to accurately quantify all components of the wall assembly, including footings and reinforcing.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Cast in Place Walls	x	m^3	Wall material	
	x	m^2	Wall Reinforcing	
	x	m^3	Footing	
	x	varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
	x	m^3	Aggregate Base	
Stack and Block Walls (ex. CMU)	x	m^3	Wall finish material	
	x	m^3	Mortar	
	x	qty	Hangers, Fasteners	
	x	m^3	Wall structure	
	x	m^2	Wall Reinforcing	
	x	m^3	Footing	
	x	varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
	x	m^3	Aggregate Base	
Panel and Modular Walls (ex. steel, precast)	x	m^3	Wall material	
	x	qty	Hangers, Fasteners	
	x	m^3	Footing	
	x	varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
	x	m^3	Aggregate Base	
Retaining Wall Drainage (include as needed with other wall assemblies)		m^3	Drain rock	
		m^2	Sub drainage	
		m^2	Geotextile	

Table 3.6 Site Improvements - Fences, Gates, and Rails

Fences, gates, guardrails, and handrails share similar assemblies while the specific components will vary depending on material and detailing. Based on the typical components listed in this table for each, identify which to include.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Fences and Gates		m^3	Top/Bottom Rails	
		varies	Fence Panel Material	Design will vary between boards, panels or other measurements so units will vary as well.
		qty	Fasteners and Hardware	
		m^3	Posts	
		m^3	Post Footings	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Guardrails and Handrails		m	Handrail Material	
		m^3	Pickets/Panels	
		m^3	Posts	
		qty	Fasteners and Hardware	
		m^3	Post Footings	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured

Table 3.7 Site Improvements - Furnishings and Lighting

Site improvements may include a wide range of furnishing elements — both products by manufacturers and custom-designed features. Site lighting and signage assemblies have similar components.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Site Furniture		varies	Furniture Element	Combined emissions provided by EPD or emissions of each
		m^3	Footing	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Site Lighting		Qty, watts	Luminaires	*Emissions from site lighting are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
		Qty, watts	Bollards	
		Qty, watts	Light Poles	
		m^3	Pole/Bollard Footing	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Signage		varies	Sign Material	Materials and forms will vary
		m^3	Post	
		m^3	Post Footing	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured

Table 3.8 Site Improvements - Site Structures and Features

There may be other site structures with more complicated, customized assemblies. This table provides some examples of these features. However, there will be considerable variation between site projects for this category. The guidance here should be applied to the measurement of remaining site improvements not covered above.				
SITE ELEMENT SUB-CATEGORY	**PRIORITY ELEMENT**	**UNITS**	**COMPONENTS**	**NOTES + EXCLUSIONS**
Covers, Shelters and Screens	x	m^3	Structure Material(s)	
	x	m^3	Structure Supports	
	x	qty	Fasteners	
	x	m^3	Footing	
	x	varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Site Bridges	x	m^3	Decking Material	
	x	m^3	Handrail/Guardrail	
	x	m^3	Trusses	
	x	m^3	Beams	
	x	m^3	Abutments	
	x	varies	Abutment Reinforcing	Abutment shapes will vary so length or area could be measured
Decks and Boardwalks	x	m^3	Decking Material	
	x	qty	Fasteners	
	x	m^3	Joists	
	x	m^3	Beams	
	x	m^3	Posts	
	x	m^3	Post Footing	
	x	varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Exterior Fountains		qty	Spout Fixture	
		m^3	Basin finish material	
		m^3	Mortar	
		m^3	Basin structure	
		varies	Basin Reinforcing	Basin shapes will vary so length or area could be measured
		m^3	Pedestal and Footing	
		varies	Footing Reinforcing	Footing shapes will vary so length or area could be measured
Pools and Spas		m^3	Pool coping material	
		m^3	Pool finish material	
		m^3	Mortar	
		m^3	Basin structure	
		varies	Basin Reinforcing	

Table 3.9 Site Improvements - Planting, Soils, and Accessories

In addition to typical hardscape improvements, softscape improvements also have embodied carbon emissions throughout the life of a project. This table includes site planting and soil elements. For each, determine the total quantity, and select the container or installation option. This information will inform the embodied carbon emissions during product and construction life cycle stages. This refers only to the embodied carbon emissions associated with site planting and soil materials. For the operational emissions from water use, refer to Chapter 4: Estimating Operational Carbon Emissions and for the landscape carbon storage potential, refer to Chapter 5: Estimating Landscape Carbon Storage and Product Carbon Storage.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS / OPTIONS	NOTES + EXCLUSIONS
Turf, Grasses, and Herbaceous Plants	x	m^2	Sod	
	x	qty	Sprigging	
	x	qty	Plugs	
	x	kg	Seed Mixes	
	x	m^2	Hydroseed	
	x	qty	Bulbs	
	x	qty	Containers	
Trees and Shrubs	x	qty	B&B	
	x	qty	Liner	
	x	qty	Container	
	x	qty	Bare Root	
	x	qty	Box	
Planting Accessories		varies	Header (within only softscape areas)	*These elements often are a very small portion of the overall project and may be excluded or optional.*
		varies	Trellis structure	
		varies	Tree stakes and ties	
		varies	Root barriers	
		varies	Watering bags	
Erosion and Stabilization		m^3	Rip rap	
		m^2	Geotextile	
Site Soil Treatment (on grade)		m^3	Mulch	
		m^3	Growing Medium	
Site Soil Treatment (on structure)		m^3	Mulch	
		m^3	Growing Medium	
		m^3	Fill Material (including geofoam)	
		m^2	Filter Fabric	

The Site Improvement category also includes select infrastructure required to support the site. It is important that the embodied carbon emissions from this infrastructure be measured across disciplines and included in a site's whole life carbon to the extent possible.

Refer to guidance from The Beginners Guide to MEP Embodied Carbon v2 where applicable for coordination with site mechanical, electrical, and plumbing systems. In general, mechanical and electrical systems located outside of the building but directly supporting the building (i.e. building transformers, generators, geothermal wells and associated piping) should be reported with other MEP impacts and not reported here.

However, MEP components directly supporting the site and civil piping – water, sanitary sewerage – should be included in a site carbon assessment, regardless of whether it is supplying the building or site features.

Table 3.10 Site Improvements - Site Irrigation System

The table below outlines the typical components of a site irrigation system, with specific assembly requirements varying by project and vegetation type.

Note: Emissions from site irrigation are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Irrigation System		qty	Backflow Preventer	*Emissions from "site irrigation" are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
		qty	Booster Pump	
		qty	Weather Station	
		qty	Controller	
		m	Mainline	
		m	Lateral lines	
		m	Dripline	
		qty	Valves	
		qty	Spray Head	
		m	Sleeves	

Table 3.11 Site Improvements - Utilities and Distribution Systems

The range of site improvements included in a project will determine the utility and distribution systems required to support these types of elements:

- Water: irrigation, hose bibbs, drinking fountains, restrooms, exterior fountains
- Sanitary Sewerage: drinking fountains, restrooms
- Storm Drainage: planting and site drains, stormwater treatment infrastructure
- Gas: fireplaces, BBQs
- Electrical: lighting, fireplaces, BBQs, charging stations, exterior fountains, site security systems

Identify which systems are present on site and coordinate with relevant disciplines to quantify the components of each. In addition to the site elements, wet utilities that supply the building may also need to be included in a site carbon assessment if they are not already tracked under MEP 2040 guidance.

SITE ELEMENT	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Water Utilities		m	Domestic and/or Recycled Water Connection	*Emissions from "civil piping" are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
		m	Domestic and/or Recycled Water Piping (to serve site and building)	
		m	Fire Protection Water Distribution	
		m	Irrigation Water Distribution (to connection for irrigation system)	*Emissions from "site irrigation" are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
Sanitary Sewerage Utilities		m	Sanitary Sewerage Connection	*Emissions from "civil piping" are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
		m	Sanitary Sewerage Piping (to serve site and building)	
Storm Drainage Utilities (grey infrastructure)		m	Storm Drainage Utility Connection	*Emissions from "civil piping" are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
		m	Storm Drainage Piping	
	x	m^3	Culverts	
		qty	Site Storm Drains (grate)	
		qty	Site Storm Drains (drain body)	
		varies	Site Subdrainage (not included in assemblies above)	
Storm Drainage Systems (green infrastructure)	x	m^3	Basin Structure	
		m^3	Drain rock and Aggregates	
		m	Standpipes	
		m^2	Geotextile fabric	
		m^3	Bioretention soils	

Estimating Embodied Carbon Emissions of Reused Materials and Structures

A1-A3 emissions can be reduced or avoided entirely by reusing or repurposing existing site assets and materials. Furthermore, if those assets and materials are protected in place or reused on-site, A4 and A5 emissions can also be avoided.

Table 3.12 shows which LCA stage and embodied carbon emissions to measure for each type of reused, reclaimed, reprocessed, and recycled materials.

Recycled content in manufactured products or material mixes is not included in this section as those emissions are part of the embodied carbon of a new product.

Table 3.12 Estimating the Embodied Carbon of Circular Materials and Structures

CIRCULAR MATERIALS	EMBODIED CARBON EMISSIONS TO MEASURE
Reused elements/structures on site (e.g., pavement, walls, overhead structures, fences)	Existing materials and assemblies can be modeled as zero impact for life cycle stages (A1-A5). Other life cycle stages of existing materials (B-C) should be modeled as if they were new, unless better information exists.
Reclaimed materials from on site (e.g., reclaimed concrete slabs, bricks, stone, curbing, boulders, metal members, wood members, etc.)	
Reprocessed materials on the site (e.g. on-site crushed concrete, crushed asphalt, chipped or mulched wood)	Existing materials and assemblies should be modelled as zero impact for life cycle stages (A1-A4), and other life cycle stages from reused or salvaged materials (A5-C) should be modeled as if they were new, unless better information exists
Reclaimed materials from off-site	Existing materials and assemblies should be modelled as zero impact for life cycle stages (A1-A3), and other life cycle stages from reused or salvaged materials (A4-C) should be modeled as if they were new, unless better information exists.
Reprocessed materials from off-site	

A4 | Material & Product Transportation

Measuring transportation (A4) emissions requires knowledge of two factors. One, the distance the material is traveling from the final manufacturing point to the construction site, and two, the mode of transport used to send it there. If a carbon assessment tool is being used, there will be distance and travel assumptions per material, but more accuracy can be achieved by updating the assumptions or manually calculating it.

The process for measuring the A4 emissions in a site carbon assessment is:

1. Determine the final manufacturing location of the material or product, and the distance to the project site.
2. Verify the transportation mode(s) with the supplier and/or contractor (medium/heavy duty truck, rail, waterborne craft, or aircraft).
3. Quantifying the emissions of transport can then rely on an a carbon assessment tool or manual calculations:

Carbon Assessment Tool:

a. If the carbon assessment tool allows, input the distances and modes of transportation the materials will travel to the project site. If the tool does not accommodate this use the default emissions factors.

Manual Calculations:

a. Multiply the distance (in short-ton mile or kilometer) by the material weight and emissions factor of the transportation method(s) being used to transport the material to the project site (Table 3.13).

Table 3.13 Recommended default emissions for typical transit modes

TRANSIT TYPE	GWP (kg CO_2 eq/tonne*km)	GWP (kg CO_2 eq/ton*mile)
Truck (less than 500 miles)[1]	0.132	0.193
Truck (more than 500 miles)	0.088	0.128
Electric Truck (less than 500 miles)*	0.041	0.059
Electric Truck* (more than 500 miles)	0.027	0.039
Aircraft	0.830	1.212
Ship or barge (ocean)	0.008	0.012
Ship or barge (inland)	0.018	0.026
Rail	0.019	0.028
Concrete Mixer Truck[1]	0.304	0.444

[1] Emissions factor figures should be used with the mileage of the outbound trip distance. Using these factors will automatically account for return trips for trucking scenarios.

Source: Torabi, M., Huang, M., Manesh, M. T., Nanayakkara, I., & Simonen, K. (Forthcoming 2026). A Data-Driven Method for Quantifying the Environmental Impacts of Freight Transportation in Construction for Prospective LCA in the United States

A5 | Site Preparation and Construction Activities

Construction Stage (A5) emissions are designated in three sub-phases:

- A 5.1 Pre-Construction Demolition
- A 5.2 Construction Activities
- A 5.3 Construction Waste

Due to project construction variability and lack of industry data, there is not a one-size fits all approach to measuring (A5) emissions. Carbon assessment tools currently include either a contingency factor or a standard emissions factor for the A5 emissions phases. If tracking project-specific A5 emissions manually, upfront planning and collaboration between the design team and the general contractor is necessary.

Estimating Site Clearing and Demolition (A5.1)

The Pre-Construction Demolition phase (A5.1) includes both demolition and site preparation activities, but the transport of demo and site prep material off-site is included in phase A5.3. The carbon released from the demolition and subsequent decay of cleared plants on a site should be accounted for as emissions in phase A5.1 of the Construction Stage. Following the recommendations of Verra and the American Forest Foundation, invasive species removal should be excluded from this figure due to its positive impact on overall ecosystem health.

The process for quantifying A5.1 emissions of a site carbon assessment is:

1. Equipment use for demolition and site preparation activities:

   Carbon Assessment Tool:

   a. Most carbon assessment tools apply a multiplier for the total embodied carbon of phase A1-A3 materials, so no additional inputs are required.

   Manual calculations:

   a. Measure the area (m^2) of the site that will be disturbed in demolition and site preparation activities. This includes areas of clearing and grubbing, vegetation removal, and hardscape demolition.
   b. Multiply this area by the carbon factor **20kg CO_2e** for the total emissions of A5.1 demolition and site preparation activities

2. Stored carbon released from vegetation and soils cleared in A5.1:

   Carbon Assessment Tool:

   a. Most carbon assessment tools apply a multiplier for the total embodied carbon of phase A1-A3 materials, so no additional inputs are required.

   Manual Calculations:

   a. Develop an inventory of vegetation cleared from the site by weight (Table 3.14). Omit invasive species.
   b. For carbon released from decayed or landfilled plants removed from the site, the following formula should be used:

   [A5.1] = ADB (kg) * 0.5 (to estimate Carbon) * 3.66 (to convert to kgCO_2e)[1 2]

   Where ABD (kg) = total weight of average dried biomass living and dead [1]

   [1]This carbon factor includes plant community demolition, assuming clear land eventually releases all of the probable landscape carbon stored in biomass

   [2]*Source: Carbon Conscience*

Table 3.14 Vegetation Removal from Site Preparation and Clearing

(for stored landscape carbon release calculations)

SITE ELEMENT	PRIORITY ELEMENT	UNITS	COMPONENTS	NOTES + EXCLUSIONS
Vegetation Removal and Trimming	x	kg	Existing Trees	
	x	kg	Existing Shrubs & Groundcover	Including Ecosystems
		kg	Existing Perennials and Grasses	

Estimating Construction Activities and Site Earthwork (A5.2)
Construction activities, and site earthwork are included in life cycle phase A5.2. This includes construction activities such as hard and softscape construction, and earthwork impacts from balancing cut and fill, importing new material, and using additional fill in on-structure conditions. Emissions from machinery used to construct the site are measured along with the release of Soil Organic Carbon (SOC) from earthwork activities.

To determine the emissions rates per area of earthworks, this guide assumes that 100% of SOC is lost from horizons O and A for the portion of the soil disturbed by earthwork. The process for quantifying A5.2 emissions of a site carbon assessment is:

1. Equipment use for site construction activities:
   Carbon Assessment Tool:
   a. Most carbon assessment tools apply a multiplier for the total embodied carbon of phase A1-A3 materials, so no additional inputs are required.
   Manual calculations:
   a. Measure the area (m^2) of the site that will be disturbed for construction activities. This includes areas of grading and new construction.
   b. Multiply this area by the carbon factor **30kg CO_2e** for the total emissions of A5.2 construction and grading activities
3. Stored carbon released from earthwork in A5.2:
   Carbon Assessment Tool:
   a. Most carbon assessment tools apply a multiplier for the total embodied carbon of phase A1-A3 materials, so no additional inputs are required.
   Manual calculations:
   a. Perform soil tests by taking samples of the O and A horizons at multiple locations on the site. Test results should include % SOC as mass ratio per kg, and mass of O and A horizons per m^2.
   b. Determine the total area (m^2) of earthwork.
   c. Multiply the mass of soil horizon O by the total area of earthwork.
   d. Multiply the mass of soil horizon A by the total area of earthwork.
   e. Multiply the % SOC (carbon) of soil horizon A by the weight of soil horizon A graded.
   f. Multiply the % SOC (carbon) of soil horizon O by the weight of soil horizon O graded.
   g. Sum the total carbon (kg) of earthwork for both A and O horizons, then multiply by 3.66 for total CO_2e of stored carbon released from earthwork in phase A5.2

Estimating Construction Waste (A5.3)
Embodied carbon emissions associated with construction waste are calculated in phase A5.3. The two types of carbon impacts calculated in this section are the transportation impacts of hauling soil, plants or demolished or deconstructed hardscape elements off the site; and the embodied carbon emissions from the manufacture, transportation, and end-of-life impacts of construction wastage (Table 3.15).

The process for quantifying A5.3 material wastage emissions of a site carbon assessment is:

Carbon Assessment Tool:

a. Most carbon assessment tools do not measure construction wastage, but those that do, apply a multiplier to the quantities of materials input for A1-A3 embodied carbon.

Manual calculations:

a. Identify materials listed in Table 3.15 that are used on the site.
b. Identify the total embodied carbon of each material then multiply it by the default onsite waste rate shown in Table 3.15 to get the embodied carbon from material wastage.
c. Total all embodied carbon figures for material A5.3 material wastage.

Table 3.15 Default On-Site Material Wastage Rates

MATERIAL	ON-SITE WASTAGE RATE
Concrete (poured in place)	5%
Sprayed concrete (Shotcrete)	10%
Blocks and bricks	5%
Metal sheets and welded wire fabric[1]	10%
Non metal sheets (plywood)[1]	15%
Lumber[2]	10%
Pipes[2]	10%
Rebar[2]	3%

[1] Standard size cut on site

[2] Delivered to site in standard lengths and trimmed to required length on site

Source: ASHRAE/Standard 240P

The process for quantifying A5.3 off haul transportation emissions of a site carbon assessment is:

1. Identify the types and quantity of materials in Table 3.16 that will be transported off site to a disposal or recycling facility.
   Carbon Assessment Tool:
   a. Most carbon assessment tools do not currently measure construction and demolition transportation emissions
   Manual calculations:
   a. Determine quantities of each of the materials in Table 3.16 that will be transported off the site to disposal or recycling facilities.
   b. Locate two of the closest facilities for each material. Identify distance to each facility from the site.
   c. Average the two distances.
   d. Multiply the average distance (in short-ton mile or kilometer) by the material weight and emissions factor of the transportation method(s) being used to transport the material to the project site (Table 3.13).
   e. Total the GWP for all materials in Table 3.13 for A5.3 Transportation embodied carbon.

Table 3.16 Construction Waste Off Haul Materials

MATERIAL	PRIORITY ITEM	UNITS	NOTES + EXCLUSIONS
Soil Offhaul		kg	
Vegetation waste		kg	
Concrete		kg	
Asphalt		kg	

B1-B5 | Site Use

Life cycle stages B1 - B5 include:

- B1 Use
- B2 Maintenance
- B3 Repairs
- B4 Replacement
- B5 Refurbishment

This guide does not address phases B1, B3, and B5 due to the lack of inclusion in carbon assessment tools and available embodied carbon factors. These phases are not included in a Site Carbon Assessment scope at this time.

Measuring Site Maintenance Activities

Embodied carbon emissions from maintenance activities (B2) can be challenging to estimate prior to site construction because actual maintenance practices could differ resulting in varied energy or gasoline use to power the equipment.

Maintenance equipment can be powered by gas or electricity. Electricity is generated from a variety of sources off or on site resulting in a broad range of embodied carbon emissions from maintenance activities. Typical measurements for site maintenance equipment are: hours of use per year and power source.

The process for quantifying B2 emissions of a site carbon assessment is:

1. Develop a maintenance schedule to estimate the emissions from maintenance equipment. The schedule should include:
   - Each design element and planting type.
   - The equipment and hours of use for each item's maintenance for every month/year.
   - Energy source and efficiency for each piece of maintenance equipment.

2. Quantifying the emissions of maintenance activities can then rely on a carbon assessment tool, manual calculations, or a combination of both:

   Carbon Assessment Tool:

   a. Input the design element type and equipment hours of use (per month or year depending on the tool) into a carbon assessment tool to calculate B2 emissions. Placeholder B2 carbon factors vary across different tools, as does the ability to manually enter fuel type and efficiencies. Carbon assessment tools are addressed in Chapter 6.

   Manual calculations:

   a. Multiply the hours of use per month or year by the fuel efficiency and the carbon factors for the energy source.

Table 3.17 Site Maintenance Equipment Use

EQUIPMENT	NOTES
Lawn Mowers	
Leaf Blowers/Vacuums	
Trimmers/Edgers/Cutters	
Other	

Measuring B4 Replacements

Site construction materials will vary in replacement (B4) impacts depending on the durability of materials, and maintenance regimes over a 60-year project life. Sixty years is a standard project life assumed in the AEC industry for life cycle assessments (ISO 14040).

Some materials and site elements will not last the full 60 years of a project life. Therefore, their replacements must be accounted for in phase B4 Replacement. Appendix III provides replacement factors for common materials and site elements. These replacement factors are multipliers, so a replacement factor of 2 means that there will likely be one full replacement during a 60 year period, doubling the embodied carbon of the structure.

The process for quantifying B4 emissions of a site carbon assessment is:

1. Identify potential replacements in the material inventory of all site elements that was developed for A1-A3 emissions.
    - Refer to Appendix III: B4 Material Replacement Factors for common site elements and material components.
    - Refer to the takeoffs for all elements in the inventory that were done for phases A1-A3.

2. Quantifying the emissions of the replacement component materials can then rely on a carbon assessment tool, manual calculations, or a combination of both:

    Carbon Assessment Tool:

    a. Most carbon assessment tools build in replacement assumptions for typical materials, so no additional action is needed beyond the input for A1-A3. Carbon assessment tools are addressed in Chapter 6.

    Manual calculations:

    a. Use the following formulas to calculate B4 emissions:

    $$CO_2e_{MAT1} = (RF * CF * kg_{MAT1})$$

    Where: MAT1 = Material 1;
    RF = Replacement factor;
    CF = Carbon factor

    a. Then:

    $$[B4] = CO_2e_{MAT1} + CO_2e_{MAT2} + CO_2e_{MAT3} + CO_2e_{MAT4}, \text{ etc.}$$

C1-C4 | Site End-of-Life

End of Life Stage C starts at the end of the site's life. Stage C phases include:

- C1 Deconstruction and demolition impacts
- C2 Transportation impacts
- C3 Waste processing for reuse, recycling, or other
- C4 Disposal impacts

This guide does not address phases C1 and C3 due to limited data and lack of inclusion in carbon assessment tools. These phases are also not included in a Site Carbon Assessment scope at this time.

Measuring C2 Transportation Embodied Carbon Emissions

Carbon assessment tools do not currently calculate phase C2 Transportation Impacts of Stage C materials being removed at the end of the site's life.

Therefore the manual calculation process for measuring the C2 emissions in a site carbon assessment is:

1. Determine the end of life scenario for each of the site materials listed in Table 3.18.
2. Determine the mass of each material used based on calculations performed for the A Stage embodied carbon emissions.
3. Determine the average distance to two closest facilities that will receive the material (in short-ton mile or kilometer) (Table 3.19).
4. For each material, identify the transportation mode(s) to these locations (medium/heavy duty truck, rail, waterborne craft, or aircraft).

5. Use the following formula to identify the C2 emissions:

    [C2] = (M x EF x TD)

    Where M = material mass from A stage (metric tons);

    EF = transportation emission factor (kgCO_2e/ton*mile) from Table 3.13;

    TD = transportation distance (miles) based on Table 3.19

Table 3.18 End of Life Scenarios for Selected Site Construction Materials for C2 and C4

MATERIAL COMPONENT	RECYCLED/REUSED	DISPOSED
Concrete	80%	20%
Asphalt	95%	5%
Metals	80%	20%
Aggregate	85%	15%

Source: US Environmental Protection Agency (US EPA) (2020). Advancing Sustainable Materials Management: 2018 Fact Sheet. Washington, DC: US EPA.

Table 3.19 Transit Distance for C2

END OF LIFE SCENARIO	TRANSPORT SCENARIO
Reuse/Recycling	Average distance to two closest construction waste processing sites that will receive the type of material.
Disposal	Average distance to two closest landfill sites that will receive the material.

Source: Based on RICS WLCA 2023

Measuring C4 Disposal Embodied Carbon Emissions

Carbon assessment tools do not currently calculate phase C4 Disposal Impacts of Stage C materials being removed at the end of the site's life.

Therefore the manual calculation process for measuring the C4 emissions in a site carbon assessment is:

1. Identify the materials in Table 3.18 that will be disposed of in a landfill.
2. Identify the mass of these materials based on calculations performed for the A Stage embodied carbon emissions.
3. Use the Landfill Emission Factor (LEF) of 0.044 kgCO2e/kg waste[1]
   [1]Source: Deru, M., & Hamot, L. (2024). TM65NA Embodied carbon in building services: a calculation methodology for North America. The Chartered Institution of Building Services Engineers.

4. Use the following formula to identify the C2 emissions:

   [C4] = (M x LEF)

   Where M = Material mass of disposed components from A Stage (kg);
   LEF = Landfill Emissions Factor

CHAPTER 4

Estimating Operational Carbon Emissions

ASLA 2026 Professional General Design Honor Award. As Far As One Can See: Indigenous Knowledges and Design at Tekαkαpimək. Katahdin Woods and Waters National Monument, Present and traditional homeland of the Penobscot Nation, Maine. Reed Hilderbrand LLC - Cambridge / James Florio

Operational carbon emissions occur throughout the service life of the site. Operational carbon emissions result from energy and fuels used to power site fixtures and equipment, such as lighting, pumps, and controllers. Operational water use carbon emissions result from treating and conveying potable water used for irrigation, water features, and site maintenance activities.

Operational carbon emissions from energy and water use can be challenging to estimate prior to site construction because actual operations could differ depending on a number of factors:

- Variable electrical use if needs for lighting or other fixture use change during operation
- Variable or unpredictable weather patterns could require greater water use or less gray water captured for irrigation and maintenance than otherwise planned. Drought could also result in less gray water captured for irrigation, maintenance, and fire suppression.

This chapter offers a standardized approach for measuring operational carbon emissions as part of a site carbon assessment. If elements are included in the site scope but determined by others, it should be noted and coordinated. Refer to Appendix II for an excel version of the tables in this chapter.

Table 4.1 Chapter 4 Operational Carbon Emissions Sections

LIFE CYCLE STAGE AND PHASE	EMISSIONS CATEGORY	SITE ELEMENT CATEGORY	SITE ELEMENT SUB-CATEGORY
Operational Energy **B6**	Operational Carbon	Site Energy Use	Fixtures Equipment
Operational Water **B7**	Operational Carbon	Site Water Use	Site Irrigation Water Features SIte Maintenance Water

B6 | Site Energy Use

A wide variety of site fixtures and equipment use energy which in turn, releases a range of greenhouse gas emissions depending on the energy source. As operational energy emissions are estimated during the design phase, it is important to record and track the assumptions made about them. This will allow for adjustments to the calculations if site power use varies from the assumptions or changes over time.

Lighting Schedule: To estimate the hours of lighting used on a site per year, create a schedule of lighting per day, per month, and per year for the reference study period (RSP) for each light fixture type. Note the energy source.

Equipment Schedule: To estimate energy use from equipment, create a schedule for the operation of each transformer, timer, sensor, pump, and other equipment. Note the energy source.

Operating energy of some site fixtures and equipment can be estimated with energy modeling tools. These tools estimate energy consumption and carbon emissions based on types of lighting, types of equipment, and energy or fuel source. Energy modeling tools can allow for quick evaluation of lighting types and tradeoffs for optimizing efficiency and lowering emissions. Selected energy modeling tools are listed in Appendix I: Resources.

Measuring Use Stage Operational Carbon Emissions (B6)

The process for estimating the Operational Energy (B6) emissions of a site carbon assessment is:

1. Develop an inventory for all fixtures and equipment that will be used on the site (Table 4.2).
2. Create schedules estimating hours of use per month/year for each fixture type or piece of equipment over the 60 year reference study period (RSP). Include:
   - Quantity of fixtures or equipment by type
   - Type of energy source
   - Watts (for manual calculations only)
3. Quantifying the emissions of the fixtures and equipment can then rely on an a carbon assessment tool, manual calculations, or a combination of both:

   Carbon Assessment Tool:

   a. Input the hours of use per month or year, and the energy source for each fixture or equipment type into a carbon assessment tool to calculate B6 emissions.

   Manual Calculations:

   a. Multiply the fixture or equipment operating hours per month or year by the watts for the fixture or equipment by the quantity of fixtures or equipment to get the total kWh. Use the formula:

      [kWh] = (OH * watts * Qty)

      Where kWh = Kilowatt hours;
      OH = Operating hours;

Qty = Qty of fixtures or equipment

b. Multiply the total kWh by greenhouse gas emissions factors for energy sources or electricity in BSR/ASHRAE/ICC Standard 240P, Quantification of Life Cycle Greenhouse Gas Emissions of Buildings for each year of the 60 year reference period (Table 7.3.2.2 for Electricity; Table 7.3.2.1 other energy sources)

c. Use the following formulas:

[B6] = For electricity: $\sum[(EC_{YEAR\,1} \times EEF_{YEAR\,1}) + ... (EC_{YEAR\,60} \times EEF_{YEAR\,60})]$

Where: EC = Electricity Consumption in specified year, annual (kWh/yr);

EEF = Electricity Emissions Factor for specified year ($kgCO_2e/kWh$)

+

For other fuel types: [(FC1 x FEF1 x RSP) + ... (FC2 x FEF2 x RSP)]

Where FC = Energy Consumption by fuel type, annual (kWh/yr);

EEF = Electricity Emissions Factor for specified year ($kgCO_2e/kWh$)

FEF = Fuel emissions factor by bulk fuel or energy units ($kgCO_2e/kWh$)

RSP = Reference study period

Table 4.2 Site Energy Use - Fixtures

FIXTURES	NOTES + EXCLUSIONS
Light Fixtures	*Emissions from light fixture operations are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
Other Fixtures	

Table 4.3 Site Energy Use - Equipment

EQUIPMENT	NOTES + EXCLUSIONS
Transformers	*Emissions from light fixture operations are noted as an optional input in MEP 2040 guidance. They should not be counted in both the SCA and in MEP 2040.*
Timers	
Sensors	
Drywell Pumps	
Irrigation Booster Pumps	
Irrigation Controllers	
Pump Lift Stations	
Submersible Groundwater Pumps	
Other	

B7 | Site Water Use

Site water use emissions result from energy used to treat and convey water. Carbon assessment tools currently model some of this water use for irrigation and water features but not for maintenance water. The water quantity, type, and source used on a site determine its embodied carbon emissions. Emissions from treatment chemicals and processes occur for potable water, while gray water captured on site is generally emission-free if it's not being treated before release. Site water use should be tracked in multiple schedules:

Irrigation Schedule: An irrigation schedule will document assumptions for water use by irrigation type and zone weekly, monthly, and annually.

Water Feature Schedule: A water feature operations schedule should be created for each water feature to estimate the water source, volume, and estimated make-up water used each week, month, and year.

Maintenance Water Schedule: The maintenance schedule should include estimates for sources and quantity of water used for maintenance by activity for each week, month, and year.

The process for quantifying Operational Water (B7) emissions for a site carbon assessment is:

Carbon Assessment Tool:

a. Develop irrigation and water feature schedules based on the project planting and water feature sizes (Tables 4.4 and 4.5) over the 60 year reference study period. Include:
   - Area (m^2) of each irrigation type and/or water feature (maintenance water is not currently calculated in carbon assessment tools).
   - Water source for the irrigation and water features (eg. potable water or gray water)
   - Estimated water use (high, medium or low)

b. Input the information into a carbon assessment tool to calculate B7 emissions.

Manual Calculations:

1. Irrigation:
   a. Develop an irrigation schedule over the 60 year reference study period (Table 4.4). Include:
      - Area (m^2) of each irrigation type.
      - Quantity of water use for each area per year
      - Water source for each irrigation type (eg. treated water, ground water, etc.).
   b. Total the quantities of water used for each irrigation type
   c. Total the quantity of water used for each water source
2. Water Features:
   a. Develop a water feature schedule over the 60 year reference study period (Table 4.5). Include:

- Volume (m^3) of each water feature type.
- Quantity of water use for each water feature per year
- Water source for each water feature type (eg. treated water, ground water, etc)

b. Total the quantities of water used for each water feature

c. Total the quantity of water used for each water source

3. Maintenance water:

   a. Develop a maintenance water schedule over the 60 year reference study period (Table 4.6). Include:

   - Quantity of water use for each maintenance task per year
   - Water source for each maintenance task (treated water, ground water, etc.).

   b. Total the quantity of water used for each water feature

   c. Then total the quantity of water used for each water source

4. Sum the total water use (m^3) for irrigation, water features, and maintenance water by water source (eg. treated water, ground water, etc.).
5. Multiply the total amount of water for each water source (m^3) by the emissions factor for the source of water in Table 4.7.
6. Multiply the total kWh for each water source by greenhouse gas emissions factors for energy sources or electricity in BSR/ASHRAE/ICC Standard 240P, Quantification of Life Cycle Greenhouse Gas Emissions of Buildings for each year of the 60 year reference period (Table 7.3.2.2 for Electricity; Table 7.3.2.1 other energy sources), to calculate B7 emissions.
7. Use the following formula:

$$[B7] = \sum [(DW_{YEAR} 1 \text{ x } WE \text{ x } EF_{YEAR} 1) + \ldots (DW_{YEAR} 60 \text{ x } WE \text{ x } EF_{YEAR} 60)]$$

Where DW = Domestic Water in meters cubed, annual (m^3/yr)(kWh/yr);
WE = Water Energy Intensity (kWh/m^3);
EF = Emissions factor for specified year

Table 4.4 Site Water Use - Site Irrigation

SITE IRRIGATION EQUIPMENT	NOTES + EXCLUSIONS
Drip Irrigation Standard	
Drip Irrigation Pressure Compensated	
Fixed Spray Pattern Irrigation	
Micro Spray Irrigation	
Rotors	

Table 4.5 Site Water Use - Water Features

WATER FEATURES EQUIPMENT	NOTES + EXCLUSIONS
Water Feature	
Spa	
Other	

Table 4.6 Site Water Use - Maintenance Water

MAINTENANCE WATER	NOTES + EXCLUSIONS
Wash waster for pavements and surfaces	
Wash water for vertical surfaces	
Wash water for cleaning equipment and vehicles	
Other water use for maintenance	

Table 4.7 Generic Energy and Water Intensity of Water Types

WATER TYPE	GENERIC ENERGY INTENSITY (kWh/m³ water)[1]
Treated Water	0.35
Ground Water	0.528
Brackish Ground Water	0.845
Desalinated Seawater	3.645
Recycled water	0.291

[1] Houde, K., Jenson, A., and Shinn K. (2026) *The Beginner's Guide to MEP Embodied Carbon Version 2*. MEP 2040 based on the International Energy Agency (IEA). Water Energy Nexus 2016.

CHAPTER 5

Estimating Landscape Carbon Storage and Product Carbon Storage

ASLA 2025 Professional General Design Award of Excellence. A Floating Forest: Fish Tail Park in Nanchang City. Nanchang, Jiangxi Province, China. Turenscape James Florio

Design disciplines that work with living plant materials have the unique opportunity to maximize climate benefits by leveraging the natural ability of plants and soil to sequester and ultimately store carbon. However, estimating landscape carbon storage capacity from site vegetation is fundamentally different and more complex than measuring embodied carbon emissions from products and materials.

Biological carbon sequestration is the process of atmospheric CO_2 being taken up by trees, grasses and other plants through photosynthesis. It is stored carbon once it is permanently fixed in the cells of biomass (trunks, branches, foliage, and roots) and soils (USDA). About one third of carbon is stored above ground in plants and two-thirds is stored in the soil, plant roots, decaying material, and fossil fuels (NASA).

Sequestered carbon becomes stored carbon when the captured carbon is locked away in a stable biological, geological, or technological sink. This allows stored carbon to mitigate the effects of climate change by reducing the amount of greenhouse gases in the atmosphere (USDA).

Landscape Carbon Storage represents the stored carbon in both existing and new plants and soil (USDA). This scope is to be tracked and reported in the newly proposed module B9 Landscape Carbon Storage.

This chapter provides methods for estimating Landscape Carbon Storage (B9) from plants (B9.1) and soils (B9.2). This methodology guide proposes B9 as a new phase in the Use Stage outside of ISO or EN standards. **In a site carbon assessment, B9.1 and B9.2 should be totaled and reported separately from the project's embodied and operational carbon emissions.** Refer to Appendix II for an excel version of the tables in this chapter.

This chapter also provides methods for estimating Product Carbon Storage (A1, C4) which refers to the storage of biogenic carbon in construction materials produced from biological materials (OneClick LCA). This biogenic carbon is stored until the product decays or burns.

Table 5.1 Chapter 5 Landscape Carbon Storage and Product Carbon Storage

LIFE CYCLE STAGE AND PHASE	EMISSIONS CATEGORY	SITE ELEMENT CATEGORY	SITE ELEMENT SUB-CATEGORY
Landscape Carbon Storage **B9**	Stored Carbon	Site Vegetation (B9.1)	Existing Vegetation to Remain Restored Vegetation New Planting
	Stored Carbon	Soils (B9.2)	Existing Soils
A1 (Carbon Stored) **C4 (Carbon Released)**	Stored Carbon	Biobased Construction Materials and Products	Curbing and Edging Play Structures Retaining Walls Fences, Gates, and Rails Site Furnishings Covers, Shelters, and Screens Decks and Boardwalks

B9.1 | Site Vegetation

The greatest benefit from design of a site will come from carbon stored by retaining, protecting and/or restoring existing plants and soils on a site, rather than from new planting and soil amendments. Refer to Table 5.2 for average carbon storage in mature ecosystems.

Landscape Carbon Storage Potential of Plants

At the completion of a project's construction, most of the embodied carbon for the construction materials has already been released, while the landscape carbon storage potential of new planting is just beginning.

It is important to understand the assumptions and limitations of landscape carbon storage models. As a future projection, landscape carbon storage is not guaranteed. Sequestration and landscape carbon storage predictions can change due to land-use and management decisions, plant mortality, disturbance, disease, fire, or removal throughout a project's lifecycle; ultimately reversing carbon storage gains.

Broadly, there are two approaches to modeling landscape carbon storage potential:

1. **Estimation based on individual plants**
   Individual plant models usually report Net Primary Productivity (NPP), the total amount of net landscape carbon stored after accounting for probable respiration and decay during the reference study period (60 years). The annual sequestration rates for each individual plant are multiplied by the number of years in the study period and totaled for the final result. This approach is used by iTree and Pathfinder for trees to estimate landscape carbon storage potential over time. If using this approach, it will be important to limit the study period – such as at 60 years – to not over estimate the potential benefits given the probable life spans of the trees and plants.

2. **Estimation based on land cover**
   Land cover approaches, such as those used by CarbonConscience and Pathfinder, are estimated based on the area and composition of plant communities (e.g. forest stands or restored prairies) or the area of shrubs or grasses. For carbon assessment tools such as Pathfinder and Carbon Conscience that use a static landscape carbon approach or for manual calculations, multipliers should be used to account for the risk of reversal in landscape carbon storage. Based on the project's design and operations scenario, the associated risk of reversal multiplier (Table 5.7) should be multiplied by the total landscape carbon storage of the new plants on the site. This final figure is called the "net carbon removal benefit" (NCRB), and would be reported in a format such as 2,000 $kgCO_2e$ NCRB.

Estimating Use Stage Landscape Carbon Storage From Site Vegetation (B9.1)
Landscape Carbon Storage (B9) is not a life cycle phase included in ISO or EN LCA standards. It is a new phase being proposed by this guide as a means of tracking the landscape carbon storage potential of vegetation and soils throughout the Use Stage of the project.

The process for estimating B9.1 landscape carbon storage of plants in a site carbon assessment is:

1. Identify the types of all mature ecosystems or existing vegetation to remain (Tables 5.3 and 5.4).
2. Identify the area or quantities of all mature ecosystems or existing vegetation to remain.
3. Identify the types and sizes of all new trees, shrubs, herbaceous plantings, and lawn (Table 5.5).
4. Identify the area or quantities of all new trees, shrubs, herbaceous plantings, and new lawn.
5. Quantifying landscape carbon storage of site vegetation can then rely on a carbon assessment tool, manual calculations, or a combination of both:
   Carbon Assessment Tool:
   a. Input the types, sizes, area or quantities of plants into a carbon assessment tool to estimate landscape carbon storage from the existing and proposed vegetation. Carbon assessment tools are addressed in Chapter 6.

   Manual Calculations:
   a. Identify landscape carbon storage factors for the mature ecosystems (Table 5.2), other existing vegetation, and new plants (iTree).
   b. Multiply area or quantities of each type of vegetation by the landscape carbon storage factors, then total them.

6. Multiply total landscape carbon storage by the risk of reversal multiplier to achieve net carbon removal benefit (NCRB) (Table 5.7).

Table 5.2 Average Landscape Carbon Storage in Mature Ecosystems (60yrs)

ECOSYSTEM TYPES	AVERAGE LANDSCAPE CARBON STORAGE IN MATURE ECOSYSTEMS (inclusive of SOC) (kg CO_2e/m^2)
Tropical Rainforest	90.936
Tropical Moist Deciduous	46.592
Tropical Dry Deciduous	39.986
Tropical Shrublands	46.574
Mangrove Forest	240.513
Forested/Shrubby Peat Swamp	463.356
Subtropical Humid Forest	44.030
Dry Forest (Mediterranean)	69.357
Temperate Oceanic Rainforest	145.119
Temperate Continental Forest	79.770
Boreal Forest	89.487
Prairie Grassland	70.272
Dry Meadows	45.700
Temperate Mixed Tree, Shrub and Forb Landscape	81.863
Temperate Wetland and Salt Marsh	97.719
Temperate Turf Lawn	39.017

Sources: Carbon Conscience dataset, from aggregated literature review, mostly based on FAO global ecological zones (FAO 2001), and urban coverage studies by (Nowak et al., 2013).

Table 5.3 Site Vegetation - Existing Vegetation to Remain

The difference in landscape carbon storage between immature and mature plant communities, trees, and forests can be substantial. Mature plant communities can store more carbon than restored or newly planted areas of the same species because they are not slowed by transplant shock. Refer to Table 5.1 for Average Landscape Carbon Storage in Mature Ecosystems.

EXISTING VEGETATION TO REMAIN	PRIORITY ELEMENT	UNITS	NOTES + EXCLUSIONS
Protected plant communities and vegetation	x	m^2	Measure by area. Use acres/hectare for larger site and square foot/meters for smaller sites
Protected individual trees	x	qty	Identify species and measure diameter at breast height (DBH). Larger healthy trees have great potential for year to year carbon sequestration.

Table 5.4 Site Vegetation - Restored Vegetation

For restored vegetation, accounting for sequestration potential by land area can be a more appropriate and accurate model. This is particularly true for restoration ecology projects and large parks, as individual trees and plants may live and die, but the overall stand or plant community can be maintained and managed to reach maturity. Even for smaller restoration projects, such as a discrete prairie grass restoration project, accounting by land area can be more feasible and accurate than counting individual plants. This is why many carbon credits focus on land area rather than stem count for evaluation.

RESTORED VEGETATION	PRIORITY ELEMENT	UNITS	NOTES + EXCLUSIONS
Restored plant communities and vegetation	x	m^2	Measure by area. Use acres/hectare for larger site and square foot/meters for smaller sites
Restored individual trees	x	qty	Identify species and measure diameter at breast height (DBH). Larger healthy trees have great potential for year to year carbon sequestration.

Table 5.5 Site Vegetation - New Planting

NEW PLANTING	PRIORITY ELEMENT	UNITS	NOTES + EXCLUSIONS
Trees	x	qty	Some carbon assessment tools categorize individual trees by mature size, conditions, and climate to account for this variability and focus on biomass growth potential.
Shrubs		qty or m^2	Some carbon assessment tools categorize shrubs by area, container size, and/or low or high intensity.
Herbaceous plantings		m^2	Quantify herbaceous plants by area because of the relatively low biomass of living tissue in most typical individual herbaceous plants.
Lawn		m^2	

B9.2 | Soils

The accumulation of landscape carbon storage in the soil is called soil organic carbon (SOC). SOC accumulates over decades and centuries. If left undisturbed, soils are one of the most stable forms of landscape carbon storage. Therefore, stabilizing SOC requires sensitive land management.

Disturbing the soil through grading, tilling, and other processes releases soil carbon far more quickly than the time taken to accumulate it. It is often overlooked when focusing on the landscape carbon storage of plants.

Soil organic carbon (SOC) can account for as much as half the total landscape carbon storage of temperate ecosystems and even more for boreal and wetland ecosystems. Testing the existing SOC on a site will provide baseline soil data for determining the carbon storage of the existing soil and any added improvements. Tests should include the O and A horizons at a minimum.

This guide provides a method for measuring SOC in protected site areas only. Research about SOC from amended soils is not advanced enough to include at this time.

Estimating Soil Organic Carbon in Protected Site Areas (B9.2)

The process for quantifying soil organic carbon in protected site areas for a site carbon assessment is:

1. Determine the type of ecosystem being preserved (e.g. temperate, boreal, tropical, etc.)
2. Measure the area (m^2) of the existing soils that will be protected (Table 5.6).
3. After these steps, quantifying the landscape carbon stored of SOC will vary between carbon assessment tools and manual calculations:

   Carbon Assessment Tool:

   a. Currently carbon assessment tools only estimate the SOC as a portion of the carbon stored in preserved ecosystems.
   b. Input the area of the existing ecosystem to be protected (m^2).
   c. Input the ecosystem type to determine the carbon stored by the ecosystem.

   Manual Calculations:

   a. Perform soil tests by taking samples of the O and A horizons at multiple locations on the site. Test results should include % SOC as mass ratio per kg, and mass of O and A horizons per m^2.
   b. <u>For protected soils:</u>
      i. Multiply the mass of soil horizon O by the total soil protection area.
      ii. Multiply the mass of soil horizon A by the total soil protection area.
      iii. Multiply the % SOC (carbon) of soil horizon A by the weight of soil horizon A graded.
      iv. Multiply the % SOC (carbon) of soil horizon O by the weight of soil horizon O graded.
      v. Sum the total carbon (kg) of earthwork for both A and O horizons, then multiply by 3.66 for total CO_2e of stored in protected soils in B9.

Table 5.6 Soils - Existing Soils

SOIL ORGANIC CARBON (SOC)	PRIORITY ELEMENT	UNITS	NOTES + EXCLUSIONS
Existing Soil Organic Carbon (SOC) to Remain	x	m^2	

Table 5.7 Landscape Carbon Storage Percentages by Project Scenarios

RISK OF REVERSAL QUALIFIER	MULTIPLIER	PROJECT DESIGN & OPERATIONS SCENARIO
Protected	1.00	The study area will have a perpetual easement, such as a park, trail, or conservation easement that prevents future development without the consent of both the landowner and the easement holder, such as a land trust or parks department, and generally must not cause a material adverse effect on the easement's purpose. In addition, the project has an operations and maintenance plan or refers to existing operational standards, such as those within an agency, that provide best practices for the maintenance and protection of trees, plantings, and soils.
Semi-Protected	0.75	The study area will have a term or appurtenant easement, such as a voluntary deferment easement for a specific piece of land that can be terminated at will, or a temporary conservation easement that prevents future development for a set period (at least 20 years). Or the owner or client is willing to sign an affidavit that the intention of the planting plans will be maintained for at least 20 years. In both scenarios, the project has an operations and maintenance plan or refers to existing operational standards.
Possible	0.50	There are no easements or legal commitments to protect the planting but the landscape is long term not temporary.
Temporary	0	If the landscape is known to be temporary for less than 10 years, it is not recommended to report storage potential.

Biobased Construction Materials and Products

Construction materials with biobased content, such as durable wood products, store biogenic carbon until they decay or burn. In Environmental Product Declarations (EPDs), GWP_{BIO} indicates product carbon storage in biobased materials that were sustainably harvested and not from native forests. In non-sustainably harvested materials or those from native forests, this number would be zero.

Product carbon storage in biobased construction materials is considered an inventory metric that is tracked as additional information, but not included in life cycle stages. When the product is removed from use and disposed of in a landfill or incineration after the project's use stage, the stored carbon is released along with other GHG emissions such as methane, depending on the disposal method. If the product is reused or recycled, the carbon emissions from the stored carbon are treated differently by different countries' standards.

The North American standard — Sustainability in buildings and civil engineering works - Core rules for Environmental Product Declarations (EPDs) of construction products and services — allows for some permanent product carbon storage at the landfill where it may never fully decompose (ISO 21913:2107). Also, this standard does not require reporting beyond the product stage, so product carbon storage can appear as if it offsets all or part of the embodied carbon emissions.

The European Standard — Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products — does not allow any permanent product carbon storage to exit the system. It requires emissions from the product carbon storage to be shown in the End of Life Stage (EN 15804:2102 + A2:2019) along with other emissions from its disposal. For wood from non-sustainably harvested (ISO 21913:2107) or native forests (EN 15804:2102 + A2:2019), product carbon storage is not counted in a carbon assessment.

Both standards require GWP biogenic carbon figures (GWP_{BIO}) to be presented separately from GWP fossil carbon (GWP_{FOSSIL}) figures for biobased products. "Discounting" the product carbon storage from the embodied carbon of the product is not allowed.

Product carbon storage is an evolving area of carbon assessments with a variety of approaches by tools and standards. In-depth information about accounting for product carbon storage in construction materials and other differences between the two product-level standards are outlined in a publication by the Carbon Leadership Forum.

As this guide is being published through American Society of Landscape Architects (ASLA), the North American Standard, ISO 21930:2017 section 7.27 should be used. This approach is also aligned with ECHO standards, which recommends reporting of product carbon storage should meet the following criteria:

- Only biobased lumber and decking products.
- Only those products that were sustainably harvested and not from native forests.
- Stored biogenic carbon is reported as product carbon storage in phase A1 (ASHRAE).
- Stored biogenic carbon is reported as emitted when combusted, decomposed, or degraded (phase C3) or combusted (phase C4) (ASHRAE).
- Stored biogenic carbon is reported separately as "additional information" from all other carbon emissions and storage (ASHRAE).

The process for quantifying product carbon storage (A1 and C4) for a site carbon assessment is:

Carbon Assessment Tool:

a. There are no additional inputs as tools automatically measure product carbon storage from the material quantity and type that is entered for A1-A3 emissions.

Manual Calculations:

a. Refer to the A1-A3 material inventory for total mass (kg) of each component listed in Table 5.8 included in the site project scope.
b. Total the mass (kg) for all wood components.
c. Multiply the total mass of all wood components by 1.83 to convert to kgCO_2e of product carbon stored. *Source: Carbon Conscience Data Set, 2024.*
d. This stored carbon (kgCO_2e) is only shown as additional information in the carbon assessment. This means that neither the negative emissions of storing the carbon from the atmosphere in the product, nor the release of it is included in carbon assessment results.

Table 5.8 Biobased Construction Materials and Products

Assembly components likely to be made from wood are listed while components such as footings and fasteners are not listed because they are not biobased. Other biobased materials such as coatings or erosion control materials are not included, as the amount of product carbon storage is minimal. This chart is tracking product carbon storage. Embodied carbon of these elements is tracked and totaled separately.

SITE ELEMENT SUB-CATEGORY	PRIORITY ELEMENT	COMPONENTS	NOTES + EXCLUSIONS
Decks and Boardwalks	*Reference Ch. 3*	Decking	
		Joists	
		Beams	
		Posts	
		Bracing	
		Rails	
		Steps	
Fences and Gates	*Reference Ch. 3*	Top/Bottom Rails	
		Fence Panel	
		Posts	
Site Furnishings	Reference Ch. 3	Benches	
		Waste Receptacles	
		Signage	
		Other	
Overhead Structures	*Reference Ch. 3*	Posts	
		Beams	
		Joists	
		Purlins/lattice/other	
Retaining Walls	*Reference Ch. 3*	Timbers	
		Deadmen	
		Boards	
		Other	
Play Structures	*Reference Ch. 3*	Posts	
		Beams	
		Joists	
		Decking	
		Rails	
		Steps	
		Other	
Curbing and Edging	*Reference Ch. 3*	Board	
		Stakes	
		Other	

CHAPTER 6

State of the Tools

ASLA 2026 Professional General Design Honor Award.
Harbor Wetland: Green Infrastructure as Civic Space. Baltimore, Maryland.
Ayers Saint Gross / Pete VonDeLinde

Carbon assessment tools allow site designers to track, analyze, and report on their project scope and associated emissions and storage potential. This chapter is an overview of those tools, noting their system boundaries.

Each carbon assessment tool has its own method and structure for its data and reporting. Refer to Table 6.1 for a quick overview of reporting features and Table 6.2 for greater detail about the inclusions and assumptions by life cycle stage for embodied carbon, operational carbon, and landscape and product carbon storage within each tool.

Table 6.1 Tool Reporting Overview

TOOL	REPORTING FEATURES				
	Emissions Broken Out by Life Cycle Stage	Product Carbon Storage Reported Separately	Landscape Carbon Storage Reported Separately	Includes Operational Energy Carbon Emissions	Includes Operational Water Carbon Emissions
CarbonConscience v2	no	yes	yes	no	no
Pathfinder v3.3	yes	no	yes	yes	yes
C.Scale	yes	yes	yes	yes	no
One Click Infrastructure LCA*	yes	yes*	no*	no*	no*

**One Click Infrastructure LCA measures emissions from site hardscape materials and infrastructure assemblies but does not measure landscape carbon storage.*

Table 6.2 Life Cycle Stages and Landscape and Product Carbon Storage of LCA Tools

CARBON ASSESSMENT TOOL	LIFE CYCLE STAGES INCLUDED						LANDSCAPE CARBON STORAGE & PRODUCT CARBON STORAGE
	A1-A3	A4	A5.1 - 5.3	B2 - B5	C1-C4	D STAGE	
Carbon Conscience v2	yes	Default & editable placeholder assumption factors for both distance &	**A5.1**: Default emissions factor applied to user demo inputs **A5.2**: 1% - 4% Emissions contingency applied to materials **A5.3**: n/a	B4 only Landscape Carbon Storage	no	no	Biogenic Carbon in construction materials is reported as a separate value from emissions & is included as an independent variable, assuming that 50% of the dry biomass of the wood used in the project is pure carbon and is sustainably sourced in accordance with EN Code 16485, 2014.Carbon Sequestration is projected by land use for a 60yr growth cycle, accounting for comparable carbon-carrying capacities by biome.

Table 6.2 (continued)

CARBON ASSESSMENT TOOL	LIFE CYCLE STAGES INCLUDED						LANDSCAPE CARBON STORAGE & PRODUCT CARBON STORAGE
	A1-A3	A4	A5.1 - 5.3	B2 - B5	C1-C4	D STAGE	
Pathfinder v3	yes	Default & editable placeholder assumption factors for both distance &	**A5.1**: Default emissions factor applied to user demo inputs **A5.2:** 2.5% Emissions contingency applied to materials **A5.3**: n/a	B2, B4 Landscape Carbon Storage + (vegetation only)	no	D2 Exported Utilities	Landscape and product carbon storage is shown for wood and other biobased materials, protected trees, and protected ecosystems. Landscape carbon storage is equal to 50% of the dry biomass. Gross sequestration and decomposition figures for each tree group and age period are summed and then subtracted to calculate net sequestration for the project over 60 years.
C.Scale	yes	Default Distance and Mode aligned with 240P per material category Assumption Factors C.Scale defaults to emission factors from the ASHRAE 240P draft guidance in table 6.5.2.1.	**A5.1:** Calculated per floor area of the demolished building, using a default emissions factor from ASHRAE 240P (2nd draft) **A5.2:** When no additional data is provided, C.Scale uses a default emissions factor from ASHRAE 240P (2nd draft) of project floor area. **A5.3** For each material and building assem-bly, C.Scale assumes a % of the installed total is wasted during construction. For all waste incurred during A5.3, we calculate A1-A4 and C2-C4 emissions for the wasted material and assign it to A5.3 emis-sion for that material's category	yes Landscape Carbon Storage reported as a separate inventory metric	yes	D1 per material, D2 Exported Utilities	C.Scale reports fossil carbon emissions (GWP-fossil) associated with manufacturing, use, and end-of-life of biobased materials, but does not include the "negative emissions" from biogenic carbon entering the "product system" in modules A1-3, nor the release of CO_2 back to the atmosphere in C3/C4. The model adopts a carbon balance approach over the lifetime of the building. Currently, C.Scale does not report biogenic carbon emissions (GWP-bio) per life cycle stage. Product carbon storage is shown as an inventory metric per ISO21931, EN15978 and ACLCA Guidance. C.Scale measures the annual landscape carbon storage of living and growing landscapes. They assume that all plantings will achieve maturity across the building project's reference period. Landscape carbon storage is accrued year over year by amortizing the total landscape carbon storage in mature landscapes over the model's reference period.

CHAPTER 7

Sustainability Certification Programs

ASLA 2026 Professional General Design Honor Award. Houston Arboretum & Nature Center. Houston, Texas. Design Workshop; Reed Hilderbrand / Brandon Huttenlocher/ Design Workshop

Green building, landscape, and infrastructure certifications have proven to be an effective method for the implementation and execution of sustainable design strategies and construction practices.

These certifications are evolving to include more robust regulations and credit pathways to reduce a project's carbon emissions, especially as it relates to site work, and landscape carbon storage opportunities. Practitioners can leverage this opportunity to make sure the site scope is analyzed and represented in the project's carbon assessments. Table 7.1 outlines the current representation of site elements in carbon assessments.

Table 7.1 Site Carbon Assessment in Sustainability Certifications

SUSTAINABILITY CERTIFICATION PROGRAM	Site Carbon Assessment Included in Certification	Required to Report Site Embodied Emissions	Required to Report Landscape Storage	Required to Report Site Operational Emissions
USGBC SITES V2	yes	yes	yes	no
USGBC LEED BD+C V5	yes	yes (just hardscape)	no	no
Living Future's Zero Carbon Certification	yes	yes	no	no
ISI's Envision	yes	yes	no	no

SITES v2, U.S. Green Building Council (USGBC)/ Green Business Certification Inc. (GBCI)
SITES, managed by USGBC/GBCI, provides a comprehensive certification framework for designing, developing, and managing sustainable and resilient landscapes and other outdoor spaces. As part of this framework, the SITES v2 Pilot Credit 3: Assess and Improve Site Carbon Performance was developed with the support of Climate Positive Design to introduce and develop standards for how projects can report on their site carbon.

In addition to the carbon assessment and quantification pilot credit, the SITES v2 Rating System covers various mandatory and optional strategies that sequester and store carbon, reduce embodied carbon, and reduce operational emissions.

LEED v5 BD+C, U.S. Green Building Council (USGBC)/ Green Business Certification Inc. (GBCI)
The newly released LEED v5 will go into effect on July 1st, 2027. LEED v5 extends the carbon assessment credits to include site hardscapes. The site scope is represented in the Material & Resources Prerequisite: Quantify & Assess Embodied Carbon and the MR Credit: Reduce Embodied Carbon.

In addition to the new LEED v5 (BD+C) prerequisites and credits, Climate Positive Design worked with USGBC to develop the LEED v4/4.1 Pilot Credit: Onsite Carbon Sequestration Through Plantings. LEED v5 has combined the Pilot, Innovation, and Regional Priority Points into a combined Project Priorities section, which includes credits for use but will continue to be updated over time. This carbon pilot credit is an option in this new LEED v5 credit arrangement.

Zero Carbon Certification, International Living Future Institute (IFLI)

This certification program addresses both operational and embodied carbon emissions. As part of the foundational certification requirements, New Building and Building Renovation projects must demonstrate a 20 percent reduction in the embodied carbon emissions of primary materials and exterior materials compared to a baseline building of equivalent size, function, and energy performance. All projects must set a goal to achieve below the ILFI-approved embodied carbon threshold for the upfront embodied carbon of the project for lifecycle stages A1-A5.

The site scope includes all structures, infrastructure, and areas disturbed as part of the project scope of work, including construction staging areas. Permanently installed site materials include roads, paths, paving, and special surfacing and paving. This does not include sitework materials, such as site preparation components, site utilities, or electrical site improvements. See Allowable Exclusions for Building Renovation, Interior, and Landscape + Infrastructure projects.

Envision, Institute for Sustainable Infrastructure (ISI)

The Envision Sustainable Infrastructure Framework is a comprehensive tool developed by ISI to help infrastructure professionals plan, design, and deliver more sustainable infrastructure projects of all types and sizes. Credit CR1.1: Reduce Net Embodied Carbon requires the project team to reduce the upfront carbon of the primary materials used on the project during construction and operation. The certification will award the project five points for a 5-percent reduction of embodied carbon compared to a baseline. Points increase as a larger amount of embodied carbon is reduced. Up to 20 points will be awarded if the team achieves a 50 percent embodied carbon reduction compared to the baseline.

CHAPTER 8

A Call to Action: Landscape Architecture 2040

ASLA 2025 Professional General Design Honor Award.
The Beach at Elliott Bay.
Seattle, Washington.
Surfacedesign, Inc. / Marion Brenner

We are at a critical point in time — the decisions made today will shape the resilience of our planet for generations.

The science is clear: we are exceeding planetary boundaries and destabilizing the systems that regulate Earth's climate, biodiversity, water, and soil. Climate change is no longer a distant threat; it is a present and accelerating crisis demanding immediate, decisive action.

This is a call to action. Landscape architects, civil engineers, and designers of the built environment need to collectively shift standard practices toward climate-and biodiversity-positive design. We need to:

1. **Commit to Greenhouse Gas Emissions Reduction**
   In 2025, ASLA joined our discipline partners (MEP2040, SE2050, AIA2030, Infrastructure 2050) in committing to greenhouse gas emission reduction targets in Landscape Architecture 2040: ASLA Climate & Biodiversity Action Plan. LA2040 encourages landscape architects to design and build for equitable climate and biodiversity solutions.

   The climate goal of our plan asks the landscape architecture community to reduce greenhouse gas emissions from projects by 50–65 percent by 2030 and double carbon sequestration and achieve zero emissions by 2040.

2. **Protect & Restore Ecosystems**
   When we protect soils and ecosystems, we preserve the landscape carbon stored there that took years to accumulate. When we increase biodiversity, natural systems bolster existing landscape carbon storage, deepen landscape storage capacity, and buffer our communities from the extremes of climate change. By designing this way, we align our work with the limits of the planet, instead of pushing beyond them.

   The biodiversity goal of our plan asks the landscape architecture community to protect, conserve, restore, enhance, and manage for biodiversity. Every project can support the global goals of protecting 30 percent of existing ecosystems and restoring 30 percent of degraded ecosystems by 2030.

3. **Measure Our Impact**
   In order to hold ourselves accountable and track momentum across the industry, we need to measure our impacts. This guide provides a standardized method of site carbon assessment and we advocate that you leverage it, share it, and report with it.

All built environment stakeholders can support a shift toward climate- and biodiversity-positive design. Collaboration is crucial with allied disciplines, product manufacturers, nurseries, contractors, and policymakers.

The urgency cannot be overstated. The time to act is now, and incremental change will not suffice. We have both the responsibility and the opportunity to lead a transformation in how we design, moving beyond minimizing harm to creating net-positive impact for our planet.

Landscape Architecture 2040 Commitment Program
The Landscape Architecture 2040: ASLA Climate & Biodiversity Action Plan introduced the idea of a new commitment program for landscape architects.

Though the plan focuses on ASLA climate and biodiversity programs and investments for 2026 to 2030, ASLA and the plan Task Force recognize the necessity of landscape architects committing to the ambitious goal of achieving zero greenhouse gas emissions and doubling carbon sequestration by 2040.

A program for landscape architects to commit to reducing the climate impacts of their projects is in development. This commitment program is evolving and will leverage this guide and an upcoming biodiversity assessment guide to standardize comprehensive site performance data collection.

Industry Site LCA Benchmarking Study
Two fundamental resources are required to facilitate the measurement and analysis of site decarbonization work for a commitment program:

1. First, standardized methods for assessing embodied carbon, operational carbon, and landscape and product carbon storage.
2. Second, a set of industry benchmarks based on these methods to track project decarbonization

This document offers standardized methods for measuring the carbon impacts of site work, while an industry benchmark study will give practitioners a unified metric of comparison on which to base their decarbonization achievements.

Leveraging the standardized framework of this document as a foundation, a practice group of landscape architecture firms, which represent an array of firm types and deliver diverse project work, are committed to conducting whole life carbon assessments of their projects using the methods provided in this document.

Collaboration and Alignment with Industry Carbon Commitments
This document has been intentionally aligned with the ecosystem of industry carbon commitments. These commitment programs include Structural Engineering 2050, MEP2040, AIA2030, and Infrastructure 2050.

Additional programs and industry groups include Climate Positive Design Challenge, Planning 2050, Contractor's Commitment Program, Innovation Design Consortium, AIA Material's Pledge, and the Embodied Carbon Harmonization and Optimization (ECHO) Project.

GLOSSARY

Above-ground biomass: The exposed living biomass of plants. Methods for measuring and evaluating above-ground biomass are well defined for both wood and herbaceous materials.

Allochthonous Carbon: This refers to carbon that moves beyond the immediate vicinity of sequestration. This can refer to leaf litter and trees falling into waterways, the extraction of timber and non-timber forest products by people, and other carbon dispersal mechanisms.

Autochthonous Carbon: This refers to carbon stored in the same vicinity as it is sequestered, such as in the trees themselves or the soils near them.

Below-ground biomass: This refers to living biomass associated with living plants, such as root systems, bulbs, corms, and rhizomes. In some ecosystems, such as salt marshes and prairies, below-ground biomass can be significantly greater than above-ground biomass.

Baseline: A starting point for a business-as-usual design that can be used to compare the environmental impact performance of a project's final design.

Benchmark: A set of environmental impact results that serve as an external reference point. It is based on a broader set of data from which the relative performance of a site can be evaluated.

Biomass to Carbon Ratio: Approximately 50 percent of dried biomass is pure carbon. To understand the CO_2e of this carbon, the mass of the pure carbon must be multiplied by 3.67 (the equivalent molecular weight of adding two oxygens to each carbon atom). This is equivalent to burning the dried biomass and releasing all the carbon into the atmosphere.

Biogenic carbon: Biogenic carbon refers to carbon that is derived from or contained in biomass (e.g. plants and trees) (EN 16485:2014). This is in contrast to fossil carbon, which comes from organic matter that has been deposited in the ground and is often emitted from the burning of fossil fuels.

Biological Carbon Sequestration is the process of atmospheric CO_2 being taken up by trees, grasses and other plants through photosynthesis. It is called stored carbon once it is permanently fixed in the cells of biomass (trunks, branches, foliage, and roots) and soils. About one third of carbon is stored above ground in plants and two-thirds is stored in the soil, plant roots, decaying material, and fossil fuels. Construction materials produced from biological materials store this biogenic carbon until they decay or burn. In LCAs and carbon assessment this is referred to as Product Carbon. Landscape carbon storage by existing and new plants and soil in a landscape is included in life cycle phase B9, Landscape Carbon Storage (Chapter 5).

Blue Carbon: Blue carbon is increasingly used to distinguish carbon sequestration through the accumulation of benthic organic material, such as peat, hydric soils, or from non-wetland soil organic carbon. Blue Carbon can be particularly important for carbon sequestration models due to the often extremely high CCC.

Business as usual: A term used in this guide to describe ordinary practices prior to use of climate or biodiversity positive design strategies. A business-as-usual scenario can be used as a baseline or benchmark when measuring embodied carbon, carbon sequestration, or biodiversity.

Carbon Carrying Capacity (CCC): This is the typical upper limit of landscape carbon storage potential for a given ecosystem or stand of trees. This metric is used in forestry and the carbon credit markets to determine the reasonable upper limit of carbon sequestration potential, as most ecosystems, at maturity, eventually reach a balance between sequestration and respiration. This can take the form of ecosystems such as tropical humid rainforests, where at maturity the forest decays as fast as it grows. This can also take the form of average potential, such as studies that model long-term averages in ecosystems adapted to periodic fire, such as lodgepole pine forests or Mediterranean shrublands.

Carbon drawdown: Removing carbon dioxide from the atmosphere, ultimately to the point that global warming starts reversing.

Carbon durability: Different forms of biomass have varying durability periods. For example, fallen deciduous leaves may leave only a small percentage of their carbon in soils after a year of decay while wood in a healthy, living tree can last for centuries.

Carbon neutral: An activity that removes as much carbon dioxide (CO_2) from the atmosphere as it emits.

Carbon sequestration is the active process by which atmospheric carbon dioxide (CO_2) is taken up by biological, geological, or technological elements. Sequestered carbon becomes stored carbon the moment the captured carbon is locked away in a stable biological, geological, or technological sink. Stored carbon contributes to mitigation of climate change by reducing the amount of greenhouse gases in the atmosphere.

Carbon Stocks: The absolute quantity of landscape carbon stored within a forest ecosystem at a specific time – typically reported in kg or tonnes CO2e. Carbon stocks can be helpful for reporting emissions from the demolition of existing plant communities or forests.

Climate Positive Design: Design that reduces emissions and increases sequestration over a project's life span while also providing environmental, cultural, and economic co-benefits, such as biodiversity, equity, and resilience.

Design for Disassembly: The design of landscapes to facilitate future change and the eventual dismantlement (in part or whole) for recovery of systems, components, and materials.

Deconstruction: The systematic dismantling of a landscape, typically in the opposite order it was constructed, to maximize the salvage of materials for reuse, salvaging materials for recycling, energy recovery, instead of sending materials to the landfill.

Embodied Carbon Emissions are the greenhouse gas (GHG) emissions generated by the raw material extraction, manufacturing, transportation, installation, and disposal of construction materials and equipment. Embodied carbon emissions also result from site maintenance equipment and materials. In the context of this guide, this refers to emissions from materials and processes for constructing and maintaining sites. Emissions are expressed in carbon equivalents (CO_2e), a standardized metric used to convert the global warming potential of all greenhouse gases such as methane or nitrous oxide into a single unit based on the equivalent global warming potential of carbon dioxide.

Environmental Product Declarations (EPDs): Standardized, third-party-verified documents that report the environmental impacts of a product based on a product life cycle assessment (LCA). EPDs are the best available mechanism for requiring product embodied carbon reporting and transparency.

Emissions Scenarios: In the context of the UN Intergovernmental Panel on Climate Change (IPCC) assessments, scenarios are directed at exploring possible future emissions pathways, their main underlying driving forces, and how these might be affected by policy interventions.

Fossil Carbon (GWP-fossil) comes from living matter that has died and been trapped underground for millions of years. Fossil carbon is emitted into the atmosphere from the oxidation or reduction of fossil fuels or materials containing fossil carbon (coal, oil, natural gas).

Global Warming Potential (GWP): The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO_2e) and is the agreed-upon metric for tracking embodied carbon.

Greenhouse Gas Emissions (GHG): Any gas in the atmosphere emitted by human activity that absorbs and re-emits heat. There are seven GHGs covered by Kyoto Protocol: carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6), and Nitrogen trifluoride (NF3).

Gross Primary Productivity (GPP): This is the total amount of carbon dioxide absorbed by the plants being studied, usually reported per year. GPP is primarily used in agricultural publications and shouldn't be used in LCA sequestration modeling because it doesn't account for respiration and decay.

Landscape Carbon Storage is carbon stored in living biomass such as trees, plants and soils. It is included in life cycle phase B9, Landscape Carbon Storage in the Use Stage.

Life Cycle Assessment (LCA): A systematic set of procedures for compiling and evaluating the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to a product or process throughout its life cycle.

Material Reuse: Installation of a previously-used material or product that requires limited to no processing for reinstallation and use on a different project.

Net Primary Productivity (NPP): This is the total amount of carbon net sequestered after discounting the probable respiration and decay within the study period. NPP is the primary metric used by the US Forest Service to estimate the sequestration potential of trees per year, as reported in the iTree application. NPP is a measure of the carbon sequestered and stored in new plant growth over a study period.

Net Zero Emissions: When the same amount of greenhouse gases being emitted are also being removed and/ or "avoided." This is accomplished by reducing embodied and operational emissions as much as possible and then investing in technologies or offsets to permanently remove emissions elsewhere.

Operational Carbon Emissions are the greenhouse gas emissions generated by the day-to-day energy and water used to operate an asset over its lifecycle. For sites and landscapes, these may include emissions from powering site equipment such as lights and controllers, as well as electricity used to clean and convey water. Operational carbon emissions result from electricity produced offsite as well as equipment on site.

Product Carbon Storage refers to biogenic carbon stored in construction materials produced from biological materials until they decay or burn.

Product Category Rule (PCR): A set of specific rules, requirements, and guidelines for conducting an LCA and developing EPDs for one or more product categories.

Sequestration Rates: These refer to the varying rates of sequestration among different species or plant communities. In general, ecosystems with dry soils, such as temperate forests or prairies, typically have changing sequestration rates depending on maturity. Typically, after a restoration or planting project, transplant stress suppresses sequestration for a period, followed by rapid sequestration that often gradually slows to a steady rate at maturity. This corresponds to "S-Curve" or logarithmic models of total landscape carbon stored. Wetlands, on the other hand, typically have more consistent sequestration rates and more linear models of landscape carbon storage accumulation.

Service Life: The duration for which a site effectively serves its intended purpose, meeting the functional needs of users without requiring substantial reconstruction. When performing whole site life cycle assessments, a service life of 60 years is typically assumed, although individual structures such as decks and pavements are often planned for 30 years.

Study Reference Period: For sequestration projections, it is important to define the model's study period. To align sequestration projects with typical LCA lifespan projections, this document recommends 60 years as the typical study period.

Soil Organic Carbon (SOC): This refers to the carbon component of soil organic matter (SOM), representing landscape carbon stored in decomposed plant and animal matter and living soil biomass, such as microbes and other soil organisms. Typically, SOC can be 50-60% of dried SOM.

System Boundary: A system boundary can describe the scope of a whole life site carbon assessment (Table 1.1), the scope of life cycle stages in a life cycle assessment, or the group of impacts to be evaluated.

Whole Life Carbon: Whole Life Carbon emissions are the sum total of all asset related GHG emissions and removals, both operational and embodied over the life cycle of an asset including its disposal (Modules: A1-A5 Upfront; B1-B7 In Use; C1-C4 End of Life). Overall Whole Life Carbon asset performance includes separately reporting the potential benefit from future energy recovery, reuse, and recycling (Module D).

Zero Emissions: An activity that releases no greenhouse gases to the atmosphere. As opposed to net-zero emissions, which allows for offsetting of emitted carbon to reach a balance of zero, the zero emissions approach focuses on the absolute emissions.

APPENDIX I: RESOURCES

Resources for Site Decarbonization Strategies

ASLA Climate & Biodiversity Action Committee Research & Guides

- ASLA Decarbonizing Specifications Guide
- ASLA Decarbonizing Design Guide
- ASLA Guide to Navigating Environmental Product Data
- Navigating Environmental Product Data: A Guide for Landscape Architects, Specifiers, and Industry Partners

Climate Positive Design Toolkit

Partner Industry Publications

- CLF Published Research
- ECHO Publications & Schema
- MEP2040 Beginners Guide to Embodied Carbon v2
- ASCE Prestandard for Assessing the Embodied Carbon of Structural Systems for Buildings

Carbon Assessment Tool Resources

- Pathfinder Methodology Report
- Pathfinder User Guide
- C.Scale Methodology
- C.Scale User Guide
- CarbonConscience v2 White Paper

EPD Databases

- Building Transparency's EC3 hosts an open-source database of 152,000 product-specific and industry-wide EPDs for the building industry. Its main function is to enable carbon smart choices during material specification and procurement. Their searchable construction material categories include concrete, masonry, steel, aluminum, wood, sheathing, thermal/moisture protection, cladding, openings, finishes, network infrastructure, asphalt, and manufacturing inputs. EC3 2.0 is in development.

LCA Standards

- ISO 14404, ASHRAE 240P, RICS
- ASCE 73-23 - Standard Practice for Sustainable Infrastructure (Pamela)

Resources for Measuring Operational Carbon Emissions

General References and Standards

- Action 1.2.3, LA 2040 ASLA Climate & Biodiversity Action Plan
- AIA 2030 Design Data Exchange (DDx) Reporting
- Energy Star
- Water Use Classification of Landscape Species (WUCOLS)
- Water Resources of the United States Hydrologic Unit Map
- Operational carbon footprint of the U.S. water and wastewater sector's energy consumption

Energy and Greenhouse Gas Emission Modeling Tools

- EnergyPlus
- Sima Pro
- Open LCA
- RETScreen
- Integrated Environmental Solutions Virtual Environment (IES VE)
- Dialux

APPENDIX I: RESOURCES

Energy Production Modeling Tools

- MEASUR Suite (DOE)
- NREL PV Watts Calculator

Resources for Landscape Carbon Storage

Carbon Sequestration & Storage Research

- i-Tree (for detailed arboriculture tools), https://www.itreetools.org/
- Society for Ecological Restoration Resource Center, https://www.ser-rrc.org/
- Lal, R., Lorenz, K., Hüttl, R., Schneider, B., & von Braun, J. (2013). Ecosystem Services and Carbon Sequestration in the Biosphere. Springer.
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Biogenic Carbon in Industry Research

- Microsoft Word - Understanding Real CO_2e Emissions in Mass Timber Production_White Paper_Clean.docx
- https://mithun.com/r-d-project/sustainable-wood-sourcing-specifications/
- https://www.pae-engineers.com/content/measuring-biogenic-carbon/

APPENDIX II: Material Quantities & Takeoff Template

Excel spreadsheet to facilitate tracking project data, site carbon assessment scope, and material quantity takeoffs.

APPENDIX III: B4 Replacement Factors

ELEMENT OR MATERIAL	EXPECTED SERVICE LIFE (years)	REPLACEMENT FACTOR (60 year project life)	NOTES
PAVEMENT			
Concrete	30-50	2	
Porous concrete	20-30	3	
Asphalt Pavement	15-25	3	
Precast concrete unit pavers	30-40	2	
Brick pavers, sand set	50-100	1	Replacement of full system; resurfacing required more often
Stone pavers, sand set	50-100	1	Releveling required
Stone dust, stabilized (binder replacement)	15-25	3	Releveling required
Stone dust, unstabilized	60-100	1	Releveling required
Safety surface	15-25	3	Plant based binders may need to be replaced every 5 years
Artificial turf	10-20	4	Releveling required
WALLS, RETAINING AND FREESTANDING			
Concrete	30-50	2	Replace whole system
Interlocking concrete block	40-70	1	
Timber	20-40	2	
Concrete cantilever, masonry veneer	30-50	2	
Dry Stack Stone	50-70	1	Repair required
Solid stone with mortar	50-70	1	Repoint estimated for every 30yrs
Solid brick with mortar	50-70	1	Repoint estimated for every 30yrs
Rammed Earth	50-70	1	Protection from moisture required
Interlocking compressed earth block	50-70	1	Protection from moisture required

ELEMENT OR MATERIAL	EXPECTED SERVICE LIFE (years)	REPLACEMENT FACTOR (60 year project life)	NOTES
STAIRS AND RAMPS			
Concrete	30-50	2	
Concrete, masonry veneer	30-50	2	
Stone with mortar	50-70	1	Repoint estimated for every 30yrs
Wood		See “Decking” and “Deck Structures”	
Metal		See “Metals”	
DECKING			
Pressure treated softwood	10-20	4	
Hardwood	25-35	2	
Thermally modified hardwood/ softwood	25-35/20-30	2/2.5	
Acetylated softwood	40-60	1.2	
Furfurylated hardwood/ softwood	25-35	2/2	
Fused bamboo	25-35	2	
Composite (plastic and wood)	25-35	2	
DECK STRUCTURE			
Pressure treated softwood	30-40	2	
Zinc-coated or powdercoated steel	50-70	1	Recoat estimated for every 30yrs
Concrete Footings	50-70	1	
SITE FURNISHING			
Steel	50-70	1	
Aluminum	50-70	1	
Wood		See “Decking” and “Deck Structures”	
METALS			
Stainless steel	50-70	1	
Galvanized Steel	50-70	1	Recoat estimated for every 30yrs
Powder coated steel	50-70	1	Recoat estimated for every 30yrs
Aluminum	25-35	2	