# EMBODIED CARBON OF BUILDINGS:
## INTERNATIONAL POLICY REVIEW

THE UNIVERSITY OF BRITISH COLUMBIA
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## Authors

The report was prepared for Forestry Innovation Investment by the University of British Columbia (UBC) Sustainability Hub. It is an update to a 2017 report by Zizzo Strategy Inc. (now Mantle Developments) and Brantwood Consulting (now Scius Advisory).

Authors:

- Angelique Pilon, UBC Sustainability Hub
- Megan Badri, UBC Sustainability Hub
- Kah Mun Wan, UBC Sustainability Hub

UBC Student Research Assistants:

- Nicole Balles, UBC Civil Engineering
- Simarjeet Nagpal, UBC School of Community and Regional Planning
- Mohini Singh, UBC School of Public Policy and Global Affairs
- Shiyao Zhu, UBC Faculty of Forestry

Contributor: Helen Goodland, Scius Advisory


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# Executive Summary

Addressing greenhouse gas (GHG) emissions from buildings is a key component of the global fight against climate change. Historically, policies have focused on reducing GHG emissions from burning fossil fuels for building operation, which represent only part of a building's total GHG footprint. There is a growing understanding that it is important to take a full life-cycle view toward construction-sector GHG emission reductions, thereby addressing embodied emissions as well as operating emissions. The United Nation's Environment Programme's 2022 Global Status Report for Buildings and Construction estimates that construction materials (i.e., concrete, steel, aluminum, glass, and bricks) were responsible for around 9% of overall energy related GHG emissions[1].

Embodied carbon emissions in buildings are the emissions generated by the resource extraction, manufacturing, installation, use and end-of-life processes of the building's materials through the combustion of fossil fuels, such as coal, oil, and natural gas directly, or indirectly for the production of electricity. The term 'carbon emissions' in this case is used to refer to a range of greenhouse gases, including methane and nitrous oxide, and embodied emissions are typically reporting as $CO_2$ equivalent ($CO_2$-eq).

This report is intended to provide an overview of current policies and technical resources in use around the world to measure and ultimately reduce embodied carbon emissions from buildings and construction materials. It was commissioned by Forestry Innovation Investment Ltd. to better understand the range of approaches taken by leading countries to addressing these embodied emissions and the strategies that could be implemented in Canada.

This version of the report, completed in March 2024, is an update to the 2017 report, "Embodied Carbon in Buildings and Construction: International Policy Review"[2]. While the objectives are the same, the scope of review is greater: there has been a significant expansion in the number and types of policies developed by national and sub-national political entities in the last seven years. The information contained in this report is based on: a review of 15 countries, including the 9 from the original report, and associated political entities; and a review of the current technical resources for measuring embodied carbon emissions in buildings and construction products.

[1] United Nations Environment Programme & Global Alliance for Building and Construction. (2024). Global Status Report for Buildings and Construction – Beyond foundations: mainstreaming sustainable solutions to cut emissions from the building https://wedocs.unep.org/20.500.11822/45095.

[2] The original report was developed by a collaborative team made up of Zizzo Strategy Inc. (now Mantle Developments) and Brantwood Consulting (now Scius Advisory). Scius Advisory provided input and review of the 2024 updated report.
Zizzo, R., Kyriazis, J., & Goodland, H (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

## Key Findings

Embodied carbon-related policies are in various stages of development across the world. While some countries have been developing tailored approaches for many years, others are in nascent phases of policy research, formulation, and planning.

An international trend is emerging where embodied carbon reduction approaches are being connected with broader net zero-emission targets, typically aligned with 2050 timelines, and integrated with low-carbon energy and economic policies across different sectors. Beyond this broad alignment, however, countries are not all following the same policy pathway. Instead, the authors found a number of consistent themes or trends within the policies:

- A section of countries, primarily in Europe, have well-established, interconnected policy ecosystems for embodied carbon reductions through stringent regulations, standardized and verified environmental performance methods and processes, and consistent research and innovations in low-carbon technologies and practices.
- More recently, economic approaches and market-oriented initiatives are starting to emerge, in the form of Buy Clean or Buy Green policies. These are generally procurement-based policies that align embodied emissions reductions with economic recovery or transition priorities through combinations of incentives or regulations that support decarbonization of local industry processes and manufacturing of low-carbon products.
- Embodied carbon reduction is only one aspect in the creation of low-carbon buildings and materials. A number of countries are also developing of complementary policies that address other aspects such as climate adaptation, building resiliency, reduction of operational carbon, etc. in parallel with embodied carbon reduction policy. Similarly, there is a connection between policies targeting embodied carbon emissions in building and policies promoting the use of mass timber, especially in countries with robust forestry industries.
- While, the primary focus of this report is to offer a broad overview of embodied carbon policies on a national scale, substantial progress is happening at the sub-national level. There are growing examples of regional and local governments taking the lead in developing new policy and piloting new strategies. A handful of international initiatives, through NGOs such as C40 Cities and World Resources Institute, support local governments in this work as well as connecting them to peers around the world.
- Financial incentives and resources are key to enabling successful embodied carbon emissions policies. The funding sources and uses are varied but are often used to support incremental policy implementation costs, establish foundational programs (e.g., databases, procurement requirements etc.) required by both the building and manufacturing industries, and facilitate training and education initiatives.

This range of policy types and approaches provide a wide set of precedents for Canada to draw from in creating its own policy ecosystem for embodied carbon emissions. To date Canada does not have a standard policy on embodied emissions reductions for buildings, although there are emerging policies and initiatives across the country, at the federal, provincial and municipal level.

This revised report, as with the original version, is written primarily for Canadian government policymakers – at the federal, provincial territorial or municipal level – who have responsibility for the built environment and for climate change mitigation. It is also relevant to those responsible for the

procurement of building and infrastructure projects or for product manufacturing and economic development. This report may also be of interest to businesses, design professionals, building product manufacturers and suppliers, non-governmental organizations, and other stakeholders who are involved in the design and construction of green buildings and infrastructure.

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# Glossary of Terms

The following definitions are sourced primarily international standards relating to embodied carbon and life cycle assessment.

**Biogenic Carbon:** the carbon that can be produced in natural processes by living organisms, but not fossilized or derived from fossil resources (ISO 21930:2017).

**Circular economy:** refers to a closed-loop model of an economy where waste is eliminated. All waste products are either sold, consumed, collected and then reused, remade into new products, returned as nutrients to the environment or incorporated into global energy flows[3].

**$CO_2$ Equivalent:** A $CO_2$ equivalent ($CO_2$-eq) is the unit of measurement for GHG emissions and it is the warming effect of a certain amount of GHG over a set period of time (usually 100 years) in comparison to $CO_2$[4].

**Embodied carbon emissions:** in construction - commonly referred to as "**embodied carbon"** refers to the GHG emissions associated with the manufacturing, maintenance, and decommissioning of a structure[5].

**Environmental product declaration:** Environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information. (ISO 21930:2017)

**Functional equivalent:** quantified functional requirements and/or technical requirements for a building or other type of construction works for use as a reference basis for comparison (ISO 21678:2020)

**Global Warming Potential (GWP):** A metric of greenhouse gas emissions impact measured relative to the impact of one molecule of carbon dioxide, usually over a 100-year time-frame[6].

**Greenhouse Gas emissions (GHG emissions):** Emissions from human activities that increase the amount and speed of greenhouse gases (e.g., carbon dioxide and methane) in the atmosphere at a pace that natural absorbers, such as forests, cannot remove these emissions[7].

**Life cycle assessment (LCA):** compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO14040:2006)

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[3] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

[4] Intergovernmental Panel on Climate Change (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf (page 122)

[5] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

[6] National Research Council of Canada (2022). National Guide for Whole Building Life Cycle Assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

[7] U.S. Environmental Protection Agency (2023). Climate Change Indicators: Global Greenhouse Gas Emissions. https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions

**Life cycle impact assessment (LCIA):** phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (ISO14040:2006).

**Life cycle inventory analysis (LCI):** phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (ISO14040:2006).

**Net zero $CO_2$ emissions:** Condition in which anthropogenic carbon dioxide ($CO_2$) emissions are balanced by anthropogenic $CO_2$ removals over a specified period[8].

**Operating emissions:** refers to the GHG emissions that are generated from the burning of fossil fuels used to heat, cool and power a building during its service life[9].

**Product category rules (PCR):** set of specific rules, requirements and guidelines for developing EPDs for one or more product categories (EN15804:2012).

**Scope 3 emissions:** Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly affects in its value chain[10].

**Upfront embodied carbon Emissions:** Emissions released into the atmosphere well before a building is operational [11].

**Whole building life cycle assessment (WBLCA):** life cycle assessment of the complete building enclosure, structural systems, interior walls, and interior finishes and trim of a building, which may include operating energy, but excludes furniture and attached cabinetry (ASTM E921).

[8] Intergovernmental Panel on Climate Change (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf (page 122)

[9] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

[10] U.S. Environmental Protection Agency (2023). Scope 3 Inventory Guidance. https://www.epa.gov/climateleadership/scope-3-inventory-guidance

[11] Perkins&Will (2020). Embodied Carbon in the Built Environment - A Primer. https://perkinswill.com/embodied-carbon-in-the-built-environment-a-primer/ (page 3)

# 1 Introduction

Addressing greenhouse gas (GHG) emissions from buildings is a key component in the global fight against climate change. Buildings and construction were responsible for 37% of all global GHG emissions in 2021[12]. However, carbon emission reduction efforts have historically been limited to GHG emissions[13] from burning fossil fuels for building operation, which represent only part of a building's total GHG footprint. There is a growing understanding that it is important to take a full life-cycle view toward construction-sector GHG emission reductions, thereby addressing embodied emissions as well as operating emissions.

Embodied carbon emissions in buildings are the emissions generated by the resource extraction, manufacturing, installation, use and end-of-life processes of the building's materials through the combustion of fossil fuels, such as coal, oil, and natural gas directly, or indirectly for the production of electricity. The United Nations Environment Programme's (UNEP) 2022 Global Status Report for Buildings and Construction estimates that construction materials (i.e. concrete, steel, aluminum, glass, and bricks) were responsible for around 9% of overall energy related GHG emissions[14].

The policies profiled within this report demonstrate that there is a growing understanding that it is important to take a full life-cycle view towards construction-sector carbon emission reductions, thereby addressing embodied emissions as well as operating emissions.

**Greenhouse Gas Emissions**

The term "GHG emissions" in this report refers to the emissions from human activities that increase the accumulation of greenhouse gases (e.g., carbon dioxide and methane) in the atmosphere at an amount and pace that natural absorbers, such as forests, cannot remove these emissions. Excessive concentration of GHGs in the atmosphere result in global climate change and the crises it causes.

Carbon dioxide ($CO_2$) makes up the vast majority of GHG emissions from the sector, but smaller amounts of methane (CH4) and nitrous oxide (N2O) are also emitted. Carbon is often used as a proxy term or unit for GHG emissions. A $CO_2$ equivalent ($CO_2$-eq) is the unit of measurement for GHG emissions, and it is the warming effect of a certain amount of GHG over a set period of time (usually 100 years) in comparison to $CO_2$.

## 1.1 STUDY OBJECTIVES

Recognizing the importance of reducing embodied GHG emissions associated with buildings and infrastructure projects, this report is intended to provide an overview of current policies and technical

[12] Global Alliance for Building and Construction (2023). Tracking Progress. https://globalabc.org/our-work/tracking-progress-global-status-report

[13] See Greenhouse Gas Emissions for the definition used in this report. U.S. Environmental Protection Agency (2023). Climate Change Indicators: Global Greenhouse Gas Emissions. https://www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions

[14] Global Alliance for Building and Construction (2023). Tracking Progress. https://globalabc.org/our-work/tracking-progress-global-status-report

resources in use around the world. It was commissioned by Forestry Innovation Investment Ltd. to better understand the range of approaches taken by leading countries to addressing embodied carbon and the strategies that could be implemented in Canada.

The original version of the report was completed in 2017 by a collaborative team made up of Zizzo Strategy Inc. (now Mantle Developments) and Brantwood Consulting (now Scius Advisory). It was based on a review of 9 countries with policies and programs aiming to reduce embodied emissions from buildings, as well as related initiatives like green building rating systems, and included technical resources and background information.

This revised version of the report was completed in 2024 by the University of British Columbia (UBC) Sustainability Hub, with input and review from Scius Advisory. The research objectives remain the same – to provide an overview of successful policies that could inform initiatives in Canada – but with a broader scope for consideration. Since 2017, there has been a significant expansion in the number and types of policies developed by national and sub-national jurisdictions around the world to reduce embodied carbon emissions associated with building and construction materials. The information contained in this report is based on:

- a review of 15 countries, including the 9 from the original report, and associated political entities; and
- a review of the current technical resources for measuring embodied carbon emissions in buildings and construction products.

This report offers an overview of the policies that have or are being developed by different countries and political entities, such as the European Union, as of February 2024. Some of these jurisdictions have multiple related policies and programs that have been refined over a number of years, while others are just beginning to develop initiatives. Together they provide an array of pathways and policies that could reduce the impacts of buildings on collective GHG emissions. They illustrate a range of options for Canadian jurisdictions to incorporate embodied carbon considerations into existing climate change mitigation toolkits.

This revised report, as with the original version, is written primarily for Canadian government policymakers–at the federal, provincial territorial or municipal level–who have responsibility for the built environment and for climate change mitigation. It is also relevant to those responsible for the procurement of building and infrastructure projects or for product manufacturing and economic development. It may also be of interest to businesses, design professionals, building product manufacturers and suppliers, non-governmental organizations, and other stakeholders who are involved in the design and construction of green buildings and infrastructure.

## 1.2 RESEARCH METHODOLOGY

The original 2017 report documented an investigation into leading policies and programs at the time. It was conducted via web searches, interviews with key contacts associated with each program and/or with the program users/stakeholders, and the authors' knowledge and expertise. A leading EU expert on embodied carbon policy validated the European examples identified for further investigation and provided additional insights. The North American and other examples were drawn from the authors' own

knowledge and their connections with governments and leading organizations in North America. Information gathering took place between November 2016 to May 2017.

The authors of the revised 2024 report reviewed the contents in the original report, and updated the information as needed. The investigation into existing and new policy was conducted via web searches and drew on the authors' own knowledge and research, as well as synthesis reports and references. This review took place between November 2023 and February 2024. The original author provided input and feedback on the revisions and updates to the content.

The embodied carbon policies are organized as follows:

- International:
    - Europe, which includes the European Union and 9 individual countries
    - Pacific Rim and South America, which includes 5 other countries developing carbon emissions policies
    - Other organization, which describes 3 NGOs with partnering relationships to support national and sub-national policy development.
- North America:
    - United States, which included the US Federal Government and 10 state-level policies.
    - Canada, which includes Canadian Federal Government, 2 Provincial level, 7 municipal level and 2 other organization policies

Throughout this report, a broad definition for the term “policy” has been used. In other words, the review has not been limited to government regulatory instruments. Market mechanisms, incentive programs, calls-to-action, and overarching stated intentions are included where appropriate and have shown to be influential. Relevant standards and other technical resources were identified and noted, where applicable. These are described in more detailed in the Appendices, including standards, databases, LCA tools and software, and green building rating systems. The term “buildings” is used primary to refer to habitable structures as well as infrastructure such as roads and civil works, unless noted otherwise. Other important technical terms, abbreviations, and acronyms are described in the Glossary.

## 1.3 EMERGING POLICY TRENDS AND STATE OF PLAY IN CANADA

Up until recently, in Canada and other jurisdictions, policymakers have predominantly focused on addressing the operating emissions of buildings. The reasons for this include:

- Operating carbon emissions have historically comprised by far the largest portion of the total carbon footprint of buildings.
- Operating carbon emissions are relatively easy to estimate since they are based on measurable energy consumption and known energy sources.
- There have been minimal regulation or incentives to report, let alone reduce, embodied carbon emissions from buildings.

- Embodied carbon emissions are more challenging to estimate, since they are accumulated across supply chains (which often span legal boundaries) and over the entire life cycle of a building (which often span different responsible parties).

As policies and practices to reduce building-related energy consumption have started to take effect and the use of renewable energy sources expanded, the operational emissions of buildings have begun to decrease. The embodied carbon emissions from building materials are becoming an increasingly large portion of the overall carbon footprint of buildings (Figure 1).

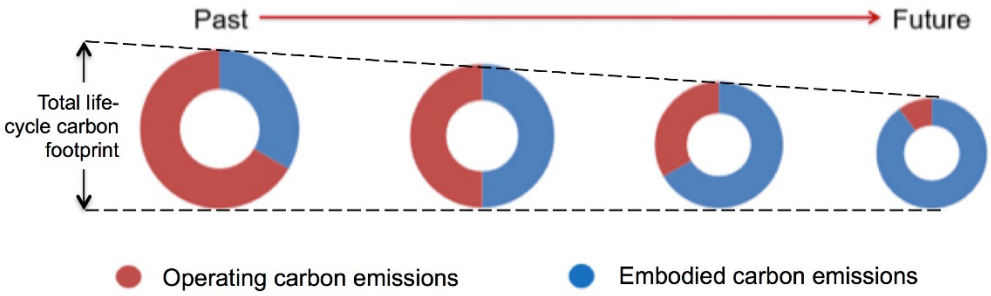


**Figure 1: Projected trend in life-cycle carbon in buildings in terms of scope and allocation (image courtesy of Athena Sustainable Materials Institute).[15]**

Additionally, reducing embodied carbon emissions from buildings can influence or support emissions reductions from related sectors, including manufacturing, transportation, and energy generation.

Over the past 5 years, the rate and intensity of climate-related environmental impacts including heat waves, wildfires and floods has accelerated, with repeats of the hottest years on record. The impacts are devastating for human health, community wellbeing and economic development. The urgent need to address climate change is being brought to public attention , which in turn is influencing political action.

Countries, other political entities and many leading businesses are committing to zero-emissions targets for 2050, and some are setting incremental targets for intervening dates. While the overall progress towards these targets has not been as fast as it needs to be, there has nevertheless been an increase in the rate at which policies, incentives and regulations aiming to reduce GHG emissions across major emitting sectors, including buildings and manufacturing, are being rolled out.

There is growing interest in climate change policies that can deliver GHG emissions reductions quickly. As the timeframes to achieve GHG emission reduction targets get shorter, so the embodied carbon portion becomes a much larger slice of the overall carbon emissions "pie" (Figure 2). The majority of embodied carbon emissions reductions are realized at the start of a building's life from the use of low-carbon

[15] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

materials and construction activities. By comparison, the benefits of operational carbon emissions measures accumulate slowly over many years.

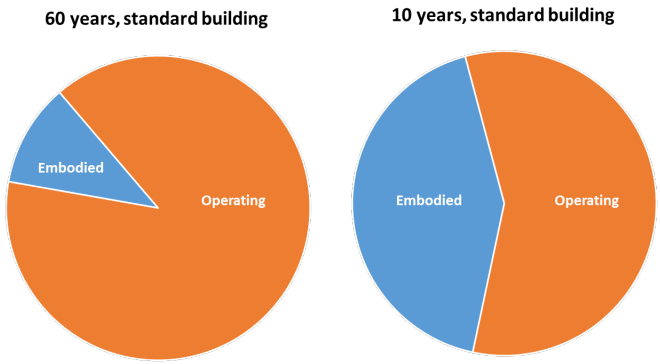


**Figure 2: The life-cycle carbon emissions for a typical building over 60 years and over 10 years, illustrating the relative impacts based on the time frame of analysis (image courtesy of Athena Sustainable Materials Institute).[16]**

Globally, the construction industry is modernizing and incorporating new digital technologies and construction processes. Powerful, data-rich tools, such as building information modelling (BIM), make it more technically and economically feasible to accurately compile building materials "take-offs" and to use embodied carbon analytical tools and calculators. There is also a growing availability of embodied carbon emissions data, analytical tools, and technical expertise which suggests that industry is becoming increasingly capable of designing and building low embodied carbon buildings. Policies and programs that send clear long-range market signals will be important in laying out the path forward and encouraging industry to make the necessary investments in skills development, technology, and equipment.

Increased availability of low-carbon or bio-based materials, such as low carbon concrete and mass timber, is encouraging project teams to specify low-embodied-carbon alternatives to conventional products. Demonstration and pilot project are promoting the spread of these products, such as mass timber, and influencing policy changes to encourage their use. An increase in the number of environmental product declarations (EPDs) helps project teams incorporate embodied emissions into procurement decisions, creating connections with economic development initiatives. However, there is growing need to invest in

[16] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf. The source of this data is an extensive Athena Institute/Morrison Hershfield LCA study of mid-rise concrete buildings (Marceau, M., L. Bushi, J. Meil, and M. Bowick. (2012). Life cycle assessment for sustainable design of precast concrete commercial buildings in Canada. 1st International Specialty Conference on Sustaining Public Infrastructure). The study is highly conservative because it covers strictly core and shell and does not include finishes, furnishings, heating, ventilation, and air conditioning (HVAC), and so forth—otherwise the actual embodied numbers would be significantly higher. The pie charts show the carbon footprint for a typical new 5-storey building in Toronto (a typical North American energy grid) over 60 years and 10 years of operation.

research and development (R&D) to continue to develop the new products, technologies and solutions needed to make low embodied carbon building design mainstream.

There are numerous well-established programs and regulations that might be viewed as proxy or precedent measures with respect to embodied carbon emissions. As currently configured, they are not perfect solutions (they may only address a portion of the embodied carbon impacts or certain building types), but they can help the industry get acquainted with new processes and approaches quickly. These policies include:

- carbon-pricing mechanisms
- GHG reporting programs
- green building codes and/or the requirement to achieve certification under green building rating systems
- green or social public procurement programs
- extended producer responsibility (EPR) programs, and
- policies that aim to reduce and divert construction, renovation, and demolition waste from landfills.

In the time between the publication of the original 2017 report and 2024, embodied carbon emissions policies and initiatives have started to emerge in Canada. This is being led at multiple scales of government, as well as by industry and non-profits groups. For example, at the federal level, a consortium led by the National Research Council of Canada (NRC) set up the LCA$^2$ Initiative, which supported the development of low-carbon concrete EPDs and resources, and national guidelines for whole building life cycle assessments (WBLCA)[17]. LCA$^2$ subsequently formed the foundation of a new research Platform to Decarbonize the Construction Sector at Scale and a newly developed Centre of Excellence in Construction Life Cycle Assessment (CECLA) at the NRC's Construction Research Centre[18]. At the municipal level, the City of Vancouver has implemented embodied carbon reduction requirements for new developments[19]. These and others are described in Section 3 of this report. However, while these initiatives are positive, they are often disconnected and inconsistent. To date, there has not been a coordinated set of policies, regulations, standards, and resources to advance embodied carbon reduction practices in Canada.

This report provides an overview of the combination of policies and approaches taken by countries and political entities around the world to reduce embodied carbon emissions associated with buildings. They illustrate a range of pathways that could inform the development of a Canadian-specific approach, as well as the types of technical resources needed to support both policy development and industry compliance.

[17] Low-carbon assets through life cycle assessment initiative, led by the national Research Council Canada. https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-assets-through-life-cycle-assessment-initiative

[18] Platform to Decarbonize the Construction Sector at Scale. https://nrc.canada.ca/en/research-development/research-collaboration/platform-decarbonize-construction-sector-scale

[19] City of Vancouver. Zero Emissions buildings. https://vancouver.ca/green-vancouver/zero-emissions-buildings.aspx#embodied-carbon

# 2 Embodied Carbon and Life Cycle of Buildings

## 2.1 DEFINITIONS AND PRINCIPLES

Embodied carbon emissions are the total GHG emissions associated with the materials and processes in a built asset from part or all of a building's life cycle stages. These emissions exclude operational energy and water uses[20] that are consumed in building operation phase. The carbon emissions throughout the building life cycle are described in Figure 3.

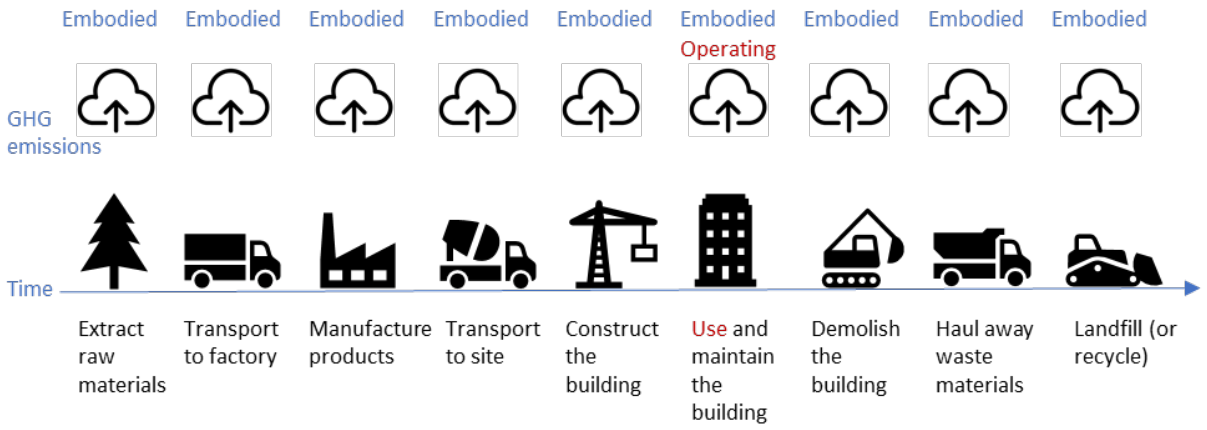


**Figure 3. Life-cycle carbon emissions due to buildings (image courtesy of Athena Sustainable Materials Institute).[21]**

The building and construction sector ranks as the third largest contributor to Canada's total carbon emissions, accounting for 12% of national GHG emissions following oil and gas sectors, and this percentage can increase to up to 18% if embodied carbon emissions are considered[22]. The urgency of addressing embodied carbon emissions will escalate as building operational energy efficiency improves and embodied emissions associated with manufacturing and use of materials become a larger proportion of total building-related emissions.

[20] Lopez, D., Kals, K., Unick, M., Teshnizi, Z., & Pilon, A. 2021. UBC Embodied Carbon Pilot - Bill of Materials Generation Methodology. https://livinglabs.ubc.ca/sites/default/files/2022-08/UBC%20Embodied%20Carbon%20Pilot%20Methodology%20%5B2021%5D.pdf

[21] Zizzo, R., Kyriazis, J., & Goodland, H. (2017). Embodied carbon of buildings and infrastructure: International policy review. Forestry Innovation Investment. https://www.naturallywood.com/wp-content/uploads/Embodied-Carbon-in-Construction-and-Infrastructure-International-Policy-Review.pdf

[22] Net Zero Advisory Body. Advice for Canada's 2030 Emissions Reduction Plan (2022). https://www.nzab2050.ca/publications/advicee-for-canadas-2030-emissions-reduction-plan

When combined with the carbon emissions produced from the operation of the building ("operating carbon") which results from burning fossil fuels for heating, cooling, lighting, and ventilation, embodied carbon emissions contribute to the total life-cycle "carbon footprint" of a building. These emissions are sometimes referred to as "Scope 3 emissions"[23]. GHG emissions from organizations can be divided into three categories, i.e., Scopes 1-3, as defined by the Greenhouse Gas Protocols[24]. Many companies and organizations are aiming to cut down their emissions across these scopes to meet internationally agreed targets on global warming reduction. **E**Figure 4 illustrates GHG emissions scopes and resources for carbon accounting.

**Carbon Footprint**

The life-cycle carbon footprint of a building is measured kg $CO_2e/m^2$ gross floor area/year and described by the following equation:

**Life-cycle carbon footprint = embodied carbon + operating carbon**

The term "carbon footprint" in the context of buildings is applied to operational carbon—the emissions associated with the process of operating the building—plus embodied emissions that comprises the GHG emissions from all other stages of the building's life cycle including resource extraction (e.g., mining and harvesting), processing and manufacturing of materials, building construction, building maintenance and repair, demolition, and disposition of materials at the project's end of life (e.g., landfilling and recycling).

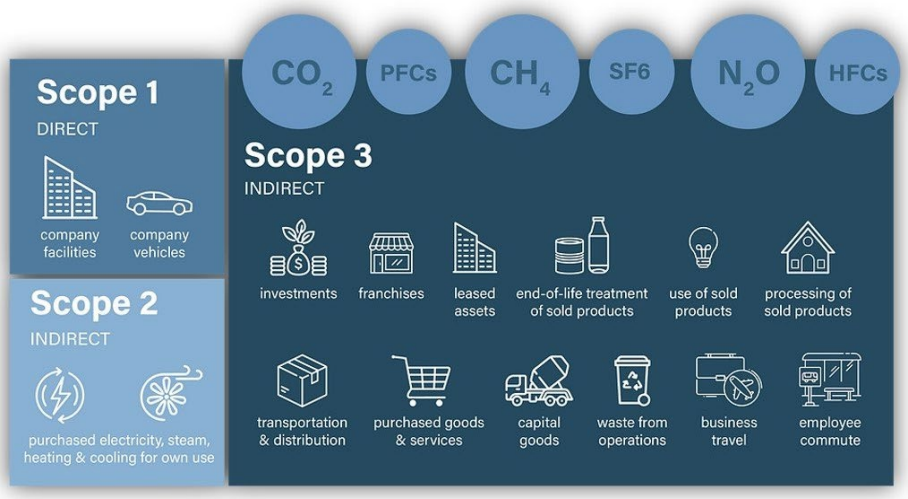


**Figure 4. Scope 1, 2, and 3 emisisons (image courtesy of Progressture Solar based on GHG protocol).** [25]

[23] Scope 3 emissions are those for which an organization is responsible, but which happen outside of the organization itself; for example, the emissions related to products purchased and disposed of. GHG Protocol Homepage. https://ghgprotocol.org/

[24] The Greenhouse Gas protocols are a standardized framework to measure and manage GHG emissions from both public and private organizations, developed by the World Resources Institute and the World Business Council for Sustainable Development. GHG Protocol Homepage. https://ghgprotocol.org/

[25] Progressture Solar (2022). Scope 1, 2 and 3 Emissions and What It Means for Your Company. https://www.progressturesolar.com/post/scope-1-2-and-3-emissions-and-what-it-means-for-your-company

For most types of buildings, embodied carbon emissions account for a significant amount of a building's total GHG emissions, the majority of which occur upstream of (that is, prior to) building occupancy [26]. These are called upfront embodied carbon emissions, and are not adjustable after building construction.

Figure 5 presents a building's carbon emission (whole life carbon vs embodied carbon vs operational carbon) over its whole life cycle stages: 1) product stage, 2) construction process stage, 3) use stage, and 4) end of life stage as defined by European standard EN 15978.

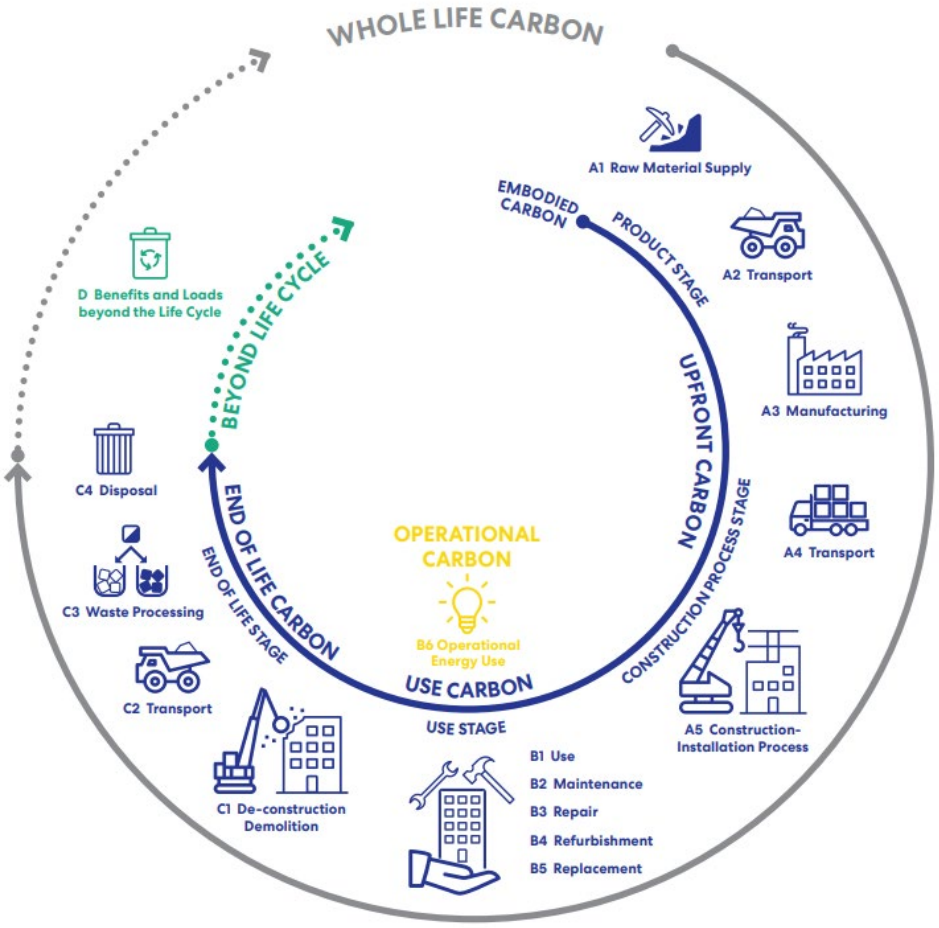


**Figure 5. Whole building life carbon stages and modules (image courtesy of Perkins&Will). [27]**

[26] Teshnizi, Z. (2019). Policy Research on Reducing the Embodied Emissions of New Buildings in Vancouver. https://vancouver.ca/files/cov/cov-embodied-carbon-policy-review-report.pdf

[27] Perkins&Will (2020). Embodied Carbon in the Built Environment - A Primer. https://perkinswill.com/embodied-carbon-in-the-built-environment-a-primer/

## 2.2 MEASURING EMBODIED CARBON

Life cycle assessment (LCA) is the internationally accepted science of measuring a product's potential environmental impacts on air, land, and water over its entire life cycle, from resource extraction to its end-of-life disposition. LCA reports on numerous lifetime environmental impacts like smog creation, water pollution, and waste generation.[28] However, embodied carbon is one of the most important impact categories in LCA. In some LCA methodologies it is captured under the "Global Warming Potential" (GWP) impact category.

LCA has been used for decades in many different industrial sectors, often by manufacturers who wish to understand—and reduce—the environmental impacts of their products. Applied to buildings, LCA is the de facto tool for calculating the environmental impacts due to manufacturing and transporting the construction materials, the process of construction, activities related to building occupancy and maintenance, demolition, and final waste disposal. Resources are consumed and emissions are produced during every life-cycle phase. LCA measures all environmental flows between a product and nature, estimates the potential environmental impact, and helps identify opportunities for reducing impacts.

Because LCA is the necessary tool for addressing embodied carbon, and because carbon is often the primary focus of LCA studies, the policy review for this report includes policies related to whole-building LCA (WBLCA) or to environmental product declarations (EPDs) (described in Section 2.3 below).

Conducting an LCA involves multiple steps and the use of a range of technical tools and resources. The LCA steps can be categorized in four phases as defined by the International Organization of Standardization (ISO) in the standards **ISO 14040: 2006, Environmental management – Life cycle assessment – Principles and Frameworks** and **ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and Guidelines.** These two standards provide the framework for consistent, transparent, and reliable LCAs. The four phases of conducting an LCA work and its iterative process are illustrated in Figure 6.

[28] Specifically, the typical LCA impact categories that are most commonly assessed within the construction sector are: global warming potential, acidification, eutrophication, smog, ozone depletion; depletion of non-renewable and renewable energy resources, depletion of non-renewable and renewable material resources, and water consumption.

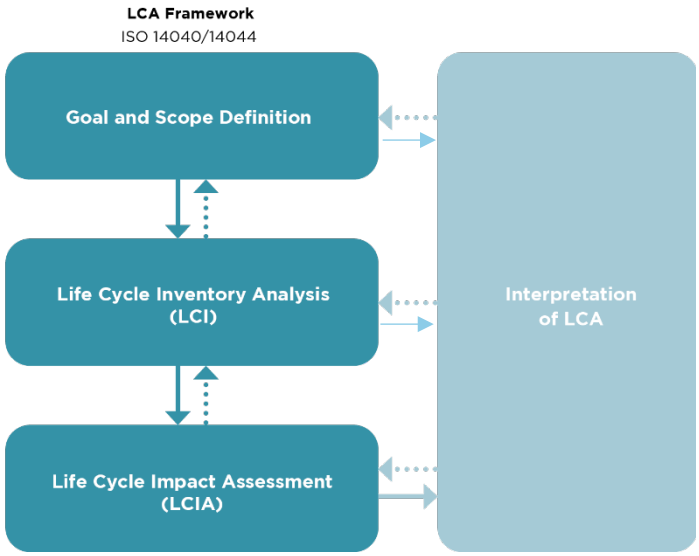


**Figure 6. Four phases of LCA process per ISO 14040 /14044 standards (image courtesy of UBC Sustainability Hub).**[29]

**Phase 1: Goal and Scope Definition**

The first step in an LCA is to establish the goal and scope of the assessment. The purpose is to clearly set out the rationale for LCA which then dictates the scope of the analysis (e.g. what is in and what is out), and the decisions needed to accomplish it.

**LCA Goal –** the goal of an LCA study should be set as the basis of the assessment. A whole building LCA can provide a range of insights on embodied carbon and/or environmental impacts of study for a building and the assessment information can be used for various purposes. For instance:

- To compare different design options at the early stage of design or design development phases.
- To enable effective communication with project teams and building stakeholders (for e.g., building owner) to design and construction buildings with less impact on the environment
- To demonstrate compliances with building environmental regulations and standards.
- To inform academic, industry and policy research and initiatives.

Depending on the LCA goal, considerations vary for the assessment's scope, data resources, tool and input method, and project phase. For instance, an LCA study to support decision-making between options at the beginning of a design process would probably include those building elements relevant to the options, such as key envelope and/or structural materials. In this scenario, the bill of materials (BOM) for the LCA study would be based on generic industry averages and estimates for component sizes. Alternatively,

[29] Adapted from Lopez, D., Kals, K., Unick, M., Teshnizi, Z., & Pilon, A. (2021). UBC Embodied Carbon Pilot - Bill of Materials Generation Methodology. https://livinglabs.ubc.ca/sites/default/files/2022-08/UBC%20Embodied%20Carbon%20Pilot%20Methodology%20%5B2021%5D.pdf (page 10)

when an LCA goal is to demonstrate regulatory compliance, the analysis would need to be comprehensive and include detailed information that reflects the building's actual materials and components.

- ***Assessment Timing***- depending on the LCA goal, the timing of when an LCA is completed is important. An LCA result based on early design documents would not be the same as an LCA result based on actual (as built) building design drawings. As design drawings are developed, project design data resources become more detailed, and it becomes increasingly important to identify the appropriate level of data development that aligns with the purpose of LCA study for a building.

**LCA Scope –** the scope of an LCA study should be well defined to ensure that the study details and choices align with the LCA goal. These choices include, but are not limited to: object of assessment, functional equivalent, system boundary (i.e., life cycle stages), reference study period, building data sources, impact categories, impact assessment methods and tools, background databases, etc.[30]

- ***Object of Assessment*** – the phrase "object of assessment" in a WBLCA study is defined as the entire building, including its construction elements, within the defined LCA scope. Current WBLCA policies and regulation typically require the inclusion of building envelope and structural elements as the object of assessment. These building elements can be described under a building classification system, which breaks down building assemblies into standardized categories and sub-levels, providing an organizational structure for classifying elements. For more information on building classification systems that can be used for standardizing WBLCA model inputs refer to NRC's national guide for WBLCA[31].
- ***Functional Equivalent*** – Functional equivalency is an important factor for comparing the results from two different WBLCAs [32]. In comparative studies, "the functional equivalent is a baseline building that represents the required characteristics and functionalities of the building to be assessed", that can be hypothetical or based on an actual building [33].
- ***System Boundary*** – the system boundary is the life cycle activities and stages that are included in a WBLCA. Figure 7 illustrates the system boundary and breakdown of modules within each stage according to Canadian National guidelines for WBLCA[34].

[30] For comprehensive list of key elements that can be considered in the scope of an LCA study refer to ISO 14044, 2006 and this reference book: Hellweg, S. (2005). The Hitch Hiker's Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application. https://emmanuelllivrepdfpopulairedanslemonde.blogspot.com/2021/03/the-hitch-hiker-guide-to-lca.html

[31] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

[32] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

[33] Pilon, A., Teshnizi, Z., Lopez, D., Kals, K., Unick, M., Pattman, G., Lorenzana, A., & Nguyen, V. Q. N. (2020). UBC Embodied Carbon Pilot. https://sustain.ubc.ca/sites/default/files/ECP%20Final%20Report-Phase%201%20June%202021.pdf (page 12)

[34] Modules B6 and B7-operational energy and water use- are part of a whole building LCA system boundary, but the result from these modules are excluded from whole building embodied carbon assessments because these two modules represent the operational emissions.

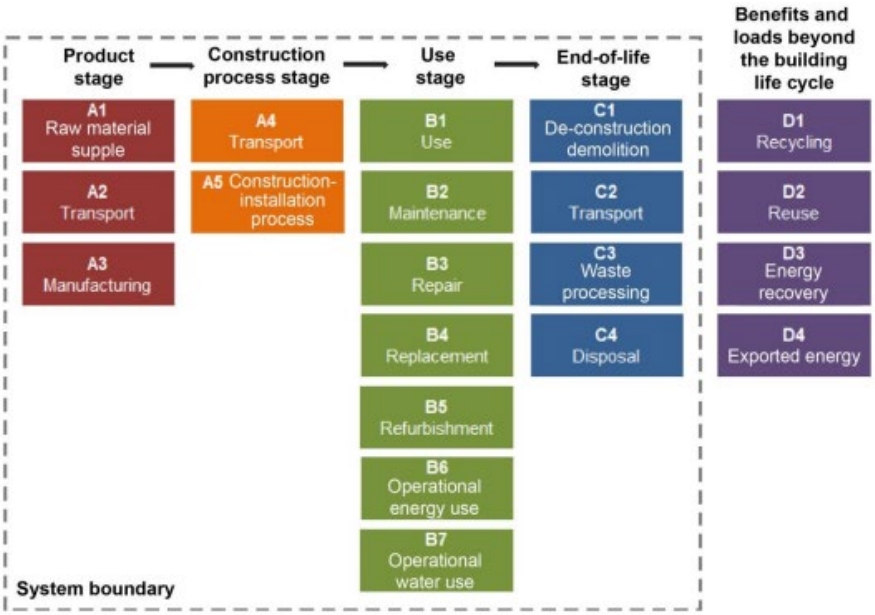


**Figure 7. System Boundary per NRC National Guildelines for Whole Building Life Cycle Assessments (image courtery of National Research Council of Canada).[35]**

- ***Reference Study Period*** **–** is the period over which the environmental impacts of a building are being assessed[36], and it often corresponds to the building service life. Current LCA regulations in Canada, such as the City of Vancouver Embodied Carbon Guide[37], require a reference study period of 60 years for WBLCA reports.
- ***Impact Assessment Tools*** **–** there is a range of software tools available for the building design community for conducting WBLCA and for carbon accountings for buildings and their products. The selection of a specific tool should be made in conjunction with other assessment parameters, such as LCA goal, timing, scope, and data source. It is also important to consider specific attributes of each tool, such as system boundaries, data input methods, and results formats. Additionally, each tool relies on its own database of environmental impact information, which can influence the accuracy, applicability, and comparability of results[38]. (See section 4.2 of this report for a list

[35] National Research Council of Canada (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/object/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910
[36] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910
[37] City of Vancouver (2023). Embodied Carbon Guidelines. https://vancouver.ca/files/cov/embodied-carbon-guidelines.pdf City of Vancouver is one of the few Canadian jurisdictions with a required design service life for new buildings and Canada does not have any standard or national policy on targeted or required service life, although other jurisdiction do. Europe has BS EN 1990 Eurocode which provide indicative design lives for various types of structures.
[38] Pilon, A., Teshnizi, Z., Lopez, D., Kals, K., Unick, M., Pattman, G., Lorenzana, A., & Nguyen, V. Q. N. (2020). UBC Embodied Carbon Pilot. https://sustain.ubc.ca/sites/default/files/ECP%20Final%20Report-Phase%201%20June%202021.pdf (page 16)

of common general and construction LCA tools and software that can be used for life cycle assessment of buildings).

- ***Impact Categories –*** refers to a class of impacts that represent the environmental issue of concern to which the LCA results may be assigned. These impact categories evaluate the potential effects on human health, ecosystems, and resources associated with different stages of a product's life cycle, including raw material extraction, manufacturing, use, and disposal[39]. Calculation of embodied carbon for demonstrating compliance with an embodied carbon standard require reporting of the Global Warming Potential (GWP) environmental impact category.

**Phase 2: Life Cycle Inventory (LCI) Analysis**

The second step of an LCA study is to identify and quantify the environmental flows (i.e., input and output) between the product's system throughout its life cycle. The Life Cycle Inventory (LCI) phase of an LCA links the building life cycle stages to the input from nature (e.g., materials and energy use) and output to nature (e.g., airborne emissions, water pollution, solid waste, etc.). For embodied carbon results, the output flows are GHG emissions. However, most of LCA software tools can also generate results for other impact categories such as ozone depletion, water pollution, etc.

The data collected from the LCI phase underpins the LCA methodology. The core activities from the LCI stage are:

- Data collection of all activities related to the building/product systems.
- Calculation of environmental loads, including resource use and pollutant emissions.

Preparing an accurate life cycle inventory for a building and/or its components can be challenging because of the use of different calculation methods, incomplete or missing data, and limitations to access data sources[40].

**Phase 3: Life Cycle Impact Assessment (LCIA)**

The third step is translating the environmental loads and impacts from the inventory result into environmental impacts for a product system throughout its life cycle. The LCI information collected in phase 2 is assessed using a life cycle impact assessment (LCIA) method to determine the consequences of the flows on the environmental impact categories. LCA tools calculate these impacts using data from different public and proprietary databases.

The Life Cycle Impact Assessment has three mandatory elements including:

- Impact category selection and definition.
- Classification – the organization of inventory data collected during the LCI phase into meaningful groups or classes. This step involves assigning the inventory data to specific environmental impact

[39] ISO/TC 207/SC 5 (2006). ISO 14040: 2006 Environmental management: Life Cycle Assessment Principles and Framework at https://www.iso.org/standard/37456.html and ISO/TC 207/SC 5 (2006). ISO14044:2006 Environmental management: Life Cycle Assessment Requirements and Guidelines at https://www.iso.org/standard/38498.html

[40] Badri, N. (2024). Multi-objective Optimization of Building Envelopes for Embodied and Operational Greenhouse Gas Emissions (A Study for Cold Climate with Carbon-Intensive Energy Grid). University of Calgary (under review).

categories, such as GHG emissions, water consumption, or land use. Classification helps to structure the data in a way that facilitates further analysis and interpretation.

- Characterization – the quantification of the environmental impacts associated with the inventory data. In this step, the classified inventory data are converted into impact scores or indicators using characterization factors. These factors represent the potential environmental effects of the inventory inputs and outputs on specific impact categories[41].

Once complete, the information and results can be compared to a benchmark such as industry averages, to a baseline established for the project in question, or a series of design alternatives.

**Phase 4: Interpretation of Result**

The last step of the LCA methodology involves the interpretation of results, through which the findings of the LCA study are combined to present the conclusions, limitations, and recommendations[42].

## 2.3 SOURCES OF ENVIRONMENTAL DATA

According to the National Research Council (NRC) Canada's National Guidelines for Whole Building Life Cycle Assessment, there are two sources of environmental data that are commonly used in WBLCAs[43]:

- **LCA databases –** LCA databases comprise life cycle inventory data for the activities a building undergoes, along with LCIA and broader life cycle assessment databases. While these databases are used for similar purposes, they have some differences. LCI databases contain inventory data on flows between a product and nature, whereas LCIA or LCA databases consist of LCA results for products. Many of these databases prioritize ease of use over comprehensiveness to encourage industry practitioners to familiarize themselves with LCA. As a result, some databases may focus on just a few categories of products (e.g., plastics) or only certain impacts (e.g., carbon and energy), or they may be tailored to specific construction typologies (e.g., roads). Appendix 2 summarizes the list of primary and fundamental LCA databases that are used in the LCA tools and/or LCA process of building and their products.
- **Environmental Product Declarations** – An Environmental Product Declaration (EPD) is a set of environmental impact data for a building product or service based on an LCA that has been conducted in accordance with product category rules (PCR), which are consensus-driven product-specific instructions for developing EPDs[44].

[41] Badri, N. (2024). Multi-objective Optimization of Building Envelopes for Embodied and Operational Greenhouse Gas Emissions (A Study for Cold Climate with Carbon-Intensive Energy Grid). University of Calgary (under review)
[42] ISO/TC 207/SC 5 (2006). ISO 14044:2006 Environmental management: Life cycle assessment Requirements and guidelines. https://www.iso.org/standard/38498.html
[43] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910 (page 33)
[44] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910 (page 33)

ISO standard 14025:2006 is the fundamental international standard for establishing principles and procedures for the development of Type III EPDs[45][46]. ISO 21930:2017 (sustainability in buildings and civil engineering works-core rules for environmental product declarations of construction products and services) complements ISO 14025 and provides core PCR documents and guidance on EPD development for construction products and services[47]. (see Appendix 1)

Once an EPD is completed, it is verified by and registered with an EPD program operator. The organizations that manage EPD programs and their dissemination are known as program operators. Each EPD should undergo third-party review to ensure conformity with LCA standards and the pertinent PCRs before being published. Market acceptance of EPDs is growing rapidly due to demands for manufacturer "transparency" related to sustainability claims and "consistency and comparability" related to other products. Factors that affect transparency, consistency, and comparability include the LCA method and background data used for the EPD, life cycle scope, and functional equivalence[48]. (see Appendix 3)

## 2.4 PERFORMANCE BENCHMARKING

A performance benchmark is established through "statistical analysis of current building stock that represents an average performance target of a building archetype"[49]. Embodied carbon policies ideally require a performance target as a reference point against which the comparison for a specific building project can be made. Sometimes, development incentives (such as density bonuses) can be aligned to a performance benchmark. This is similar to the current approach for operational energy and carbon regulations.

Benchmarking embodied carbon in construction projects is complex. WBLCAs include so many variables that achieving "apples-to-apples" comparisons can be difficult. If a performance target is not set, a baseline method can be defined to measure and validate the embodied carbon result for a project. In this method, an LCA analyst creates a generic baseline design that either reflects a typical building typology or is based on an earlier iteration of the proposed project. The LCA analysis is then conducted for a base building with the same scope, size, function, and construction practices as the proposed project, comparing the proposed design against this self-defined baseline. The proposed design should not exceed

[45] Lewis, M., Waldman, B., Carlisle, S., Benke, B., and Simonen, K. (2023). Advancing the LCA Ecosystem: A Policy-Focused Roadmap for Reducing Embodied Carbon. Carbon Leadership Forum. https://carbonleadershipforum.org/advancing-lca-ecosystem/. According to the report, a type III EPD is defined as "a third party verified document that reports the environmental impacts of a product based on the results of an LCA" (page 19).

[46] ISO/TC 207/SC 3 (2006). ISO 14025:2006 Environmental labels and declarations: Type III environmental declarations Principles and procedures. https://www.iso.org/standard/38131.html

[47] ISO/TC 59/SC 17 (2017). ISO 21930:2017 Sustainability in buildings and civil engineering works: Core rules for environmental product declarations of construction products and services. https://www.iso.org/standard/61694.html

[48] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910 (page 33)

[49] Perkins&Will (2020). Embodied Carbon in the Built Environment - A Primer. https://perkinswill.com/embodied-carbon-in-the-built-environment-a-primer/ (page 8).

the embodied carbon limits of the self-defined baseline. Due to the flexibility of this method, this approach is not reliable for comparing performance among different projects.

ISO 21678:2020 "defines principles, requirements and guidelines for the development and use of benchmarks." It provides a framework for the development of benchmarking methods and for the development of programs or policies that require benchmarking[50].

Many rating systems, such as Canada Green Building Council (CAGBC) LEED V5 and CAGBC Zero Carbon Building Design Standards, use this approach to benchmark and validate a project's LCA results. The City of Vancouver's new Building By-Law mandates embodied carbon reporting for new developments and requires either a performance target or a baseline path for benchmarking embodied carbon emissions results [51].

## 2.5 STRATEGIES FOR REDUCING EMBODIED CARBON IN BUILDINGS

There are many ways to reduce embodied carbon in buildings and construction projects. The AIA-CLF Embodied Carbon Toolkit for Architects report[52] summarizes these approaches into two main areas of focus:

- **Building design and material selection strategies,** that help project teams make design and material/system choices that will reduce embodied carbon emissions throughout the building's life cycle.
- **Procurement process and specification strategies,** that help design teams apply methods that minimize carbon footprints associated with sourcing and procuring building products and construction services.

Table 1 provides examples of embodied carbon reduction strategies that can be applied at the design, materials selection, and procurement stages.

Table **1. Examples of design, materials selection, and procurement strategies to reduce embodied emissions from buildings design and construction.**

| **Design Strategies** |
|---|
| Reuse/renovate/retrofit part or all of existing buildings |
| Reduce new buildings floor area |
| Reduce new buildings construction (such as below-grade concrete parkade) |
| Design lightweight and efficient building structures |
| Design for flexible and adaptable buildings |

[50] Bowick, M., O'Connor, J., Salazar, J., Meil, J., & Cooney, R. (2022). National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/ft/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

[51] City of Vancouver (2023). Embodied Carbon Guidelines. https://vancouver.ca/files/cov/embodied-carbon-guidelines.pdf (page 8)

[52] This report was prepared for the American Institute of Architects (AIA) and the Carbon Leadership Forum (CLF). Lewis, M., Huang, M., Carlisle, S., Simonen, K. 2021. AIA-CLF Embodied Carbon toolkit for Architects, Part III: Strategies for reducing embodied carbon. https://content.aia.org/sites/default/files/2021-10/21_10_STN_DesignHealth_474805_Embodied_Carbon_Guide_Part3.pdf

| |
|---|
| Use comparative WBLCAs to optimize building envelope design options |
| Design to optimize for prefabrication (design for modular systems, consider digital fabrication in project planning and use of BIM) |
| **Materials and System Selection Strategies** |
| Select and design timber/wood structure |
| Select biogenic materials over typical envelope materials (e.g., replace mineral insulation materials with fiberwood insulation type) |
| Choose insulation thickness and materials carefully to balance embodied and operation carbon trade-offs |
| Choose mechanical, electrical, and plumbing (MEP) systems with low to zero-carbon refrigerants |
| Select salvaged and refurbished materials that can have longer lives when repaired and recycled |
| Design for disassembly for the building end-life |
| Select building finishes or remove and minimize interior finishes where possible |
| Select local products to reduce transportation emissions |
| **Procurement Strategies** |
| Integrate EPDs and GHG emission limits into project specifications |
| Optimize materials specifications for use of low-carbon materials such as low-carbon concrete |
| Source sustainable wood materials: include procurement strategies for using salvages wood and/or locally harvested wood materials |
| Use EPDs during procurement |

Beyond building materials selection, and design and procurement strategies, construction processes can significantly reduce buildings environmental impacts including embodied carbon. While it is not currently considered in LCA frameworks, the use of electric construction machinery in regions with low carbon intensity grids, for example, can reduce embodied carbon emissions. The use of reclaimed materials, use of prefabrication, and support of circular economy principles are other important examples of strategies that indirectly guarantee embodied emissions reduction, but can be decided ahead of time in design phase of projects.

# 3 Global Embodied Carbon Policies

This section provides an overview of policies from countries around the world that impact embodied carbon emissions reduction for the building industry. The focus is on policies that are specifically targeting embodied carbon emissions of construction products or whole buildings, which sometimes influence manufacturing practices, energy grids, waste reduction and other activities that could also reduce embodied carbon. These are included when the policies explicitly note a connection.

The policies presented in this section are broadly organized into two categories:

- International - which looks at policies that are being developed in Europe, the Pacific Rim and South America. It also includes policies that are being led by several global organizations, and
- North America – which includes policies in the USA and Canada at both the national, state/provincial, and local levels.

## 3.1 INTERNATIONAL: EUROPE

The following leading example policies were developed within the context of a Europe-wide commitment to address climate change for the built environment[53]. The overview looks at the European Union as a whole and nine individual European countries: Belgium, France, Finland, Germany, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

### European Union

The European Union has an established legislative framework that targets energy efficiency and carbon reduction in the built environment. This framework is currently being revised and expanded following the **European Green New Deal**[54] and Covid-19 recovery.

The EU's **Energy Performance of Buildings Directive** (EPBD)[55] and the **Energy Efficiency Directive** (EED)[56], both last updated in 2023, promote policies to improve energy efficiency in buildings and decarbonize building stock by 2050[57]. While member states are able to develop measures best suited to their specific context and needs, the Directives provide a mechanism to channel EU financing towards the building sector in member states. Measures in the EPBD that address (directly or indirectly) embodied carbon in

[53] EUR-Lex, Environment and climate change. https://eur-lex.europa.eu/summary/chapter/20.html
[54] European Commissions, The European Green Deal: Striving to be the first climate-neutral continent https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[55] EUR-Lex (2021). Consolidated text: Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0031-20210101
[56] European Commissions (2023). Energy efficiency directive. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en
[57] EU EPBD was first implemented in 2002 and has been updated 4 times since then, with increasingly broad measures and stringent performance, and in alignment with other energy and emissions policies. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

buildings, include the introduction of minimum energy performance standards, energy reduction approaches, and increased quality and standardization of Energy Performance Certificates for buildings[58].

Established in 2005, the **European Union Emission Trading Scheme** (ETS) is a cap-and-trade system that limits the total amount of GHG emissions for different industry sectors and allows companies to buy or trade emissions credits. The current version for 2021-2030 is aligned with other EU climate and energy policies and goals and covers the manufacturing of several construction materials, including bricks, aluminum, iron, steel, and glass[59]. In 2023, a new and distinct system, ETS 2[60], was created to address the GHG emissions from buildings, road transport and additional sectors not covered in the original ETS. ETS 2 will begin to operate in 2027 and will target upstream suppliers and producers with a cap to reduce emissions by 42% by 2030 compared to 2005 levels. A share of the revenues from ETS 2 will be channelled into a Social Climate Fund to support vulnerable groups in the green economy transition through targeted investments or income support[61].

The **European Green Deal** is a set of interconnected policies and initiatives to transform the European Union into a "modern, resource-efficient and competitive economy" targeting GHG emissions reductions and economic growth for all, disconnected from resource use[62]. The **European Climate Law**[63] legislates the European Green Deal's goal of net-zero GHG emissions by 2050 and sets a GHG emissions reduction target of 55% by 2030, compared to 1990 levels. The European Green Deal includes both review and updates of existing policies for the EU and member states, as well as the creation of new policies. The updates to the EPBD and ETS 2 are part of these initiatives.

To drive the renovation of public and private buildings to improve energy performance and decarbonization, as well as address energy poverty and support economic development, the **Renovation Wave**[64] strategy was published in 2020. This initiative is designed to channel funding towards research and innovation, solving market barriers, technical assistance, and new construction jobs. Under the Renovation Wave, the EU is currently developing a roadmap to reduce whole-life carbon in the building sector.

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[58] Energy Performance Certificates provide information to buyers and renters on the energy performance of a specific building, as well as recommendation for energy efficiency improvements. They are included in promotional materials for sales or rentals. European Commission Certificates and inspections for Energy efficient buildings. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/certificates-and-inspections_en

[59] European Commission Directorate-General Climate Action (2021). Update of benchmark values for the years 2021 – 2025 of phase 4 of the EU ETS: Benchmark curves and key parameters. https://climate.ec.europa.eu/system/files/2021-10/policy_ets_allowances_bm_curve_factsheets_en.pdf

[60] EU Emissions Trading System 2. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-2-buildings-road-transport-and-additional-sectors_en

[61] EU Emissions Trading System Social Climate Fund. https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/social-climate-fund_en

[62] The European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[63] European Climate Law. https://climate.ec.europa.eu/eu-action/european-climate-law_en

[64] A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

In 2020, the European Commission adopted the new **Circular Economy Action Plan**[65] (CEAP), with initiatives aimed at reducing the consumption of natural resources and production of waste across the entire life cycle of products, while creating sustainable jobs and economic growth. The CEAP targets industry sectors with a high potential for material reuse, including construction and buildings. The construction industry is tasked with addressing the sustainable performance of projects, improving durability and adaptability of buildings, integrating LCAs in public procurement, exploring setting carbon reduction targets or carbon storage requirements, and setting material recovery targets for construction and demolition waste, and the re-habitation of old building sites. The European Commission is developing minimum mandatory criteria and targets for **Green Public Procurement** to reduce the environmental impact of public good services and works throughout their lifetime[66]. Currently the Commission publishes voluntary Green Public Procurement guidelines for members states choose to adopt in whole or part.

A variety of standards written by the **European Committee for Standardization (CEN)** Technical Committee aid the adoption of embodied carbon policies and use of LCA in building design and construction (see Section 4.1 for an overview). Typically, EU member countries adhere to these standards when adopting formal reporting requirements for LCA-based building performance or development of EPDs.

### Belgium

Belgium's Federal Public Service of Health operates a national program and database for environmental product declarations (EPDs), called **Belgium-EPDs** or **B-EPDs**[67] for building products and materials. When making environmental or performance claims, manufacturers must conduct an LCA, create and verify an EPD for their product in compliance with B-EPD requirements, and submit it to the database[68].

To complement the EPD database, Belgium has developed an LCA tool to assess the environmental impacts of building across their lifecycle and optimize the environmental impact of materials[69]. **The Tool to Optimise the Total Environmental Impact of Materials** (TOTEM)[70] draws on the EPDs in the B-EPD database and is recommended for use across Belgium to unify efforts to green the building industry. TOTEM aligns with a variety of green building rating systems, including BREEAM, LEED and DNGB, for use in Europe. TOTEM is based on a national LCA methodology called MMG ("Milieugerelateerde Materiaalimpact van Gebouwen"), which was developed from European LCA Standards.

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[65] European Commission Circular economy action plan. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

[66] European Commission Green Public Procurement. https://green-business.ec.europa.eu/green-public-procurement_en

[67] Belgium Health and Food Chain Safety, the Belgium EPD programme B-EPD. https://www.health.belgium.be/en/belgian-epd-programme-b-epd

[68] Public Health, Food Chain Safety and Environment of Belgium (2022). Environmental Product Declaration (EPD): A Concise Guide for Producers in the Construction Sector, B-EPD. https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/bepd-guide-en.pdf

[69] TOTEM was developed by a partnership between organisation representing three Belgian regions: the Public Waste Agency of Flanders (OVAM), Brussels Environment and the Public Service of Wallonia. TOTEM. https://circulareconomy.europa.eu/platform/en/toolkits-guidelines/totem-online-tool-architects-calculates-environmental-footprint-buildings

[70] Welcome to TOTEM. https://www.totem-building.be/

## France

**INIES**[71] is France's national reference database for environmental and health data on construction products and equipment. INIES is composed of two primary programs that provide verified Environmental and Health Declaration Sheets for construction products (Fiches de Déclaration Environnementale et Sanitaire - FDES vérifite) and Environmental Profiles (Profils Environnementaux Produits - PEP ecopassport) for electrical, electronic and climate engineering equipment. INES supports web access to allow design and LCA tools to interface with the digital data in the INIES systems. **PEP Ecopassport** is another EPD program specifically for electrical, electronic, and HVAC products[72]. It is a voluntary system that provides declaration of products adhered to ISO 14025 and 14040.

France's **2015 Energy Transition Law** (Transition Energétique pour la Croissance Verte, or TECV)[73] and **National Low Carbon Strategy** (Stratégie Nationale Bas-Carbone or SNBC) encourage new construction projects to be low energy and low carbon, as part of the pathway to achieving EU GHG reduction targets. The SNBC sets a goal of carbon neutrality by 2050 and outlines a transition to a low carbon economy, and set sector-based carbon caps. For the building sector, it sets a 2030 target of 49% reduction in GHG emissions compared to 2015 levels, and a 2050 target of complete decarbonization[74].

In 2016 and 2017, the government of France ran a voluntary pilot program called **Energie Positive et Réduction Carbone**[75] (formerly "Energie Carbone" or E+C-), to encourage better energy performance in buildings along with the reduction of operational and embodied carbon through training and incentives. Findings from the pilot informed new regulations, which built on the 2015 TECV and SNBC.

One of these was a 2022 energy and environmental regulation for building construction called **RE2020**[76]. RE2020 encompasses both residential and commercial developments and focuses on three areas: operational energy and associated emissions, comfort in hotter climate conditions, and embodied carbon emissions. It sets incremental improvements to improve the robustness of LCAs and EPDs through ongoing engagement with manufacturers of construction materials and equipment, and establishes increasingly stringent maximum carbon thresholds for construction sites[77].

Also applicable to embodied carbon in buildings, the French **Plan Ambition Bois Construction 2030** aims to increase the use of wood in French buildings and aligns with the embodied carbon reduction objectives of RE2020[78].

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[71] INIES: Who are we? https://www.inies.fr/en/inies-and-its-data/who-are-we/
[72] PEP Ecopassport Program. http://www.pep-ecopassport.org/
[73] The Energy Transition for Green Growth (2021). Government of France. http://www.gouvernement.fr/action/la-transition-energetique-pour-la-croissance-verte
[74] Government of France Ministry of Ecological Transition (2020). National Low Carbon Strategy. https://unfccc.int/sites/default/files/resource/en_SNBC-2_summary_4-pages.pdf
[75] Energy Positive Building and Carbon Reduction (Bâtiments à Énergie Positive et Réduction Carbone). http://www.batiment-energiecarbone.fr/
[76] France, RE2020 replaces RT2012 which set out standards for the energy efficiency of structures. https://www.ecologie.gouv.fr/reglementation-environnementale-re2020
[77] French Ministry of Ecological Transition (2021). RE2020 Environmental Regulations. https://www.ecologie.gouv.fr/sites/default/files/2021.02.18_DP_RE2020_EcoConstruire_0.pdf
[78] National Committee for Wood Development of France (2021). Plan Ambition Bois Construction 2030. https://cndb.org/actualite/plan-ambition-bois-construction-2030/

## Finland

Finland's **Climate Act** sets the goal for the country to be carbon neutral by 2035 and carbon negative soon after that[79]. Decarbonization of government assets is a part of this plan which includes operational emissions targets, and strategies to reduced embodied emissions by managing construction site energy, greening of the production chains, responsible procurement, and reducing material waste.

In 2023, Finland adopted a new **Building Act**, which establishes technical requirements for low-carbon buildings and incorporates measures for carbon reduction in buildings via the assessment of both negative and positive climate impacts throughout the building's lifecycle[80]. Additional policies on climate and material declaration and carbon limits are being developed and will be included in the National Building Code. A national **Built Environmental Information System** is also being set up to digitize development information and processes.

Finland is building an online database of GHG emissions data for construction products, processes, and services, **CO2data.fi**[81]. It currently includes industry average emissions, construction waste, durability, and recyclability information for common construction products, as well as services such as transportation, construction, and waste management. Since 2016, EPDs of construction materials are submitted to the Building Information Foundation RTS[82].

Additional measures[83] under the Ministry of the Environment (Ympäristöministeriö Miljöministeriet) include the **EcoDesign Act** to improve the integration of environmental issues and life cycle thinking into product design, and the **Low-carbon Built Environment Programme**, which provides funding for sustainable building projects. It also supports initiatives to develop a circular economy[84], including a Materials Marketplace (materiaalitori) service for waste producers. The **National Energy and Climate Strategy**[85] aims to increase the use of wood through funding initiatives, local policies, strengthening regional skills bases, and highlighting low carbon materials in procurement of public buildings.

## Germany

Germany's **ÖKOBAUDAT** is a national standardized database for ecological evaluations of buildings, managed by the Federal Ministry for Housing, Urban Development and Building[86]. The database includes life cycle datasets for building materials, construction, transportation, energy, and disposal processes with

[79] Ministry of Finance Finland (2022). Net Zero Government Initiative (NZGI) Finland. https://www.sustainability.gov/pdfs/finland-nzgi-roadmap.pdf

[80]. Finnish Government (2022). Government's Legislative Proposals to Parliament Aim to Reduce Emissions from Building and Promote Digitalisation. https://valtioneuvosto.fi/en/-//1410903/government-s-legislative-proposals-to-parliament-aim-to-reduce-emissions-from-building-and-promote-digitalisation

[81] Construction emission database. https://www.hiilineutraalisuomi.fi/en-US/Tools_and_services/Construction_emission_database

[82] Construction information Ltd (Rakennustieto Oy). Environmental services. https://ymparisto.rakennustieto.fi/en

[83] https://ym.fi/en/building-and-land-use

[84] https://ym.fi/en/circular-economy-in-the-construction-sector

[85] Ministry of Economic Affairs and Employment of Finland (2019). Finland's Integrated Energy and Climate Plan. https://energy.ec.europa.eu/system/files/2020-01/fi_final_necp_main_en_0.pdf

[86] ÖKOBAUDAT Sustainable Construction Information Portal. https://www.oekobaudat.de/en.html

both generic materials data and EPDs[87]. The Ministry also supports eLCA[88], a free LCA software tool for buildings connected to ÖKOBAUDAT. Institut Bauen und Umwelt e.V. (IBU) is a German organization that publishes EPDs in accordance with ISO and EN standards that is recognized internationally in several countries[89].

The **Assessment System for Sustainable Buildings** (Bewertungssystem Nachhaltiges Bauen für Bundesgebäude or BNB) for new buildings[90] sets out evaluation criteria in six groups – economic quality, sociocultural and functional quality, technical quality, process quality, and location – across their life cycle. Germany requires specific BNB Certification levels for federal projects, including a WBLCA, using ÖKOBAUDAT data. This is in addition to the voluntary green building rating system, **Deutshe Gesellschaft für Nachhaltiges Bauen** (DGNB[91]) that is used in all German speaking countries, which has an LCA performance strategy similar to BNB.

The German government set a goal of making the building sector climate-neutral by 2045, and in 2023 sponsored a **Climate-Friendly New Construction funding program** (Kreditanstalt für Wiederaufbau or KFN) to provide low-interest loan programs for climate-friendly buildings[92] that was administered by the Federal Promotion Agency for Efficient Buildings (BEG).

Many regions in Germany have supplemented this program with their own funds, often with a focus on wood construction to reduce carbon impacts. For example, Hamburg's **Modernisation of Non-Residential Buildings Programme**[93] subsidizes the cost of wood for new non-residential construction in Hamburg. The city of Freiburg's **Timber Construction Funding Programme**[94] was rolled out in 2020 to promote using renewable raw materials in construction. The **Timber Construction Campaign** embarked by the region of Baden Wurttemberg sets out targeted measures to achieve sustainable construction. These funds support Germany's **Charter for Wood 2.0**[95] which advocates for the sustainable use and management of wood.

[87] ÖKOBAUDAT datasets. https://www.oekobaudat.de/no_cache/en/database/search.html
[88] Terms eLCA in beta. https://www.bauteileditor.de/
[89] Institut Bauen und Umwelt e.V. (2023). 49 new members 2023 from all over the world. https://ibu-epd.com/en/47-new-members-2023-from-all-over-the-world/
[90] Bewertungssystem Nachhaltiges Bauen Homepage. https://www.bnb-nachhaltigesbauen.de/
[91] Building Sustainably with the DGNB. https://www.dgnb.de/de
[92] Federal Ministry of Housing, Urban Development and Construction of German (2023). Funding Program for Climate-friendly New Buildings (Förderprogramm für Klimafreundlichen Neubau (KFN)). https://www.bmwsb.bund.de/SharedDocs/faqs/Webs/BMWSB/DE/bauen/kfn-klimafreundlicher-neubau/kfn-liste.html
[93] Department of Environment, Climate, Energy and Agriculture, State of Hamburg. New funding for commercial buildings: 80 cents per kilogram of wood (Neue Förderung für gewerbliche Bauten 80 Cent je Kilogramm Holz). https://www.hamburg.de/nachhaltiges-bauen/10018974/holzbaufoerderung/
[94] The City of Freiburg (2020). Guideline for The Timber Construction Funding Program of The City of Freiburg. https://www.pefc.de/media/filer_public/e6/e1/e6e1416b-b646-4860-b565-cd8a22612ca7/freiburg_-_richtlinie_zum_foerderprogramm_holzbau_der_stadt_freiburg_i_br.pdf
[95] Federal Ministry of Food and Agriculture of Germany (2021). Mitigating climate change. Creating value. Utilising resources efficiently. https://www.bmel.de/SharedDocs/Downloads/EN/_Forests/charter-for-wood-2.pdf?__blob=publicationFile&v=7

## The Netherlands

The Netherlands embodied carbon policy has been in place since 2013. The national **Building Code Decree 2012** (Bouwbesluit 2012[96]) governs the design and development of buildings and introduced LCA reporting for new residential buildings and office buildings. To obtain a construction permit, projects must assess and report total global warming potential (GWP), depletion of raw materials and depletion fossil fuels.

To support the environmental impact assessments, the Netherlands established a **National Environmental Database** and an **Assessment Method Environmental Performance of Buildings**[97], operated by an independent non-profit organization, Stichting Nationale Milieudatabase (NMD). The National Environmental Database holds a range of proprietary and non-proprietary product information, with different levels of verification, as well as a process database that can be used to prepare EPDs or as a generic alternative to specific product information[98]. The Assessment Method provides calculation tools and protocols, aligned with European LCA standards, to assess the environmental performance of buildings[99].

In 2020, the Stichting NMD began an overhaul of the Assessment Method, which combined the assessment for buildings and civil engineering projects into a new **Assessment Method Environmental Performance for Construction Works**[100] (see Figure 8), which expanded the database, protocols, and other resources and increased the number of environmental impact categories from 11 to 19. The Netherlands has also developed a road map for the **Circular Dutch Economy** by 2050, which includes reducing and substituting raw materials, extending product lifecycles and high-grade processing techniques to recycle materials[101]. The Dutch **Concrete Awareness (Beton Bewust**) label is an industry-managed quality certification for concrete mortar manufacturers to encourage the reduction of GHG emissions from their production and increase in the use of secondary materials in their products or their products' ability to be reused as secondary materials[102].

The Dutch version of the modern EPD program is the **Milieu Relevante Product Informatie** (MRPI), operated by the MRPI Foundation, which was founded in 1999 by the Dutch Construction Industry

[96] Draft Building Decree (Bouwbesluit) (2012). https://technical-regulation-information-system.ec.europa.eu/en/notification/7312 (English Language)
[97] An introduction to the NMD: The Assessment Method. https://milieudatabase.nl/en/an-introduction-to-the-nmd/
[98] The Stichting NMD databases. https://milieudatabase.nl/en/database/
[99] The Environmental Performance Assessment Method for Construction Works (Assessment Method). https://milieudatabase.nl/en/environmental-performance/assesment-method/
[100] From 11 to 19 environmental impact categories. https://milieudatabase.nl/en/environmental-data-lca/information-for-life-cycle-assessment-lca-practitioners/environmental-impact-categories/
[101] Circular Dutch economy by 2050. https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050
[102] European Commission (2019). European Construction Sector Observatory. https://single-market-economy.ec.europa.eu/system/files/2021-01/ecso_tp_circular_economy_april_2019_0.pdf. Label was introduced by the Dutch Association of Concrete Mortar Manufacturers (Vereniging van Ondernemingen van Betonmortelfabrikanten in Nederland or VOBN).

Association. The MRPI Foundation collaborates with the central government with the aim of communicating clearly and unambiguously about the environmental aspects of construction products[103].

The City of Amsterdam has developed an **Implementation Agenda for a Circular Amsterdam**[104] which include measures to improve the built environment. It encourages the use of bio-based materials, the adoption of circular procurement in school buildings, and the reuse of existing materials from public space. The Metropolitan Region of Amsterdam's **Green Deal Timber Construction**[105] aims to increase homes to be built with wood and other bio-based materials by 20% from a 2025 baseline. The deal was signed under the Green Deal Timber Construction Covenant which unites over 80 organizations.

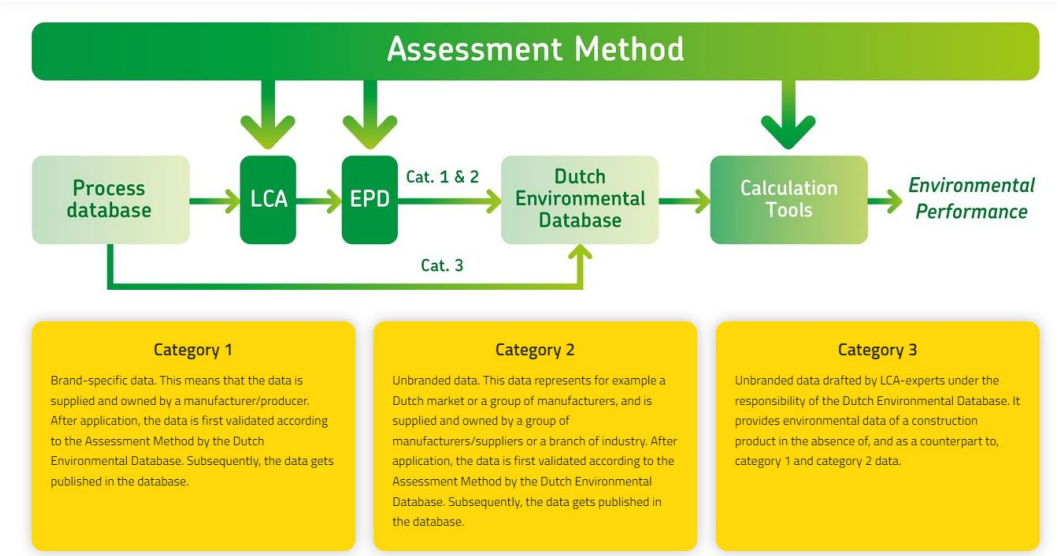


**Figure 8. An example of assessment method for environmental performance of construction projects for The Netherlands (image courtesy of National milieu database).**[106]

## Norway

In 2021, Norway passed the **Climate Action Plan 2021-2030** to meet targets under the Paris Agreement, which includes an increase in GHG taxes and alignment with EU climate legislation[107]. The Plan includes the development of Norway's manufacturing sector to produce low-carbon goods and products, as well as support to transition to fossil-fuel-free construction sites, and an increased use of wood products[108].

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[103] History about the Milieu Relevante Product Informatie Foundation. https://www.mrpi.nl/over-mrpi/historie/
[104] City of Amsterdam (2023). Implementation Agenda for a Circular Amsterdam. 2023-2026. https://assets.amsterdam.nl/publish/pages/1043702/implementation-agenda-circular.pdf
[105] Metropolitan Region Amsterdam (2024). Timber construction. https://www.metropoolregioamsterdam.nl/houtbouw/
[106] National milieu database. An introduction to the Dutch system of environmental performance of construction works. https://milieudatabase.nl/en/an-introduction-to-the-nmd/
[107] International Energy Agency (2022). Norway Climate Action Plan 2021–2030. https://www.iea.org/policies/14454-climate-action-plan-20212030
[108] Norwegian Ministry of Climate and Environment (2022). Norway's Climate Action Plan for 2021-2030. https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/en-gb/pdfs/stm202020210013000engpdfs.pdf

Norway is also creating plans for a green, circular economy, in alignment with the **EU Circular Economy Action Plan** (noted in the EU section), including support for bio-based products and the re-use of existing buildings and construction materials[109].

Norway's **Technical Construction Regulations** are being expanded to address GHG emissions. New regulations on the technical requirements for building, TEK 17,[110] increase the performance targets for standard housing, closer to the Norwegian **Passive House Standard** (NS3700) through improved building envelopes with considerations for the health and environmental impacts of products. **NS 3720**[111] is the Norwegian standard for calculating greenhouse gas emissions for buildings, as either WBLCA or partial LCA, and including all life cycles.

EPD-Norge is the program operator for the **Norwegian EPD** program. The Norwegian EPD program aims to guide businesses in communicating the environmental performance of products through verified and understandable environmental declarations. The program must ensure that the development of EPD for all types of products must be carried out in accordance with the requirements given in ISO 140251, ISO 219302 and associated industry standards (EN 158043 for construction products) and climate track ISO/TS 140674[112].

### Sweden

Since 2015, Sweden has focused heavily on reducing emissions from transportation and infrastructure projects. All large-scale infrastructure projects are required to calculate their embodied carbon throughout the design and construction phases, following guidelines established by the Swedish Transport Authority and using "**Klimatkalkyl**" a national web-based LCA tool [113].

The Swedish Climate Act (2018) mandates government reporting of climate impacts and policy actions across sectors, including buildings[114]. In 2022, the Swedish National Board of Housing, Building and Planning (Boverket) implemented new regulations on climate declarations for buildings[115]. Today, new

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[109] Norwegian Ministry of Climate and Environment (2022). Norway's Strategy for Developing A Green and Circular Economy: A Summary. https://www.regjeringen.no/contentassets/a116f209e493471bb26c81cf645152a3/kld_strategi_sirkularokonomi_sammendrag_eng_0507.pdf

[110] TEK17 is one of the strictest building standard in Europe, and was developed by the Norwegian Husbanken Institution in accordance with the Norwegian Building Act. https://www.ecobustas.lt/production/technology/TEK17-building-standards

[111] Greenhouse gas calculations for buildings – NS 3720. It builds upon the NS-EN 15978 standard, the Norwegian adaptation to the EN 15978. https://standard.no/fagomrader/energi-og-klima-i-bygg/bygningsenergi/klimagassberegninger/

[112] About EPD-Norway. https://www.epd-norge.no/om-oss/

[113] Swedish Transport Administration (Trafikverket) (2018). Klimatkalkyl – Calculating Greenhouse Gas Emissions and Energy Use of Transport Infrastructure from A Life Cycle Perspective. https://bransch.trafikverket.se/contentassets/eb8e472550374d7b91a4032918687069/klimatkalky_report_v_5_0_and_6.0_english.pdf

[114] Sweden's Climate Act and Climate Policy Framework. https://www.naturvardsverket.se/en/topics/climate-transition/sveriges-klimatarbete/swedens-climate-act-and-climate-policy-framework/

[115] Boverket (2023). Building as A Developer: Voluntary Environmental Certification. https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/environmental-certification/

buildings have to calculate and report on GHG emissions as part of the building permit application, and on climate impacts through the construction phase. There is. a national construction product database to support. this process. Through Boverket, Sweden is also developing policy on emissions limits for new buildings, expanding the declaration requirements to a WBLCA, and expanding the climate declaration regulations to renovations of existing building[116].

Boverket also supports the use of several voluntary environmental certification programs, including **Miljöbyggnad[117],** the green building rating system operated by Sweden's Green Buildings Council for both new and existing buildings, and **Swan EcoLabel** for product health and environmental factors[118].

**EPD International AB**, registered in Sweden, serves as the program operator responsible for the administration and operation of the International EPD System. EPD International is a subsidiary of the IVL Swedish Environmental Research Institute, an independent non-profit research institute owned by a foundation jointly established by the Swedish Government and Swedish industry. The International EPD system is now the world's leading global program for Environmental Declarations[119].

### Switzerland

The Swiss **Federal Act on the Reduction of $CO_2$ Emission** (the $CO_2$ Act) has been in effect for over two decades and has been updated multiple times. In 2023, this was supplemented by the **Climate and Innovation Act** which sets a goal for the country to become climate neutral by 2050, by gradually reducing the consumption of oil and natural gas with financial assistance from the government[120]. The focus of these policies has been on operational emissions across sectors.

Since 2010, the **Swiss Buildings Programme** has promoted the energy-efficiency and renewable energy in federal and cantonal buildings[121]. It is supported through levies on fossil fuels through the $CO_2$ Act and provide resources to cantons for subsidies and incentive programmes.

There are several voluntary green building rating systems used in Switzerland, although different jurisdictions and organization have implemented them as requirements. **Minergie** is a collection of Swiss national rating system programmes and the most widely used in the country. The **Minergie-ECO** is

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[116] Boverket (2023). The Assignment to Investigate How the Introduction of a Limit Value Can Be Done Earlier Than 2027. https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/the-assignment-on-limit/

[117] Miljöbyggnad (MB) Version 3.1- Sweden Green Building Council: Background. https://se2050.org/miljobyggnad-mb-version-3-1-sweden-green-building-council/

[118] Boverket (2023). Building as A Developer: Voluntary environmental certification. https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/environmental-certification/

[119] Introduction of EPD international AB, the company behind the system. https://www.environdec.com/about-us/epd-international-ab-about-the-company-behind-the-system

[120] The Climate and Innovation Act was proposed in 2022 and passed a voter referendum in 2023. It was a response to an earlier referendum, the 2019 Glacier Incentives that sought to ban the use of fossil fuels. https://www.admin.ch/gov/en/start/documentation/votes/20230618/climate-and-innovation-act.html

[121] Federal Office for the Environment of Switzerland (2020). The Federal and Cantonal Buildings Programme. https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/buildings/buildings-programme.html

program includes considerations for health and environmental impacts of building products, including dismantling and reuse[122].

The City of Zurich has committed to a net-zero emissions portfolio by 2050, through the implementation of a number of initiatives, including participation in the **2000-Watt Society**[123] and mandating government buildings obtain Minergie-ECO certification. In 2023, Zurich signed the **Circular Cities Declaration** for the built environment[124].

### United Kingdom

The United Kingdom has committed to reaching net-zero by 2050, through policies like the **Net Zero Strategy and Net-Zero Growth Plan** to develop a low carbon economy[125]. The United Kingdom's **Industrial Decarbonisation Strategy**[126], released in March 2021, outlines a blueprint for decarbonizing the manufacturing sector in alignment with net-zero goals, including procurement practices within the construction industry and market growth for low-emission industrial products. In 2023, the **Timber in Construction Roadmap**[127], set commitments for a long-term supply of domestic wood products to the building industry as one strategy to reduce embodied emissions in construction. The **Timber in Construction Innovation Fund**[128] supports this roadmap by encouraging the increased use of wood grown from sustainably managed woodlands.

The UK building industry has led efforts in developing voluntary standards, rating systems and resources to reduce embodied carbon emissions. The **UK Net Zero Carbon Buildings Standard**[129] is the UK's first cross-industry Net-Zero Carbon standard for all major building types. **Building Research Establishment Environmental Assessment Method (BREEAM)** is the UK's predominant green building rating system, which includes LCA components[130]. Building Research Establishment Limited (BRE) is the EPD program operator that supports BREEAM rating system in building life cycle assessment and Environmental Impacts from construction products[131].

British Standards Institute has published **BS EN 15978 (2011), Sustainability of construction works - Methodology for the assessment of performance of buildings**, which is the British adaptation to a

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[122] Minergie-ECO: Healthy, ecological and recyclable. https://www.minergie.ch/de/standards/neubau/eco/

[123] Member of the 2000-Watt Society commit to daily rate of energy consumption per capita to 2,000 watts; it has been adopted by over 100 cities, towns, and cantons across Switzerland and Germany. https://www.2000watt.swiss/english.html

[124] Circular Cities Declaration: Zurich, Switzerland. https://circularcitiesdeclaration.eu/cities/zurich

[125] UK Parliament (2023). The UK's Plans and Progress to Reach Net Zero By 2050 [Research Briefing]. https://commonslibrary.parliament.uk/research-briefings/cbp-9888/

[126] Government of the United Kingdom (2021). Industrial Decarbonisation Strategy. https://assets.publishing.service.gov.uk/media/6051cd04e90e07527f645f1e/Industrial_Decarbonisation_Strategy_March_2021.pdf

[127] UK Department for Environment, Food & Rural Affairs (2023). https://www.gov.uk/government/publications/timber-in-construction-roadmap/timber-in-construction-roadmap

[128] UK Forestry Commission (2022). Timber in Construction Innovation Fund Guidance. https://www.gov.uk/guidance/timber-in-construction-innovation-fund

[129] UK Net Zero Carbon Buildings Standard. https://www.nzcbuildings.co.uk/

[130] What is BREEAM? https://bregroup.com/products/breeam/

[131] BRE Environmental Product Declaration EN 15804. https://bregroup.com/services/testing-certification-verification/en-15804-environmental-product-declarations/

European standard of the life cycle assessment using EPDs[132], **PAS 2050 (2011), Specification for the assessment of the life cycle greenhouse gas emissions of goods and services**, which provides guidelines for product based carbon footprint assessments[133], and **PAS 2080 (2023), Carbon Management in Buildings and Infrastructure** [134]. The building industry has also developed a **Built Environment Carbon Database**, to support carbon estimating and benchmarking[135]. UK-based **NBS digital specification platform** hosts a comprehensive database of construction products, digital objects, and extraneous data, that originally intended for creating and managing high-quality construction specifications[136].

The City of London has implemented mandatory WLC assessments and reporting under the **London Plan 2021** for the Greater London Area, including supporting guidance documentation[137].

## 3.2 INTERNATIONAL: PACIFIC RIM

Outside of Europe, there are a number of countries in various stages of developing policies and regulations that will address embodied carbon emissions. This list of countries below may not be exhaustive, but based on this research, are the ones with policies in place or in development that may inform Canadian initiatives.

### Australia

In 2022, Australia enacted the **Climate Change Bill 2022**[138], which set a 2050 target of net-zero GHG emissions and a 2030 target of 43% reduction in GHG emissions compared to 2005 levels. The Australian Government is currently developing a national **Net-Zero Plan** to establish pathways for the transition to a net zero economy, with sector specific decarbonization plans for electricity and energy, industry, resources, agriculture and land, transportation, and the built environment[139].

Australia currently has no embodied carbon policy. The **National Australian Built Environment Rating System** (NABERS) is an initiative by the government of Australia to measure and compare buildings' environmental performance for energy, water, waste, and indoor environment. NABERS is in the early

[132] BS EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. https://www.en-standard.eu/bs-en-15978-2011-sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method/
[133] PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. https://knowledge.bsigroup.com/products/specification-for-the-assessment-of-the-life-cycle-greenhouse-gas-emissions-of-goods-and-services?version=standard
[134] PAS 2080:2023 Carbon Management in Buildings and Infrastructure. https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-2080-carbon-management-in-infrastructure-and-built-environment/
[135] The Built Environment Carbon Database. https://www.becd.co.uk/
[136] NBS Source: Powerful product data, unique insights. https://manufacturers.thenbs.com/nbs-source
[137] Greater London Authority (2022). Whole Life Cycle Carbo Assessment – London Plan Guidance. https://www.london.gov.uk/sites/default/files/lpg_-_wlca_guidance.pdf
[138] Prest, J. (2022). Climate Change Bill 2022 [and] Climate Change (Consequential Amendments) Bill 2022. https://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/bd/bd2223a/Climate_Change_Bill_2022_and_Climate_Change_Consequential_Amendments_Bill_2022
[139] Australia's path to Net Zero. https://www.dcceew.gov.au/climate-change/emissions-reduction/net-zero

stages of developing an embodied carbon assessment tool and methodology for building projects, building off of pilots with New South Wales and industry consultation[140].

The Green Building Council of Australia (GBCA) administers the voluntary **Green Star** green building rating system, which incorporates a credit for the mitigation of upfront carbon emissions and supports a carbon emission calculator[141]. Green Star is used in Australia, New Zealand, and other countries in the Pacific Rim. GBCA, in collaboration with NABERS, has issued an **Upfront Carbon Emission Calculation Guide** for calculating reductions against a reference building[142].

#### *State of New South Wales*

In 2022, the State of New South Wales passed **the Sustainable Buildings State Environmental Planning Policy** (SEPP) to encourage the design and construction of sustainable building and contribute to the state's net-zero targets[143]. The SEPP introduced embodied emissions measurement and reporting for all building types, with the aim of capturing data to inform future policy. There are no targets or caps for embodied carbon at this time.

New residential buildings must meet the **Building Sustainability Index** (BASIX)[144] requirements for energy, water and thermal performance, and a new **BASIX Materials Index**[145] has been developed to assess embodied emissions of construction materials through an online tool. New non-residential buildings must comply with new energy, water, and materials requirements, in conjunction with BASIX and other applicable NSW policies. Non-residential development report emissions through the NABERS Embodied Emissions Materials Form until the embodied emission framework and national tool become available.

### New Zealand

New Zealand's original **Climate Change Response Act** dates from 2002. In 2019, this legislation was amended to the **Climate Change Response (Zero Carbon) Amendment Act**[146] which sets new 2050 targets for a net zero GHG emissions and methane reduction of up to 47% below 2017 levels and provided a framework to develop and implement climate change mitigation and adaption policies.

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[140] National Australian Built Environment Rating System (2023). NABERS Embodied Carbon Public Consultation. https://www.nabers.gov.au/publications/nabers-embodied-carbon-public-consultation

[141] Green Building Council of Australia (2020). GBCA launches first phase of Green Star Online. https://new.gbca.org.au/news/green-star-news/gbca-launches-first-phase-green-star-online/

[142] Green Building Council of Australia (2022). Upfront Carbon Emissions calculation guide – interim. https://www.aiqs.com.au/sites/default/files/uploaded-content/website-content/upfront_carbon_emissions_calculation_guide_interim_v1_r1.pdf

[143] New South Wales Department of Planning and Environment (2023). Sustainable Buildings SEPP Overview. https://www.planning.nsw.gov.au/sites/default/files/2023-03/sustainable-buildings-sepp-overview.pdf

[144] https://pp.planningportal.nsw.gov.au/development-and-assessment/basix

[145] New South Wales Department of Planning and Environment (2022). BASIX Materials Index Help Notes. https://shared-drupal-s3fs.s3.ap-southeast-2.amazonaws.com/master-test/fapub_pdf/NSW+Planning+Portal+Documents/All+Materials+help+notes+2023.10.06.pdf

[146] New Zealand Ministry for the Environment (2021). Amendment Act 2019. https://environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/

In 2020, New Zealand launched the **Building for Climate Change Programme**[147] to guide the building and construction sector in responding to climate change, specifically in contributing to national net zero emissions targets for 2050 and preparing building for changing climate conditions. The Programme contains a range of initiatives targeting climate adaptation, resiliency, and emission reductions.

As part of the Programme, the Ministry of Business, Innovation and Employment developed a **Whole-of-Life Embodied Carbon Emissions Framework**[148] to mitigate carbon emissions throughout a building's entire life cycle, encompassing the production of construction materials to the end-of-life phase. The Framework seeks to maximize new building efficiency and upgrade existing buildings, increase building material efficiency, and reduce the carbon intensity of materials. The Ministry proposes a voluntary reporting-based approach to start, with incremental addition of whole life carbon cap, and the utilization of public buildings as leaders and demonstration project.

Based on feedback from industry, the Ministry has also developed a **Whole-of-life Embodied Carbon Assessment: Technical Methodology**[149] to outline a proposed standard methodology for assessing the embodied carbon emission of new building in New Zealand with the aim of reducing those emissions. The Methodology would be required for future embodied carbon regulation but is now intended to support industry in building knowledge and skills. The Method covers all life cycle stages, except operational energy and water, is based on international standard for WBLCA and allow the inclusion of EPDs.

The New Zealand Green Building Council (NZGBC) in collaboration with thinkstep-anz is developing an **Embodied Carbon Calculator**[150] to assess upfront carbon and whole-of-life embodied carbon for building projects. The calculator is intended to be a resource for the industry in developing a consistent approach to measuring and reporting embodies emissions, in support of the Building for Climate Change Programme initiatives. It is compatible with the Green Star rating system that evaluates the environmental performance and sustainable practices of buildings and infrastructure projects in New Zealand.

### Singapore

Singapore's Building and Construction Authority and the Singapore Green Building Council developed the **Singapore Green Building Masterplan** (SGBMP) in 2006. It was updated in 2021 to align with the broader **Singapore Green Plan** 2030[151], a national sustainable development initiative with five focus areas: city in nature, energy reset, sustainable living, green economy, and resilient future. The SGMBP sets 2030 targets

[147] Building for climate change: Program details, key changes and programme updates. https://www.building.govt.nz/getting-started/building-for-climate-change/

[148] New Zealand Ministry of Business Innovation and Employment (2020). Whole-of-Life Embodied Carbon Emissions Reduction. https://www.mbie.govt.nz/dmsdocument/11794-whole-of-life-embodied-carbon-emissions-reduction-framework

[149] New Zealand Ministry of Business, Innovation and Employment (2022). Whole-of-Life Embodied Carbon Assessment: Technical Methodology. https://www.building.govt.nz/assets/Uploads/getting-started/building-for-climate-change/whole-of-life-embodied-carbon-assessment-technical-methodology.pdf

[150] Thinkstep-anz (2023). New embodied carbon calculator for New Zealand. https://www.thinkstep-anz.com/resrc/news/new-embodied-carbon-calculator-for-new-zealand/

[151] What Is the Singapore Green Plan 2030? https://www.greenplan.gov.sg

for greening buildings and improving energy performance, including incorporating embodied carbon emissions accounting[152].

Singapore's **Code of Environmental Sustainability of Buildings**[153] outlines minimum environmental standards for construction and compliance with the **2008 Building Control Environmental Sustainability Regulations**. The code uses a combination of base requirements for better energy performance plus selected carbon reduction measures in design, construction, or technology applications under Green Mark rating system.

The BCA **Green Mark** program is a green building rating system[154] specifically designed for tropical climates. Originally launched in 2005 to assess environmental performance of new and existing buildings, it is a cornerstone of the SGBMP and mandatory for larger projects in Singapore. The newest version, **Green Mark 2021**, has a Whole Life Carbon Section[155], which includes assessment of embodied carbon emissions, sustainable construction, retrofit methods, tenant fit outs, and asset management using the **Singapore Building Carbon Calculator**[156].

The Singapore Building Carbon Calculator is a free, online embodied carbon calculator for the country's building industry[157]. It incorporates EPDs, LCA methods and local factors to the Singapore context, and aligns with the Singapore Code for Environmental Sustainability of Buildings and the Green Mark 2021 Whole Life Carbon requirements.

## 3.3 INTERNATIONAL: SOUTH AMERICA

### Colombia

Colombia has set targets of carbon neutrality by 2050, and GHG emission reduction target of 51%. In 2022, Colombia developed a **National Roadmap to Net Zero Carbon Buildings**[158] (Hoja de Ruta Nacional de Edificaciones Neto Cero Carbono), which aims to achieve net zero emissions for all new buildings by 2030, and all building stock by 2050[159] (see Figure 9). The roadmap sets out goals and strategies for reducing carbon emissions across the value chain for buildings, including urban planning, material supply,

[152] About the Green Building Masterplan. https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans

[153] Singapore Building and Construction Authority (2021). Code for Environmental Sustainability of Buildings Edition 4.0. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/es-code_reg-2008_edition-4-0.pdf

[154] Singapore Green Mark Certification Scheme. https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme

[155] Singapore Building and Construction Authority (2024). Green Mark 2021 Whole life Carbon section. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/20240101_wholelifecarbon_simplified_-r2.pdf?sfvrsn=3e1592a6_0

[156] Singapore Building Carbon Calculator: Embodied carbon calculation made easy. https://carboncalculator.sg/

[157] Building Carbon Calculator is currently in a beta version and was developed in collaboration between Singapore Building and Construction Authority, Singapore Green Building Council, private industry, and National University of Singapore. https://carboncalculator.sg/

[158] Colombian Sustainable Construction Council (2022). National Road Map of Net Zero Carbon Buildings. https://www.cccs.org.co/wp/wp-content/uploads/2023/03/Hoja_de_Ruta_ENCC_compressed.pdf

[159] Rakes, K. (2022). Colombia Launches National Roadmap for Net Zero Carbon Buildings. https://www.wri.org/update/colombia-launches-national-roadmap-net-zero-carbon-buildings

construction, use/operation/maintenance, and deconstruction. The roadmap incorporates LCA, increasing demand for sustainable materials and decarbonization of energy sources as formative actions. It also flags the informal construction sector has a major consideration in an inclusive transition to net-zero economy.

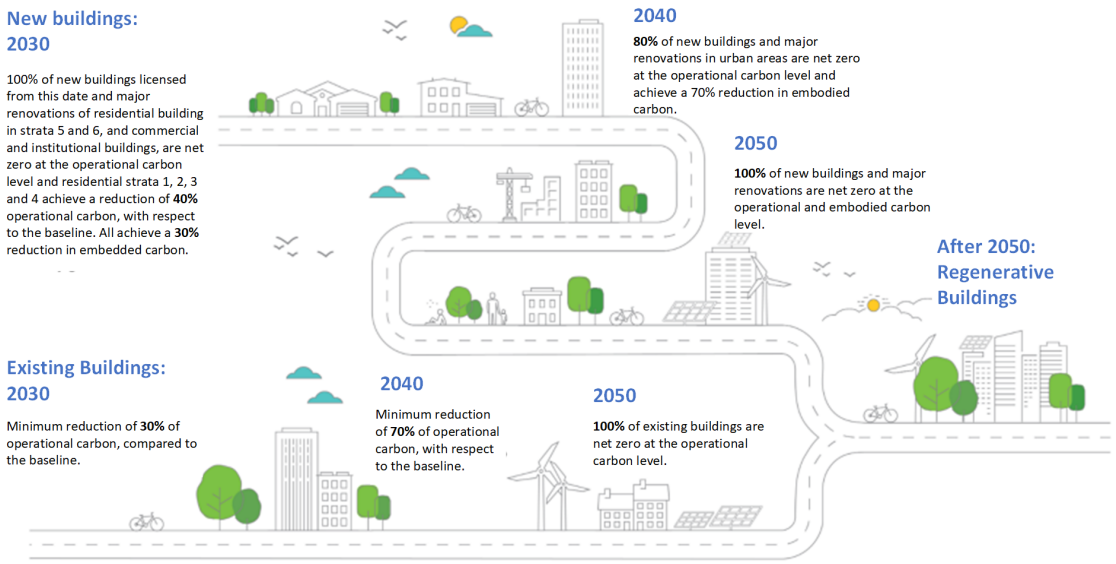


**Figure 9. Colombia National Roadmap to Net Zero Carbon Building (image courtesy of Colombia Green Building Council).[160]**

## Chile

Chile has implemented a set of actions that will have an impact on the embodied carbon of buildings through the diversion of waste into reclaimed materials for new buildings. The **Roadmap for a Circular Chile by 2040** sets goals for 2030 and 2040, including increase material productivity and recycling rates that include building construction[161]. It also supports the development of technical standards for building demolition, the reuse of construction materials, and requirements for public projects to use recycled materials. It also encourages the use of interactive platforms for the development of secondary materials markets, to create links between waste generators and potential users, starting with high priority waste streams, specifically construction and agriculture.

[160] Colombia Green Building Council (Consejo Colombiano de Construcción Sostenible) (2022). National Roadmap for Net-Zero Carbon Buildings in Colombia (Hoja De Ruta Nacional De Edificaciones Neto Cero Carbono). https://www.cccs.org.co/wp/wp-content/uploads/2023/03/Hoja_de_Ruta_ENCC_compressed.pdf (page 13)
[161] Ministry for the Environment of the State of Chile (2021). Roadmap for a Circular Chile by 2040. https://economiacircular.mma.gob.cl/wp-content/uploads/2022/01/HOJA-DE-RUTA-PARA-UN-CHILE-CIRCULAR-AL-2040-EN.pdf

## 3.4 INTERNATIONAL: OTHER ORGANIZATIONS

In addition to country-specific policies, there are international organizations with program and initiatives that are partnering with national and sub-national governments to advance policies on carbon emissions, including embodied carbon. A small selection is described here:

### United Nations

The United Nations Environment Programme (UNEP) **Breakthrough Agenda** [162] provides a framework for countries to engage in international collaboration and strengthen actions to meet the targets of the Paris Agreement. In 2023, at COP28, the UNEP launched the **Buildings Breakthrough** initiative to accelerate the transformation of the building sector with the aim of making near-zero emission and climate resilient buildings the new normal by 2030[163]. Also at COP28, Canada and the United Arab Emirates launched the **Cement and Concrete Breakthrough** to accelerate the decarbonization of the cement and concrete sectors[164].

The United National Industrial Development Organization (UNIDO) **Clean Energy Ministerial Industrial Deep Decarbonization Initiative**[165] (IDDI) is a global public-private coalition of organizations increasing demand for low carbon industrial materials, particularly steel and concrete. IDDI works to standardize carbon assessments, establish procurement targets, support low-carbon product development, design industry guidelines and incentivize investment.

### C40 Cities

C40 is a global network and non-profit of almost 100 mayors of world's cities, joining together to address the climate emergency[166]. Members often include cities in countries that do not yet have robust climate policies. Through a variety of sector-specific programmes, C40 runs a variety of networks, accelerators, and other initiatives to support cities in their response to climate change.

The **Net Zero Carbon Buildings Accelerator**[167] and **Clean Construction Accelerator**[168] commit member cities to 2030 targets to reduce embodied emissions by at least 50% for all new building, major building retrofits, and new infrastructure projects, and require zero-emissions construction site (where technology is available). Approximately 29 cities, including Montreal, Toronto, and Vancouver are part of C40's Net Zero Carbon Buildings Accelerator, and 8 cities are signatories to the Clean Construction Accelerator. Montreal, Toronto, and Vancouver are part of C40's Net Zero Carbon Buildings Accelerator.

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[162] The Breakthrough Agenda. https://breakthroughagenda.org/

[163] UN Environment Programme (2023). The Buildings Breakthrough: Global push for near-zero emission and resilient buildings by 2030 unveiled at COP28 (press release). https://www.unep.org/news-and-stories/press-release/buildings-breakthrough-global-push-near-zero-emission-and-resilient

[164] Government of Canada (2023). Canada launches the Cement & Concrete Breakthrough initiative at COP28 (news release). https://www.canada.ca/en/innovation-science-economic-development/news/2023/12/canada-launches-the-cement--concrete-breakthrough-initiative-at-cop28.html

[165] The Clean Energy Ministerial Industrial Deep Decarbonization Initiative. https://www.unido.org/IDDI

[166] About C40. https://www.c40.org/about-c40/

[167] C40 Net Zero Carbon Buildings Accelerator. https://www.c40.org/accelerators/net-zero-carbon-buildings/

[168] C40 Clean Construction Accelerator. https://www.c40.org/accelerators/clean-construction/

**Cities Race to Zero**[169] is a track in the UN-backed **Race to Zero** campaign to build support and engagement in healthy, resilient, zero carbon economy in alignment with the Paris Agreement goals. Under this program, cities pledge to recognize global climate emergency, meet Paris Agreement, put inclusive climate action at the center of decision-making, and engage partners in working towards these goals.

### World Resources Institute Zero Carbon Building Accelerator

The World Resources Institute (WRI) is a global non-profit working to advance sustainability practices around the world[170]. In 2015, WRI launched the **Building Efficiency Accelerator** (BEA), in support of the United Nation's **Sustainable Energy for All** initiative, to assist national and subnational governments in accelerating building sector efficiency, reduce energy consumption and scale-up energy access. More than 50 cities and subnational governments are part of the BEA.

As part of BEA, in 2021, WRI launched the **Zero Carbon Building Accelerator** (ZCBA) to support decarbonizations of the building sector globally by 2050[171], including reducing embodied carbon emissions. ZCBZ supports governments in adopting zero carbon emission policies and practices through four strategies: outreach, dialogue, plan and enable. ZCBA is supporting Columbia and Türkiye, as well as six cities from India, Kenya, and Costa Rica to develop plans for building sector decarbonization.

## 3.5 NORTH AMERICA: UNITED STATES OF AMERICA

Within North America, only the United States and Canada have embodied carbon policies. For the United States, we have described the federal policies as well as state-level policies. It is important to note that these are largely new developments, and more states and sub-national jurisdiction are likely to develop them in the next few years. The driving force behind the state-level initiatives seems to be recent US federal policies, specifically the **Buy Clean Initiative** under the **2022 Inflation Reduction Act**[172].

### US Federal Government

In 2021, the US Federal Government launched a **Buy Clean Task Force** and Initiative to promote and prioritize the use of American-mad, low-carbon construction materials in Federal procurement and federally funded projects[173].

[169] C40 Cities Race to Zero. https://www.c40.org/what-we-do/building-a-movement/cities-race-to-zero/
[170] World Resources Institute Homepage. https://www.wri.org/
[171] Zero Carbon Building Accelerator: Helping cities reduce building emissions to meet climate goals. https://www.wri.org/initiatives/zero-carbon-building-accelerator
[172] The White House (2023). Clean Energy Economy: A Guidebook to The Inflation Reduction Act's Investments in Clean Energy and Climate Action Version 2. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/
[173] Federal Buy Clean Initiative. https://www.sustainability.gov/buyclean/

Established under Executive Order 14057[174] on the **Federal Sustainability Plan**[175], the Buy Clean Task Force is co-chaired by the Federal Chief Sustainability Officer and the White House Office of Domestic Climate Policy and includes representatives from multiple government agencies that in total account for 90% of all federally-financed and purchase construction materials[176]. The Task Force is developing recommendations on policies and procedures to expand consideration of embodied emissions in Federal procurement and federally funded projects, which includes:

- Identifying construction materials and products with the highest embodied carbon concerns[177]—such as steel, cement/concrete, asphalt and flat glass—to prioritize for lower embodied carbon consideration in Federal procurement and federally-funded projects;
- Increasing the transparency of embodied emissions through supplier reporting of EPDs, including incentives and technical assistance to help domestic manufacturers better report and reduce embodied emissions; and,
- Launching pilot programs to boost Federal procurement of cleaner construction materials and learn more about their performance in real-world applications.

Since 2021, the federal agencies and department have invested funding into decarbonization programs for industry, to support the development of EPDs, and to support the purchasing of low-carbon products for federally supported projects. Agencies have also developed new programs within their own purviews, such as the 2023 General Services Administration pilot of **IRA Buy Clean Specifications** on 11 construction and modernization projects using their Interim **IRA Low Embodied Carbon Materials Requirements**[178].

In 2023, the US Federal Government expanded the Buy Clean Initiatives through a **Federal-State Buy Clean Partnership**[179] with 13 states: California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Jersey, New York, Oregon, and Washington. These states have committed to support the procurement of lower-carbon infrastructure material in state-funded projects.

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[174] The White House (2021). Executive Order on Catalyzing Clean Energy Industries and jobs Through Federal Sustainability. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/

[175] The Federal Sustainability Plan directs the US Federal Government to achieve net zero emissions by 2050. https://www.sustainability.gov/federalsustainabilityplan/index.html

[176] The Task Force includes representatives from the Departments of Commerce, Defense, Energy, Homeland Security, Housing and Urban Development, Health and Human Services, Interior, State and Transportation; the Environmental Protection Agency; the General Services Administration; the National Aeronautics and Space Administration; the Veterans Administration; the White House Domestic Climate Policy Office, Council on Environmental Quality, Infrastructure Implementation Team, Office on Clean Energy Innovation and Implementation, and Office of Management and Budget. About the Buy Clean Task Force: https://www.sustainability.gov/buyclean/#aboutpartnership

[177] On December 12, 2023, The U.S. General Services Administration (GSA) announced IRA Low Embodied Carbon material requirements that will be applied to 150 Federal Inflation Reduction Act projects involving $2B in IRA low-carbon materials.

[178] US General Services Administration (2023). Interim IRA Low Embodied Carbon Material Requirements. https://www.gsa.gov/system/files/Interim%20IRA%20LEC%20Material%20Requirements%20-%20used%20in%20Pilot%20May%202023%2005162023.pdf

[179] The White House (2023). Federal-State Buy Clean Partnership Principles. https://www.sustainability.gov/pdfs/federal-state-partnership-principles.pdf

## California

The **Buy Clean California Act** (Public Contract Code Section 3500-3505[180]) was passed in 2017 and mandated the Department of General Services, with the California Air Resources Board, to establish maximum GWP limit for key construction materials used in public works projects: structural steel, concrete reinforcing steel, flat glass, and mineral wool board insulation. Since 2022, the compliance with the GWP limits has been through EPDs. In 2023, The Department of General Services released a **Buy Clean California Act EPD Compliance Guide**[181] to provide authorities with information on EPD information and review requirements for compliance.

The **California Green Building Standards Code**, also referred to as **CALGreen**[182], includes mandatory measures for both residential and non-residential projects aim to ensure material conservation and resource efficiency. The 2022 Intervening Cycle updates to CALGreen, effective July 2024, includes embodied carbon requirements for commercial building projects over 100,000 square feet and school building projects over 50,000 square feet. Projects are required to comply with one of three pathways[183]:

- Reuse at least 45% of an existing's building's structure and exterior.
- Complete a WBLCA demonstrating 10% lower embodied carbon emissions than a baseline project.
- Document EPDs for listed materials (steel, glass, mineral wool, concrete) that are on average lower than a specific GWP threshold.

In addition to the Building Code, California has recently passed a number of bills that update or expand on existing law under the **California Global Warming Solutions Act** of 2006. The Act designates the State Air Resources Board as the agency responsible for monitoring and regulating sources of GHG emissions, and to ensure that state-wide GHG emissions are reduced to at least 40% below the 1990 level by 2030[184].

The Assembly Bill No.2446 Chapter 352[185]was passed in 2022, requiring the Board to develop a framework for measuring and then reducing the average carbon intensity of the materials used in the construction of new buildings, including those for residential uses by July 1, 2025. Under this Act, the Board must set a baseline and develop a comprehensive strategy for the state's building sector to achieve a 40% net

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[180] California Legislative Information: Public Contract Code, Division 2, Pat 1, Chapter 3: Article 5 Buy Clean California Act. https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5. The BCCA was originally introduced as Assembly Bill 262 (referenced in the 2017 report).

[181] Buy Clean California Act Team (2023). Buy Clean California Act EPD Compliance Guide. https://www.dgs.ca.gov/-/media/Divisions/PD/Engineering/EPP/Buy-Clean-California-Act/BCCA-EPD-compliance-guide-final-1-23-23.pdf

[182] CALGreen is Title 24 of the California Code of Regulations, and is development by the California Building Standards Commission. It contains the regulations that govern structural safety and sustainability for California's public schools, community colleges and state essential services buildings; sustainability for state buildings; and accessibility for public accommodations of buildings in California. https://www.dgs.ca.gov/DSA/Resources/Page-Content/Resources-List-Folder/Overview-Title-24-Building-Standards-Code

[183] 2022 California Green Building Standards Code, Title 24, Part 11. https://codes.iccsafe.org/content/CAGBC2022P1

[184] California Air Resources Board (2018). AB 32 Global Warming Solutions Act of 2006. https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006

[185] California Legislative Information (2022). Assembly Bill no. 2446. https://legiscan.com/CA/text/AB2446/id/2607014

reduction in GHG emissions of building materials by 2035, with an interim net reduction of 20% by 2030. It includes provisions for the Board to leverage state and federal incentives and support market demand to encourage the products and use of low-carbon materials.

The Assembly Bill No. 43 Chapter 316[186], passed in 2023, authorizes the Board to establish an embodied carbon baseline for building materials, based on industry average of EPDs reported during 2026 or on the most relevant, up-to-date information available to the board. It also empowers the Board to establish an embodied carbon trading system and to integrate that system into a framework for measuring the average carbon intensity of the materials used in the construction of new buildings, including regulation of credit allocations, anticipated carbon prices and trading periods.

### Colorado

In 2021, the State of Colorado passed the **Global Warming Potential for Public Project Materials Bill** (House Bill 21-1303[187]), which requires the Office of the State Architect and the Department of Transportation to establish policies regarding GWP of eligible materials in public projects, via industry averages and EPDs. These polices, the **Buy Clean Colorado Act** (C.R.S. 24-92-117[188]) focus on reducing embodied carbon emissions of state funded public projects through design optimization and responsible material selection. For building projects, the eligible materials include asphalt, cement and concrete, glass, steel and structural wood.

### Hawaii

In 2022, Hawai'i passed **Relating to Energy Efficiency** (HB1801[189]), a measure which required state facilities to implement energy efficiency measures, and to collect and report energy usage data. It also required the design of new state building to maximize energy and water efficiency, energy generation and use building materials that reduce the carbon footprint of the project, where feasible and cost-effective.

### Illinois

Illinois is currently debating the **Concrete Carbon Utilization, Reduction and Removal Breakthrough Act** (HB5461[190]), which would create a performance-based tax credit for concrete producers to incentivize the use of materials and methods to reduce embodied carbon emissions from concrete production, encourage the storage of atmospheric carbon in concreate products and create EPDs. It would also establish new performance-based concrete specification standards and support testing and assessment of new concrete decarbonization materials and methods.

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[186] California Legislative Information (2023). Assembly Bill no. 43. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB43

[187] Colorado 74th General Assembly (2021). Global Warming Potential for Public Project Materials. https://leg.colorado.gov/bills/hb21-1303

[188] Colorado Office of the State Architect (2021). Buy Clean Colorado Act. https://osa.colorado.gov/energy-environment/buy-clean-colorado-act

[189] Hawai'i State Legislature Archived Information (2022). Energy Efficiency Measure HB1801 HD1 SD1 CD1. https://www.capitol.hawaii.gov/session/archives/measure_indiv_Archives.aspx?billtype=HB&billnumber=1801&year=2022

[190] Illinois 103rd General Assembly (2024). Concrete Carbon Act. https://www.ilga.gov/legislation/BillStatus.asp?DocNum=5461&GAID=17&DocTypeID=HB&SessionID=112&GA=103

### Maryland

In 2023, Maryland passed its **Buy Clean Act, Eligible Project- Procurement of Construction Materials Bill** (HB0261[191]). The Act requires that cement and concrete mix producers submit EPDs to the Department of General Services for all eligible public projects by end of 2024, and that the DGS establish maximum acceptable GWP for certain categories of construction materials by end of 2025. It also creates an Environmental Product Declaration Assistance Fund to support the development of environmental product declarations.

### Minnesota

In 2023, Minnesota passed the **Buy Clean Buy Fair Minnesota Act** (Senate File 2156[192]) which requires the establishment of global warming impact standards for certain construction materials in public projects, creates the Environmental Standards Procurement Task Force and processes for government agencies to incorporate their recommendations, and a pilot program to encourage EPD submittals through grants and other incentives.

### New Jersey

In 2023, the state of New Jersey passed the **Low Embodied Carbon Concrete Leadership Act** (Senate Bill S287[193]), which establishes a performance-based tax credit for manufacturers that can demonstrates the embodied carbon emissions concrete on their state-funded project is below a baseline created by the New Jersey Department of Environment Protection.

### New York

The 2022 **New York State Low Embodied Carbon Concrete Leadership Act** (Senate Bill S542A[194]) allows for the development of procurement guidelines for low-carbon concrete for state construction projects and create a system for awarding government contracts based on climate performance as well as price.

The GreenNY Council is a multi-department working group implementing sustainability and climate goals across New York State government agencies. The **GreenNY Specification: Lower Carbon Concrete**[195] was approved in 2022 with a goal to inform how project teams specified concrete in order to reduce the embodied carbon emissions from the entire building industry. For ready-mix concrete, the requirements are: 1) provide an EPD where available, 2) set cement content limits, 3) include pozzolans, and 4) use blended aggregates when available. For concrete masonry units and concrete bricks, the requirements are: 1) provide industry EPDs when available, 2) consider a reduced-profile web design, and 3) reduce cement content.

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[191] Maryland General Assembly (2022). Eligible Projects - Procurement of Construction Materials (Buy Clean Maryland Act). https://mgaleg.maryland.gov/mgawebsite/Legislation/Details/HB0261?ys=2023RS

[192] Minnesota Legislature Office of the Revisor of Statutes (2023). Buy Clean and Buy Fair Minnesota Act. https://www.revisor.mn.gov/bills/bill.php?f=SF2156&y=2023&ssn=0&b=senate

[193] New Jersey Legislature (2022). Bill S287 ScsSca (SCS/1R) Session 2022 – 2023. This bill provides CBT and gross income tax credits for certain deliveries of low carbon concrete and for costs of conducting EPD analysis of low carbon concrete. https://www.njleg.state.nj.us/bill-search/2022/S287

[194] New York Senate Bill S542A. This bill relates to the provisions in state procurement contracts involving the use of low embodied carbon concrete. For more details see https://legislation.nysenate.gov/pdf/bills/2021/S542A

[195] New York Office of General Services (2022). GreenNY Specification: Lower Carbon Concrete. https://ogs.ny.gov/greenny/greenny-specification-lower-carbon-concrete

*New York City, NY*

New York City's Executive Order 23[196] includes requirements for using low-carbon concrete on capital projects and concrete sidewalks, submitting EPDs to the EC3 tool, using low-emission vehicles and equipment, performing LCAs where practical, and developing action plans that incorporate embodied carbon.

### Oregon

Executive Order 17-20[197], enacted in 2017, is primarily focused on increasing the energy and water efficiency of new and existing buildings, but included a provision that new state commercial buildings must consider options to reduce the embodied carbon of building materials, while achieving carbon-neutral operations. Agencies were directed to consult with the Department of Environmental Quality (DEQ) Materials Management Program to reduce the embodied carbon of the building materials on their projects.

In 2022, **Buy Clean Oregon** (House Bill 4139[198]) was enacted to reduce GHG emission associated with state transportation systems and infrastructure. It requires state regulators to conduct LCA for certain construction materials in public transportation infrastructure projects, requires the submittal of EPDs by contractors, and provides grants to industry to create or submit EPDs, although it also prohibits the use of EPDs in selection processes prior to 2027.

### Washington

In 2022, the state of Washington passed the **Buy Clean and Buy Fair Washington Act**[199] (HB 1103) to promote the procurement of low-carbon materials produced with fair labour practices. The policy applies to concrete, steel and engineered wood products used on large publicly funded projects, and requires reporting via submittals of EPDs with supply chain specific data, as well as Health Product Declarations (if available) and working conditions in production facilitates and supply chain management. Washington is creating a central database for reporting.

Washington is also currently considering the **Washington Build Clean Act** (Senate Bill 5391[200]), which would regulate the modeling, measurement and reporting of embodied carbon emission reductions from structural building products in state-funded projects.

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[196] City of New York (2022). Executive Order 23: Clean Construction. https://www.nyc.gov/office-of-the-mayor/news/023-002/executive-order-23

[197] Office of the Governor, State of Oregon (2017). Accelerating efficiency in Oregon's built environment to reduce GHG emission and address climate change. https://www.oregon.gov/deq/mm/Documents/eo-energy-17-20.pdf

[198] Oregon State Legislature 2022 Regular Session: HB 4139. https://olis.oregonlegislature.gov/liz/2022R1/Measures/Overview/HB4139

[199] BlueGreen Alliance (2022). The Buy Clean and Buy Fair Washington Act: Leveraging Public Purchasing to Cut Emissions and Grow Clean Manufacturing. https://www.bluegreenalliance.org/wp-content/uploads/2022/01/Buy-Clean-Buy-Fair-WA-011822-vFINAL.pdf

[200] Washington State Legislature (2023). SB 5391 Bill Information 2023-24. Modeling, measurement, and reporting embodied carbon emission reductions from structural building products in state-funded projects. https://app.leg.wa.gov/billsummary?BillNumber=5391&Initiative=false&Year=2023

## 3.6 NORTH AMERICA: CANADA

### Canada Federal Level

Introduced in 2017, **Canada's Greening Government Strategy**[201] focuses on reducing environmental impacts and transitioning to net zero carbon and climate resilient government operations with the goal of net zero emissions by 2050. The Strategy sets commitments for four key areas: mobility and fleets, property and workplaces, climate resilient services and operations, and procurement of goods and services.

The **Policy on Green Procurement**[202] was originally developed in 2006 and updated in 2018, and requires environmental considerations be integrated into government procurement processes to support sustainable development and environmental protection. The objectives are to leverage the purchasing power of the federal government to support environmentally preferable goods and services, creating market demand and reducing costs, improve government practices and work environments, and improving resiliency.

In 2022, the **Standard on Embodied Carbon in Construction**[203] was established to reduce embodied carbon emissions from government building projects, as part of the Policy on Green Procurement and in alignment with the Greening Government Strategy. It creates requirements for project teams to disclose and reduce by 10% the embodied carbon of structural materials, starting with concrete, on major government projects. The Standard outlines compliance pathways through the use of LCA and/or EPDs during design and construction phases, and collects project information through a standard an **Embodied Carbon Disclosure Template**.

Currently under development is a **Canadian Buy Clean Strategy**[204], focused on low embodied carbon materials and products, preferably sourced within Canada. The Strategy is being developed by Public Services and Procurement Canada and Treasury Board Secretariat with other government agencies, for government funded building and infrastructure projects. It will include embodied carbon disclosure, reducing embodied carbon emissions from structural materials, particular concrete.

Between 2019 and 2023, the National Research Council of Canada (NRC) operated a "**Low-carbon assets through life cycle assessment" (LCA$^2$) initiative**[205] to provide research and support to federal government initiatives and policy development on low carbon assets for buildings and infrastructure. The LCA$^2$ initiative formed the foundation of a new research **Platform to Decarbonize the Construction Sector at**

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[201] Government of Canada, Greening Government Strategy: A Government of Canada Directive, led by the Treasury Board of Canada. https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html

[202] Government of Canada, Green Procurement Policy. https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=32573

[203] Government of Canada, Standard for Embodied Carbon in Construction. https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=32742

[204] Government of Canada, Buy Clean Strategy overview: Committee of the Whole—May 19, 2022. https://www.tpsgc-pwgsc.gc.ca/trans/documentinfo-briefingmaterial/lcp-cow/2022-05-19/p18-eng.html

[205] National Research Council of Canada Low-Carbon Assets Through Life Cycle Assessment Initiative. https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-assets-through-life-cycle-assessment-initiative

**Scale**[206] , which includes a new Centre of Excellence in Construction Life Cycle Assessment (CECLA) at the NRC's Construction Research Centre and a new **Low Carbon Built Environment Challenge Program**[207], which builds on the work that was completed under the LCA[2] initiative.

Another key outcome of LCA[2] was the centralized repository for Canadian life cycle inventory (LCI) datasets of primary construction materials, including cement, ready-mix concrete, precast and prestressed concrete elements, and concrete masonry block. Under LCA[2], the NRC also published **National Guidelines for Whole-building Life Cycle Assessment**[208] which provides comprehensive instruction for the practice of life cycle assessment applied to buildings. According to the Canadian Board for Harmonized Construction Codes (CBHCC), the embodied carbon technical requirements will be introduced in **National Model Codes 2030**[209].

### British Columbia

Since 2009, British Columbia (B.C.) has required all new public sector buildings achieve LEED Gold certification [210], which includes recognition of the use of low carbon building materials. B.C. also encourages the use of wood as a low carbon material, through the **Wood First Act** (SBC2009[211]), which requires wood to be used as a primary structural material on all publicly funded projects.

Implemented in 2017, The **B.C. Energy Step Code**[212] is a voluntary provincial standard that provides an incremental and consistent approach to increasing energy efficiency in buildings beyond the requirements of the B.C. Building Code. Local governments have the ability to require or incentivise developments to meet one or more steps, which are divide into two pathways: one for Part 3 buildings (complex, larger buildings e.g. most commercial or multi-unit residential) and one for Part 9 buildings (small, simple buildings e.g. houses)[213]. The **B.C. Zero Carbon Step Code**[214] is a companion standard launched in 2023 that provides similar incremental steps to reducing GHG emissions from building operations, specifically

[206] National Research Council of Canada. Platform to Decarbonize the Construction Sector at Scale. https://nrc.canada.ca/en/research-development/research-collaboration/platform-decarbonize-construction-sector-scale

[207] National Research Council of Canada. Low Carbon Built Environment Challenge Program. https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-built-environment-challenge-program

[208] National Research Council of Canada National guidelines for whole-building life cycle assessment. https://nrc-publications.canada.ca/eng/view/object/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

[209] Canadian Architect (2023). Input Sought on Greenhouse Gas Considerations in the National Model Codes. https://www.canadianarchitect.com/input-sought-on-greenhouse-gas-considerations-in-the-national-model-codes/

[210] British Columbia Ministry of the Environment and Climate Change Strategy (2017). Low Carbon Building Material LEEDv4: A Guide to Public Sector Organizations. https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/resources/lcm-public-sector-guide.pdf

[211] British Columbia Wood First Act. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_09018_01

[212] British Columbia, Energy Efficiency https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/energy-efficiency

[213] British Columbia Energy Step Code. https://energystepcode.ca/how-it-works/

[214] British Columbia Zero Carbon Step Code. https://energystepcode.ca/zero-carbon/

space heating and water heating systems and equipment, with the aim of achieving zero emissions for new building by 2030.

Originally launched in 2018, **CleanBC**[215] is B.C.'s plan to lower GHG emissions 40% by 2030, and to achieve net zero by 2050. It has been updated and expanded with additional policies.

In 2019, the **CleanBC Government Buildings Program**[216] was established to demonstrate public sector leadership in reducing GHG emissions. It sets targets to reduce GHG emissions in government buildings and operations by 50% below 2010 levels by 2030, and by 80% below 2010 levels by 2050, and notes embodied carbon emissions as an area of focus for future policy.

In 2021, the **CleanBC Roadmap to 2030**[217] was developed to implement CleanBC goals and sets out a series of pathways to support low carbon innovation across economic sectors. The **CleanBC Building Innovation Fund** (CBBIF)[218] provides incentives to develop and commercialize new energy efficient and low-carbon building technologies, designs, and practices in B.C., including approaches to reduce embodied carbon emissions.

In 2022, B.C. released the **Mass Timber Action Plan**[219] to maximize opportunities for the province as the mass timber market grows across North America. The plan focuses on developing mass timber as an innovative economic sector, to build local knowledge, skills, and competencies, and support a more sustainable low-carbon future. Low carbon materials strategies include expanding market adoption, developing carbon calculators to assess and reduce embodied carbon in projects, and reducing construction waste to build a construction sector circular economy. It is part of the **StrongerBC Economic Plan**[220] goals of inclusive growth and clean growth.

### Quebec

The **Quebec Wood Charter**[221], first developed in 2013, aimed to increase the use of wood in constructions in Quebec, in order to reduce GHG emissions in building, develop market for added-value wood products, and increase economic development and employment opportunities in the province. Every project

[215] CleanBC, B.C. is rising to the challenge of climate change. https://cleanbc.gov.bc.ca/
[216] CleanBC Government Buildings Program Year 3 Report 2021/22. https://www2.gov.bc.ca/assets/gov/environment/climate-change/data/provincial-inventory/cleanbc_report_gbp_year_3-rpd.pdf
[217] Released in 2021, the Roadmap includes a range of accelerated and expanded actions across low carbon energy, transportation, buildings, communities, industry, forest bioeconomy, agriculture, aquaculture and fisheries, and negative emissions technologies. https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/cleanbc/cleanbc_roadmap_2030.pdf
[218] CleanBC Building Innovation Fund. https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/energy-efficiency-conservation/programs/cleanbc-building-innovation-fund
[219] Government of British Columbia (2022). BC's Mass Timer Action Plan. https://www2.gov.bc.ca/assets/gov/business/construction-industry/bc_masstimber_action_plan_2022.pdf
[220] Government of BC (2022). BC's Economic Plan: A Plan for Today, A Vision for Tomorrow. https://news.gov.bc.ca/files/StrongerBC_Economic_Plan_2022.pdf
[221] Government of Quebec (2022). The Wood Charter: Taking Stock (English). https://mffp.gouv.qc.ca/wp-content/uploads/BilanCharteduBois_anglais.pdf

financed at least partially by public funds must consider the possibility of using wood before a project begins and carry out a comparative analysis of the GHG emissions using the provincial **Gestimat** tool[222].

This was expanded in 2020, through the **Policy for the Use of Wood in Construction**[223], which applies to public and private infrastructure in both the residential and non-residential building sector. The policy focuses on five areas:

- Government buildings as leaders: enhance the use of wood and document the carbon performance of government buildings.
- Regulations: update provincial building regulations and speed up approval process for equivalent measures.
- Research: support new R&D initiatives relating to construction and wood, manufacturing.
- Training: improve training opportunities and diversify technical support for industry.
- Outreach: increase demonstration projects and communications of benefits of wood.

In 2020, Quebec launched the **2030 Green Economy Plan**[224], an electrification and climate change policy framework. The plan focused on mitigating climate change in the transportation, industry, building, agriculture and energy generation sectors, as well as building a green economy and adapting to climate change impacts in the Province. The Green Economy Plan states that the government will encourage the use of materials with a lower carbon footprint, such as wood and other bio-based materials, but did not set specific targets or requirements. The Plan also encourages the electrification of manufacturing across the Province.

### City of Edmonton, AB

In 2021, the City of Edmonton passed the **C627 Climate Resilience Policy**[225] to ensure that City buildings are constructed and operated in a sustainably and to limit the carbon footprint. All new City buildings must be built to be emissions neutral, and consider passive design and energy-efficiency strategies, including on-site energy generation. New construction project must complete an embodied carbon analysis as outlined in the City's **Facility Design and Construction Consultant Manual**(s), must consider low carbon material alternatives where feasible, and must report as part of the embodied carbon assessment.

### City of Langford, BC

In 2021, the City of Langford adopted the POL-0167-PLAN **Carbon Mineralization Policy**[226] (POL-0167-PLAN) a low carbon concrete policy with a view to accelerating the deployment of technologies to

[222] Gestimat 2.0: Considering the Embodied Carbon of Buildings. https://cecobois.com/gestimat/
[223] Government of Quebec (2020). Policy for the Use of Wood in Construction (English). https://cdn-contenu.quebec.ca/cdn-contenu/forets/documents/entreprises/PO_wood_construction_MRNF.pdf
[224] Government of Quebec, Plan for a Green Economy 2030. https://www.quebec.ca/gouvernement/politiques-orientations/plan-economie-verte
[225] The City of Edmonton (2021). Procedure: Climate Resilient Design and Construction of City Buildings. https://www.edmonton.ca/sites/default/files/public-files/assets/PDF/C627_Climate_Resilient_Design_and_Construction_of_City_Buildings_Administrative_Procedure.pdf?cb=1702415674
[226] City of Langford (2020). Staff Report to Council: Policy No. POL-0167-PLAN - Carbon Mineralization Policy. https://langford.ca/wp-content/uploads/2021/11/10.2-Carbon-Mineralization-Policy.pdf

decarbonize the built environment: the first city in Canada to do so[227]. It required that all the concrete for City projects and all other projects greater than 50m$^3$, must be built using post-industrial $CO_2$ mineralization technologies, or an equivalent which offers concrete with lower embodied carbon. However, the policy was later revised in2022, removing the mineralization requirement[228].

### City of Nelson, BC

In 2020, the City of Nelson in partnership with the City of Castlegar created the **Low Carbon Homes Pilot**[229] to complement the City's energy efficiency programming and identify ways to reduce embodied carbon within building sector. The Pilot included a study to determine the average amount of embodied carbon emissions associated with new construction in Nelson and Castlegar, the creation of an Embodied Carbon Advisory Group, support for embodied carbon analysis of project and education and training activities. As a result of the pilot Nelson produced a series of educational materials, including a **Material Carbon Emissions Guide**, information briefs on embodied carbon in retrofits concrete, and Case Studies summarizing learning from the pilot activities, to help local municipal staff, builders and others understand the embodied carbon emissions associated with building materials.

Currently, Nelson is working on Phase 3 of the Pilot, to integrate the lessons learnt into internal City processes, and continue to build embodied carbon knowledge in the community.

### District of North Vancouver, BC

In 2022, the District of North Vancouver adopted a **Climate Ready Rezoning Policy**[230] , which encourages the design of low-carbon resilient building to reduce GHG emissions and strengthen the District's resilience to climate change impacts. It applies to rezoning applications for large buildings that fall under Part 3 in the B.C. Building Code BCBC, with requirements for embodied emissions and refrigerant emissions, ventilation, and cooling. Projects are required to conduct and report on a WBLCA, include a description of project-specific measures to reduce embodied emissions, and calculate and report on carbon emission from the refrigerants used in building systems[231].

### City of Toronto, ON

In 2021, the City of Toronto adopted **TransformTO Net Zero Strategy**[232] to reduce local GHG emissions and improve community health, economy, and social equity. It builds on a previous TransformTO Strategy and the **2019 Toronto Climate Emergency Declaration**, and outlines a pathway to achieve net zero emissions by 2040.

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[227] City of Langford (2021). City of Langford Announces Bold, Low Carbon Concrete Policy. https://langford.ca/city-of-langford-announces-bold-low-carbon-concrete-policy/

[228] Moreton, B. (2023). Langford Tweaks Low-Carbon Concrete Policy. https://www.goldstreamgazette.com/news/langford-tweaks-low-carbon-concrete-policy-650161

[229] City of Nelson, Low Carbon Building Materials. https://www.nelson.ca/905/Low-Carbon-Building-Materials

[230] District of North Vancouver, Climate Ready Rezoning Policy. https://www.dnv.org/business-development/climate-ready-rezoning-policy

[231] Corporation of the District of North Vancouver (2022). Climate Ready Rezoning Policy for New Part 3 Buildings. https://www.dnv.org/sites/default/files/edocs/climate-ready-rezoning-policy.pdf

[232] https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/

In 2023, Toronto updated the **Green Standard v4.0** to set whole-building embodied carbon caps for major structural and envelope materials in new city-owned buildings[233]. The caps are for upfront embodied carbon emissions from life cycle stages A1-A5[234], and have two intensity levels: 350 kg $CO_2e/m^2$ and 250 kg $CO_2e/m^2$. The embodied emissions assessment must but in accordance with the **CAGBC Zero Carbon Building Standard** methodology for the Upfront Carbon Lifecycle Stage and identify low carbon material alternatives to the proposed structure and/or envelope. Results are reported via the Zero Carbon Embodied Carbon Reporting template, and include information on the LCA tools, input assumptions and results, as well as the changes made to the proposed design to minimize the embodied carbon emissions. The assessment is only on new materials, building retrofits, salvaged and reused materials are considered to have no embodied emissions for accounting purposes[235].

### City of Vancouver, BC

In 2016, the City of Vancouver develop the **Zero Emissions Building Plan**, with the intent to transition to zero emissions building for all new construction by 2030[236].

In 2019, City of Vancouver declared a Climate Emergency and developed the **Climate Emergency Action Plan**[237] to reduce GHG emissions by 50% by 2030 and be carbon neutral by 2050. The Plan sets a target to reduce embodied emissions from new building and construction projects by 40% compared to a 2018 baseline[238].

Starting in 2020, City of Vancouver began developing an **Embodied Carbon Strategy** to achieve the targets outlined in the Climate Emergency Action Plan, including changes to policy and regulations, removing market barriers, and providing incentives, working with industry to build capacity and knowledge, and developing complementary actions to create a "construction ecosystem [that] enables and encourages low-carbon buildings"[239].

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[233] City of Toronto (2023). Toronto Green Standard Update: Advancing Net Zero Emissions in New Development. https://www.toronto.ca/legdocs/mmis/2023/ph/bgrd/backgroundfile-235868.pdf. This update replaces previous requirements in Green Standards 4.0 to track and report upfront embodied carbon. The earlier version did not set performance targets or caps on embodied emissions, pending studies on local building projects to inform appropriate targets.

[234] A1: Raw Material Supply, A2: Transport (of raw materials to manufacturer), A3: Manufacturing, A4: Transport (from manufacturer to construction site), A5: Construction: https://mantledev.com/insights/toronto-becomes-first-jurisdiction-in-north-america-to-enact-whole-building-embodied-carbon-caps-on-new-city-owned-buildings/

[235] City of Toronto, Buildings Energy, Emissions & Resilience: https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-version-4/mid-to-high-rise-residential-non-residential-version-4/buildings-energy-emissions-resilience/

[236] City of Vancouver, Zero Emissions Buildings. https://vancouver.ca/green-vancouver/zero-emissions-buildings.aspx#embodied-carbon

[237] City of Vancouver, Climate Emergency Action Plan. https://vancouver.ca/green-vancouver/vancouvers-climate-emergency.aspx

[238] City of Vancouver (2020). Climate Emergency Action Plan. https://council.vancouver.ca/20201103/documents/p1.pdf

[239] City of Vancouver (2020). Climate Emergency Action Plan. Appendix K: Embodied Carbon Strategy. https://council.vancouver.ca/20201103/documents/p1.pdf (page 12)

In 2022, the City of Vancouver updated the **Green Buildings Policy for Rezoning**[240] to require all Part 3 building projects demonstrate the project is on track to meet Vancouver Building ByLaw energy and emissions limits and the life-cycle embodied carbon limits, among other requirements. Embodied carbon requirements have been implemented in the Vancouver Building Bylaw since 2023, under a new Low Carbon Materials and Construction section[241], although final code changes will be approved in 2024.

As part of these updates, the City of Vancouver has developed supporting resources, including an **Embodied Carbon Guidelines**[242], which outlines baselines and methodologies for assessing embodied carbon emissions, and demonstrating compliance with policies, and the **Embodied Carbon Design Report**, which provides a template for compliance reporting.

In 2024, the City of Vancouver amended the Zoning and Development By-Law with **Tools and Incentives to Encourage Mass Timber Buildings**[243] which are to be piloted for 2 years. These incentives include allowing for 2 additional storeys for buildings in 8 to 11 storey areas, 3 additional storeys for buildings in 12 or more storey areas, 10% extra height for applications under existing zoning, and additional pre-application support. The intention is to promote mass timber construction and support the transition to new practices.

### City of Whistler, BC

Whistler's 2020 **Climate Action Big Moves Strategy** [244], is a framework to address climate mitigation and adaption in the transportation, building and waste sectors, with incremental GHG emissions reductions targets through 2060**. As part of Big Move 4: Build Zero Emissions Buildings**, Whistler set a goal for all new buildings to achieve the top level of performance in the B.C. Energy Step Code, use only low carbon heating systems, and reduce embodied carbon emissions by 40% by 2030[245]. Key initiatives under development include encouraging low carbon design, material use and construction practices for new buildings, and the deployment of a roadmap to require embodied carbon calculations for Part 3 buildings as part of permit submissions.

Whistler's **Green Building Policy G-28**[246], adopted in 2022, is a guiding document that proposes a flexible, performance-based framework for new buildings that included energy and emissions, building materials, sustainable sites, green mobility, water conservation and management, and solid waste. It includes guidelines for reporting WBLCA at rezoning, incorporating low carbon and plant-based materials where

[240] City of Vancouver (2023). Green Buildings Policy for Rezoning. https://guidelines.vancouver.ca/policy-green-buildings-for-rezonings.pdf. The Green Building Policy for Rezoning was originally implemented in 2010, and in 2016 included reporting requirements for embodied carbon emissions through WBLCA via LEED gold certification.
[241] City of Vancouver (2023). Vancouver Building By-law 2019. Section 10.4. Low Carbon Materials and Construction. https://free.bcpublications.ca/civix/document/id/public/vbbl2019/1069567153
[242] City of Vancouver (2023). Embodied Carbon Guidelines. https://vancouver.ca/files/cov/embodied-carbon-guidelines.pdf
[243] City of Vancouver, Mass timber buildings. https://vancouver.ca/green-vancouver/mass-timber-buildings.aspx
[244] Resort Municipality of Whistler (2020). 2020 Climate Action Big Moves Strategy. https://www.whistler.ca/wp-content/uploads/2022/12/climate_action_big_moves_strategy_final.pdf
[245] Resort Municipality of Whistler, Big Move 4: Build zero emission buildings. https://www.whistler.ca/climate-action/big-moves/4-build-zero-emission-buildings/
[246] Resort Municipality of Whistler (2022). Green Building Policy. https://www.whistler.ca/business/land-use-and-development/planning/green-building-policy/

possible, use of locally sourced materials, use of certified sustainable harvested wood, and descriptions of project-specific measures to reduce embodied emissions. The Policy also includes a template for project teams to use in embodied carbon and LCA reporting.

### University of British Columbia, BC

Although not a municipality, UBC has development control over its campus lands, buildings, and infrastructure. To address embodied carbon emissions in the Vancouver and Okanagan campuses, UBC has developed multiple policies including:

- The **Green Building Action Plan** which mandates WBLCAs for all institutional projects by 2025[247]
- a **Whole Systems Infrastructure Plan** which establishes monitoring and tracking[248]and
- **Climate Action Plan 2030** which sets a target of 50% reduction of embodied carbon emissions by 2030[249].

UBC is also currently developing a **Neighbourhood Climate Action Plan** for residential developments on campus, that will likely align with City of Vancouver's approach to embodied carbon emissions targets and performance. UBC has developed guidelines and resources to support these targets, including **Whole Building Life Cycle Analysis Guidelines** for project teams performing LCAs[250].

### B.C. Green Care, BC

Provincial Health Services Authority, including Fraser Health, Vancouver Coastal Health and Providence Health Care created **Low Carbon, Resilience and Environmental Sustainability Guidelines for Healthcare New Construction** (LCRES Guidelines)[251]. This brings health organizations in line with the provincial 2023 goals requiring all facilities to achieve LEED v4 Gold or equivalent certification. It will soon be updated to v4.1 and will further include Guidance for Low Carbon Accountability Mechanisms. The guidelines currently require a reduction of lifetime embodied carbon emissions by 10% to baseline building. Furthermore, the most recent update of the Health Capital Policy Manual will also align with the provincial policies and required v4.1 gold certification or equivalent for baseline for major new or replacement projects.

[247] University of British Columbia Campus Planning (2018). Green Building Action Plan 2016. https://planning.ubc.ca/sustainability/sustainability-action-plans/green-building-action-plan
[248] University of British Columbia Okanagan Campus Sustainability Office. Whole Systems Infrastructure Plan. https://sustain.ok.ubc.ca/policies/whole-systems-plan/
[249] University of British Columbia Campus Planning, Climate Action Plan 2030. https://planning.ubc.ca/cap2030
[250] University of British Columbia (2023). UBC Whole Building Life Cycle Assessment Guidelines v1.0. https://planning.ubc.ca/sites/default/files/2023-04/UBC%20WBLCA%20GUIDELINES%20v1.0%20March%2029.pdf
[251] BC GreenCare (2022). Low Carbon Resilience and Environmental Sustainability Guidelines for Health-care New Construction. https://bcgreencare.ca/wp-content/uploads/2022/03/LCRES-Guidelines_Final.pdf

# 4 Findings

## 4.1 FINDINGS FROM GLOBAL POLICY OVERVIEW AND EMERGING TRENDS

Embodied carbon-related policies are in various stages of development across the world. While some countries have been developing tailored approaches for many years, others are in nascent phases of policy research, formulation, and planning. The following examples are prevailing trends in the integration of embodied carbon policy considerations across different national policies around the world:

- The Netherlands boasts a long commitment to addressing embodied carbon emissions. It has had policies in place for over a decade and currently takes a comprehensive and integrated approach, e.g., building codes, a national database, and assessment methodologies tailored to its building sector.
- Singapore has implemented energy and emissions planning and construction regulations since the mid-2000s. It utilizes the Green Marks green building rating system to incentivize whole building carbon measures in design and construction practices.
- Finland enacted a new Building Act in 2023, which included measures for embodied carbon assessment and technical requirements for low-carbon buildings and is creating an online national emissions database for construction products, processes, and services.
- Norway's approach to implementing embodied carbon into its policy framework is multifaceted. Norwegian 2021-2030 climate action plan has items on encouraging low-carbon manufacturing, promoting wood product use, transitioning to fossil-fuel-free construction activities, and supporting the circular economy by reusing materials. The new NS3720 standard requires calculating GHG emissions from a building life cycle perspective.
- Australia is currently developing an embodied carbon assessment tool and methodology for building projects through the National Australian Built Environment Rating Systems (NABERS), building off of successful 2022 pilot programs with the support of New South Wales and industry experts.

Embodied carbon reduction approaches are being connected with broader net zero-emission targets, typically aligned with 2050 timelines, and integrated with low-carbon energy and economic policies across different sectors. Some prominent examples from the policy review include:

- Norway passed a Climate Action Plan in 2021-2030 to meet commitments in the Paris Agreement and EU climate legislation. It includes measures to support local manufacturers of low-carbon products, transition to fossil-fuel-free construction sites, and increase the use of wood products.
- Switzerland's Climate and Innovation Act set a goal of carbon-neutral by 2050 and focuses on reducing oil and natural gas consumption across sectors through levies on fossil fuels and support for renewable sources.
- Sweden's Climate Act mandates government reporting of climate impact across sectors, including transportation and buildings, and is supported by regulations and incentives to calculate and report on embodied emissions.

Some countries, mostly in Europe, have established interconnected policy ecosystems for embodied carbon reductions through stringent regulations, standardized and verified environmental performance methods and processes, and consistent research and innovations in low-carbon technologies and practices. Countries like Belgium, France, Germany, and the Netherlands are examples of countries that have developed:

- Protocol and requirements for EPDs and product-level environmental performance claims, which are verified and collected in national databases.
- Standards, guidelines, and methodologies for building-scale LCA or upfront carbon calculations, often using EPDs in the database as well as developed/localized national LCI databases.
- Nationally developed or approved third-party tools and rating systems for conducting assessment at the building and often product scale.

More recently, economic approaches and market-oriented mechanisms are starting to emerge, such as procurement-based policy pathways that align embodied emissions reductions with green economic transition priorities through policies incentivizing or regulating the decarbonization of industry processes and manufacturing of low-carbon products. This trend reflects the current US approach to industry decarbonization efforts. Examples include:

- The US Buy Clean Initiative, which promotes the use of American-made, low-carbon construction materials through government procurement policies, and support for industrial decarbonization and creation of EPDs.
- The US State of Washington has built of off the federal initiative to develop procurement policies that encompass not just carbon emissions but fair labor practices and health impacts reporting.

Embodied emissions policies are often not material specific, but there is a connection between development upfront or whole-life carbon emissions in building and mass timber policies. Some European countries, for example, take regulatory mechanisms to increase the use of mass timber in their construction:

- Germany's Charter for Wood 2.0 advocates for sustainable forest management, sustainable wood use, and using wood as a substitute for energy-intensive materials to achieve climate change mitigation targets.
- Netherlands's Green Deal Timber Construction in the Metropolitan Region of Amsterdam aims to increase new timber/bio-based construction by 20% from 2025.
- The US has increased the use of mass timber construction through current changes to its national building code, expanding the use of engineered timber.

Embodied carbon reduction is one aspect of creating low-carbon buildings and materials. Some countries are developing complementary policies that address other aspects, such as climate adaptation, building resiliency, operational carbon, etc. in parallel with embodied carbon reduction policy. For example:

- New Zealand is creating a policy framework to advance whole-life GHG emissions reductions and climate adaptation and resiliency strategies in buildings and urban development.
- Government of Singapore is advancing its national agenda based on sustainable construction outcomes, like embodied carbon reduction, along with other pillars such as resiliency, green economy, and sustainable living.

The primary focus of this report is to offer a broad overview of embodied carbon policies on a national scale. However, substantial progress is happening at the sub-national level. Regional and local governments are increasingly taking the lead in supporting new policies development and piloting new strategies. Some examples from this trend include:

- The US state of California's Green Building Standards Code was recently updated to include mandatory embodied carbon emissions reduction for larger commercial and institutional buildings.
- The city of Vancouver, Canada, includes embodied carbon reduction requirements in its development policy for rezoning applications.
- The city of Toronto, Canada, imposes upfront carbon emissions caps for major structural and envelope materials in city-owned buildings.
- Organizations like C40 Cities and the World Resources Institute have programs that are supporting cities worldwide in setting climate change goals, and developing pathways to reduce their emissions, including embodied carbon in building projects.

Financial incentives are key to enabling policies, by supporting incremental implementation costs, stablishing foundational programs (e.g., databases, procurement requirements etc.), facilitating training and education initiatives. Examples of policies that have increased support through financial incentives include:

- European Union Directives provide financial support to member states provided their individual policies align with minimum performance requirements.
- The EU Renovation Wave channels funding towards research, training, and new job creation, as well as technical support to expand market opportunities in building renovations.
- The US Federal-State Buy Clean Partnerships is a mechanism to align funding in support of low-carbon procurement in state-level infrastructure projects.

## 4.2 OPPORTUNITIES FOR FUTURE RESEARCH

Although there has been significant development and expansion of embodied carbon related policies between 2017 and 2024, these types of policies are still quite new and emerging around the world. Through the process of developing this report, the authors have identified the following opportunities for future investigation:

- The effectiveness of current and proposed policies in actual reductions of GHG emissions.
- The evolution of the policies and programs in countries over time (e.g. what changed and why), and identification of key foundational policies or critical actors.
- The governance and resources required to implement the policies (e.g. human, technology, procedural).
- The types of knowledge, skills and resources required to comply with the policies (e.g. who is impacted by the policy and what do they need in order to meet the policy requirements)
- Economic considerations of the policies, such as the costs to develop, implement, and administer the policy; funded sources, and responsible agencies.

- In-depth review into the international standards to identify gaps in information or conflicts in processes and outcomes.
- The relationship between embodied carbon emissions and other environmental impacts (ozone depletion, air quality, etc.) or social impacts (economic development, social equity, etc.) in terms of successful policy synergies.
- The relationship between policies and technical resources explicitly addressing embodied carbon emissions, and ones that target different aspect of the built environment (waste reduction, clean construction, retrofits etc.) that also can impact the embodied emissions.
- Social, cultural, and economic contexts that influence the success or failures of different types of policies, such as low carbon procurement vs. whole building emissions targets.
- The role of industry, non-profits, and educational institutions in developing, revising, and implementing different types of policies.
- The relationships between complementary policies at different levels of government, and 'best fit' for different types of policy at local, regional, national, or multi-national scales.
- Legal barriers or challenges to implementing different types of policy packages in the Canadian context, considering the division of roles between federal, provincial, and local governments.
- The impacts of the policies in terms of 'actual' reductions in carbon emissions, and successful strategies and approaches to measure those reductions at scale.
- Embodied carbon requirements need to be established for all building types and set targets/ to net zero carbon where they do not currently exist.
- Durability and resilience are key to reducing embodied carbon impacts at all of the life stages of a building but has yet to figure in design discussions. More work is needed to define, quantify, and set standards for the service lives of products and buildings.

# 5 Appendices

The Appendices list the key resources that bolster the LCA process for buildings and their products. These resources that include standards, databases, EPD program operators, LCA tools and software, and green building rating systems provides necessary data, tools, and frameworks for assessing building impacts including embodied carbon, validating results, and ensuring quality throughout the assessment process.

## 5.1 APPENDIX 1. STANDARDS

Standardization is necessary to ensure that the environmental impacts of buildings and their products are consistently and accurately calculated and presented. The standards development process for LCA addresses the implications that the methodological requirements will have on the practicality of completing LCAs, as well as how an LCA methodology requirement may affect project outcomes. The participation of many experts with different interests in standards development ensures the broad credibility of the developed standards. Standards are now available that cover the LCA process itself, and the various data requirements, tools, methods and means to establishing and declaring the embodied carbon in buildings.

### *Standards for LCA Processes*

Two foundational LCA standards–**ISO 14040-2006** (Environmental management Life cycle assessment Principles and framework[252]) and **ISO 14044-2006** (Environmental management life cycle assessment requirements and guidelines[253])–are globally recognized as the high-level consensus-based international standards for general LCA practices and are considered as the basis for WBLCAs. These standards are developed by the International Organization for Standardization (ISO)[254].

In addition to the fundamental LCA standards above, ISO Subcommittee 17 (or ISO/TC59/SC17)[255] has published several standards that define the LCA framework as it applies to buildings and civil engineering construction works[256]. **ISO 15392:2019** (Sustainability in buildings and civil engineering works -general principles) identifies general principles for sustainable development as it applies to the life cycle of buildings and construction works[257]. This standard is a revised version of the original ISO 15392:2008.

[252] ISO/TC 207/SC 5 (2006). ISO 14040: 2006 Environmental management-life cycle assessment-principles and framework. https://www.iso.org/standard/37456.html

[253] ISO/TC 207/SC 5 (2006). ISO14044:2006 Environmental management- life cycle assessment-requirements and guidelines. https://www.iso.org/standard/38498.html

[254] ISO is an independent, non-governmental international organization composed of national standards bodies. Experts from these bodied are drawn on to develop the voluntary, consensus-based standards published through ISO. https://www.iso.org/about-us.html

[255] Technical Committees (1947). ISO/TC 59 Buildings and civil engineering works https://www.iso.org/committee/49070.html

[256] ISO/TC 59 (2002). ISO/TC 59/SC 17 Sustainability in buildings and civil engineering works. https://www.iso.org/committee/322621.html

[257] ISO/TC 59/SC 17 (2019). ISO 15392:2019 Sustainability in buildings and civil engineering works General principles. https://www.iso.org/standard/69947.html

Other ISO Standards that address requirements and frameworks for Building LCA modeling and construction works are:

- **ISO/TS 12720: 2014** Sustainability in buildings and civil engineering works — Guidelines on the application of the general principles in ISO 15392.
- **ISO 16745-1:2017** Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication.
- **ISO 16745-2:2017** Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 2: Verification.
- **ISO 20887:2020** Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance.
- Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements, and guidelines.
- **ISO 21928-2:2023** Sustainability in buildings and civil engineering works — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works.
- **ISO 21929-1:2011** Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings.
- **ISO/CD TS 12720** Sustainability in buildings and civil engineering works guidelines on the application of general principles in ISO 15392 (under development)[258]

In addition to ISO, the European Committee for Standardization (CEN) develops its own suite of standards to provide details for topics that are not specified in ISO standards, thus facilitating harmonization. The CEN Technical Committee 350 (CEN/TC 350) 'Sustainability of Construction Works', is responsible for providing standardization sustainability assessment of new and existing buildings and engineering works[259] and has developed and published a series of standards, technical reports, and specifications that complement ISO standards. These publications are:

- **EN 15643:2021** Sustainability of construction works - Framework for assessment of buildings and civil engineering works. Similar to the relation between buildings and construction in ISO 15392:2019, EN 15643 is the highest-level CEN standard to define a framework for building sustainability assessment.
- **EN 15978:2011** Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.
- **EN 17472:2022** Sustainability of construction works - Sustainability assessment of civil engineering works - Calculation method.
- **EN 17680: 2023** Sustainability of construction works - Evaluation of the potential for sustainable refurbishment of buildings.

[258] ISO/TC 59/SC17 (n.d.). ISO/CD TS 12720 Sustainability in Buildings and Civil Engineering works: Guidelines on the Application of the general Principles in ISO 15392 (under development). https://www.iso.org/standard/83265.html

[259] European Committee for Electrotechnical Standardization (CEN-CENELEC), Sustainability, Safety and Accessibility. https://www.cencenelec.eu/areas-of-work/cen-sectors/construction/sustainability-safety-and-accessibility

The American Society for Testing and Materials (ASTM) is dedicated to formulating technical standards for the testing and classification of materials in the U.S.[260]. Among its library of standards, there is one that provides a model language for building LCAs:

- **ASTM E2921-22** Standard practice for minimum criteria for comparing whole building life cycle assessment for use with building codes, standards, and rating systems.

### *Standards for EPD Development*

ISO has also sought to provide standardization specific to the completion of environmental impact assessments of building products. **ISO 14025-2006** (Environmental labels and declarations – Type III environmental declarations – Principles and procedures) sets out how the ISO 14040 series of standards are to be applied in developing EPDs and outlines the procedures for establishing an EPD program. All EPD programs cite ISO 14025 as a governing standard in their program operator documents and in all EPDs that they publish. In addition, ISO Subcommittee 17 has published **ISO 21930:2017** (Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services) that complements ISO 14025 by providing requirements for the EPD of construction products and services[261].

ISO has also published standardization specific to the completion of carbon footprints of products through the publication of **ISO 14067: 2018 Greenhouse gases, carbon footprint of products Requirements and guidelines for quantification.**[262]

ISO 14067 draws heavily on ISO 14044 as a normative reference for scoping and modeling the life cycle of a product but provides specific carbon footprint and climate change impact assessment guidance not found elsewhere in the ISO standards. Other ISO standards to supplement ISO 14067 standards with materials carbon assessment guides and EPD generation are:

- **ISO/DIS 14026: 2017** environmental labels and declarations principles, requirements, and guidelines for communication of footprint information.[263]
- **ISO/TS 14027:2017** Environmental labels and declarations- Development of product category rules.[264]

Biogenic carbon –the carbon can be stored in biological materials such as wood – is a key consideration in the treatment of GHG emissions analyses at the material levels; yet there are limited standards cover its calculation methodology. **ISO 21930: 2017** incorporates biogenic carbon accounting and concrete

[260] American Society for Testing and Materials International. https://webstore.ansi.org/SDO/ASTM
[261] ISO/TC 59/SC 17 (2017). ISO 21930:2017 ISO 21930:2017 Sustainability in buildings and civil engineering works: Core rules for environmental product declarations of construction products and services https://www.iso.org/standard/61694.html
[262] ISO/TC 207/SC 7 (2018). ISO 14067:2018 Greenhouse gases: Carbon footprint of products Requirements and guidelines for quantification. https://www.iso.org/standard/71206.html
[263] ISO/TC 207/SC 3 (2017). ISO 14026:2017 Environmental labels and declarations: Principles, requirements and guidelines for communication of footprint information. https://www.iso.org/standard/67401.html
[264] ISO/TC 207/SC 3 (2017). ISO/TS 14027:2017 Environmental labels and declarations: Development of product category rules. https://www.iso.org/standard/66123.html

carbonation into the product system[265]. Additionally, for computing the amount of biogenic carbon in bio-based products, two other European standards are available:

- **CSN EN 16449 Wood and wood-based products** - Calculation of the biogenic carbon content of wood and conversion to carbon dioxide.
- **CSN EN 16485** Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction.

These two CSN standards are developed by Commonwealth Standard Network (CSN), a framework for international European standards that is shaped for facilitating trades, including sustainable products and services, among commonwealth countries[266].

In addition to ISO Standards, CEN has published a series of standards for the provision of construction EPDs. These standards are:

- **CEN/TR 15941:2010** Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data.
- **EN 15804:2012+A2:2019/AC: 2021** Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.
- **CEN/TR 16970:2016** Sustainability of construction works - Guidance for the implementation of EN 15804.
- **EN 15942:2021** Sustainability of construction works - Environmental product declarations - Communication format business-to-business.

ASTM does not have standards for the life cycle assessment of building materials. Instead, ASTM E2921-22 relies on ISO standards, i.e., ISO 14025 and ISO 21930, for materials impact assessments and EPDs generation[267].

Other international standards provide the fundamental rules for EPDs generation and material impact assessments. One example is the National Sanitation Foundation (NSF) suite of standards that guide building industry professionals and trades through an ISO 14025-compliant process in the development of PCRs[268].

[265] National Research Council of Canada (2022). National guidelines for whole-building life cycle assessment. https://publications.gc.ca/collections/collection_2022/cnrc-nrc/NR24-101-2022-eng.pdf
[266] Commonwealth Standards Network (2019). CSN Framework of International Standards. https://www.commonwealthstandards.net/files/file/3-csn-framework-of-international-standards-2019-05/
[267] American Society for Testing and Materials International (2014). E1991: Standard Guide for Environmental Life Cycle Assessment (LCA) of Building Materials/Products (withdrawn 2014). https://www.astm.org/e1991-05.html
[268] National Sanitation Foundation Standards, Product Category Rules. https://www.nsf.org/nsf-standards/product-category-rules

### *Other Standards and Resources*

There are other international standards that support additional resources and activities for carbon accounting of building product and LCA of buildings, including methodological frameworks for assessment, data templates, and communication formats. Some examples are:

- **ISO/TR 21932:2013** Sustainability in buildings and civil engineering works — A review of terminology.
- **ISO 21931-1:2022** Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social, and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings.
- **ISO 21931-2:2019** Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works.
- **ISO 20887:2020** Sustainability in buildings and civil engineering works — Design for disassembly and adaptability — Principles, requirements and guidance.
- **ISO 22057:2022** Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modeling (BIM).
- **CEN/TR 17005:2016** Sustainability of construction works - Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings.
- **EN 15942:2021** Sustainability of construction works - Environmental product declarations - Communication format business-to-business.
- **EN 17672:2022** Sustainability of construction works - Environmental product declarations - Horizontal rules for business-to-consumer communication.
- **EN ISO 22057:2022** Sustainability in buildings and civil engineering works - Data templates for the use of EPDs for construction products in building information modelling (BIM)

In addition to international standards mentioned above, section 3 of this report references some national-level standards, including:

- **SN-NS 3720:2018** Method for greenhouse gas calculations for buildings**.** This is a Norwegian standard based off of European standards.
- **PAS 2050: 2011** Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. This publicly available specification (PAS), published by British Standards Institution (BSI), specifies life cycle GHG emissions of products.
- **PAS 2080** Carbon management in infrastructure and built environment is another PAS standard that is published by BSI to set the requirements for the management of whole building carbon in buildings and infrastructure in the UK.

Currently, policymakers and industry professionals in North America, including Canada, are using a combination of European ISO and CEN standards and US-based ASTM as the overall structure and scoping rules for completing LCAs on building products and whole buildings.

## 5.2 APPENDIX 2. DATABASES

LCA processes for buildings or the development of EPDs rely on environmental performance information that is collected and organized into databases. These databases include different types of information that are used in different ways in the LCA process. Broadly, these resources include LCI databases containing inventory data on flows between a product and nature, and LCIA and LCA databases providing endpoint environmental results for products. Additionally, EPD databases are LCIA data sources specifically for building products.

Databases may be one of the above types, or a combination of two or more types. They can be regulated and managed by government organizations, non-profits, or industry-specific groups, with different protocols for verification and use of the datasets within them.

This sub-section lists 14 databases that are used in the policies and regulations described in Section 3. While all of these databases follow accepted standards, such as those published by ISO and CEN, they are administered by a variety of types of organizations, are applicable to project and manufactures in different regions and support the use of different assessment tools – see Table **2**.

**Table 2. Overview of Databases.**

| # | Database (version/date) | Administrator | **Regions/ Countries Applicable** | **LCA Tools Integration** | Type of Information |
|---|---|---|---|---|---|
| 1 | Athena (March 2022) | Athena Institute | US and Canada | Athena IE | LCI, LCIA/LCA |
| 2 | AusLCI and EPD Australiasia[269] (Version 1.26/2016) | Australian Life Cycle Assessment Society | Australia and New Zealand | OpenLCA, SimaPro | LCI(material, energy, transport, processing, waste treatment), LCA(EPD) |
| 3 | Belgium Environmental Product Declaration Database (V. 1.1.) | Government | Belgium | TOTEM | EPD |
| 4 | Built Environment Carbon Database (2022) | Industry-Public Consortium | UK | OneclickLCA | LCIA/LCA (product and entity level data) |
| 5 | Climate Database from Boverket (V. 02.05.000/January 2024) | Government | Sweden | No specific integration. | LCIA/LCA (product and energy) |
| 6 | CO2Data.fl (February 2021) | Finnish Environment Institute SYKE (Government) | Finland | No specific integration | LCIA/LCA (product, process and service) |
| 7 | Eco-Profiles of the European Plastics Industry (V.3.0/ October 2019) | Plastics Europe | Europe | No specific integration | LCI, EPD for plastics |
| 8 | GaBi (January 2023) | Sphera | Europe, Global | GaBi LCA, openLCA, Athena, Tally | LCI (process) |
| 9 | INIES (2022) | Industry-Public Consortium | France | No specific integration | LCIA/LCA(product and equipment) |

[269] Australian Life Cycle Assessment Society, About As. https://www.alcas.asn.au/

| | | | | | |
|---|---|---|---|---|---|
| 10 | International EPD System (2023) | EPD International AB (Swedish Non-profit) | Global | LEED | EPD (product and service) |
| 11 | Inventory of Carbon and Energy (V.3.0 / 2019) | Circular Ecology | Global | No specific integration | LCI(building materials) |
| 12 | Nationale Milieudatabase (V.3) | Stitching NMD | Netherlands NTA 8800:2023 | GPR Materiaal, MPG Toetchulp, DuboCalc, MRPI-MPG Tool | LCIA/LCA(product) |
| 13 | OKOBAUDAT (2023/ January 2023) | Government | Germany | eLCA | LCI (building materials, energy and process), LCIA/LCA (building products) |
| 14 | US Life Cycle Inventory (2023-Q4-v1/ December 2023) | NREL (Government) | US | OpenLCA. Building for environmental and Economic Sustainability BEES | LCI (material and energy) |

- **Athena Impact Estimator (IE)**

Athena IE is a software used to perform life cycle analyses of building materials that has an in-house database developed by the Athena Sustainable Materials Institute and applicable to the Canadian and US construction sectors. The database is developed by in-house research and engineered process models independent of government data sources[270], and is mostly based on industry averages with some EPDs from other institutions, such as the Canadian Precast/Prestressed Concrete Institute. The database is specific to the life cycle analysis tool, Athena Impact Estimator. The most recent material report used in the database was published in 2022.

- **AusLCI**

The Australian National Life Cycle Inventory (AusLCI) Database is a national, publicly accessible database managed by the Australian Life Cycle Assessment Society (ALCAS), with environmental information on a wide range of Australian products and services over their entire life cycle[271]. It includes more than 600 datasets for materials (including construction materials), energy, transportation, processing, and waste treatment categories[272], and can be integrated into many LCA software such as OpenLCA and SimaPro.

- **Belgium Environmental Product Declaration Database**

The Belgium Environmental Product Declaration (EPD) Database is administered by the Federal Public Service Health through the Belgium EPD Programme[273]. It contains environmental performance data from manufactures developing EPDs in accordance with the Royal Decree on Environmental Messages [274].

[270] Athena Sustainable Materials Institute, LCI Databases. https://www.athenasmi.org/our-software-data/lca-databases/
[271] About the Australian National Life Cycle Inventory Database. https://www.auslci.com.au/
[272] AusLCI datasets. https://www.auslci.com.au/index.php/Datasets
[273] FPS Public Health (2022). The Belgian EPD Programme. https://www.health.belgium.be/en/belgian-epd-programme-b-epd
[274] FPS Health, Food Chain Safety and Environment (2017). Royal Decree on environmental messages. https://www.health.belgium.be/en/royal-decree-environmental-messages

Product information in the database includes but is not limited to construction products sold in Belgium or used in Belgium buildings. The database can be integrated with TOTEM, a life cycle analysis program used in Belgium. The latest version is version 1.1.

- **BECD- Built Environment Carbon Database**

The Built Environment Carbon Database (BECD) is an open-access online repository that includes whole life cycle embodied and operational emissions data for built assets and building products in the United Kingdom. It was developed by a collaboration of British non-profits and industry partners[275], and is managed by Building Cost Information Service (BCIS) Ltd. The latest version is ECD version 1.0.0, dated from 2023.

- **Climate Database from Boverket**

Sweden uses the Climate Database from Boverket, managed by the Swedish National Board of Housing, Building and Planning[276]. The database sets generic conservative climate data of construction products that are about 25% higher than the average from existing environmental product declarations. Information covers stages A1 to A5. The database is designed for use by industry practitioners when product-specific data is not available. The latest update was in January 2024 for version 02.05.000[277].

- **CO2data.fl**

Finland has been developing CO2data.fi, an online service on the climate impact of commonly used construction products, as well as transportation, waste management and other construction processes [278] . Datasets are based on publicly-sourced information on average environmental performance, not individual products. CO2data.fi is managed by the Finnish Environment Institute (SYKE) and is funded by ministry of Environment. The latest version published in February 2021 was supported by close collaboration with Sweden and Nordic Countries.[279]

- **Ecoinvent Database**

Ecoinvent is one of the largest and most used life-cycle inventory databases, with more than 20,000 datasets across different sectors, including building and construction[280]. Datasets are developed for regions around the globe and include scores for various impact assessment methods and their corresponding categories. Ecoinvent was developed through a collaboration of Swiss research institution,

[275] The Built Environment Carbon Database. https://www.becd.co.uk/
[276] Boverket (2023). About the Climate Database from Boverket. https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/climate-database/about-climate-database/
[277] Boverket (2023). About the Climate Database from Boverket. https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/climate-database/about-climate-database/
[278] Finnish Environment Institute (2019). Construction emission database CO2data.fi. https://www.hiilineutraalisuomi.fi/en-US/Tools_and_services/Construction_emission_database
[279] Finnish Environment Institute (2024). Emissions Database for Construction. https://co2data.fi/rakentaminen/#en
[280] Introduction to the Ecoinvent Database. https://support.ecoinvent.org/introduction-to-the-database

and is now managed by the not-for-profit ecoinvent Association[281]. It was designed for use primarily in Europe but is used internationally by a range of LCA tools and policies. The latest version is Ecoinvent 3.10.

- **Eco-Profiles of the European Plastics Industry (original report TBC)**

Plastics Europe maintains a database of Eco-profiles for plastic products (i.e., polymers and precursors) manufactured in Europe. Eco-profiles are a combination of LCI datasets —from SimaPro industrial database and GaBi and Ecoinvent (v. 3.6 and after) databases—and EPDs[282] and are intended to be used in cradle-to-gate system[283]. The database is administrated by the Association of Plastics Manufacturers in Europe. This database is open-access and compliant with ISO 14040 and ISO 14044.

- **GaBi Database (Sphera Managed LCA Content)**

GaBi database, now known as Sphera Managed LCA Content, is a global life cycle inventory database for products across multiple sectors, including building and construction [284]. It is managed by Sphera, a private company providing performance and risk assessment software, and part of the US-based Blackstone business portfolio. The Managed LCA Content is tailored for use with Sphera's other LCA software and consulting services but also is used by LCA tools globally. As of 2023, all GaBi software and tools was being reorganized and branded under Sphera[285].

- **International EPD System**

The International EPD System is an EPD database and program managed by EPD International AB, a subsidiary of the Swedish Environmental Research Institute[286]. It is a collection of third-party verified EPDs with additional resources and reporting services in use in almost 50 countries, that can interface with green building rating systems and design tools. The International EPD Systems is the inventor of the Environmental Product Declaration and the Product Category Rules. and designed to be used globally[287].

- **Inventory of Carbon and Energy (ICE) Database**

The Inventory of Carbon and Energy (ICE) Database is an embodied carbon database for building materials in the United Kingdom, managed by Circular Ecology, an environmental consulting company. It is a free, downloadable database with information in over 30 material categories last updated in 2019[288].

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[281] Mission and History of Ecoinvent. https://ecoinvent.org/mission-history/
[282] Plastics Europe, Eco-profiles for determining environmental impacts of plastics. https://plasticseurope.org/sustainability/circularity/life-cycle-thinking/eco-profiles-set/
[283] Plastics Europe (2019). Eco-profiles Program and Methodology Version 3.0. https://plasticseurope.org/wp-content/uploads/2021/12/PlasticsEurope-Ecoprofiles-program-and-methodology_V3.0.pdf
[284] Sphera, Life Cycle Assessment Datasets Search Engine. https://sphera.com/product-sustainability-gabi-data-search/
[285] Sphera (2023). A Quick Guide to Sphera's 2023.1 LCA Databases Update. https://sphera.com/blog/a-quick-guide-to-spheras-2023-1-lca-databases-update/
[286] EPD International, Our DNA is made out of EPD and PCR. https://www.environdec.com/about-us/epd-international-ab-about-the-company-behind-the-system
[287] Global EPD programme for publication of ISO 14025 and EN 15804 compliant EPDs. https://www.environdec.com/about-us/the-international-epd-system-about-the-system
[288] Circular Ecology, Embodied Carbon - The ICE Database. https://circularecology.com/embodied-carbon-footprint-database.html

- **INIES**

INIES is a French reference database and program for environmental and health data on construction products and equipment. It is managed by a multi-stakeholder supervisory board, chaired by Alliance-HQE-GBC[289]. The database includes third-party verified EPDs and EHPDs (environmental and health) declaration for products as along with product environmental profiles for electrical and HVAC equipment[290]. The last database update was in 2022.

- **Nationale Milieudatabase**

The Netherlands' Nationale MilieuDatabase (NMD)is an Environmental Database that included environmental performance information on products and processes based on LCAs[291]. Datasets include including proprietary and non-proprietary information from specific manufacturers or industry groups, and NMD generated data for new products and supply chains processes, such as energy generation, transportation and waste treatment. The NMD is managed by Stiching Nationale MilieuDatabase an independent organization established specifically to administer and maintain the database, resources and overall protocols for the ENvironmetnal Performance Assessment Method for Construction Works[292]. The latest version of the database is the NMD 3.0.

- **ÖKOBAUDAT**

**Ö**kobaudat is Germany's national standardized database for the ecological evaluations of buildings, managed by the Federal Ministry for Housing, Urban Development and Building[293]. The database includes EPDs and generic LCA datasets for building materials, as well as construction, transportation, energy generation, and waste disposal processes. Datasets in the system are largely based on the background database of GaBi or ecoinvent. The latest version is Okobaudat 2023-1[294].

- **U.S. Life Cycle Inventory (USLCI) Database**

The U.S. Life Cycle Inventory (USLCI) Database is a publicly available database of energy and material information for different life cycle phases associated with producing a material, component, or assembly in the United States[295]. This database is a project of the National Renewable Energy Laboratory (NREL)[296] and partners with applicability in different sectors, including the construction and building industries. USLCI is an open-access LCI database that is integrated with professional software tools, such as OpenLCA. Its latest version is USLCI 2023-Q4-v1[297].

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[289] INIES: Who Are We? https://inies-old.armstrong.space/who-are-we/
[290] What is the INIES database? https://www.inies.fr/en/faq/what-is-the-inies-database
[291] The Stichting NMD databases. https://milieudatabase.nl/en/database/
[292] The Environmental Performance Assessment Method for Construction Works (Assessment Method). https://milieudatabase.nl/en/environmental-performance/assesment-method/
[293] The ÖKOBAUDAT platform. https://www.oekobaudat.de/en.html
[294] ÖKOBAUDAT Database. https://www.oekobaudat.de/en/service/downloads.html
[295] U.S. Life Cycle Inventory Database. https://www.nrel.gov/lci/
[296] About the National Renewable Energy Laboratory. https://www.nrel.gov/index.html
[297] National Renewable Energy Laboratory, U.S. Life Cycle Inventory Database. https://www.lcacommons.gov/lca-collaboration/National_Renewable_Energy_Laboratory/USLCI_Database_Public/datasets

Although there are several European and national-level databases available for general and building specific LCAs, there are currently no released national Canadian databases for building industry and construction projects. However, the National Research Council of Canada (NRC) is currently collaborating with openLCA to develop and maintain LCI databases that can be used in LCA across various sectors[298]. Furthermore, the International Reference Center for Life Cycle Assessment and Sustainable Transition (CIRAIG) is working to adopt ecoinvent to the Quebec and Canadian context[299].

[298] National Research Council of Canada (2022). NRC open LCA collaboration server: reference manual. Volume 1. https://nrc-publications.canada.ca/eng/view/object/?id=cdd100e1-9ca2-4f4c-ab0b-53b7daca8bd5

[299] The International Reference Center for Life Cycle Assessment and Sustainable Transition (2010). Quebec Life Cycle Inventory Database. https://ciraig.org/index.php/project/quebec-life-cycle-inventory-database/

## 5.3 APPENDIX 3. EPD PROGRAM OPERATORS

Environmental product declarations (EPD)s, also known as EPD type III, are third party verified documents that disclose the environmental impacts of a product based on LCA results. EPDs are complaint with ISO 14025 standard and are generated, registered, and/or verified by EPD program operators. These operators set standards and establish criteria for product category rules, manufacturer or industry-level product data, environmental performance metrics, and product data verification[300]. Program staff may work with manufacturers to conduct LCAs to develop EPDs, and either verify or coordinate a third-party verification of the results. EPD Program operators may also organize and publish verified EPDs as datasets or via online portals. Several program operators exist across the world. The following is list of most common program operators in Europe and North America:

### *Current European EPD Program Operators*

A number of European countries operate coordinated programs with preferred LCA tools, databases, and other resources for assessing environmental impacts and demonstrating compliance with policy targets. The EPD programs associated with these collect, verify, organize, and publish EPDs in alignment with the other national resources.

ECO Platform, as an international non-profit association that acts as an umbrella organization for supporting these national EPD program operators in Europe, support creation of a Core EPD system creation based on European standards (i.e., EN 15804). ECO Platform has been established by European program operators, and its role is to mainstream LCA for buildings and infrastructure projects by provision of reliable product data[301].ECO Platform oversees and audits the network of all established ECO EPD Programme-approved operators, many of whom play active role in shaping European embodied carbon policies at the national level. Below is the list of examples of the EPD program operators that are audited by ECO EPD Programme and associated with the policy ecosystem in Section 3 (sorted in alphabetical order):

- **Bauen und Umwelt eV (IBU)**

The IBU EPD Program was developed in Germany to harmonize the recognition of EPDs across European and non-European practitioners since 2013. Members of the program voluntarily create EPDs adhering to EN 15804 and ISO 14025[302]. The program serves as an independent information system for construction products and components. It is recognized in several countries internationally to promote comprehensive life cycle assessments. Institute Construction and Environment e.V. is the administrator of the program.

- **B-EPD**

In 2016, Belgium developed the Belgian EPD program (B-EPD) for building products that are made available or used in Belgium[303]. EPDs submitted in the program must adhere to NBN EN ISO 14025 and are used to build the national EPD database. The Belgium Federal Public Service of health is the

[300] Environmental Product Declarations. https://www.environdec.com/all-about-epds/the-epd
[301] Welcome to Eco Platform. https://www.eco-platform.org/home.html
[302] What is an EPD? Purpose and Use of Environmental Product Declarations. http://ibu-epd.com/en/epd-program/
[303] FPS Health, Food Chain Safety and Environment (2022). The Belgian EPD programme B-EPD. https://www.health.belgium.be/en/belgian-epd-programme-b-epd

administrator of the program. The program applies the requirements of the Royal Decree on Environmental Messages.

- **BRE**

Building Research Establishment Limited (BRE) is an EPD program operator in the UK that supports BREEAM rating system in two ways: 1) Building life cycle assessment, by presenting data in the EPD result tables that are being used within a building level life cycle assessment to demonstrate how different options have been considered to improve the design. 2) Environmental Impact assessment of construction products, by providing materials data and supporting the relevant BREEAM credit that encourages the use of at least 20 products with BRE-approved EPDs in the build[304].

- **EPD international system**

The international EPD® System is the world's first and longest operational EPD programme, originally founded in 1998 as the Swedish EPD System by the Swedish Environmental Protection Agency (SEPA) and industry. It operates in accordance with the ISO 14025, TS/14027,14040, and other standards. For the building and construction sector, it complies with the ISO 21930 and EN 15804 standards. It is operated by EPD International AB[305].

- **MRPI**

MRPI (Environmental Relevant Product Information) is the official program operator of the ECO Platform in the Netherlands. It is operated by the MRPI® Foundation which was founded in 1999 by the NVTB (Dutch Construction Industry Association). MRPI is one of the most important building blocks for the National Environmental Database (NMD). MRPI certificates can be used as input for national environmental databases, EPDs and for $CO_2$ ladder calculations[306].

- **PEP Ecopassport**

PEP Ecopassport is a program developed and implemented in France for electrical, electronic, and HVAC products[307]. EPDs in the program adhere to ISO 14025 and are shared in the INIES database. PEP Ecopassport provides information for carbon calculations of RE 2020 and other environmental regulations. Under the French Ministry for Housing and Urban Planning regulatory initiative, the program has been a reference for applying product categories[308]. The P.E.P Association is the administrator of the program.

[304] What is an Environmental Product Declaration (EPD)? https://bregroup.com/services/testing-certification-verification/en-15804-environmental-product-declarations/
[305] A short introduction to EPDs. https://www.environdec.com/home
[306] About Environmental Relevant Product Information (milieu relevante product informatie). https://www.mrpi.nl/over-mrpi/
[307] About the PEP ecopassport. http://www.pep-ecopassport.org/
[308] PEP ecopassport, Product Environmental Profile. http://www.pep-ecopassport.org/fileadmin/webmaster-fichiers/version_anglaise/Plaquette_PEP_EN.pdf

- **Programme INIES**

INIES is France's national reference database for environmental and health data on construction products and equipment in France, and Program INIES is the French EPD program operator that draft the rules of EPDs verification and accredits Environmental Health Declaration Sheets (FDES) for construction products. The HQE-GBC Alliance[309] is the owner of Programme INIES. Programme INIES and PEP ECOpassport are working to support INIES national database in France.

- **Rakennustieto EPD**

Rakennustieto EPD is a voluntary declaration submitted and approved by Rakennustieto, the leading construction information organization in Finland [310]. The national EPD program started in 2016. Declaration of construction products are submitted to the program and must adhere to EN 15804:2012+A2:2019. The goal of the program is to promote low-emission building materials. Rakennustieto, comprised as associations and organization of the Finnish building industry, is the administrator of the program.

- **The Norwegian EPD Foundation (EPD-Norge)**

EPD-Norge is an operator that provides a continuous update of the current laws and regulations for the Norwegian EPD programme. It was established by the Norwegian Confederation of Business and Industry in 2002[311]. EPD-Norge supports organizations in Norway and outside with verifying and approving Type III environmental declarations in accordance to ISO 14025, ISO 14040/14044 and other relevant standards or methodology guides.

### *Current North American EPD Program Operators*

North America does not have the same coordinated approach to LCAs and EPDs as many of the European countries, and the EPD programs operators are often not explicitly connected to government or policy. However, there are a number of independent EDP program operations in Canada and the United States, a sample list is below (all sorted in alphabetic order).

- **ASTM International EPD Program**

In 2012, ASTM International developed an EPD program in conformance with ISO 14025[312], which draws on its network of experts to assist in developing and verifying EPDS. The program is run by ASTM International, a US-based, international standard organization.

[309] The HQE-GBC Alliance, Our History. https://www.hqegbc.org/qui-sommes-nous-alliance-hqe-gbc/notre-histoire-alliance-hqe-gbc/
[310] About Rakennustieto. https://www.rakennustieto.fi/en
[311] The Norwegian EPD Foundation. https://www.epd-norge.no/
[312] ASTM International, Environmental Product Declarations. https://www.astm.org/products-services/certification/environmental-product-declarations.html

- **Canadian Standards Association (CSA)**

Canadian Standards Association has developed a PCR and EPD program in conformance with ISO 14025[313], which similar to ASTM, draw on its network of technical experts. The program is run by the CSA Group, an independent, non-profit, member association.

- **EPD North America**

EPD North America is an EPD program operator delivering integrated EPD verification, digital EPD development, and EPD publishing in compliance with ISO 14025, EN 15804+A2, ISO 21930, ILCD+EPD, OpenEPDTM, and other standards[314]. It is run by the North America EDP® System, a branch of the International EPD System, and operated by EPD NA, a collaborative multi-member limited liability corporation[315].

- **FPInnovations EPD Program**

FPInnovations has been EPD program operator since 2011, in compliance with ISO 14040, 14044, 14025 and 21930 and focused on forestry products[316]. It published the first PCRs for North American architectural and structural wood products, and has developed PCRS for the pulp and paper, and corrugated product manufacturing. FPInnovations is a private, not-for-profit organization that supports innovation and competitiveness in Canada's forest industries.

- **ICC Evaluation Service EPD Program**

The ICC-ES SAVE (Sustainable Attributes Verification and Evaluation) Environmental Program provides manufacturers with independent sustainability evaluation and product certification through Environmental Report and EPD Programs[317]. ICC Evaluation Service is a non-profit, limited liability company offering technical evaluations of building products, materials and system for code compliance.

- **Smart EPD**

Smart EPD is a fully digital North America EPD program operator that conforms with ISO 14025, EN 15804+A2, ISO 21930, and other supporting PCRs[318]. It manages an integrated web portal using open-access digital EPD formats to expedite workflow and connect with LCA tools and calculators. Smart EPD is a private company focused solely on EPD development.

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[313] CSA Group, Introduction to EPDs and PCRs. https://www.csaregistries.ca/GHG_VR_Listing/EPD_IntroductionPage

[314] The North American EPD System, Why Choose EPD North America? https://epdna.com/

[315] The International EPD (2023). The International EPD System announces the North American EPD System. https://www.environdec.com/news/the-international-epd-system-announces-the-north-american-epd-system

[316] FPInnovations, Environmental Product Declaration services. https://web.fpinnovations.ca/environmental-product-declarations-services/

[317] ICC Evaluation Service, Introduction to Environmental Product Declarations. https://icc-es.org/environmental-program/environmental-product-declarations/

[318] Smart EPD Homepage. https://smartepd.com/

- **UL Environment EPD Program**

UL Solutions operates an ISO 14025 compliant international EPD program, as well as UL SPOT a sustainable product database for design, manufacturing, procurement and other product selections[319]. UL Solutions is part of UL Enterprise, a US-based, international safety science company.

[319] UL Solutions, Environmental Product Declaration Certification. https://www.ul.com/services/environmental-product-declaration-certification

## 5.4 APPENDIX 4. LCA TOOLS AND SOFTWARE

As noted in Section 2, LCA is the internationally accepted science of measuring a product's potential environmental impacts on air, land, and water over its entire life cycle, from resource extraction to its end-of-life disposition. LCA tools are the software programs that integrate the various dataset required to do these measurements, whether that is a WBLCA or an EPD.

There are several general-use LCA tools available for assessing the environmental performance of products, processes or organizations. These tools are generally developed by and for professional LCA consultants, who use them to create customized life cycle inventories and impact assessments. While powerful they are highly technical.

In addition to general-use LCA tools, several LCA tools have been developed specifically to assess the environmental impacts of construction projects and building materials. Typically, these tools simplify the LCA process and LCI data in user-friendly, construction-specific interfaces.

Table 3 below captures all the prevalent tools in alphabetical order. The table is a list of tools with a brief description, categorized into two sections: (a) General professional LCA tools, and (b) LCA tools for construction projects and materials carbon accounting. These tools are sourced and collected based on information from section 3 of this report and tools collected by key LCA resources such as the Carbon Leadership Forum (CLF) [320][321].

**Table 3. Prevalent LCA Tools.**

| # | Tool (Latest version) | Offered by | Regions/ Countries Applicable | Tool Applicability | | |
|---|---|---|---|---|---|---|
| | | | | General LCA | Construction Projects LCA | Materials Carbon Accounting |
| 1 | Air.e LCA (Version 3.2) | Solid Forest | Global | ✓ | | ✓ |
| 2 | Athena Eco Calculator | Athena Institute | North America | | ✓ | |
| 3 | Athena Impact Estimator (Version 5) | Athena Institute | North America | | ✓ | |
| 4 | Beacon (Beta v0.7.0.0) | CORE studio, Thornton Tomasetti | North America | | ✓ | |

[320] Carbon Leadership Forum, Measuring Embodied Carbon. https://carbonleadershipforum.org/toolkit-2-measuring/

[321] Lewis, M., Waldman, B., Carlisle, S., Benke, B., and Simonen, K. (2023). Advancing the LCA Ecosystem: A Policy-Focused Roadmap for Reducing Embodied Carbon. Carbon Leadership Forum. https://carbonleadershipforum.org/advancing-lca-ecosystem/

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | BEES Online 2.1 | National Institute of Standards and Technology (NIST) | North America | | ✓ | |
| 6 | Building Carbon Calculator (Beta) | Singapore Green Building Council | Singapore | | ✓ | ✓ |
| 7 | Build Carbon Neutral (2.0 – Mithun) | Mithun | United States | | ✓ | |
| 8 | Buildings and Habitat Object Model (BHoM 7.0.β.0) | Buro Happold | Global | | ✓ | ✓ |
| 9 | CARE tool | Architecture 2030 | USA | | ✓ | |
| 10 | DuboCalc (Version 6.0.8) | Rijkswaterstaat | Europe | | ✓ | |
| 12 | eLCA (version 0.9.7) | Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) | Spain | | ✓ | ✓ |
| 13 | Embodied Carbon Calculator | New Zealand Green Building Council | New Zealand | | ✓ | ✓ |
| 14 | Embodied Carbon in Construction Calculator (EC3) | Building Transparency | Global | | ✓ | ✓ |
| 15 | EPIC tool (Beta v2.0.3) | EHDD | USA | | ✓ | |
| 16 | eTool | Cerclos | Europe | | ✓ | |
| 17 | Gestimat (Version 2.0) | CIRAIG | Global | | ✓ | |
| 18 | GPR Material | W/E advisors | Europe | | | ✓ |
| 19 | Hawkins Brown Emission Reduction Tool (H\B:ERT, version 2.1.5) | Hawkins\Brown | UK | | ✓ | |
| 20 | Kaleidoscope | Payette | Globe | | | ✓ |
| 21 | Klimatkalkyl (version 5 and 6) | Trafikverket | Sweden | | | ✓ |
| 22 | LCA for Experts (formerly known as GaBi) | Sphera | Global | ✓ | ✓ | ✓ |
| 23 | MRPI-MPG Tool (Version 3) | MPRI | Europe | | ✓ | |
| 24 | One Click LCA Carbon Designer 3D | One Click LCA Ltd | Global | | ✓ | |
| 25 | OneClick LCA | One Click LCA Ltd | Global | | ✓ | |
| 26 | OneClick LCA Planetary | One Click LCA Ltd | Global | | ✓ | |
| 27 | OpenLCA (Version 2.1) | GreenDelta | Global | ✓ | ✓ | ✓ |
| 28 | Pathfinder (version 0.1.0) | Climate Positive Design | Global | | ✓ | |
| 29 | SimaPro (Version 9.5) | PRé Sustainability | Global | ✓ | ✓ | ✓ |
| 30 | Tally (2024) | KT Innovations | Global | | ✓ | ✓ |
| 31 | TOTEM | OVAM, Brussels Environment and Public Service of Wallonia | Belgium | | ✓ | ✓ |
| 32 | Umberto (Version 11) | iPoint | Global | ✓ | ✓ | ✓ |
| 33 | ZGF Concrete Tool | ZGF Architecture | US | | | ✓ |

## *General LCA Tools*

General LCA tools are software and online platforms that are designed to assess environmental impacts associated with various products, that can include building and construction components assessment.

- **Air.e LCA**

Air.e LCA is a professional multisectoral software of life cycle analysis for the study of environmental product performance, service, and organizations. It includes the Environmental Footprint methodology promoted by the European Commission[322]. It is developed by Solid Forest. The latest version is Air.e LCA 3.13.

- **LCA for Experts (formerly known as GaBi)**

LCA for Experts (formerly known as GaBi) is a product sustainability solutions software that measure carbon footprint at the general products level including construction materials.

- **OpenLCA**

OpenLCA is a worldwide open source and free software for Sustainability and Life Cycle Assessment. It is versatile and able to meet the needs of different user groups, including industry, consultancy, education, and research. It is managed by GreenDelta. The most recent version 2.1 was released from January 2024[323].

- **SimaPro**

SimaPro is an LCA software for measuring product sustainability. It is primarily utilized for sustainability reporting, carbon, environmental, social and water foot printing, biodiversity assessments, sustainable product design, and more[324]. It is developed by PRé Sustainability. The latest version is SimaPro 9.5 released in 2023.

- **Umberto**

Umberto is an LCA software for analyzing the environmental impact of the company and its products[325]. It is used among industry, manufacturing, consulting, research, and education. It is managed by iPoint. The latest version is Umberto 11.11.1 released in 2023.

### *Construction Projects and Materials LCA Tools*

This section includes tools for carbon accounting of building products and LCA of construction projects. This section particularly focuses on tools that are applicable for building components and whole building LCAs.

- **Athena Eco Calculator**

Developed by Athena, EcoCalculator is a free tool that facilitates quick LCA for common building assemblies. Available for commercial and residential buildings and customized for several North American regions, it instantly displays embodied energy use, global warming potential, acidification potential,

[322] Overview of Air.e LCA - Multiple Environmental Impacts Calculation. https://www.solidforest.com/en/software/overview.html
[323] OpenLCA download page. https://www.openlca.org/download/
[324] About SimaPro. https://simapro.com/about/
[325] About Umberto. https://www.ifu.com/umberto/lca-software/

eutrophication potential, and smog potential. Equipped with pre-defined building assemblies which have been assessed using Athena Impact Estimator for Buildings, the tool takes includes all life cycle stages[326].

- **Athena Impact Estimator**

The Athena Impact Estimator for Buildings is the free software tool in North America that is designed to evaluate whole buildings and assemblies based on internationally recognized life cycle assessment methodology. It is managed by the Athena Sustainable Material Institute. The Athena Impact Estimator is applicable for new construction, renovations, and additions in all North American building types. The latest version is Version 5.5.01 (version 5.5 Build 0109) released in February 2024[327].

- **Beacon**

A plug-in for Revit, Beacon provides quick information on project's embodied carbon, further highlighting opportunities to optimize embodied carbon within the structural design such as concrete, steel and wood. It provides high-level feedback with clear visualizations to professionals allowing tracking and management of embodied carbon in their structural projects. The plug-in allows integration of latest embodied-carbon coefficients and best practices during assessment[328].

- **BEES Online 2.1**

Developed by the National Institute of Standards and Technology (NIST), Building for Environmental and Economic Sustainability (BEES), uses life-cycle assessment approach specified in the ISO 14040 series of standards, to measure the environmental performance of building products. BEES Online 2.1 LCIA results are based on Product Category Rules (PCRs) which are used for developing EPD[329].

- **Building Carbon Calculator**

The Singapore Building Carbon Calculator is a free, online embodied carbon calculator for the country's building industry. It incorporates EPDs, LCA methods and local factors to the Singapore context, and aligns with the Singapore Code for Environmental Sustainability of Buildings and the Green Mark 2021 Whole Life Carbon requirements[330].

- **Buildings and Habitat Object Model (BHoM)**

BHoM is an open computational toolkit facilitating WBLCA in addition to comparisons of building systems, assemblies, and individual materials. An open coding initiative, BHoM toolkit supports analysis via Grasshopper/Rhino, Excel etc. Further BIM integration and direct import of material quantities is also feasible. the toolkit establishes links between material quantities and LCA data extracted from diverse open-source databases such as EC3, Quartz, ICE, and others[331].

[326] About the Athena EcoCalculator. https://www.athenasmi.org/our-software-data/ecocalculator/
[327] Athena Sustainable Materials Institute, Impact Estimator Revision History. https://calculatelca.com/software/impact-estimator/revision-history/
[328] About Beavon. https://www.thorntontomasetti.com/capability/beacon
[329] About BEES Online 2.1. https://ws680.nist.gov/BEES2/
[330] Singapore Building Carbon Calculator. https://carboncalculator.sg/
[331] Sustainable Code at Scale: The Buildings and Habitats object Model. https://bhom.xyz/

- **CARE tool**

The CARE (Carbon Avoided: Retrofit Estimator) Tool facilitates the comparison of carbon impacts between renovating an existing building and replacing it with a new one. Used for comparing operating, embodied and avoided carbon impacts for the two scenarios, the tool currently supports assessment for USA regions. Further the assessments underscore the benefits of reusing or upgrading buildings/ building materials compared to replacing with a new construction[332].

- **DuboCalc**

DuboCalc is a Dutch tool developed on behalf of Rijkswaterstaatis and managed by Netcompany and Witteveen+Bos. It performs cradle-to-grave or extraction-to-demolition LCAs in accordance with ISO 14040 and the Dutch Environmental Performance Assessment Method[333]. The tool is for tenders of civil engineering works. It uses the National Environmental Database 3.0. The latest version is DuboCalc 6.0.8 released in 2023.

- **eLCA**

By utilizing specific data sourced from environmental product declarations (EPD) or the OeKOBAU.DAT database and considering various life-cycle phases, eLCA facilitates a quantified evaluation of buildings. Both OeKOBAU.DAT and eLCA are initiatives overseen and maintained by the Federal Institute for Research on Building, Urban Affairs, and Spatial Development (BBSR), a research institution under the purview of the Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety (BMUB)[334].

- **Embodied Carbon in Construction Calculator (EC3)**

The Embodied Carbon in Construction Calculator (EC3) tool is a free and easy-to-use tool that allows benchmarking, assessment and reductions in embodied carbon, focused on the upfront supply chain emissions of construction materials[335]. It was incubated at the Carbon Leadership Forum and developed by Building Transparency. EC3 is updated every two weeks with bug fix, new features, and improved performance.

- **ENVEST**

The ENVEST tool provides details on both the operational and materials impacts of a building's evolution in design. This comprehensive approach sheds light on crucial design trade-offs aimed at minimizing greenhouse gas emissions and other environmental impacts throughout the building's lifespan. Moreover, ENVEST provides simultaneous estimations for construction costs and the overall life cycle expenses[336].

- **Embodied Carbon Calculator**

The New Zealand Green Building Council (NZGBC) in collaboration with Thinkstep-anz is developing an Embodied Carbon Calculator to assess upfront carbon and whole-of-life embodied carbon for building

[332] The CARE Tool. https://www.caretool.org/
[333] About DuboCalc. https://www.dubocalc.nl/en/what-is-dubocalc/
[334] Terms eLCA in beta. https://www.bauteileditor.de/
[335] Carbon Leadership Forum, Embodied Carbon in Construction Calculator (EC3). https://carbonleadershipforum.org/ec3-tool/
[336] About ENVEST. https://clarityenv.com.au/envest/

projects. The calculator is intended to be a resource for the industry in developing a consistent approach to measuring and reporting embodies emissions, in support of the Building for Climate Change Programme initiatives. It is compatible with the Green Star rating system that evaluates the environmental performance and sustainable practices of buildings and infrastructure projects in New Zealand[337].

- **EPIC tool**

The Early Phase Integrated Carbon (EPIC) assessment is developed by EHDD to support climate-positive design decisions in data-scarce early design project stages of buildings. With highest emission reduction potential, the early design stage assessments supported by EPIC combines regionally specific data, projections, and assumptions to evaluate carbon impacts. These assessments support iterative low-carbon design process to meet project defined targets[338].

- **eTool**

eTool is an online life cycle assessment management platform for construction and civil engineering projects. It helps quantify, compare, and reduce embodied carbon and whole life carbon emissions of project[339]. It is managed by Cerclos.

- **Gestimat**

Gestimat enables comparative assessments of material manufacturing (from production to delivery at the factory) across different building structure scenarios to comprehend their greenhouse gas (GHG) emissions stemming. Offered by Cecobois, CIRAIG supported computing of inventory data for the Gestimat project[340].

- **GPR Material**

GPR Materiaal is one of the tools endorsed by Stiching NMD[341] used in the Netherlands. It is managed by W/E adviseurs. The tool is used to compute the environmental performance of existing and new buildings[342] in adherence to the Dutch Environmental Performance Assessment Method for Buildings and Civil Engineering 3.0. Individuals in the construction industry, such as architects and developers, are meant to use the software. It uses the National Environmental Database 3.0. The software was updated last in 2023[343].

[337] Thinkstep-anz (2023). New embodied carbon calculator for New Zealand. https://www.thinkstep-anz.com/resrc/news/new-embodied-carbon-calculator-for-new-zealand/
[338] The Early Phase Integrated Carbon (EPIC) Homepage. https://epic.ehdd.com/
[339] The eTool's Design Features. https://etool.app/features/
[340] About Gestimat. https://ciraig.org/index.php/project/gestimat/
[341] Dutch Environmental Database, Calculation tools. https://milieudatabase.nl/en/environmental-performance/calculation-tools/
[342] GPR Building Decree indispensable tool for Building Decree calculations. https://gprsoftware.nl/gpr-materiaal/over-gpr-materiaal/
[343] GPR Software updates in 2023 and plans for 2024 (2024). https://www.w-e.nl/kennisbank/updates-gpr-software-in-2023-en-2024/

- **Hawkins Brown Emission Reduction Tool (H\B:ERT)**

H\B:ERT is a plug-in for Revit that enables quick analysis of whole building, building assemblies, design options and materials embodied carbon emissions any time during the design process. An open-source project, the uses publicly accessible ICE database to perform WBLCA and assess embodied carbon emissions[344].

- **Kaleidoscope**

Payette introduced Kaleidoscope: Embodied Carbon Design Tool to support integration of embodied carbon assessment during design processes without using a 3D model. Facilitating assessment during early design stages, Kaleidoscope, helps in quick comparisons of typical building systems for use in early design decisions[345].

- **Kilmatkalkyl**

Klimatkalkyl tool supports calculating energy use and greenhouse gas emissions of transport infrastructure from a life cycle perspective. Starting from 2015, Sweden has placed significant emphasis on minimizing emissions from transportation and infrastructure endeavors. It mandates that all major infrastructure projects compute their embodied carbon during both design and construction stages, adhering to directives set by the Swedish Transport Authority[346].

- **MRPI-MPG Tool**

MRPI-MPG is the final tool endorsed by Stitching NDM. It is managed by Stitching MRPI. The tool is used to compute environmental building performance in adherence to the Building Decree 2012[347]. The tool is used by plays in the building industry, such as designers and architects. It uses the National Environmental Database 3.0. The latest version is MRPI-MPG Tool 3.0.

- **OneClick LCA**

Norway came into a five-year agreement with One Click LCA as a tool to execute the Building Research Establishment Environment Assessment Method[348]. The Norwegian government property agency, Statsbygg, came into an agreement with the eponymous company. One Click LCA was named Bionova prior to July 2021 and is also designed for global use. The tool is used for whole-building LCA in the construction industry and is designed for global use. There are plans to have One Click incorporated into

[344] About the Hawkins\Brown Emission Reduction Tool. https://www.hawkinsbrown.com/sub-services/hbert-emissions-reduction-tool/

[345] Introducing Kaleidoscope: Embodied Carbon Design Tool. https://www.payette.com/research-innovation/introducing-kaleidoscope-embodied-carbon-design-tool/

[346] Swedish Transport Authority (Trafikverket). Climate calculation – the infrastructure's climate impact and energy use in a life cycle perspective. https://bransch.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/minskad-klimatpaverkan/Klimatkalkyl/

[347] About the MRPI-PROtool. https://www.mrpi-mpg.nl/

[348] Epressi (2017). Norwegian government towards zero carbon buildings with One Click LCA (press release). https://www.epressi.com/media/userfiles/54047/1504680820/pr_oneclicklca_five_year_agreement_with_norwegian_government_6sept2017_final.pdf

the assessment methods used in Switzerland and Netherlands. Information from the Built Environment Carbon Database and Eco invent is used. The most recent update of the tool occurred in January 2024[349].

- **One Click LCA Carbon Designer 3D**

Developed by One Click LCA, Carbon Designer 3D is an early carbon optimization tool supporting quick visualization of a building design carbon impacts. It a user-friendly tool, which does not require LCA expertise, BIM models or material quantities. An updated version of Carbon Designer tool, the Carbon Designer 3D is helpful is providing early estimated on carbon hot spots[350].

- **OneClick LCA Planetary**

Available in nine languages and with global database, Planetary is developed by OneClick CLA as a planetary solution making it suitable for global organisations including investors. Currently covering ten most important construction materials and selected essential assemblies, the online, free to use tool also allows manufacturers to add their product EPDs. The tool provides embodied carbon metrics, materials efficiency and global EPD database[351].

- **Pathfinder**

Pathfinder is a web-based calculator for quantifying carbon emissions and carbon sequestration potential of projects based on the project landscape and site design. The high-level information provided by the tool can be helpful during early design stages supporting optimization of embodied carbon emissions within a project[352].

- **Tally**

The Tally application allows architects and engineers working in Revit® software to quantify the environmental impact of building materials for whole building analysis as well as comparative analyses of design options[353]. It is a joint development project used worldwide from Building Transparency, KT (Kieran Timberlake) innovations, thinkstep, and Autodesk. The current version Tally 2024 was released in September 2023. It requires Autodesk Revit 2016-2024.

- **The Footprint Embodied Carbon Calculator**

The web-based tool supports the whole life carbon assessment at four levels – product, tenancy/fit-out, building and the precinct level. Facilitating embodied carbon assessments from feasibility to as-built, the tool can help completing comprehensive LCAs in three hours. Driving sustainable design decision, the tool results can be used to demonstrate compliance with built environment rating systems such as LEED, Greenstar etc. [354].

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[349] Masson, S. (2024). Release Notes January 2024. https://oneclicklca.zendesk.com/hc/en-us/articles/12296108224668--Release-Notes-January-2024
[350] One Click LCA, Carbon Designer 3D. https://www.oneclicklca.com/carbon-designer-3d/
[351] One Click LCA, Planetary. https://www.oneclicklca.com/planetary/
[352] Climate Positive Design, Pathfinder. https://climatepositivedesign.com/pathfinder/
[353] About Tally. https://choosetally.com/
[354] The Footprint Company, Footprint Calculator 2.0. https://footprintcompany.com/footprint-embodied-carbon-calculator/

- **TOTEM**

Belgium uses TOTEM (Tool to Optimise the Total Environmental impact of Materials)[355] to evaluate the environmental impact of buildings. The tool was developed by Brussels Environment, Public Service of Wallonia, and the Public Waste Agency of Flanders[356]. TOTEM is used by players in the construction sector such as architects and contractors. An assessment of the life cycle from the product stage to end of life is performed with information taken from the Belgian Environmental Product Declarations (B-EPDs) Programme. The most recent update of the tool occurred in December 2023.

- **ZGF Concrete Tool**[357]

ZGF concrete tool is an excel file for generating and comparing LCA results for specific concrete mix designs that are developed by ZGF architecture firm. This is a free tool.

### *EPD Generators*

In addition to LCA tools for construction projects and materials carbon accounting, EPD generators are tools that are recently being developed in response to increasing trend among policy and industry for the generation of environmental product declarations and use of low carbon materials. These tools support data collection and analysis of product environmental impacts in compliance with standards and regulations. Below are some examples of current EPD generators that are being used in the construction market globally:

- **Climate Earth's EPD Essential**

Developed by Climate Earth EPD Essential offers a user-friendly EPD generator tailored for concrete producers experiencing early interest in EPDs. This tool empowers Ready Mix producers to target customers valuing lower embodied carbon and transparency. It operates as a cloud-based software accessible via web browsers or smartphones, making EPD creation convenient. With simple setup, users can input new mix designs, triggering the automated, verified, and secure generation of EPDs[358]. This tool can be integrated with EC3 tool so that the updated EPDs are accessible to buyers and specifiers.

- **EPD-generator**

The EPD generator empowers companies to create their own EPDs by establishing an industry-specific database at the project's outset, containing data on raw materials, energy, transport, and waste. Companies input their product details, transport data, energy use, and production waste, with the system automatically generating EPD-formatted environmental impact calculations. All calculations and data undergo third-party verification, ensuring integrity and preventing user manipulation[359].

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[355] Welcome to TOTEM. https://www.totem-building.be/

[356] TOTEM: an online tool for architects that calculates the environmental footprint of buildings. https://circulareconomy.europa.eu/platform/en/toolkits-guidelines/totem-online-tool-architects-calculates-environmental-footprint-buildings

[357] ZGF (2019). LCA Calculator Reduces Concrete's Embodied Carbon. https://www.zgf.com/ideas/2493-lca-calculator-reduces-concrete-s-embodied-carbon

[358] Climate Earth's EPD Essential. https://climateearth.com/solutions/ready-mix/

[359] LCA.no AS, EPD Tools for digital environmental declarations. https://lca.no/en/epd-generator-2/

- **One Click LCA EPD Generator**

The One Click LCA EPD Generator conducts LCAs and generates EPDs, enabling the creation of customer-specific private EPDs and TM65-compliant calculations. The tool helps in streamlining the process by automatically importing bill of materials into One Click LCA through Excel upload or API integration. By offering various templates to choose from, the tool helps in Save time in generating EPDs for construction products[360].

- **One Click LCA Pre-verified EPD Generator**

The One Click LCA Pre-verified EPD Generator is a cost-effective and automated solution for developing robust environmental product declarations (EPDs). It offers industry-specific templates and seamlessly transfers your bill of materials into One Click LCA through file uploads (such as Excel) or API integration. The tool simplifies the EPD process, providing a centralized platform for LCA tools, databases, EPD generation, third-party verification, and publishing[361].

- **Theta EPD**

Theta offers LCA and EPD generation solutions tailored for industries impacted by the U.S. Federal Government's Inflation Reduction Act (IRA) and state-level Buy Clean Programs. Theta simplifies the process through automated LCAs and EPDs for various industries including cement, steel, glass, etc., ensuring compliance with federal and state-level Buy Clean Policies[362].

- **Theta EPD + GCCA**

WAP and the Global Cement and Concrete Association (GCCA) have collaborated to offer an on-demand, web-based EPD tool for North American concrete producers. The tool efficiently creates precise and affordable EPDs for the construction industry and the results adheres to the EPD Requirements of the Federal Buy Clean Initiative[363].

[360] One Click LCA, EPD Generator. https://oneclicklca.com/software/manufacturing/epd-generator
[361] One Click LCA, Pre-verified EPD Generator. https://oneclicklca.com/software/manufacturing/pre-verified-epd-generator
[362] WAP Sustainability, Theta EPD, The Buy Clean Compliance Software. https://wapsustainability.com/software/theta-epd/
[363] WAP Sustainability, Theta EPD + GCCA, EPDs On-Demand for Ready Mix Concrete. https://wapsustainability.com/software/theta-gcca/

## 5.5 APPENDIX 5. GREEN BUILDING RATING SYSTEMS

Green building rating systems provide frameworks to evaluate and certify the sustainability performances of buildings and development projects. The use of specific ratings systems is sometimes required or incentivized through policies, as a strategy to improve the environmental performance of buildings.

A growing number of green building rating systems incorporate criteria related to LCAs and strategies to reduce embodied carbon emissions. Below is a list of ten prevalent green building rating systems examples and some of them are noted in Section 3.

- **Bewertungssystem Nachhaltiges Bauen**

Bewertungssystem Nachhaltiges Bauen (BNB) is a German rating system for sustainable construction managed by the German Federal Office for Building and Regional Planning for publicly funded projects[364]. It assesses the sustainability of a project over its entire lifecycle through weighted criteria of ecological quality, economic quality, sociocultural and functional quality, technical quality, process quality, and location characteristics[365].

- **BREEAM**

The Building Research Establishment Environmental Assessment Method (BREEAM) is a sustainability assessment framework for new construction, renovations, master planning and infrastructure projects, managed by the BRE Group, which is a profit-for-purpose organization based in the United Kingdom[366]. BREEAM International New Construction[367] version 6.0 gives credit for having at least 5 verified EPD products identified at the design phase and installed during construction.

- **Carbon Risk Real Estate Monitor**

The Carbon Risk Real Estate Monitor (CRREM) was developed by a consortium of universities in EU and UK, under the EU's Horizon 2020 programme[368]. It is an open access tool for assessing operational emissions to inform retrofit decisions by owners and investors, in order to ensure existing buildings can meet future energy and emissions standards through financially viable upgrades. The tools connect with service providers across the UK for audits and improvements.

- **Deutsche Gesellschaft für Nachhaltiges Bauen Certification**

Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) Certifications is a voluntary sustainable building rating system managed by the German Green Building Council. DGNB is used in Germany but includes a

[364] Federal Ministry for Housing, Urban Development and Building of German, Sustainable Building Assessment System, Other Contacts and Certification Bodies. https://www.bnb-nachhaltigesbauen.de/austausch/weitere-ansprechpartner/
[365] Federal Ministry for Housing, Urban Development and Building of German, Sustainable Building Rating System. https://www.bnb-nachhaltigesbauen.de/en/assessment-system/
[366] About BREEAM. https://bregroup.com/products/breeam/
[368] Carbon Risk Real Estate Monitor. https://www.crrem.eu/
[368] Carbon Risk Real Estate Monitor. https://www.crrem.eu/

systematic approach to adapting local conditions for use internationally[369]. It has different versions for new construction, renovations, and construction sites, and assesses project performance over their life cycle in environmental, economic, and sociocultural and functional quality as well as technical, process and site quality.

- **Green Mark 2021**

Green Mark 2021 is an international certification standard for new and existing buildings managed by the Government of Singapore[370]. The current version, GreenMark:2021 2nd Edition for New Buildings, awards points for conducting whole life carbon assessment or embodied carbon calculations, as well as for reducing the embodied carbon emissions for concrete, steel, and glass. Green Mark uses the Singapore Green Building Council's Building Embodied Carbon Calculator to demonstrate carbon emissions reductions.

- **Green Star Rating System**

The Green Star is a set of rating systems for new building, building operations, interior fit outs and communities, managed by the Green Building Council of Australia (GBCA)[371]. The newest version of Green Start Buildings includes credits to reduce upfront carbon emissions using a carbon emission calculator or LCA comparison against a theoretical reference building.

- **Green Star NZ**

Green Star NZ is an adaptation of the Green Star Rating System for New Zealand and is managed by the New Zealand Green Building Council[372]. The newest version in 2024, provides credit for minimum reduction of upfront carbon emissions between 10% and 25% against a theoretical or benchmark buildings, as well as credit for offsetting demolition and long-term carbon storage beyond the construction phase.[373]

- **Leadership in Energy and Environmental Design (LEED)**

LEED is a widely used green building rating system managed by the U.S. Green Building Council (USGBC) or comparable organization in different counties. It includes versions for new buildings, interiors, operations, neighborhoods, houses, and cities. The current versions of LEEDv4 includes credits for

[369] DGNB. Certify Projects Internationally. https://www.dgnb.de/en/certification/important-facts-about-dgnb-certification/certify-projects-internationally

[370] Singapore Building and Construction Authority, Green Mark 2021. https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme/green-mark-2021

[371] Green Building Council of Australia, Green Star Rating System. https://new.gbca.org.au/green-star/rating-system/

[372] New Zealand Green Building Council, Introduction to Green Star. https://nzgbc.org.nz/introduction-to-green-star

[373] Green Star Buildings NZ. Green Star Buildings Draft: 21 Upfront Carbon Emissions. https://23159811.fs1.hubspotusercontent-na1.net/hubfs/23159811/Green%20Star%20technical%20resources/Green%20Star%20Buildings%20NZ%20consultation/Draft%20credits/21%20Upfront%20Carbon%20Emissions.pdf

conducting WBLCA and using EPDs, as well as reusing and recycling materials, and reducing construction waste[374].

- **Miljobyggnad**

Miljobyggand is a Swedish voluntary green rating system, managed by the Green Building Council of Sweden[375]. There are different versions for new construction and existing buildings, which are rated in three categories: energy, materials, and indoor environmental quality[376]. Credits are awarded for the use of EPDS and LCA, and the demonstration reduction in embodied carbon emissions. Environmental product declarations are used in the evaluation. The latest version is Miljobyggand 4.0.

- **Minergie-Eco**

Minergie-Eco is a green rating system developed in Switzerland and used globally. It is managed by Minergie Association. There are different rating schemes for new construction and renovation projects[377]. Health and ecological requirements are taken into consideration in the assessment. Ecological requirements include using building materials with low environmental impact. Projects are awarded with a Minergie-Eco label, if successful. The latest version is Minergie-Eco 2020.

- **NABERS**

NABERS (National Australian Built Environment Rating System) is a national government rating system program for commercial buildings administered by the New South Wales Government and overseen by a national Steering Committee comprised of all State and Territory representatives, and the Australian Government.[378] NABERS is in the process of releasing upfront carbon benchmarks and is currently for Operational Energy Performance benchmarks.

NABERSNZ is an adaptation for New Zealand. NABERSNZ is licensed to the Energy Efficiency and Conservation Authority (EECA) and is administered by the New Zealand Green Building Council (NZGBC).[379]

- **Zero Carbon Building Standard**

Canada Green Building Council (CAGBC) has two zero emissions focused green building frameworks for Canadian projects: Zero Carbon Building – Design Standard guides the design of new buildings and the retrofits of existing buildings, and the Zero Carbon Building – Performance Standard can be used to

[374] Canada Green Building Council (2019). Life Cycle Assessment in LEED v4.1. https://www.cagbc.org/news-resources/cagbc-news/life-cycle-assessment-in-leed-v4-1/
[375] Sweden Green Building Council, What is Miljöbyggnad? https://www.sgbc.se/certifiering/miljobyggnad/vad-ar-miljobyggnad/
[376] Sweden Green Building Council, Embodied Carbon in Green Rating Systems: Miljöbyggnad (MB) Version 3.1. https://se2050.org/miljobyggnad-mb-version-3-1-sweden-green-building-council/#1651081819601-815a2bb0-60e2
[377] Minergie, Certification with ECO. https://www.minergie.ch/fr/certification/eco/
[378] Australia National Australian Built Environment Rating System, Governance. https://www.nabers.gov.au/about/governance
[379] New Zealand National Australian Built Environment Rating System, Background. https://www.nabersnz.govt.nz/about-nabersnz/background/

demonstrate that a building has achieved net-zero operations, through annual verification[380]. The ZCB standards can be used on any building type. The Design Standard requires a minimal level of 40% reduction in embodied carbon by 2030, and the Performance Standard requires that embodied carbon emissions be offset.

- **Zero Carbon Certification**

The ILFI (International Living Future Institute) Zero Carbon Certification is a worldwide Zero Carbon third-party certified standard[381]. Project teams are required to calculate the total embodied carbon emissions of the project by using an approved life-cycle assessment (LCA) tool. Calculations should list the estimated carbon impact of each of the final construction materials and processes associated with the foundation, structure, enclosure, and interior the project. The latest version is Zero Carbon Standard 1.0.

[380] Canada Green Building Council, Zero Carbon Building Standard. https://www.cagbc.org/our-work/certification/zero-carbon-building-standard/

[381] International Living Future Institute, Zero Carbon Certification Overview. https://living-future.org/zero-carbon/zero-carbon-certification/