BUY CLEAN WASHINGTON STUDY

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A reference document for embodied carbon policy for the State of Washington

Professional report commissioned by the State of Washington 65th Legislature through the Engrossed Substitute Senate Bill 6095

FINAL REPORT

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BUY CLEAN WASHINGTON STUDY

OVERVIEW

This report is a compilation of work generated in developing embodied carbon policy options and recommendations for the State of Washington. The majority of work contained in this report was completed from June 2018 to December 2018.

This report is part of the Buy Clean Washington Study (91000022) commissioned by the State of Washington 65th Legislature through the Engrossed Substitute Senate Bill 6095: Sec. 5014 (see **Appendix A.4**). The University of Washington (College of Built Environments) led the study in collaboration with Central Washington University (Construction Management Program) and Washington State University (Architecture and Engineering School).

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EXECUTIVE SUMMARY

On January 8, 2018, members of the Washington (WA) State House of Representatives introduced House Bill (HB) 2412 – Creating the Buy Clean Washington Act[1] to the state legislature. Modeled after the Buy Clean California Act,[2] HB 2412 proposed that WA state authorities awarding construction contracts must require environmental product declaration (EPDs) for an eligible list of materials. Although the bill did not advance to voting in the 2018 legislative session, a pilot project and study was included in the capital budget. The capital budget authorized the UW College of Built Environments to collaborate with the Central Washington University (CWU) Construction Management Program and the Washington State University (WSU) Architecture and Engineering School to "analyze existing embodied carbon policy and propose methods to categorize structural materials and report structural material quantities and origins."[3] Note that this study focuses on each of the structural material categories (concrete, masonry, metals, wood) in isolation of the others; it does not aim to compare between the material categories, but rather seeks to incentivize low-carbon purchasing in each.

The results of the study are contained in five parts along with an Appendices, which includes relevant resources for policymakers. The five parts are outlined below:

1. **Chapter 1: Introduction** – summarizes the history of the Buy Clean Washington bill, and describes the directions for the study.
2. **Chapter 2: Policy Review** – reviews a wide range embodied carbon policies, program, and initiatives from all around the world, distilling common themes.
3. **Chapter 3: Technical Review** – analyzes the major construction materials in-depth with regards to their embodied carbon impacts, and provides recommendations on how to further the development of supply chain environmental data, such as EPDs, in Washington.
4. **Chapter 4: Pilot Study** – presents the pilot projects used for this study and proposes a method for collecting data in the pilot study.
5. **Chapter 5: Policy Evaluation** – provides a comprehensive analysis of Buy Clean policy as enacted in California, a framework for developing Buy Clean policy for Washington State, and a list of potential investments that Washington State could undertake to facilitate consideration of embodied carbon in public procurement. This chapter assesses potential impacts and outcomes, including cost impacts.

The key takeaways from each chapter are presented below.

Chapter 1: Introduction

Under increasing global pressure, governments worldwide are deploying policy as a catalyst to transform markets and accelerate the reduction of carbon emissions across all sectors. Carbon dioxide is one of multiple greenhouse gas emissions (GHG), which are reported in kilograms of CO_2 equivalent (kg CO_2e), and is often referred to as "carbon." Government programs often focus on operational energy

[1] Washington State Legislature, "HB 2412 - 2017-18 Creating the Buy Clean Washington Act," 2018, https://app.leg.wa.gov/billsummary?BillNumber=2412&Year=2017.
[2] California Legislative Information, "Buy Clean California Act [3500 - 3505]," 2017, https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5.
[3] Washington State Legislature, "SB 6095 - 2017-18 Concerning the Capital Budget," 2018, http://apps2.leg.wa.gov/billsummary?Year=2017&BillNumber=6095&Year=2017&BillNumber=6095.

impacts of buildings, but it is also important to consider the hidden, "embodied" impacts of building materials. When aggregated across sectors, more than half of all carbon emissions are related to construction materials.[4] *Embodied carbon* refers to the CO_2e emissions resulting from resource extraction and product manufacturing, which originate in the early stages of the supply chain. A number of countries, largely in Europe, have established embodied carbon policies to help reduce this significant source of environmental impacts in the building sector.

Chapter 2: Policy Review

Through a review of existing and developing embodied carbon policies around the world, several themes emerged as key components or strategies that policymakers have adopted to build support for, develop, and implement new policies. These themes are:

A. Policy implementation is often supported by technical resources that are aligned under a shared framework or program.
B. New embodied carbon policies are often aligned with existing, official international and/or national programs.
C. Incentive programs are often provided early during implementation of a new policy, usually through a voluntary, trial period.
D. Governments benefit from engaging with industry stakeholder groups during policy development and implementation.
E. Politicians can "champion" policy by delivering key messages. This helps cultivate political and public goodwill.
F. Government-industry partnership interdisciplinary coalition is helpful for informing policy development and garnering industry support for compliance standards.
G. It is also helpful to identify, leverage, and support sustainability-focused industry groups and/or existing industry-led initiatives.
H. To overcome concerns about the risks of new policies, governments can present case studies as "success stories" to demonstrate how compliance can be achieved, satisfying the goals of the new policy.
I. It is helpful to implement an incremental timeline where requirements are phased in, including a voluntary trial period.
J. Performance-based pathways to compliance, instead of disclosure-based, are recommended by policy experts.
K. Increasingly, embodied emission policy experts are emphasizing the need to consider the 'circular economy' of construction materials, with the goal of minimizing natural resource extraction and toxic waste disposal.
L. Lastly, policymakers should assess factors unique to their local context and shape policy accordingly.

Chapter 3: Technical Review

This study focused on four types of construction materials: concrete, masonry (concrete or clay units), metals (steel, specifically), and wood. The intent of this technical review is to evaluate options for

[4] OECD, "Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences" (Paris, 2019), https://doi.org/https://doi.org/10.1787/9789264307452-en.

differentiating products of the same material category, e.g. selecting the 'cleanest' structural steel available. The purpose of this study is not to compare different material categories, such as steel versus concrete, and thus cannot answer questions such as, "Is a steel or concrete structure a lower-emission option for a building?" The technical review explores these materials in detail, explaining how these materials are produced, where emissions arise along the supply chain, strategies or innovations that can lead to lower carbon-intensive uses of these materials, and the current status of environmental data on these materials. In industry, environmental data are typically encapsulated in environmental product declarations (EPDs), which can be useful sources of environmental data for the purposes of Buy Clean. Some EPDs are industry-wide, which are averaged values, and do not represent the unique characteristics of a specific product. Facility-specific EPDs, which represent the supply-chain and manufacturing impacts of a particular facility or manufacturer, could inform procurement choices provided they include facility-specific information about critical upstream material processes. The technical review also discusses how the State can support the further development of EPDs in Washington, and next steps for establishing performance targets for each material category.

To improve the state of EPDs in general, the following technical issues should be addressed:

1. **Quality:** The background data (LCI datasets) are crucial for the accuracy and comparability of EPDs. North American LCI data initiatives (**Appendix C.2** and **C.3**) would benefit from increased government support.
2. **Availability:** Technical and/or financial incentives for local businesses to create EPDs could help increase the availability of EPDs and streamline the process of creating EPDs.
3. **Usability:** In order for designers, builders, and owners to act on EPD data, the industry needs tools to find and sort EPDs, and could benefit from training materials to educate professionals on how to use EPDs appropriately.
4. **Comparability:** Each material category has unique issues related to improving EPD quality and establishing appropriate performance targets.

Chapter 4: Pilot Study

This study engaged several pilot projects in order to understand how the project teams would be able to utilize facility-specific EPDs on their project. This part of the study also developed a system to categorize eligible structural materials, methods to report EPDs, and structural material quantities and origins. These methods are described in this chapter, which is also supplemented with:

- Model specifications that project teams can use to require contractors to adhere to Buy Clean policy requirements (**Appendix B.1**)
- Structural material quantity reporting template that contractors can use to report material quantities of interest under the Buy Clean umbrella (**Appendix B.2**). This template will be refined with input from pilot teams.

Five public works projects were identified to participate in this study. Due to the varying schedules of the projects (several will not begin construction until 2020 or later), a timeline extension would be needed to support state agency personnel and/or external researchers to test methods developed by the study and collect information from pilot project teams.

Chapter 5: Policy Evaluation

This chapter develops a framework for establishing a Buy Clean policy for Washington. It analyzes existing Buy Clean policy in California, then proposes a pathway for developing a similar policy for Washington State. Each step is accompanied by a more detailed exploration that describes some options to select between. This framework is outlined as follows:

- Step 1: Establish policy goals
- Step 2: Establish Policy Scope
    - Select eligible materials
    - Select type of policy (disclosure or performance)
    - Select type of compliance (mandatory or voluntary)
- Step 3: Establish methods
    - Select embodied carbon disclosure method (e.g. EPDs)
    - Select method to report material quantities
    - Select method to establish performance targets
    - Select method to assess environmental performance
- Step 4: Establish timeline
    - Consider construction industry practices
    - Select when to evaluate embodied carbon (if appropriate)
    - Select method to update embodied carbon targets (if appropriate)
- Step 5: Implement and evaluate

This chapter presents potential impacts of Buy Clean policy options, including opportunities, challenges and cost impacts. Regardless of status of Buy Clean legislation, the State can still invest in the following recommendations to support environmentally-conscious construction procurement:

1. Support continual evaluation of Buy Clean policy
2. Develop a standardized delivery approach
3. Build internal capability to implement policy
4. Lead ongoing industry engagement and workforce development
5. Use technical infrastructure to support policy
6. Align with existing policies, programs, and initiatives
7. Establish program to manage policy

CONCLUSION

This study is designed for those who are interested in embodied carbon reduction strategies to understand the background, technical issues, and options for implementation of embodied carbon policy to inform procurement decisions. A primary strength of this approach is the potential for purchasing decisions to incentivize low carbon material extraction and product manufacturing up through the supply chain.

End of Executive Summary

GLOSSARY

A. KEY TERMS

Benchmark	A set of environmental impact results that provide a reference point from which the relative performance can be evaluated.[5]
Carbon loophole	Refers to the embodied greenhouse gas emissions associated with production of goods that are ultimately traded across countries.[6]
Embodied carbon	Refers to greenhouse gas emissions arising from materials extraction, manufacturing, transportation, and construction.
Environmental product declaration	An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products.[7]
Global warming potential (GWP)	A standardized term for the environmental impact category that describes potential changes in local, regional, or global surface temperatures caused by an increased concentration of greenhouse gases in the atmosphere, which trap heat from solar radiation through the "greenhouse effect."
Life cycle assessment (LCA)	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14044).
Operational carbon	Refers to the greenhouse gas emissions arising from building operations.
Whole building life cycle assessment (WBLCA)	Process that calculates environmental impacts resulting throughout the life cycle of a building, including during raw material extraction and production, construction, building operation, and end-of-life activities.
Zero net carbon (ZNC) buildings	Highly energy efficient building(s) that produce on-site, or procure, enough carbon-free renewable energy to meet building operations energy consumption annually. Can, but does not commonly, include the impacts of embodied carbon.

[5] https://www.iso.org/standard/37456.html
[6] Daniel Moran, Ali Hasanbeigi, and Cecilia Springer, "The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products," 2018, https://buyclean.org/media/2016/12/The-Carbon-Loophole-in-Climate-Policy-Final.pdf.
[7] The International EPD® System, "What Is an EPD? - The International EPD® System," accessed December 28, 2018, https://www.environdec.com/What-is-an-EPD/.

B. ABBREVIATIONS

Below are a list of abbreviations used throughout the text. Note that some names have been translated from a different language into English. Non-US country names or US states are added (in parentheses) for clarification.

AB	Assembly Bill
AIA	American Institute of Architects
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
APA	Engineered Wood Association
ASBC	Austrian Sustainable Building Council
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
B3	Buildings, Benchmarks, and Beyond (Minnesota)
BAAQMD	Bay Area Air Quality Management District
BCA	Building and Construction Authority (Singapore)
B-EPD	Belgium EPD program
BMVBS	Federal Ministry of Transport, Building and Urban Development (Germany)
BNB	Assessment System for Sustainable Building (Germany)
BOF	basic oxygen furnace
BPDO	Building Product Disclosure and Optimization
BRE	Building Research Establishment (UK)
BREEAM	Building Research Establishment Environmental Assessment Method (UK)
CA	Canada
CaGBC	Canada Green Building Council
CALGreen	California Green Building Standards Code
CBEI	consumption-based GHG emissions inventory
CDN	Canadian dollar
CLT	Cross laminated timber
CM	construction management
CMU	concrete masonry unit
CRSI	Concrete Reinforcing Steel Institute
CSI	Cement Sustainability Initiative
CWU	Central Washington University
DEQ	Department of Environmental Quality (Oregon)
DES	Department of Enterprise Services (Washington)
DGNB	German Sustainable Building Council
DGS	Department of General Services (Washington, Oregon, or California)
DNR	Department of Natural Resources
DRI	direct reduced iron
EAF	electric arc furnace
EC3	Embodied Carbon Construction Calculator
ECN	Embodied Carbon Network

EN	European Standard
EO	Executive Order
EPD	Environmental product declaration
ESSB	Engrossed State Substitute Bill (US)
EU	European Union
FDES	Environmental and Health Declaration Sheets (France)
FHWA	Federal Highway Administration
FP	FPInnovations (non-profit organization)
FSC	Forest Stewardship Council
GC	general contractor
GHG	Greenhouse gas
GWP	Global warming potential
GWW	Dutch Assessment Method: Environmental Performance Construction and Civil Engineering Works
HB	House Bill
IBO	Austrian Institute for Healthy and Ecological Building
ICC	International Code Council
IEA	International Energy Agency
IES	Illuminating Engineering Society
IgCC	International Green Construction Code
INIES	environmental and health reference data for buildings (France)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
JEMAI	Japan's Environmental Management Association for Industry
KBOB	Association of Public Builders of Switzerland
ksi	thousand pounds per square inch
LCA	Life cycle assessment
LCI	Life cycle inventory
LEED	Leadership in Energy and Environmental Design
LVL	Laminated veneer lumber
MCAA	Masonry Contractors Association of America
METI	Ministry of Economy, Trade and Industry (Japan)
MGB	Environmental Policy Committee (the Netherlands)
N/A	Not applicable
NA	North America
NGO	non-governmental organization
NMD	National Environmental Database (the Netherlands)
NPCA	National Precast Concrete Association
NRC	National Research Council (Canada)
NRMCA	National Ready-Mix Concrete Association
NWCMA	Northwest Concrete Masonry Association
OCAPA	Oregon Concrete Aggregates Producer Association
OECD	Organisation for Economic Co-operation and Development

OI3	Ökoindex 3 (Austria)
OR	Oregon
OSB	oriented strand board
OVAM	Public Waste Agency of Flanders (Belgium)
PCA	Portland Cement Association
pcf	pounds per cubic foot
PCR	Product category rule
PCI	Precast Concrete Institute
PEP	Product Environmental Profiles (PEP)
PSPC	Public Services and Procurement Canada
RFP	request for proposal
RFQ	request for proposal
RICS	Royal Institution of Chartered Surveyors (UK)
RPB	Real Property Branch (PSPC, Canada)
SBK	Stichting Bouwkwaliteit (the Netherlands)
SCM	supplementary cementitious material
SCS	Scientific Certification Systems, Inc.
SE2050	Structural Engineers 2050 Initiative
SEK	krona (Swedish currency)
SFI	Sustainable Forest Initiative
SGNI	Swiss Sustainable Building Council
SIA	Swiss Society of Engineers and Architects
SNBS	Standard for Sustainable Construction (Switzerland)
TIC	Technical Content Committee (the Netherlands)
TOTEM	Tool to Optimise the Total Environmental impact of Materials, formerly "MMG" (Belgium)
UK	United Kingdom
UKGBC	UK Green Building Council
UL	Underwriters Laboratories Inc.
ULe	UL Environment
US	United States
USGBC	United States Green Building Council
UW	University of Washington
WA	Washington
WACA	Washington Aggregates & Concrete Association
WBLCA	Whole building life cycle assessment
WSEC	Washington State Energy Code
WSU	Washington State University
ZNC	Zero net carbon

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CHAPTER 1:

INTRODUCTION

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

On January 8, 2018, members of the Washington (WA) State House of Representatives introduced House Bill (HB) 2412 – Creating the Buy Clean Washington Act[1] to the state legislature. Modeled after the Buy Clean California Act,[2] HB 2412 proposed regulation that would position WA State agencies and public entities awarding construction contracts to require facility-specific environmental product declaration (EPDs) for an eligible list of materials. Furthermore, HB 2412 proposed that the WA Department of Enterprise Services (DES) establish a maximum global warming potential (GWP) threshold for each eligible material category, which successful bidders would need to demonstrate meeting before installing products on state-funded construction projects.

The House Capital Budget Committee introduced a second version of the bill (Substitute House Bill 2412) in February 2018 that included a study period to pilot requirements proposed by the original HB 2412.[3] The revised bill modified the eligibility list to consider materials that function as part of a structural system or assembly, for the following material categories: concrete, unit masonry, metal of any type, and wood of any type.

The original HB 2412 received a public hearing, and the subsequent substitute bill passed out of the House Capital Budget Committee, but did not advance for voting in the 2018 legislative session. However, a pilot project and study was included in the capital budget. Through the Washington State Engrossed Substitute Senate Bill (ESSB) 6095,[4] Washington State allocated funding and defined the scope for a Buy Clean Washington assessment in two parts: (1) Sec. 1030 - Buy Clean Washington Pilot (91000447) for the Department of Enterprise Services, and (2) Sec. 5014 - Buy Clean Washington Study (91000022) for the University of Washington (UW) College of Built Environments.

Signed in March 2018, the ESSB 6095 outlined pilot requirements based on definitions from the previous substitute bill. Through Sec. 1030, the bill authorized DES to coordinate with five state-funded project teams and the UW College of Built Environments to develop and test methods for meeting proposed Buy Clean Washington requirements. Through Sec. 5014, the bill authorized the UW College of Built Environments to collaborate with the Central Washington University (CWU) Construction Management Program and the Washington State University (WSU) Architecture and Engineering School to “analyze existing embodied carbon policy and propose methods to categorize structural materials and report structural material quantities and origins.”

[1] Washington State Legislature, “HB 2412 - 2017-18 Creating the Buy Clean Washington Act,” 2018, https://app.leg.wa.gov/billsummary?BillNumber=2412&Year=2017.
[2] California Legislative Information, “Buy Clean California Act [3500 - 3505],” 2017, https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5.
[3] House Capital Budget, “Substitute House Bill 2412” (2018), http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bills/House Bills/2412-S.pdf.
[4] Washington State Legislature, “SB 6095 - 2017-18 Concerning the Capital Budget,” 2018, http://apps2.leg.wa.gov/billsummary?Year=2017&BillNumber=6095&Year=2017&BillNumber=6095.

The full text of the bill is directly accessible through the WA state legislature (see pg. 52-53 for Sec. 1030, and pg. 121 for Sec. 5014).[5]

See **Appendix A** for copies of the relevant documentation:

- Appendix A.1: HB 2412
- Appendix A.2: ESSB 6095 Signed legislation page
- Appendix A.3: ESSB 6095 Sec. 1030: Buy Clean Washington Pilot (91000447)
- Appendix A.4: ESSB 6095 Sec. 5014: Buy Clean Washington Study (91000022)

1.2 REQUIREMENTS/ELIGIBILITY

This section presents the general requirements, eligible materials, and definitions relevant to this study.

A. GENERAL REQUIREMENTS

ESSB 6095 - Sec. 1030 established the following requirements for the Buy Clean Washington Pilot (pg. 52-53):

> "(2) An awarding authority for the [pilot state-funded] projects listed…shall require the successful bidder for a contract to submit current third-party verified [facility-specific] EPDs for the eligible materials used if available and currently utilized.
>
> (3) The awarding authority shall report to the department [Department of Enterprise Services] the [structural material] quantities and any environmental product declarations collected [during the pilot period]
>
> (4) (a) The department shall provide a preliminary report to the fiscal committees of the legislature by June 30, 2019, of the [pilot] findings…and on any obstacles to the implementation of [pilot requirements], and the effectiveness of [pilot requirements] with respect to reducing carbon emissions. (b) The department shall report any positive or negative impacts to project costs… [and] (c)…any positive or negative economic impacts to Washington state based on where the eligible materials are purchased."

B. ELIGIBLE MATERIALS

Sec. 1030 lists the following materials as subject to the Buy Clean Washington Pilot (see ESSB 6095 pg. 53). "Eligible materials" include any of the following that function as part of a structural system or structural assembly:

1. Concrete, including structural cast in place, shotcrete, and precast
2. Unit masonry
3. Metal of any type
4. Wood of any type including, but not limited to, wood composites and wood laminated products.

[5] Washington State Legislature.

C. DEFINITIONS

Sec. 1030 provides the following language to define general requirements for the EPDs and eligible materials (see ESSB 6095 pg. 53):

> "**Environmental product declaration**" means a facility-specific type III EPD, as defined by the International Organization Standardization (ISO) standard 14025 or similarly robust life cycle assessment methods that have uniform standards in data collection consistent with ISO standard 14025, industry acceptance and integrity for each eligible material proposed to be used.
>
> **"Structural"** means a building material or component that has, but is not limited to having, the following properties: Supports gravity loads of either building floors or roofs, or both, and (or) is the primary lateral system resisting wind and earthquake loads, such as shear walls, braced frames, or moment frames, and includes foundations, below-grade walls, and floors.

Note, the project team provides further discussion and input on definitions and potential language related to pilot requirements in other chapters of this report (see Chapter 3 - Technical Review and Chapter 4 - Pilot Study).

1.3 BUY CLEAN WASHINGTON STUDY

Per Section 5014 of ESSB 6095, the UW College of Built Environments conducted a six-month study in collaboration with Central Washington University and the Washington State University to assess pilot requirements and propose options for future state-led policy development. The project team conducted the study with the following objectives:

- Assess and apply knowledge from an international review of embodied carbon policies established by governments at national, regional and local levels
- Evaluate supply chains of eligible material categories and identify opportunities to spur EPD development in Washington-based product markets
- Propose methods for collecting and reporting environmental impacts (i.e. EPDs and structural material quantity data)
- Formulate policy options, approaches and potential impacts, as well as recommend potential investments WA State could make to support policy implementation.

The study report comprises five chapters:

> **Chapter 1: Introduction** provides background on state-led effort to introduce Buy Clean Washington regulation, summarizes the scope and objectives of the Buy Clean Washington evaluation (pilot phase and study).
>
> **Chapter 2: Policy Review** summarizes and analyzes international policies, programs and initiatives with components related to embodied carbon
>
> **Chapter 3: Technical Review** analyzes embodied carbon impacts of construction materials relevant under eligible material categories, and provides recommendations on how to advance EPD development in Washington-based product markets.

Chapter 4: Pilot Projects presents the pilot projects used for this study and proposes a method for collecting data to determine compliance with a Buy Clean Policy.

Chapter 5: Policy Evaluation provides options and recommended investments to support WA State develop and implement embodied carbon policy. This chapter includes analysis of Buy Clean policy components, describes several approaches to develop standards and discusses potential impacts of policy implementation, including cost impacts.

Supplemental documents attached to this report include a resource guide for policy makers (**Appendix C.1**) and other appendices.

CHAPTER 2:

POLICY REVIEW

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CHAPTER 2: POLICY REVIEW

2.1 INTRODUCTION

This chapter presents findings from a policy review of current embodied carbon initiatives led or adopted by governments around the world. It summarizes key components of relevant programs, legislation, building codes, standards and rating systems, and discusses common themes related to introducing new policy goals, policy development and implementation.

A. BACKGROUND

Under increasing global pressure, governments worldwide are deploying policy as a catalyst to transform markets and accelerate carbon emissions reduction across all sectors. Generating nearly 40% of annual global carbon emissions,[1] the building sector has become a significant component of government-led initiatives, including climate action plans, emissions reduction targets, regulatory legislation and calls-to-actions aiming to integrate environmental sustainability principles into standard industry practice. Government programs focused on the building sector often promote uptake of renewable energy sources, and set targets related to energy and water consumption for operating buildings – all common measures considered pivotal for meeting emissions reduction targets.

Such policies have helped significantly reduce emissions generated by building operations (e.g. buildings operating at zero-net energy); however, the 'hidden' carbon emissions emitted at various stages during a building's lifecycle – beyond the operational phase – remain a growing issue. Emissions resulting from the manufacturing and construction of building materials (often termed 'embodied carbon') account for 11% of annual global carbon emissions and 28% of building sector emissions[2] – emissions which must be phased out by 2050.[3]

National and local governments across the European Union (EU) have set a precedence for embodied carbon policy, implementing programs that require or incentivize building industries to measure, report and reduce environmental impacts occurring throughout the lifespan of construction materials. In nations with well-established embodied carbon policies, green building associations and other industry stakeholder groups played a key role to develop and standardize life cycle assessment (LCA) methodology, tools and data, and worked closely with governments to align existing industry-led initiatives and resources with new policy.

In the United States (US) at national, state and local levels, government-led embodied carbon programs with mandatory standards are less prevalent and established compared to legislation adopted by EU counterparts. Non-regulatory green building programs and industry-led initiatives have evolved to promote measurement of embodied carbon; however, industry and policy experts commonly express that improved standardization and availability of data, tools and guidelines is needed to develop

[1] UNEP and IEA, "Global Status Report 2017: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector," 2017.
[2] Architecture 2030, "Why The Building Sector? | Architecture 2030," 2017, http://architecture2030.org/buildings_problem_why/.
[3] Intergovernmental Panel on Climate Change, "Summary for Policymakers — Global Warming of 1.5 ºC," 2018, https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/.

regulatory guidelines and performance targets, and to support industry capability to meet compliance standards.

While regulation focused on embodied carbon reduction is sparse across federal, state and local levels, US-based industries, businesses, governments and environmental groups are increasingly becoming more aware of the potential environmental and health impacts of construction materials. Several green building codes, standards and rating systems adopted by governments have evolved to include LCA and whole building life cycle assessment (WBLCA) pathways for project teams to assess and report environmental impacts of materials – some of which include optional performance targets for buildings to meet as an alternative pathway to mandatory, prescriptive standards.

Furthermore, some US jurisdictions are exploring procurement policies to reduce embodied carbon, which would position government bodies to directly regulate materials purchased for public works projects. Upon passing the Buy Clean California Act in 2017, the state of California established a precedent for US-based procurement policy, becoming the first state government to require submission of facility-specific environmental product declarations (EPDs) for an eligible list of materials used on state-funded construction projects.[4] In 2021, California will also require manufacturers to meet global warming potential (GWP) thresholds established by the state for each eligible material category. Following California's lead, the states of Oregon and Washington both introduced similar legislation in 2017 and 2018, respectively. While the proposed bills in Oregon and Washington did not move forward, policymakers in both states continue to explore options for future policies with similar goals.

In March 2018, based on a modified, substitute version of House Bill 2412: Creating the Buy Clean Washington Act,[5] the Washington State Legislature commissioned the University of Washington's College of Built Environments to conduct a Buy Clean Washington Study in collaboration with Central Washington University and the Washington State University. The study included the embodied carbon policy review presented in this chapter to inform potential policy options and recommendations for Washington State (see **Chapter 5: Policy Evaluation**).

B. SCOPE

The policy review occurred over a four-month period. It considered policies that require or incentivize building industries to measure, report and/or reduce greenhouse gas (GHG) emissions attributed to construction materials (emissions often termed 'embodied carbon'). Its scope did not include a comprehensive assessment of all international policies with embodied carbon components. Rather, the review focused on recent US-based policy initiatives (particularly state-level) and nations with multi-faceted government programs that often include and align multiple embodied carbon policy standards and support systems (e.g. national EPD databases).

This chapter summarizes both policies that consider embodied carbon occurring throughout the lifespan of construction materials and policies that focus on a defined lifecycle stage, such as product manufacturing or recycling and reuse. Commonly, policies reviewed aim to address embodied carbon

[4] California Legislative Information, "Buy Clean California Act [3500 - 3505]," 2017, https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5.
[5] Washington State Legislature, "HB 2412 - 2017-18 Creating the Buy Clean Washington Act," 2018, https://app.leg.wa.gov/billsummary?BillNumber=2412&Year=2017.

through four target areas: (1) materials selection, (2) materials reuse, (3) existing buildings, and/or (4) new buildings.

This chapter applies the term 'policy' broadly to encapsulate government and non-government mechanisms to address embodied carbon. Government mechanisms include: (1) procurement policies for public-funded facilities and infrastructure, (2) measures to regulate private sector commercial and residential development within a jurisdiction, and (3) city planning to optimize use of building materials (e.g. through waste management measures such as recycling). Non-government mechanisms include a range of initiatives, such as voluntary green building codes, standards and rating systems, as well as technical resources (e.g. LCA tools) often used to support policy implementation.

US-based public polices summarized in this chapter were developed by state and city governments in California, Oregon, Minnesota and Washington. International policy examples are from Austria, Belgium, Canada, France, Germany, Japan, the Netherlands, Singapore, Sweden, Switzerland, and the United Kingdom.

2.2 KEY CONSIDERATIONS

Through review of current embodied carbon policies around the world (particularly initiatives led by national governments in Europe), several themes emerged as key components or strategies policymakers adopted to build support for, develop and implement new policy. The subsections below discuss these themes.

A. HARMONIZED TECHNICAL RESOURCES SUPPORT POLICY IMPLEMENTATION

Government-led development or sponsorship of technical tools and resources that support the building industry's capacity to meet regulation is common across the European countries reviewed. Governments often align multiple technical resources – such as guidelines, tools and databases – under a single system or program, providing standard, consistent methodology and tools that complement compliance standards. Examples of technical resources used to support policy include: WBLCA or LCA methodology guidance documents, WBLCA or LCA tools/software, LCA and EPD databases, and prescriptive guides that support decision-making.

B. NEW POLICY ALIGNS WITH GOVERNMENT LEGISLATION, PROGRAMS AND PLANS

Where there is opportunity and relevance, governments often cite and align new policy language with official international and/or national programs, connecting proposed requirements to pre-existing goals, standards and targets already recognizable by building industries, other governments and environmental stakeholder groups. The EU and national governments such as the United Kingdom (UK) have developed common language and technical guidance for smaller jurisdictions to apply in their own policymaking. Other examples include integrating new requirements into future editions of building code (France) or introducing building permit guidelines that require new projects to demonstrate low environmental impact (the Netherlands).

In the US, green building programs such as the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) standards (which include WBLCA and EPD credits) are commonly understood across industry, providing an opportunity for governments at all levels to align new policy goals and language with recognizable, established guidelines. Numerous cities

have developed pathways for policy compliance to count toward green building credit(s), through incorporating LEED in building codes[6] and zoning rules.[7]

C. GOVERNMENTS PROVIDE INCENTIVES OR RECOGNIZE NON-GOVERNMENT INCENTIVE PROGRAMS

Governments often support or provide incentives during early implementation of a new policy, sometimes through a voluntary, trial period. Types of incentives include financial support, technical support and training, density bonuses, approval fast-tracking and green building labels that firms can use for environmental marketing purposes.

In California, USGBC – Los Angeles (USGBC-LA) is helping product manufacturers prepare for the Buy Clean California Act through providing a financial incentive program. USGBC-LCA will offer incentives of up to $15K to manufacturers of steel, flat glass, and mineral insulation to help them publish EPDs, before the mandatory EPD requirement begins in January 2020.[8]

In Oregon, while there is no state-level requirement for EPD reporting, the Oregon Department of Environmental Quality (DEQ) provides a program to help concrete manufacturers measure and report environmental impacts of concrete mixes through EPDs. The program provides a web-based tool, reimbursement incentive, and direct technical assistance to manufacturers.

D. GOVERNMENTS ENGAGE WITH INDUSTRY STAKEHOLDER GROUPS DURING POLICY DEVELOPMENT AND IMPLEMENTATION

European policymakers worked closely with their local building industries, consulting stakeholder groups, and supporting and integrating existing industry-led initiatives into policy programs. The importance of industry engagement was notable in the Netherlands, where the Dutch government worked closely with industry groups to gain support for – and pass – legislation in 2013 that included similar standards previously opposed by stakeholders when first introduced.

E. POLITICIANS CAN 'CHAMPION' POLICY BY DELIVERING KEY MESSAGES TO CULTIVATE POLITICAL AND PUBLIC WILL

Embodied carbon policies target a complex, nearly 'invisible' issue and propose multifaceted, technical-based solutions not widely understood beyond experts, advocates, and researchers from industry and academic groups focused on environmental sustainability. This complexity gives rise to barriers affecting regulatory-based proposals throughout legislative processes that often prioritize policies widely understood and supported by – and often immediately impacting – politicians, industry representatives, advocacy groups, and the general public. Therefore, political 'champions' in the form of engaged politicians who can translate a complex topic into clear, simple messaging are key advocates who can help secure the buy-in needed from other policymakers and stakeholder groups.

[6] Everblue, "Cities Requiring LEED New Construction & LEED Compliance | Everblue Training," 2018, https://www.everbluetraining.com/blog/cities-requiring-or-supporting-leed-2015-edition.
[7] Seattle, "Living Building & 2030 Challenge Pilots," accessed December 31, 2018, https://www.seattle.gov/sdci/permits/green-building/living-building-and-2030-challenge-pilots.
[8] USGBC-LA, "Buy Clean California – USGBC LA," accessed December 12, 2018, https://usgbc-la.org/programs/buy-clean-california/.

This is an important factor to consider in the US, where there is not yet an established foundation of embodied carbon legislation. Policy advocates cannot readily leverage policy case studies or frameworks from other US jurisdictions. In California, as plans solidified to propose a state-procurement regulation, California State Assemblyman Rob Bonta emerged as the 'political champion' for the Buy Clean California Act, delivering targeted messaging and maintaining engagement with key stakeholders throughout bill development. When describing buy clean policy goals at a 2018 Global Climate Action Summit public event, Bonta used 'call-to-action' language that invoked a sense of urgency, connecting policy solutions to recent extreme weather events directly affecting Californians. Bonta also called upon the state to 'walk the walk' in terms of upholding its environmental values and commitments through government-led action.

F. AN INTERDISCIPLINARY COALITION TO INFORM BILL DEVELOPMENT AND DEMONSTRATE BROAD SUPPORT FOR POLICY GOALS

As noted, government-industry partnership is important to inform policy development and foster industry support for compliance standards. In California, non-government policy advocates established a multi-sector partnership or 'coalition' to signal broad (and bipartisan) support for proposed regulation. Policy advocates established the coalition during the early stages of California's buy clean proposal, recruiting members representing government, labor union groups, product/industry businesses, and environmental advocacy organizations. The coalition identified shared goals that the bill would support, and members later reflected that the group composition was a "head turner." A united front between environmentalists and industry representatives helped capture political and public attention and build interest to move the bill forward.

G. IDENTIFY, LEVERAGE, AND SUPPORT SUSTAINABILITY-FOCUSED INDUSTRY GROUPS AND/OR EXISTING INDUSTRY-LED INITIATIVES

In Europe, many policies built upon or leveraged existing progress made by national green building councils and other building industry groups. In Germany, the German Sustainable Building Council (DGNB) led efforts to track and reduce embodied carbon, forming a close partnership with federal agencies to establish policies, while in the UK, the UK Green Building Council worked closely with industry to publish guidance and provide educational resources to move the market toward embodied carbon measurement.

In California, during development of the Buy Clean California Act, industry groups such as ClimateWorks and companies such as Central Concrete provided technical input and drafted key messages used to encourage stakeholder support for the bill. Since passing of the Act, state agencies have worked closely with external LCA/EPD subject matter experts, as well as USGBC-LA, which has participated in educational workshops. Further, USGBC-LA is exploring options with California State to have Buy Clean compliance count toward the LEED EPD credit.

Relevant to Washington State, there are several current state- and regional-based industry groups and initiatives that policymakers could leverage as the State assesses similar embodied carbon policy options. These include the Bay Area Materials Working Group, the West Coast Climate & Materials Management Forum, the Embodied Carbon Network, and the SE 2050 Initiative. **Section A.10 Regional Initiatives** provides more detail on these programs.

H. CASE STUDIES USED TO DEMONSTRATE SUCCESS

Where jurisdictions attempt to implement policies with unprecedented goals and new compliance guidelines, a common barrier is apprehension of the unknown, resulting in risk-aversion from politicians and government bodies to introduce new measures. Concerns include potential for adverse outcomes that undermine initial environmental goals; posing undue burden to industry; and disrupting local product markets and economies. To counter these concerns, policy proponents identify and communicate 'success stories' from building projects that followed principles similar to proposed regulation.

In the Washington State, the new, LEED Platinum-certified Helen Sommers Building serves as a case study to support Buy Clean policy goals (collection of EPDs and reduction of embodied carbon). For this project, the design-build team, led by firm Sellen Construction, focused on concrete as a source of significant embodied carbon reduction, redesigning concrete mixes to reduce emissions and producing EPDs for nearly all mixes. Sellen estimates that the project reduced overall embodied carbon of concrete by 27% compared to regional averages, and 31% compared to national averages.[9] In this case study, the general contractor required product-specific EPDs for the project and pursued embodied carbon performance reduction goals. This requirement led to publication of ninety new concrete EPDs. Shortly after, other suppliers decided to publish EPDs for their ready-mix products, which serve for broad use by architects, engineers and owners in the Seattle/Olympia regions.

I. IMPLEMENTATION PLANS WITH AN INCREMENTAL TIMELINE

Similar to the Buy Clean California Act, the Washington State considered a two-pronged policy requirement: (1) manufacturers of eligible construction materials would need to collect and submit facility-specific EPDs; and (2) EPDs would need to demonstrate that embodied carbon impact falls below a pre-established GWP threshold. Throughout Europe, jurisdictions approaching similar regulatory goals often phase in requirements, and include a voluntary trial period that precedes mandatory compliance scheduled for a future date known to the industry. This allows product markets and other affected industry groups time to build capacity to meet compliance standards, and for government regulators to assess and refine requirements before mandatory implementation.

California has planned a staged approach to implement the Buy Clean California Act. In year one (2019), the State will request (but not require) facility-specific EPDs from state construction projects. In year two (2020), project teams will be required to submit facility-specific EPDs in order to be considered in the bidding process. In year three (2021), the State will publish the GWP thresholds for each product category, a standard that successful bidders will be required to meet beginning in June 2021.

J. PERFORMANCE-BASED PATHWAYS

Embodied carbon policies generally include either prescriptive-based or performance-based standards, or a combination of both. Prescriptive-based approaches establish requirements on *how* a material is produced, whereas performance-based approaches set a measurable target or threshold that a material to measure performance against, allowing design teams flexibility to determine how to achieve the required outcome.

[9] Dave Walsh, "Measuring and Reducing Embodied Carbon in Concrete," accessed December 12, 2018, https://www.sellen.com/wp-content/uploads/Measuring-and-Reducing-Embodied-Carbon-Dave-Walsh.pdf.

Prescriptive guidelines and incentives can simplify decision-making and improve specific practices (e.g. drive product markets to publish EPDs), while policies tied to measurable performance outcomes are likely more complex and costly to implement. However performance-based embodied carbon policies have benefits since environmental impact targets can enable creative problem solving by product manufacturers, help quantify the impacts of construction materials, and support establishment of standard metrics for embodied carbon.

France's voluntary national building pilot program (*Energie Positive et Réduction Carbone*) includes a performance-based approach, which establishes life cycle performance benchmarks for carbon emissions and provides incentives for meeting targets. The program accounts for embodied carbon, establishing indicators (called 'Carbon Levels') for emissions arising from the whole life cycle of a building, and carbon emissions attributed to construction products and building equipment.

In the US, the International Green Construction Code (IgCC) and the United States Green Building Council (USGBC) set both prescriptive and performance standards. Prescriptive standards include setting minimum recycled content rates and performance standards use whole building LCA to assess options.

K. CONSIDER THE CIRCULAR ECONOMY OF CONSTRUCTION MATERIALS

Increasingly, there is emphasis on the need to consider the 'circular economy' of construction materials to develop policy that assesses and minimizes environmental impact occurring over the whole lifecycle of building products to reduce reliance on natural resource extraction and decrease toxic material waste.

The life cycle of embodied carbon resulting from construction materials includes four main stages: (A) production and construction, (B) use, (C) end-of-life, and (D) beyond system boundary. LCA is typically applied to assess impacts occurring throughout all stages (cradle-to-grave) or occurring during one defined phase (e.g. cradle-to-gate). A 'circular economy' approach would consider 'cradle-to-cradle' or 'closed-loop system' impacts, accounting for and promoting sustainable end-of-life practices such as recycling, repair and reuse of materials.[10]

L. ASSESS LOCAL 'READINESS' TO DEVELOP AND IMPLEMENT POLICY

As noted, policymakers should assess factors unique to their local context and shape policy accordingly. Key considerations include the capability of product markets and industry groups potentially affected; prevalence and maturity of existing environmental policies relevant to local context; environmental policy knowledge of policymakers championing bill; capacity and capability of state agencies to implement and regulate legislation; and political and public will to pass legislation that addresses a technical, complex issue.

[10] Stopwaste and ARUP, "Circular Economy in the Built Environment: Opportunities for Local Government Leadership," 2018, http://www.stopwaste.org/sites/default/files/Circularity in the Built Environment-20180619.pdf; Carbon Leadership Forum, "Life Cycle Assessment of Buildings: A Practice Guide," 2018, https://doi.org/http://hdl.handle.net/1773/41885.

2.3 CURRENT POLICIES, PROGRAMS AND INITIATIVES

This section outlines key features from embodied carbon policies, programs and initiatives at national and subnational levels. **Section A** describes recent national and sub-national efforts in the US, **Section B** outlines initiatives from European countries with established embodied carbon policies, and **Section C** outlines new or emerging activities in other international countries.

A. UNITED STATES

In the US, several voluntary national-based programs (e.g. LEED and Living Building Challenge) have evolved to strengthen focus on embodied carbon, but regulatory policies are sparse across federal, state and local levels. Some state and city jurisdictions view procurement-based policy as a key opportunity to reduce carbon emissions. In the US, 55% of emissions attributed to public institutions are a result of government-purchased goods and products.[11] Implementation of Buy Clean California procurement policy may provide a model to inform other jurisdictions considering similar embodied carbon regulation.

A.1 LEED

The USGBC manages LEED,[12] a green building rating program that provides multi-level, point-based certifications. Since its establishment in 1993 as a single standard, LEED has evolved to become the most widely adopted and recognized green building rating system in the world. Through LEED v4, USGBC introduced Building Product Disclosure and Optimization (BPDO) credits to encourage transparency and use of products that disclose and optimize whole life-cycle impacts. Three new credits were established under BPDO: (1) the Environmental Product Declarations (EPD) credit,[13] (2) the Sourcing of Raw Materials (Sourcing) credit,[14] and (3) the Material Ingredients credit,[15] as well as a Low Emitting Materials credit[16] established under Indoor Environmental Quality. The EPD credit is widely used by industry and accredited with helping move the market toward understanding and addressing embodied carbon. LEED v4 also offers a credit for conducting a WBLCA that demonstrates environmental improvements compared to a baseline building. These credits are intended to encourage manufacturers to disclose the full life cycle environmental impacts of building products.

[11] West Coast Climate and Materials Management Forum, "Climate Friendly Purchasing Toolkit," accessed December 12, 2018, https://westcoastclimateforum.com/cfpt.
[12] USGBC, "LEED," accessed December 12, 2018, https://new.usgbc.org/leed.
[13] USGBC, "LEED BD+C: New Construction | v4 - LEED v4: Building Product Disclosure and Optimization - Environmental Product Declarations," accessed December 12, 2018, https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthca-22.
[14] USGBC, "LEED BD+C: New Construction | v4 - LEED v4: Building Product Disclosure and Optimization - Sourcing of Raw Materials," accessed December 12, 2018, https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthca-23.
[15] USGBC, "LEED BD+C: New Construction | v4 - LEED v4: Building Product Disclosure and Optimization - Material Ingredients," accessed December 12, 2018, https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthca-24.
[16] USGBC, "LEED BD+C: Schools | v4 - LEED v4: Low Emitting Materials," accessed December 12, 2018, https://www.usgbc.org/credits/schools-new-construction-healthcare/v4-draft/eqc2.

A.2 INTERNATIONAL LIVING FUTURE INSTITUTE

The International Living Future Institute (ILFI) operates the Living Building Challenge,[17] a program widely considered as the most rigorous green building standard in the world. Launched in 2014, the Living Product Challenge[18] requires building teams accepting the challenge to assess the lifecycle of construction materials from cradle-to-grave and meet standards established to reduce a product's impact on energy consumption, water use, and human health. It includes a "Materials Petal" component, which requires project teams to estimate and offset embodied carbon footprint (using an approved carbon offset provider.)[19]

ILFI also operates the Zero Carbon Certification program[20], launched in 2018 to establish a standard requiring projects to offset (1) 100% of operational energy through new renewable energy sources, and (2) the total embodied carbon impact of construction.

A.3 ARCHITECTURE 2030

Architecture 2030 is a US-based nonprofit organization that has worked closely with the building industry and governments over the past decade to integrate zero net carbon (ZNC) standards and carbon reduction targets into policy. It is well known for its 2030 Challenge, which establishes energy consumption and emissions performance standards, leading to carbon neutrality by 2030.

It also operates the 2030 Challenge for Products, which provides a set of GWP reduction targets for each decade until 2050. The reduction targets start at 35% below a product category average, and incrementally increase until GWP reduction is 75% (or higher) by 2040 and 100% by 2050.[21]

Further, Architecture 2030 recently launched the Carbon Smart Materials Palette[22], a decision-making tool that provides designers with attribute-based guidelines for (1) designing buildings with low- or zero embodied carbon, and (2) specifying construction materials with low- or no- embodied carbon. Designed to support and complement LCA and EPDs, the Carbon Smart Materials Palette is a prescriptive method that identifies key attributes that contribute to a material's environmental impact, and offers guidelines and options for emissions reductions.

A.4 INTERNATIONAL GREEN CONSTRUCTION CODE (IGCC)

Established in 2010 through a collaborative effort led by the International Code Council (ICC), the American Institute of Architects (AIA), and ASTM International, the International Green Construction Code (IgCC) regulates construction of new and existing commercial buildings by setting mandatory and optional, performance- and prescriptive- based targets for local jurisdictions to adopt as code. Under Section 303, the IgCC includes a voluntary WBLCA project elective that if met, waives the need to

[17] International Living Future Institute, "Living Building Challenge | Living-Future.Org," accessed December 12, 2018, https://living-future.org/lbc/.
[18] International Living Future Institute, "Living Product Challenge | Living-Future.Org," accessed December 12, 2018, https://living-future.org/lpc/.
[19] International Living Future Institute, "Materials Petal | Living-Future.Org," accessed December 12, 2018, https://living-future.org/lbc/materials-petal/.
[20] International Living Future Institute, "Zero Carbon Certification | Living-Future.Org," accessed December 12, 2018, https://living-future.org/zero-carbon-certification/.
[21] Architecture 2030, "2030 Challenge for Products," accessed December 12, 2018, https://architecture2030.org/2030_challenges/products/.
[22] Architecture 2030, "Carbon Smart Materials Palette – Actions for Reducing Embodied Carbon at Your Fingertips," 2018.

comply with a mandatory section of the code that sets prescriptive standards for materials selection (Section 505).

Project teams opting to meet Section 303 must submit a WBLCA report based on comparable, alternative building designs that shows the building project achieves at least a 20% improvement in environmental performance for global warming potential. The building project must also achieve a 20% reduction for at least two of five other categories: primary energy use, acidification potential, eutrophication potential, ozone depletion potential, or smog potential. The pathway is intended for state and local jurisdictions to adopt into their own building codes to reduce embodied carbon.[23]

An updated version of the IgCC was recently released in October 2018, developed collaboratively with more industry organizations – the ICC, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), USGBC, AIA, and the Illuminating Engineering Society (IES). It is 'powered' by ASHRAE Standard 189.1, "Standard for the Design of High-Performance Green Buildings."[24]

A.5 GREEN GLOBES

Operated by the Green Building Initiative (GBI), Green Globes is a green building certification program established in 2004. Within their materials section there are two pathways for assessing the performance of a building core and shell. Path A (performance path) requires a whole building LCA comparing a minimum of two different core and shell designs based on LCA to demonstrate at least 20% decrease in GWP as well as including other required performance thresholds for other common LCA impact metrics.[25]

A.6 CALIFORNIA

California is a state leader in establishing green building regulations and standards. The 2012 amendment of the California Green Building Standards Code (CALGreen)[26] includes an optional LCA pathway that requires emissions reduction against a baseline, and several performance measures related to energy efficiency. The LCA pathway offers an alternative approach to prescriptive requirements on materials selection. Building projects can use CALGreen to pursue other sustainability initiatives such as LEED.

BUY CLEAN CALIFORNIA

In October 2017, California passed the Assembly Bill (AB) 262: Buy Clean California Act,[27] a new law requiring state-funded building projects to consider the global warming potential (GWP) of certain construction materials during procurement. The bill requirements are two-pronged: manufacturers of

[23] International Code Council, "Synopsis: International Green Construction Code. Public Version 1.0," 2010, http://media.iccsafe.org/IGCC/docs/IGCC-Synopsis.pdf; International Code Council, *International Green Construction Code™ Public Version 2.0*, 2010, http://www.iccsafe.org/cs/IGCC/Pages/PublicVersionDevelopment.aspx.

[24] ASHRAE, "2018 International Green Construction Code® Powered by Standard 189.1-2017," 2018, https://www.ashrae.org/technical-resources/bookstore/standard-189-1.

[25] GBI, "Green Globes for New Construction Technical Reference Manual Version 1.50," 2018, https://www.thegbi.org/files/training_resources/Green_Globes_NC_Technical_Reference_Manual.pdf.

[26] California Building Standards Commission, *2016 California Green Building Standards Code California Code of Regulations, Title 24, Part 11* (International Code Council, 2016), https://www.ladbs.org/docs/default-source/publications/code-amendments/2016-calgreen_complete.pdf?sfvrsn=6.

[27] California Legislative Information, "Bill Text - AB-262 Public Contracts: Bid Specifications: Buy Clean California Act," 2017, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB262.

eligible materials must submit facility-specific EPDs, and the eligible materials must demonstrate (through submitted EPDs) GWP below the product-specific compliance limits defined by the Department of General Services (DGS), which will regulate policy implementation. The eligible materials include structural steel, carbon steel rebar, flat glass and mineral wool insulation.

An amendment (Assembly Bill 1817) to the original Buy Clean California Act passed in June 2018, extending the timeline for compliance. In January 2019, awarding state agencies will request voluntary submission of facility-specific EPDs and in January 2020, successful bidders must submit facility-specific EPDs. By January 2021, DGS will establish and publish the 'maximum acceptable' GWP for each product category – a two year extension from the original bill – which bidders must meet for eligible materials to be used for state-funded projects.

While many industry groups and leaders support the intent of California's new Buy Clean policy, some stakeholders from affected product markets view the bill as inequitable due to its limited eligible materials list, most notably the omission of concrete and cement. Product market representatives highlighted that exclusion of a carbon-intensive material (concrete) was not congruent with the policy goal to cut emissions. Product market stakeholders also expressed concern that inclusion of some materials and not others could affect competition. Recognizing these limitations, California policymakers and government implementation partners have expressed interest to integrate concrete and other materials into the law.

As mentioned, the USGBC-LA is administering a Buy Clean Incentive Program to assist manufacturers from affected product markets develop facility-specific EPDs.

At a 2018 Global Climate Action Summit public event, a panel of representatives from a coalition that championed the Buy Clean proposal identified key features that helped pass the law:

- Establishment of a diverse coalition that was a 'trifecta' of business, labor, and environmental groups with shared values toward environmental stewardship
- Engagement with industry representatives who viewed regulation as an opportunity to be rewarded and gain competitive advantage for having environmental manufacturing processes
- A policy 'champion' from state legislation, described as someone 'who knows how to work a bill' and ensure legislative support to move the bill forward
- Grassroots effort to communicate the policy to different stakeholder groups and the public in "language that people understood"
- Simplicity and flexibility in bill language
- Early and frequent engagement with – and support from – people representing state procurement and government agencies, and representatives from industry groups with subject-matter expertise. Representatives provided a 'sounding board' throughout bill development and helped make the 'best case' for signing the bill into law.

STOPWASTE AND SAN FRANCISCO BAY AREA CONCRETE CODE PROJECT

StopWaste is a public agency in Alameda County, California that focuses on reducing waste in homes, at work, and in schools. StopWaste also has a focus on embodied carbon in the built environment.[28]

[28] StopWaste, "Materials-Climate Nexus," accessed December 12, 2018, http://www.stopwaste.org/preventing-waste/business/built-environment/climate/materials-climate-nexus.

StopWaste and Marin County were recently funded by the Bay Area Air Quality Management District (BAAQMD) for a collaborative project to increase demand for low-carbon concrete through policy.[29] The project consortium will produce model code language for local governments to adopt low embodied-carbon concrete specifications for residential and non-residential applications. The project will also provide technical assistance to four pilot projects to apply the specifications, and will also form a Bay Area Materials Working Group.

CALTRANS

Prior to adoption of the Buy Clean California Act, the California Department of Transportation (Caltrans) had been evaluating the use of LCA and EPDs in evaluating material use. In parallel with the Buy Clean California Act, Caltrans has established the Caltrans Environmental Product Declaration (EPD) Implementation Project to begin collecting EPDs for materials used in construction projects. In addition to the materials specified in Buy Clean California Act (carbon steel rebar, structural steel, flat glass, and mineral wool board insulation), the Caltrans project includes materials used extensively in transportation (concrete, asphalt and aggregate). For pilot projects this is identified as a separate bid item. This process fits into a roadmap aimed to eventually integrate into full life cycle assessment (cradle to grave) with future phases addressing construction, use and end of life as well as developing strategies to lower GHG emissions from project and testing implementation in pilot projects. This process is introduced on the department website[30] and explained in presentation slides posted on Buy Clean California's website.[31]

CALIFORNIA HIGH SPEED RAIL

Prior to adoption of the Buy Clean California Act, the California High Speed Rail project had begun using EPDs as part of their procurement process. The High Speed Rail Sustainability Report[32] identifies that the construction projects will: 1)Require Environmental Product Declarations (EPDs) for construction materials, including steel products and concrete mix designs, 2) Require 'optimized life-cycle scores for major materials' and include additional strategies to impacts across the life cycle of the project.

A.7 WASHINGTON STATE

Washington State has a longstanding reputation for its environmental stewardship and an established foundation of state, city, and county-level green building and energy efficiency policies. The 2015 version of the Washington State Energy Code (WSEC) is considered among the most stringent energy codes in the nation, and the LEED rating system is widely adopted across the state, due in part to a law passed in 2011 that required public agency facilities and state-funded projects to attain at least LEED

[29] Alice Zanamiller, "Low Carbon Concrete Project - County of Marin," accessed December 30, 2018, https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete-project.
[30] Caltrans, "Environmental Product Declarations," 2018, http://www.dot.ca.gov/mets/ab-262/.
[31] DGS, "Buy Clean California Act (AB 262)," accessed December 30, 2018, https://www.dgs.ca.gov/pd/Programs/Engineering/AB262.aspx.
[32] HSR, "California High Speed Rail Sustainability Report," 2016, https://www.hsr.ca.gov/docs/programs/green_practices/sustainability/Sustainability_Report_Dec_2016.pdf.

silver certification.[33] In its 2017 annual list of 'Top States' for LEED , the USGBC ranked Washington as the 11th place state in terms of square feet of LEED space per capita.[34]

BUY CLEAN WASHINGTON

In 2018, Washington State policymakers demonstrated commitment to embodied carbon reduction policy, signaling to the market government commitment to transition state procurement toward low-carbon materials selection.

On January 16, 2018, Washington Governor Jay Inslee signed Executive Order 18-01 "State Efficiency and Environmental Performance" which mandated state agencies to consider and account for GHG emissions during decision-making, stating, "where cost-effective and workable solutions are available…decision makers shall select the lower-emissions options" and "…include consideration of net-embodied carbon."[35]

On January 8, 2018, Representative Beth Doglio of the House Capital Budget Committee introduced to the Washington State legislature House Bill (HB): 2412 – Creating the Buy Clean Washington Act.[36] Modeled after the Buy Clean California Act, the draft bill would require state-funded building projects to report environmental impact data through facility-specific EPDs for an eligible list of materials that function as part of a structural system or assembly, including concrete, unit masonry, metal of any type, and wood of any type. The environmental impact would need to fall below a GWP threshold established by the State in order for eligible materials to be considered in the bidding process. HB 2412 received a public hearing[37] and passed out of its original committee, but ultimately did not advance in the 2017 legislative cycle.

KING COUNTY

At the local level, King County has considered embodied carbon in recent policies. Its 2015 Strategic Climate Action Plan[38] highlights consumption and materials management as a priority ('Goal Area 4'), outlining strategies, measures, and targets for minimizing GHG emissions attributed to the production, transport, use, and disposal of locally consumed products.

Following its climate action plan, King County conducted a consumption-based inventory of sources and quantities of GHG emissions occurring over a one-year period (2015). The consumption-based inventory reviewed embodied carbon associated with production, transport, use and disposal of goods, foods and services consumed in King County (regardless of where goods were produced), and isolated construction as an emissions category in its models (separating it from a homes and buildings category).[39] In 2015,

[33] Washington State Legislature, "RCW 39.35D.030: Standards for Major Facility Projects—Annual Reports.," 2011, https://app.leg.wa.gov/rcw/default.aspx?cite=39.35D.030.
[34] USGBC, "Honorable Mentions for 2017 Top States for LEED," 2018, https://www.usgbc.org/articles/honorable-mentions-2017-top-states-leed.
[35] Jay Inslee, "Executive Order 18-01 State Efficiency and Environmental Performance" (Office of the Governor, State of Washington, 2018).
[36] Washington State Legislature, "HB 2412 - 2017-18 Creating the Buy Clean Washington Act."
[37] Washington State's Public Affairs Network TVW, "House Capital Budget Committee," (2018), https://www.tvw.org/watch/?eventID=2018011119.
[38] King County, "2015 Strategic Climate Action Plan," 2015, https://your.kingcounty.gov/dnrp/climate/documents/2015_King_County_SCAP-Full_Plan.pdf.
[39] Cascadia Consulting Group and Hammerschlag & Co. LLC, "King County Greenhouse Gas Emissions Inventory 2015 Update," 2017, https://your.kingcounty.gov/dnrp/climate/documents/2015-KC-GHG-inventory.pdf.

nearly 90% of construction emissions occurred during the production phase of materials. While overall emissions attributed to construction decreased by four percent since 2008, the inventory found that government demand for construction increased. Further, it highlighted that government demand on foreign production increased by 94% during this time, estimating that emissions associated with foreign production are twice the amount of emissions associated with domestic production.[40]

The decrease of local emissions attributed to King County in tandem with the increased reliance on foreign production is a dichotomy that reflects a growing, global trend of developed countries 'offshoring' carbon-intensive manufacturing practices to developing countries. While governments from developed countries report progress against national or local emissions targets, recent research shows that global GHG emission rates have stagnated and recently increased due to product manufacturing in – and exportation from – developing countries. The trend is worth noting and considering in future policy development to ensure effort to reduce local emissions does not result in increased emissions overseas.

A.8 OREGON

In 2017, state representatives introduced HB 3161 and HB 3162 to the Oregon State legislature.[41] The bills proposed a pilot program for the Oregon Department of Transportation, which would require EPD collection and GHG emissions inclusion into contract pricing for projects. Neither bill advanced, but some Oregon legislators may continue pursuing similar policy options. Further, in November 2017, Governor Kate Brown signed Executive Order 17-20,[42] outlining a number of energy efficiency measures for Oregon's building sector, including a requirement to establish carbon neutral operations for new state buildings, which included a directive for Oregon state agencies to analyze feasible options for lowering embodied carbon of construction materials.

Over the past decade, the Oregon Department of Environmental Quality's (DEQ) Materials Management Program has increasingly sought to understand and reduce the emissions attributed to materials. More recently, Oregon's Environmental Quality Commission directed DEQ to 1) urge climate programs to acknowledge the limitations of the incomplete traditional sector-based inventory; 2) develop an accounting solution that would tell a more comprehensive story; and 3) encourage other jurisdictions and programs to follow this example.

Oregon's accounting solution is the consumption-based GHG emissions inventory (CBEI),[43] which shows that over 40% of Oregon's GHG emissions are attributed to material-related purchases. About 8% of total emissions are from construction services, which includes the production of building materials. Overall, using a consumption lens has allowed Oregon DEQ to more easily communicate the impacts of materials, and develop policies and programs to reduce those impacts. One key aspect of Oregon's ability to focus on the lifecycle impacts of materials was a recent statutory change that now explicitly states that funding received from solid waste disposal fees can be used to reduce the impacts of

[40] Cascadia Consulting Group and Hammerschlag & Co. LLC.
[41] Oregon State Legislature, "HB3161 2017 Regular Session," 2017, https://olis.leg.state.or.us/liz/2017R1/Measures/Overview/HB3161; Oregon State Legislature, "HB3162 2017 Regular Session," 2017, https://olis.leg.state.or.us/liz/2017R1/Measures/Overview/HB3162.
[42] Kate Brown, "Executive Order No. 17-20" (Office of the Governor, State of Oregon, 2017), https://www.oregon.gov/gov/documents/executive_orders/eo_17-20.pdf.
[43] Oregon Department of Environmental Quality, "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon," accessed December 12, 2018, https://www.oregon.gov/DEQ/mm/Pages/Consumption-based-GHG.aspx.

materials across their entire lifecycle.[44] This was a key change to help DEQ shift resources and staff to seek opportunities for reduction across the entire lifecycle. This shift has also allowed Oregon DEQ to hire staff who specialize in life cycle assessment and focus on "upstream" work with material producers and business.

Oregon's state and city governments have implemented other initiatives, including:

- **Oregon Concrete EPD Program**: [45] As a partnership between Oregon DEQ and the Oregon Concrete Aggregates Producer Association (OCAPA), the program helps concrete manufacturers measure and report environmental impacts of concrete mixes through EPDs, This program includes a web-based tool, a reimbursement incentive, and direct technical assistance to manufacturers. As of October 2018, there are three manufacturers enrolled in the program. Two companies have completed EPDs for seven plants in the Portland, Oregon area. Over 500 individual mixes EPDs have been published.

  City of Portland Deconstruction Requirements: In July 2016, Portland City Council adopted an ordinance (including code language) that established deconstruction (selective dismantlement of building components for reuse, recycling and waste management) requirements for house or duplex structures built before 1917 or are considered designated historic resources, mandating that projects seeking demolition permits for historic building structures ensure that valuable materials are salvaged for reuse instead of disposal. Portland became the first US city to pass a deconstruction ordinance, presenting the opportunity to save an estimated 4,000 annual tons of materials waste for reuse.[46]

- **Eugene Community Climate and Energy Action Plan:**[47] The 2010 climate action plan prioritizes a "Consumption and Waste Action Area," underpinned by objectives and actions to (1) promote recycling, reuse and repurposing of materials and (2) reduce GHG emissions throughout the life cycle of products and goods, including construction materials.

- **City of Portland/Multnomah County Climate Action Plan:**[48] The City of Portland's 2015 Climate Action Plan performed a consumption-based emissions inventory and identified the purchasing of goods (materials) as comprising over half of the emissions. Many actions in the plan focus on reducing consumption-related emissions. The city expects an update to the plan in 2019 with potential actions to further reduce the embodied carbon of building materials.

[44] Oregon State Legislature, "Chapter 459A -- Reuse and Recycling, 2017 Edition," 2017, https://www.oregonlegislature.gov/bills_laws/ors/ors459A.html.
[45] Oregon Concrete & Aggregate Producers Association, "Oregon Concrete EPDs," accessed December 13, 2018, https://www.ocapa.net/index.php?option=com_content&view=article&id=247:oregon-concrete-epds&catid=20:site-content&Itemid=201s.
[46] City of Portland, "Deconstruction Requirements," 2016, https://www.portlandoregon.gov/bps/70643.
[47] City of Eugene, "A Community Climate and Energy Action Plan for Eugene," 2010, https://www.eugene-or.gov/Archive/ViewFile/Item/80.
[48] City of Portland and Multnomah County, "Climate Action Plan: Local Strategies to Address Climate Change," 2015, https://www.portlandoregon.gov/bps/article/531984.

- **Oregon Global Warming Commissions Interim Roadmap to 2020:**[49] In 2010, Oregon's Global Warming Commission published a roadmap to reaching the state's 2020 carbon reduction goals. This is Oregon's most complete "plan" to address greenhouse gas reductions. There is a substantial focus on materials in the report and some specific recommendations related to building materials to include "carbon footprinting of products" and the development of a net-zero carbon standard that includes the embodied impacts of building materials.

A.9 MINNESOTA

In 2017, Minnesota introduced the Buildings, Benchmarks, and Beyond (B3) program,[50] described as "like a LEED system for Minnesota State only."[51] Under Guideline M.1, the B3 program includes a WBLCA component with two requirements: (1) submit documentation of GWP reduction, which can be met through three different pathways and (2) select at least five different permanently installed products with sources from at least five different manufacturers that meet disclosure criteria (either product-specific declaration or an industry-wide or product-specific EPD). Guideline M.1 is required for new buildings and major renovation projects.

The primary goal of Guideline M.1 is to improve data collection and increase submission of EPDs, and thus improve documentation and disclosure, but not necessarily drive measurable, embodied carbon reduction. Minnesota's government developed Guideline M.1 (and the overall B3 program) in close consultation with the design community (i.e. architects, engineers, etc.) through focus group sessions. Whereas government procurement policies such as Buy Clean California aim to improve manufacturing standards, the B3 program was developed to improve practices and decision-making at the design level.

Guideline M.1 is supported by an Excel-based LCA Material Selection Calculator and requires use of approved WBLCA software tools (Tally and Athena Impact Estimator, though other methods can be used upon vetting and approval). It was developed to align with and/or adapt language from established standards such as LEED v4, IgCC, and ANSI/ASHRAE/USGBC/IES Standard 189.1.[52]

While implementation is still in its early phase, this program has the potential to establish a model that other states and cities could adopt.

A.10 REGIONAL INITIATIVES

Based throughout the US West Coast, several collaborative initiatives work to bring building industry, government, nonprofit, and academic partners together to measure and reduce embodied carbon. Examples include:

- **The West Coast Climate and Materials Management Forum (the Forum)**:[53] a collaborative of state, local, and tribal governments working to institutionalize sustainable materials

[49] Oregon Global Warming Commission, "Interim Roadmap to 2020," 2010, https://static1.squarespace.com/static/59c554e0f09ca40655ea6eb0/t/5a0a0ea14192029150c02f93/1510608553554/2010-10-28+Interim+Roadmap+to+2020.pdf.
[50] Minnesota B3, "B3 – Buildings Benchmarks and Beyond," accessed December 13, 2018, https://www.b3mn.org/.
[51] West Coast Climate & Materials Management Forum, "2017 10 12 10 03 Built Environment and Embodied Carbon Emissions - YouTube," 2017, https://www.youtube.com/watch?v=nkDj3VzQyYs&feature=youtu.be.
[52] Minnesota B3, "Guideline M.1: Life Cycle Assessment," n.d., https://www.b3mn.org/guidelines/3-0/m_1/.
[53] West Coast Climate and Materials Management Forum, "West Coast Climate and Materials Management Forum," accessed December 13, 2018, https://westcoastclimateforum.com/.

management practices. The Forum identifies and shares effective strategies that reduce greenhouse gas emissions and improve how communities source, use, and recover materials throughout their life cycles. Its leadership team includes government representatives from regional EPA agencies, and state and county agencies in California, Oregon, and Washington. The Forum provides webinars, research summaries, toolkits, and other resources for sustainable materials management.

- **Embodied Carbon Network (ECN)**:[54] a Washington-based initiative convened by the University of Washington's Carbon Leadership Forum that brings together building sector professionals, researchers, and environmental advocates focused on reduction of carbon emissions caused by construction materials. The ECN comprises ten topical work groups focused on specific focus areas related to embodied carbon, including a Policy Focus Group. Currently, there are over 360 members based throughout the world representing industry, academia, nonprofits, governments and businesses.

- **Structural Engineers (SE) 2050 Commitment Initiative**: The SE 2050 Initiative challenges structural engineers to meet embodied carbon benchmarks and increasingly higher reduction targets by 2050. The initiative aims to enlarge the collection of structural material quantities data from buildings projects to help determine an embodied carbon baseline. The American Institute of Civil Engineers Structural Engineer's Institute Sustainability Committee is exploring the potential benefit and impact of tracking structural material quantities and embodied carbon with the aim to establish and promote embodied carbon reduction targets for a variety of building types and structural systems over time. The Committee includes members from all across the US.

- **Embodied Carbon Construction Calculator (EC3)**: The EC3 tool is a pilot program hosted at the University of Washington's Carbon Leadership Forum that is developing an open-source EPD/LCA database in consultation with architecture, engineering, construction and manufacturing stakeholders, as well as academic researchers and certification representatives. The database will align with and support existing building sector initiatives that would benefit from integrated data and tools. As of the time of this writing, phase 1 of the database and tool has been fully funded through the Charles Pankow Foundation with sponsorship from diverse industry organizations. The plan is to have an open access EPD database available for public use by the end of 2019.

A.11 FEDERAL HIGHWAY ADMINISTRATION (FHWA)

The FHWA regulates construction, maintenance and preservation of US highways bridges and tunnels, and conducts research and provides technical assistance to state and local agencies, including environmental sustainability. Specifically, FHWA is working on initiatives to assist states in moving toward 'green' public procurement or applying LCAs to pavements.[55] This effort includes the creation of

[54] Embodied Carbon Network, "Embodied Carbon Network," accessed December 13, 2018, http://embodiedcarbonnetwork.org/.
[55] FHWA, "FHWA Order 4460.3A Green Procurement Planning," 2010, https://www.fhwa.dot.gov/legsregs/directives/orders/44603a.cfm.

tools to support the sustainability of pavement construction operations[56] as well as an LCA framework specific to pavements.[57]

B. EUROPEAN COUNTRIES LEADING EMBODIED CARBON POLICY

In 2014, the EU adopted the 2030 Climate and Energy Framework,[58] which established a shared goal for EU member states to cut GHG emissions by at least 40% by 2030 (from 1990 levels).

In 2017, to boost the building sector's role in meeting EU-established emissions reduction targets by 2030, the European Commission published Level(s),[59] a voluntary reporting framework for building assessment. Level(s) provides a common EU approach and technical guidance to inform policymaking across Europe that helps Member States meet both national and EU-wide goals. The framework provides a set of common indicators and metrics for measuring environmental performance of buildings throughout their lifecycle, including life cycle tools. The toolset includes four scenario tools and one data collection tool, accompanied by simplified LCA methodology.

Guided by leadership at the EU level, national and subnational jurisdictions across Europe have implemented sustainable building policies aligned with EU-wide policy frameworks and goals, targeting energy efficiency, renewable energy and whole-building life cycle emissions (operational and embodied).

This section outlines and describes key components of embodied carbon policies in Austria, Belgium, France, Germany, the Netherlands, Sweden, Switzerland, and the United Kingdom. It is not a comprehensive assessment or holistic view of all European-based policies with embodied emission components. Rather, it highlights nations with systems or programs that include (and often align) multiple embodied carbon policy initiatives.

For a holistic assessment of global polices addressing embodied carbon, please access the recent *Embodied Carbon Review*[60] (November 2018). For additional detail and analysis on country-specific policy components listed throughout this section, please refer to *Embodied Carbon of Buildings and Infrastructure: International Policy Review*[61] (September 2017).

B.1 AUSTRIA

Austria's national government has worked alongside industry groups to accelerate adoption of green building methods, supporting a market that applies LCA to both public and commercial construction

[56] FHWA, "How Do We Assess Pavement Sustainability?," accessed December 12, 2018, https://www.fhwa.dot.gov/pavement/sustainability/how.cfm.
[57] FHWA, "Pavement Life Cycle Assessment Framework," 2016, https://www.fhwa.dot.gov/pavement/sustainability/hif16014.pdf.
[58] European Commission, "2030 Climate & Energy Framework," accessed December 13, 2018, https://ec.europa.eu/clima/policies/strategies/2030_en.
[59] Joint Research Centre and European Commission, "Level(s) - A Common EU Framework of Core Sustainability Indicators for Office and Residential Buildings Part 3: How to Make Performance Assessments Using Level(s) (Beta v1.0)," 2017, https://doi.org/10.2760/95143.
[60] Bionova Ltd, "The Embodied Carbon Review - Embodied Carbon Reduction in 100+ Regulations and Rating Systems Globally," 2018, https://www.oneclicklca.com/embodied-carbon-review/.
[61] Ryan Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review," 2017, https://www.bcfii.ca/system/files/reports/public/embodied_carbon_in_construction_and_infrastructure_-_international_policy_review.pdf.

projects. Austria has implemented multiple certification systems with embodied carbon standards. The government also provides a cash bonus incentive through its social housing program linked to overall environmental performance.[62]

Several Austrian states and cities have developed other policy requirements and incentives specific to their jurisdictions.

Key initiatives in Austria include:

- **OI3 - Ökoindex 3**[63] is a nationally-adopted evaluation methodology developed by IBO, the Austrian Institute for Healthy and Ecological Building (*Österreichisches Institut für Baubiologie und –ökologie*). The methodology is a weighted score of three environmental criteria (GWP, primary energy used, and acidification potential). Methods to calculate OI3 performance measures are not open-source. Industry stakeholders are pushing IBO to make the calculation methods publicly available and revise the methodology to align with EN 15804.
- **IBO ÖKOPASS**[64] is a widely used assessment system that provides certification ("building pass") for residential building projects. It applies the Ökoindex 3 methodology.
- **Klimaaktiv**[65] is a national rating system that also applies the Ökoindex 3 methodology to assess environmental impacts of building materials. The assessment is a mandatory component of certification. Based on level of performance against the assessment, residential building projects may be eligible for environmental subsidies. The certification has been applied to over 500 buildings in Austria.
- **ÖGNB / TQB**[66] is a building assessment system operated by ÖGNI - the Austrian Sustainable Building Council (ASBC).[67] It provides points toward an optional component for embodied carbon.

B.2 BELGIUM

At its national and regional levels, Belgium has focused on developing embodied carbon policy underpinned by LCA. Key initiatives include national legislation aligned with a standard EPD program, and a region-led collaboration that established a framework for LCA methodology:

- **Belgium EPD program (B-EPD):**[68] The national B-EPD provides a framework for developing and reporting EPDs in accordance with mandatory requirements established by legislation passed in 2014 (The Royal Decree on Environmental Messages).[69] Launched in early 2017, B-EPD includes a national EPD database aligned with international standards. Manufacturers are required to

[62] Bionova Ltd, "The Embodied Carbon Review - Embodied Carbon Reduction in 100+ Regulations and Rating Systems Globally."
[63] Austrian Institute for Healthy and Ecological Building, "Ökoindex 3," 2011, https://www.baubook.at/m/Daten/Bilder/Infos/k4_OI3_Folder.pdf.
[64] https://www.ibo.at/en/building-assessment/ibo-oekopass/
[65] Federal Ministry for Sustainability and Tourism (Austria), "Klimaaktiv," n.d., https://www.klimaaktiv.at.
[66] Austrian Sustainable Building Council, "Total Quality Building Assessment," accessed December 21, 2018, https://www.oegnb.net/en/tqb.htm.
[67] Austrian Sustainable Building Council, "ÖGNI," accessed December 21, 2018, https://www.ogni.at/.
[68] Federal Public Service (FPS), "The Belgian EPD Programme B-EPD | FPS Public Health," 2017, https://www.health.belgium.be/en/belgian-epd-programme-b-epd.
[69] Federal Public Service (FPS), "Royal Decree on Environmental Messages | FPS Public Health," 2017, https://www.health.belgium.be/en/royal-decree-environmental-messages.

conduct LCAs and submit EPDs for all construction products in order to make environmental marketing claims. Submitted EPDs must be verified by an approved inspector before publication.

- **LCA methodology and tool developed by regions:** Flanders' public waste agency (OVAM) led a five-year collaboration with Belgian universities, engineering firms and government agencies from the nation's three regions to develop LCA framework for calculating and communicating environmental performance of construction materials.[70] The project resulted in voluntary LCA calculation methodology applicable to building elements and whole-buildings, and TOTEM[71] (formerly called 'MMG'), an LCA tool released in February 2018 to support manufacturing and construction professionals assess environmental impacts of building projects during the design phase.

B.3 FRANCE

In August 2015, France passed the Energy Transition for Green Growth Law,[72] setting energy consumption and fossil fuel use targets for its construction sector to meet by 2030. The national strategy established GHG emissions targets for the building sector: a 50% reduction by 2030 and 87% reduction by 2050. Key features of the law and other French programs considering embodied carbon include:

- **A voluntary pilot program incentivizing compliance:** *Énergie Positive et Réduction Carbone*[73] incentivizes builders and developers to achieve energy and carbon performance-based targets. Incentives include financial support toward LCA studies, additional construction/zoning rights, and/or an Energy-Plus & Carbon Reduction Certificate (E+C- label) for complying with energy and life cycle carbon performance benchmarks. The trial period aims to assess the economic and technical feasibility of regulation to ensure that compliance standards are realistic to the capabilities (financial and technical) of manufacturing firms. The program accounts for embodied carbon, establishing indicators (called 'Carbon Levels') for emissions resulting during the whole life cycle of a building, and carbon emissions attributed to construction products and building equipment.[74]

  France intends for the pilot program to become mandatory in 2020 – this transition would remove incentives and require building projects to meet life cycle carbon-performance standards. In the meantime, manufacturers voluntarily participating in the pilot phase must submit data to a national "observatory" or inventory of information assessing technical and economic feasibility of the program standards, as well as general feedback and recommended best practices.

[70] OVAM, "Totem: A New Tool to Improve the Environmental Performance of Buildings (MMG) - OVAM," 2018, https://www.ovam.be/materiaalprestatie-gebouwen-0.
[71] TOTEM, "TOTEM: Tool to Optimise the Total Environmental Impact of Materials," accessed December 13, 2018, https://www.totem-building.be/.
[72] Legifrance, "LOI N° 2015-992 Du 17 Août 2015 Relative à La Transition Énergétique Pour La Croissance Verte | Legifrance," 2015, https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000031044385&categorieLien=id.
[73] Ministère de la Transition Écologique et Solidaire and Ministère de la Cohésion des Territoires, "BâTiment à Énergie Positive & Réduction Carbone," accessed December 13, 2018, http://www.batiment-energiecarbone.fr/fr/.
[74] Ministère de la Transition Écologique et Solidaire and Ministère de la Cohésion des Territoires, "LA RÉGLEMENTATION ÉNERGÉTIQUE ET ENVIRONNEMENTALE DE DEMAIN Construire Ensemble BâTiment et Climat," 2017, http://www.batiment-energiecarbone.fr/documents/plaquette-eprc-2017-11-27.pdf.

As of April 2018, over 120 building projects were participating in the trial scheme, 45 of which received E+C- labels. At this time, a Deputy Director involved in implementation reflected that the lower carbon indicator (C1) was more accessible compared to the second (C2), which led program participants to recommend establishing an intermediate level between C1 and C2. Other participants recommended establishing an even more demanding, third level. France estimates that over 800 projects will have participated by the end of 2018.[75]

- **National EPD database**: Launched in 2004, the "*environmental and health reference data for buildings*" (INIES) is a national database with datasets provided voluntarily by manufacturers and trade associations.[76] Datasets include Environmental and Health Declaration Sheets (FDES) for building products, Product Environmental Profiles (PEP) for equipment, material life cycle inventories, and building services (e.g. water) information. LCA is a prerequisite for submitted data. Datasets must comply with the European standard EN 15804 "Sustainability of construction works – Environmental product declarations – Core rules for the construction products category," which France adopted in 2014 and subsequently published complementary national standards, which INIES data must also comply with.

- **Software requirements for LCA tools:** Software used to calculate EPD data must be verified by France's Ministry of Environment. This builds upon a standardized background life cycle inventory dataset and methodology similar to the initiatives proposed for Canada and the North America in **Appendix C**.

B.4 GERMANY

In 2007, construction and real estate industry stakeholders in Germany founded the German Sustainable Building Council (DGNB),[77] a non-profit membership group that led national progress to track and reduce emissions including the use of LCA. Through a two-year collaboration with the Federal Ministry of Transport, Building and Urban Development (BMVBS), DGNB developed a voluntary certification system (DGNB System) to assess sustainable construction of a building, awarding points based on a building's overall performance. Similar to LEED, the DGNB System includes three levels awarded based on number of points. LCA is included as a criterion under the system's Ecological Quality assessment category. For each criterion, the DGNB System outlines how it aligns to national and international standard and legislation, such as the Germany Sustainability Strategy and the United Nations Sustainable Development Goals.[78]

Building from the foundation established with DGNB, the German government established mandatory measures for federal buildings through the Assessment System for Sustainable Building (BNB).[79] In effect

[75] batiactu, "Réglementation Environnementale 2020 : L'Etat Donne Des Précisions," 2018, https://www.batiactu.com/edito/re2020-un-socle-unique-minimal-energie-carbone-sera-52796.php.
[76] INIES, "INIES | Environmental and Health Reference Data for Building," accessed December 13, 2018, http://www.inies.fr/home/.
[77] DGNB, "DGNB – German Sustainable Building Council," accessed December 13, 2018, https://www.dgnb.de/en/index.php.
[78] DGNB, "The Most Important Changes to Version 2018 of the DGNB System," 2018, https://static.dgnb.de/fileadmin/en/dgnb_system/system/The-most-important-changes-to-Version-2018-of-the-DGNB-System.pdf.
[79] Federal Ministry of Transport, Building and Urban Development, "Assessment System for Sustainable Building Administration Buildings Economical Quality Ecological Quality Process Quality Technical Quality Socio-Cultural / Functional Quality," 2011, https://www.nachhaltigesbauen.de/fileadmin/pdf/Systainable_Building/Assessment_System_Sustainable_Building1.pdf.

since 2011, BNB specifies minimum benchmarks for performance, requiring new federal building projects to conduct WB, similar to the voluntary DGNB System approach.

Established within the framework of BNB, Germany also has the national EPD/LCA database ÖKOBAUDAT and provides a free one-source LCA tool (openLCA) and eLCA software supported by ÖKOBAUDAT's interface.[80]

Key features include:

- **Mandatory green rating system:** Assessment System for Sustainable Building (BNB) requires WBLCA for new federal building projects (office and administrative buildings) costing over 2M EUR ($2.35 million USD). BNB allocates points based on LCA performance against pre-determined standard benchmarks set at 'low', 'medium', and 'high' – the higher the benchmark, the more points awarded. Other features include alignment with Germany's Guidelines for Sustainable Buildings and a database of BNB-certified buildings.
- **Industry-led voluntary rating system**: The DGNB Certification System includes an LCA benchmark component similar to BNB, and maximum embodied carbon threshold – points are awarded based on performance relevant to the ceiling. It encourages non-government building projects to pursue embodied carbon standards.[81]
- **National LCA EPD database:** ÖKOBAUDAT provides free company-specific EPDs and generic (average) datasets publicly available for LCA application. The platform includes data from over 1000 construction products. Its interface also supports (through authorized LCA software tools) direct import of EPD datasets. ÖKOBAUDAT was developed through a funded project with partnering research institutes and sustainability software companies, who consulted stakeholders from Germany's construction materials industry throughout development.[82]
- **Free LCA tool and software:** Germany provides free access to the LCA tool openLCA and eLCA, software developed specifically for application on federal building projects. eLCA is taught and used in universities to familiarize building professionals.[83] For non-federal building projects, other market-based tools are commonly used. Both openLCA and eLCA are supported by the national EPD database.[84]
- **Life Cycle Assessment Guide**: In April 2018, DGNB published a basic guide on LCA – its benefits, uses, and how to perform an LCA and communicate results.[85]

B.5 THE NETHERLANDS

The Netherlands attempted to pass embodied carbon policy in 2003, an effort that failed in part due to strong opposition from industry. In 2013, the nation passed a whole-building LCA requirement for non-

[80] ÖKOBAUDAT, "ÖKOBAUDAT," accessed December 13, 2018, https://www.oekobaudat.de/.
[81] DGNB, "DGNB Criteria 'Building Life Cycle Assessment,'" 2018, https://www.dgnb-system.de/en/system/version2018/criteria/building-life-cycle-assessment/index.php.
[82] ÖKOBAUDAT, "ÖKOBAUDAT."
[83] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[84] Zizzo et al.; ÖKOBAUDAT, "ÖKOBAUDAT."
[85] DGNB, "Life Cycle Assessments - A Guide on Using the LCA," 2018, https://static.dgnb.de/fileadmin/en/dgnb_ev/reports/LCA-guide.pdf.

government buildings, after a decade of close engagement and collaboration with industry stakeholders, including those who opposed the original policy proposal. During this period, LCA use also increased as availability of tools and methodology evolved. Through increased uptake of LCA practice, manufacturers used multiple private Dutch EPD programs to publish EPDs. In an effort to align the various EPD programs and standardize LCA practice, the Dutch government commissioned Stichting Bouwkwaliteit (SBK) to develop a standard LCA framework, which resulted in a national database and standard LCA methodology currently managed and operated by SBK.[86]

Key components include:

- **Whole building LCA for non-government buildings:** Building Code 2012 (Bouwbesluit 2012) – enacted in 2013 – became the first known legislative measure mandating WBLCA for non-government buildings, requiring new residential and office buildings over 100 m^2 to submit an 'environmental profile' which included a component for estimating embodied carbon in order to receive a building permit. As of 2018, the policy requires a building's total environmental profile to fall below a threshold.[87] Relative to other embodied carbon measures, this new component to the policy is unique, since it requires building projects to go a step further than measurement and reporting only, and requires meeting an established emissions target in order to receive a building permit.

- **National EPD database:**[88] The National Environmental Database (NMD) is a single database operated by SBK with whole life cycle assessment data. It includes environmental data (producer- and branch- specific) of materials and products, which are vetted according to the SBK Verification Protocol. SBK engages industry to ensure transparency and ongoing improvements to the database through an Environmental Policy Committee (MGB) and Technical Content Committee (TIC).

- **Standardized WBLCA methodology:**[89] The Assessment Method: Environmental Performance Construction and Civil Engineering Works (GWW or the Dutch Assessment Method) is a single, national methodology for WBLCA. This method is based on the European Assessment Method for environmental declarations of construction products (EN 15804) and aligns with EN 15978, and includes scenarios relevant to the Netherlands. The Dutch Assessment Method is "inseparably connected" to the national EPD database, and is required per Building Code 2012 Article 5.9.[90]

- **WBLCA software/tools aligned with methodology:** The NMD and Dutch Assessment Method align with a SimaPro database, LCA software commonly used in the Netherlands with standardized LCI background database and LCA methodology similar to the programs proposed for Canada and North America in **Appendix C**.

[86] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[87] Zizzo et al.
[88] Stichting Bouwkwaliteit, "Nationale Milieudatabase," accessed December 13, 2018, https://www.milieudatabase.nl/.
[89] Stichting Bouwkwaliteit, "Assessment of the Environmental Performances of Constructions and Civil Engineering Works," 2015, https://www.milieudatabase.nl/imgcms/Brochure_Assessment_Method_Environmental_Performance__TIC_versie.pdf.
[90] Stichting Bouwkwaliteit.

B.6 SWEDEN

In 1991, Sweden was the first nation to pass a carbon tax, setting precedence for sustainability practices adopted by Swedish industries today. Specific to embodied carbon, Sweden's carbon tax has focused on tracking and reducing emissions from construction of transportation infrastructure projects. More recently, Sweden has worked to incorporate LCA into building industry practice, through a new version of its national green building rating system, and through effort by the Swedish Board of Housing (Boverket).

Key features include:

- **Carbon accounting of transportation infrastructure construction:** Since 2015, new transportation infrastructure projects over 50 million SEK ($5.6 million USD) are required to calculate and disclose embodied carbon impacts. The program offers financial incentives for embodied carbon emissions reduced relative to a pre-defined target.[91]
- **National LCA-based tool**: Klimatkalkyl[92] is a web-based tool or 'climate calculator' that includes a database of embodied energy and GHG emissions of different transportation infrastructure types.
- **Voluntary environmental certification system:** Miljobyggnad[93] is a green building rating system, providing certification based on performance against 16 indicators. The Sweden Green Building Council recently published a new version of Miljobyggnad, which includes a voluntary LCA performance target.[94]
- **LCA guidelines:** In summer 2018, Boverket – the Swedish Board of Housing (Boverket) responsible for writing building code – published new guidelines on LCA, including methodology for calculating environmental impacts over the whole lifecycle of a building. The document provides guidance on how to conduct an LCA, LCA analysis, and environmental certification.
- **Stockholm LCA calculation guideline:** In 2014, Stockholm launched the program "Routine environmental calculations of larger construction projects with LCA." This guideline is not required/enforced.[95]

B.7 SWITZERLAND

Switzerland has several rating systems including WBLCA language. Notable features in Switzerland include strong leadership from its corporate community to hold itself accountable to emissions tracking and reduction; leadership at the city level to require voluntary standards set at the national level; and strong industry support for its national building rating system.

[91] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[92] "Start - Klimatkalkyl," n.d.
[93] Sweden Green Building Council, "Miljobyggnad," n.d., https://www.sgbc.se/certifiering/miljobyggnad/.
[94] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[95] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."

Key features include:

- **National green building rating system**: The program Minergie[96] sets WBLCA-based performance targets for embodied carbon through the Minergie – Eco standard.[97] Minergie – Eco compliance is voluntary in Switzerland, with a few exceptions: the City of Zurich requires new government building projects to achieve Minergie – Eco, while other public and private organizations (e.g. the Zurich Cantonal Bank) require compliance for both new buildings and major renovation projects, or offering density incentives and subsidies to buildings voluntarily achieving certification.[98] Minergie is similar to LEED in that it requires documentation at two stages – at design completion and construction completion.

- **Other rating systems:** Switzerland also uses other voluntary rating systems with similar methodology and data for WBLCA calculation. These include the Swiss Sustainable Building Council (SGNI; based on the German DGNB system), Standard for Sustainable Construction Standard (SNBS), and 200-Watt-Areale.[99]

- **National dataset:** The Association of Public Builders of Switzerland (KBOB) – a body of Swiss federal building authorities – provides a dataset that is used by most Swiss energy-calculation tools aligned with regulatory requirements.[100] Ecoinvet, a non-profit association founded with the mission to "promote the use and good practice of LCI within Switzerland and worldwide."[101] The ecoinvent Life Cycle Inventory database is one of the leading global sources of the background data used to create LCAs.

- **Standard LCA Tool:** Lesosai[102] uses the list of impacts maintained by KBOB (extracted from EcoInvent database) to calculate lifecycle environmental impact of buildings and construction materials. The tool methodology conforms to Swiss Standard SIA 2032.[103]

- **Call-to-action:** First introduced in 1998, Switzerland's 2000-Watt Society[104] is an environmental call-to-action, aiming to limit per-capita energy consumption and lifecycle GHG emissions. The vision is referenced in several national and local government programs seeking to align their language with the vision's goals. The City of Zurich aligned its municipal code with the 2000-Watt Society and set a 2050 target for reducing embodied carbon emissions from residential buildings.[105]

[96] Minergie, "MINERGIE Schweiz," accessed December 13, 2018, https://www.minergie.ch/.
[97] Minergie, "Minergie-ECO | Ecolabel Index," accessed December 13, 2018, http://www.ecolabelindex.com/ecolabel/minergie-eco.
[98] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[99] Zizzo et al.
[100] KBOB, "Koordinationskonferenz Der Bau- Und Liegenschaftsorgane Der Öffentlichen Bauherren KBOB," accessed December 13, 2018, https://www.kbob.admin.ch/kbob/de/home.html.
[101] ecoinvent, "Mission & Vision – Ecoinvent," accessed December 30, 2018, https://www.ecoinvent.org/about/mission-and-vision/mission-and-vision.html.
[102] Minergie, "Lesosai 2018 : Certification and Thermal Balance Calculation for Buildings," accessed December 13, 2018, http://www.lesosai.com/en/.
[103] "Lesosai 2018 : Certification and Thermal Balance Calculation for Buildings," n.d.
[104] United Nations University, "2,000 Watt Society," 2009, https://ourworld.unu.edu/en/2000-watt-society.
[105] City of Zurich, "2000-Watt Society," accessed December 13, 2018, https://www.stadt-zuerich.ch/portal/en/index/portraet_der_stadt_zuerich/2000-watt_society.html.

- **Municipality LCA standards:** Several local governments including Zurich require all new government buildings to conduct whole-building LCA and meet an embodied carbon performance target for certain building types.[106]

B.8 UNITED KINGDOM

The UK Climate Change Act 2008[107] established the world's first legally binding target to cut 80% of emissions by 2050, outlining multi-sectoral policy to transition industries toward low carbon practices, including carbon capture and storage, and low carbon construction through increased use of renewable materials. The Act established five-year carbon budgets (until 2022) for all major UK Government departments, mandating agencies to develop and implement their own low carbon transition plans. The UK government attributes its progress toward emissions reduction to the Act – emissions decreased by 42% between 1990 and 2016, and in 2016 alone, emissions decreased by six percent.[108]

To support further progress towards targets outlined by the Act, the UK Government published the Clean Growth Strategy[109] in 2017, which included language on the UK's commitment to stimulate innovation of "advanced materials" in order to support cost-effective low carbon products to replace materials with carbon-intensive manufacturing processes.

While the UK government has established a strong foundation of aligned policies and strategies targeting GHG emissions reduction, federal regulation specific to embodied carbon is limited. However, the nation's longstanding voluntary assessment programs recognize the importance of tracking and reducing environmental impact of construction materials through LCA.

Further, UK industry groups play a leadership role to develop industry standards and capacity to account for embodied carbon. The UK Green Building Council (UKGBC) provides practical guidance documents and workshops to help industry professionals work with clients to measure embodied carbon, and in 2012, the UK Government established a joint industry-government board focused on green construction. The Green Construction Board[110] published *The Low Carbon Routemap for the Built Environment,*[111] a visual tool outlining policies, actions and strategies for the UK building industry to meet the UK Government's target to cut GHG emissions by 80% by 2050. The roadmap addresses both operational and embodied carbon emissions.

[106] Zizzo et al., "Embodied Carbon of Buildings and Infrastructure, International Policy Review."
[107] Legislation.gov.uk, "Climate Change Act 2008" (Statute Law Database), accessed December 13, 2018, https://www.legislation.gov.uk/ukpga/2008/27/contents.
[108] United Kingdom Department for Business, Energy, and Industrial Strategy, "The Clean Growth Strategy: Leading the Way to a Low Carbon Future," 2017, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf.
[109] Department for Business, Energy, and Industrial Strategy.
[110] Designing Buildings Wiki, "Green Construction Board," 2017, https://www.designingbuildings.co.uk/wiki/Green_Construction_Board.
[111] The Green Construction Board, "The Low Carbon Routemap for the Built Environment," 2013, http://www.carbonaction2050.com/sites/carbonaction.ciobrebuild.io1dev.com/files/document-attachment/GCB_Carbon_ROUTEMAP_1.pdf.

Key features include:

- **Voluntary green building rating programs:** Two well-established programs - Building Research Establishment Environmental Assessment Method (BREEAM)[112] and Home Quality Mark[113] – include LCA and embodied carbon goals. Established in 1990, making it the oldest certification tool used (with LCA focus since 1996), BREEAM awards two types of points for 1) low-impact materials selection and 2) WBLCA application. Focused on residential buildings, Home Quality Mark includes a WBLCA incentive.
- **BREEAM certification tools and database:** BREEAM provides 'BREEAM Projects', an online platform providing pre-assessment tools and performance data from certified BREEAM projects.[114] The Building Research Establishment (BRE) Group (BREEAM's operator) provides GreenBookLive, a free database that helps industry professionals select low impact products. This is complemented by the BRE Green Guide.
- **UKGBC Embodied Carbon – Practical Guidance**: The 2017 publication provides industry professionals with knowledge and resources to use when working with clients to request embodied carbon measurements.[115]
- **RICS Whole Life Carbon Assessment for the Built Environment:**[116] The UK Royal Institution of Chartered Surveyors (RICS) is a professional body that accredits professionals within the land, property, construction, and infrastructure sectors worldwide. In 2017, RICS published a guidance document that mandates its professional members adopt a whole life cycle approach to carbon emissions reduction in the building industry. The guidance document establishes specific mandatory principles and supporting guidance for interpreting and implementing EN 15978 (*Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method*) methodology.[117] Language included in the RICS document also aligns with BREEAM guidance and standards.

C. OTHER INTERNATIONAL COUNTRIES: NEW/EMERGING POLICIES

This section presents new/emerging policies related to embodied carbon from other international countries – Canada, Japan, and Singapore.

[112] Building Research Establishment, "BREEAM: The World's Leading Sustainability Assessment Method for Masterplanning Projects, Infrastructure and Buildings," accessed December 13, 2018, https://www.breeam.com/.
[113] Building Research Establishment, "Home Quality Mark," accessed December 13, 2018, https://www.homequalitymark.com/.
[114] Building Research Establishment, "BREEAM Projects," accessed December 13, 2018, https://tools.breeam.com/projects/index.jsp.
[115] UK Green Building Council, "Embodied Carbon - Practical Guidance," 2017, https://www.ukgbc.org/ukgbc-work/embodied-carbon-practical-guidance/.
[116] RICS, "Whole Life Carbon Assessment for the Built Environment, 1st Edition," 2017, https://www.rics.org/uk/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment/.
[117] European Committee for Standardization, "EN 15978:2011 Sustainability of Construction Works - Assessment of Environmental Performance of Buildings - Calculation Method," *International Standard*, 2011.

C.1 CANADA

To date, Canada has lacked a national approach to tracking and reducing embodied carbon. However, a wide range of initiatives are developing or underway:

- The National Research Council (NRC) is leading a unified approach to begin development in 2019 of a high-quality national life cycle inventory (LCI) database including regionally-specific (provincial-level) data. This database could be used to create high-quality LCA studies and EPDs for Canadian-based construction materials. This effort is considered a critical first step toward potentially requiring future construction projects – including government procurement – to meet specific low-carbon targets. See **Appendix C** for additional information on the developing LCI initiative.

Key features include:

- **City of Vancouver, Canada:** In 2016, the City of Vancouver passed the *Green Buildings Policy for Rezoning,*[118] which included a requirement for new construction projects to use WBLCA to calculate embodied carbon impact. To receive a rezoning permit, design teams need to commit at the start of commercial building projects whether to pursue either the Passive House (or similar "near-zero" emissions) standard **OR** the City's 10 Low Emission Building requirements, one of which includes reporting the building's embodied carbon through a WBLCA.[119]

- **Province of Quebec, Canada**: In 2013, the province adopted the Quebec Wood Charter to promote the use of wood in construction.[120] The policy updated the provincial building code to increase the maximum height for wood structures by two stories (six stories total), and requires developers of government-funded projects to consider wood as a material option, through requiring a comparative analysis of GHG emissions for structural materials. While buildings must submit emissions data at the funding application state, funding is not dependent on whether the project selects a low-carbon material.

- **CaGBC Zero Carbon Building Standard**: In May 2017, the Canada Green Building Council (CaGBC) published a Zero Carbon Building Standard – a voluntary program providing a pathway to Zero Carbon certification for new and existing buildings projects.[121] While operational carbon emissions are the core focus of the initiative, it requires applicants to use LCA software to report embodied carbon of a building's structural and envelope materials. The reporting requirement is intended to help Canada's building industry develop familiarity and capacity to conduct LCA.

[118] City of Vancouver - Planning Urban Design and Sustainability Department, "Green Buildings Policy for Rezoning - Process and Requirements (Formerly: Green Rezoning Process)," 2017, https://bylaws.vancouver.ca/Bulletin/G002_2017April28.pdf.
[119] Light House Sustainable Building Centre, "We Are Ready for New City of Vancouver Rezoning Requirements – Are You? | Light House," accessed December 13, 2018, http://www.sustainablebuildingcentre.com/we-are-ready-for-new-city-of-vancouver-rezoning-requirements-are-you/.
[120] Ministère des Forêts, de la Faune, et des Parcs, "The Wood Charter" (Québec), accessed December 13, 2018, https://mffp.gouv.qc.ca/english/publications/forest/wood-charter.pdf.
[121] Canada Green Building Council®, "Zero Carbon Building Standard," 2017, https://www.cagbc.org/cagbcdocs/zerocarbon/CaGBC_Zero_Carbon_Building_Standard_EN.pdf.

- **Public Services and Procurement Canada's (PSPC) Real Property Branch (RPB)** adopted an Integrated Design Process[122] (IDP) approach for new construction projects, incorporating whole-building performance assessment tools into its decision-making.[123]

C.2 JAPAN

In 2000, the National Diet of Japan passed a law to promote a 'recycling-oriented economy and society', aiming to proliferate uptake of environmentally-friendly products and services. As a result, Japan's Environmental Management Association for Industry (JEMAI) with support from the Japanese Ministry of Economy, Trade and Industry (METI) established EcoLeaf Environmental Label in 2001, a national EPD program.[124] EcoLeaf includes a national database of type III EPDs and an EcoLeaf label for manufacturers and suppliers meeting EcoLeaf guidelines.

C.3 SINGAPORE

Singapore's Building and Construction Authority (BCA)[125] establishes programs and standards for the city-state's building sector. BCA operates the Green Mark Scheme, a building rating system established in 2005, which includes a voluntary LCA-based component.[126] Green Mark standards include guidance for materials selection and calculating embodied carbon; BCA provides a Carbon Calculator to assist quantification of embodied carbon impacts.

2.4 DISCUSSION

Embodied carbon policy is increasingly viewed as a critical component for phasing out global carbon emissions by 2050. In the short-term, new policies encourage the building sector to track, report and consider environmental impact data including embodied carbon – a pivotal first step to help motivate industries with limited self-led, scalable initiatives to promote emissions accounting as standard practice. In the mid- to long-term, embodied carbon policies underpinned by a robust technical framework, clear goals, and standards targeting carbon-intensive are valuable tools helping jurisdictions to meet emissions reduction targets.

The growing focus on embodied carbon arises from increasing recognition of a life cycle emissions gap not addressed by longstanding energy efficiency and renewable energy measures, or 'operational carbon' policies. While existing and emerging embodied carbon policies across the world are well-positioned to reduce the total carbon footprint of a building, recent research on the global 'carbon

[122] Public Services and Procurement (Canada), "Integrated Design Process - Knowledge Areas - NPMS - Real Property - PSPC," 2005, https://www.tpsgc-pwgsc.gc.ca/biens-property/sngp-npms/bi-rp/conn-know/enviro/pci-idp-eng.html.
[123] Public Works and Government Services (Canada), "Integrated Design Process - Knowledge Areas - NPMS - Real Property - PSPC," November 2005, https://www.tpsgc-pwgsc.gc.ca/biens-property/sngp-npms/bi-rp/conn-know/enviro/pci-idp-eng.html.
[124] Japan Environmental Management Association for Industry, "EcoLeaf Overview | EcoLeaf Environmental Label," accessed December 13, 2018, http://www.ecoleaf-jemai.jp/eng/; Japan Environmental Management Association for Industry, "JEMAI Environmental Label Program (EcoLeaf/Carbon Footprint Communication Program) Base Document," 2013, http://www.ecoleaf-jemai.jp/eng/data/JG-01-02.pdf.
[125] Singapore Government, "Building & Construction Authority," accessed December 13, 2018, https://www.bca.gov.sg/AboutUs/about_bca.html.
[126] Singapore Government, "About BCA Green Mark Scheme," accessed December 13, 2018, https://www.bca.gov.sg/greenmark/green_mark_buildings.html.

loophole' highlights a significant gap in current policy that governments must address in order to make a true impact on global GHG emissions reduction.[127]

The 'carbon loophole' describes policies and national emission levels in an international context, considering the trajectory of embodied carbon attributed to goods and products through the global economy. The term considers emissions 'offshoring', a growing issue impeding international progress to meet global climate action targets. As developed countries phase out local production-based emissions and demonstrate progress toward meeting national emissions targets, they increasingly rely on developing countries to carry out carbon-intensive manufacturing practices no longer permitted or financially viable due to stringent local measures. This results in a redistribution of emissions that most policies are not considering, meaning that nations can lack a holistic understanding of the carbon footprint of imported materials.

[127] Daniel Moran, Ali Hasanbeigi, and Cecilia Springer, "The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products," 2018, https://buyclean.org/media/2016/12/The-Carbon-Loophole-in-Climate-Policy-Final.pdf; Renilde Becqué et al., "Europe's Carbon Loophole - Draft Report for Consultation," 2017, https://www.climateworks.org/wp-content/uploads/2017/09/EU-carbon-loophole_final-draft-for-consultation.pdf.

CHAPTER 3:

TECHNICAL REVIEW

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CHAPTER 3: TECHNICAL REVIEW

3.1 INTRODUCTION

Globally, the building and construction sectors account for nearly 40% of global energy-related carbon dioxide emissions in constructing and operating buildings (including the impacts of upstream power generation).[1] Current building codes address operating energy, but do not typically address the impacts 'embodied' in building materials and products. However, more than half of all greenhouse gas (GHG) emissions are related to materials management (including material extraction and manufacturing) when aggregated across all industrial sectors.[2] As building operations become more efficient, these embodied impacts related to producing building materials become increasingly significant.

This technical review discusses the sources of embodied impacts in the major structural material categories selected in this study (concrete, masonry, steel, and wood), and discusses recommendations on how to incorporate embodied carbon in procurement policy, which includes technical support of EPD development and establishing performance targets.

A. QUANTIFYING PRODUCT EMISSIONS

In order to understand the magnitude of emissions produced by materials manufacturing, an accounting of emissions along the supply chain is required. Life cycle assessment (LCA) is a standardized environmental accounting method that can track these emissions, beginning with raw materials extracted from nature through manufacturing, use of materials, and end-of-life processes. LCA reports a range of potential environmental impacts of these emissions, including GHG emissions reported as a standard metric termed global warming potential (GWP), which is expressed in kilograms of carbon dioxide equivalent (kg CO_2e).

There is a strong global consensus on how to calculate GHG emissions and agreement that these emissions have the same global impact no matter where they are emitted. GHG emissions arising from material extraction and product manufacturing is commonly referred to as *embodied carbon*, which is the focus of this document and this study. Reducing the embodied carbon of products consumed in Washington State could have significant regional and global impacts.

Generally, the GHG emissions from product manufacturing can be attributed to four primary variables:

1. The source of energy used (both from electrical grid and fuels combusted during manufacturing)
2. Any chemical reactions that take place to create materials
3. The efficiency of the manufacturing facility, which affects the amount of energy used
4. The transportation method (e.g. barge or truck) and fuel source (e.g. diesel or electric)

Low embodied carbon in materials manufacturing is associated with:

- Low-carbon electrical grids

[1] UNEP and IEA, "Global Status Report 2017: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector," 2017.
[2] OECD, "Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences" (Paris, 2019), https://doi.org/https://doi.org/10.1787/9789264307452-en.

- High investment in recycling infrastructure
- Stringent emissions control standards
- Newer, more process-efficient manufacturing processes

LCA standards divide the impacts that occur over the life cycle of a product according to the modules shown in Figure 3.1. Modules A1-A3 cover the product manufacturing stage from raw material extraction to manufacturing, and is often characterized as 'cradle-to-gate,' or from beginning-of-life to the factory gate. This cradle-to-gate scope comprises the 'embodied' in 'embodied carbon.'

In addition to estimating the emissions directly attributable to a product, LCA tracks impacts that are beyond the system boundary using module D. Examples of such impacts would include recycling at end-of-life for steel, or the carbon sequestered in wood products due to the biological process of growing trees. These impacts beyond the system boundary can be interpreted differently depending on the perspective and values of the interpreter, and care should be taken if stage D impacts are integrated into decision-making processes.

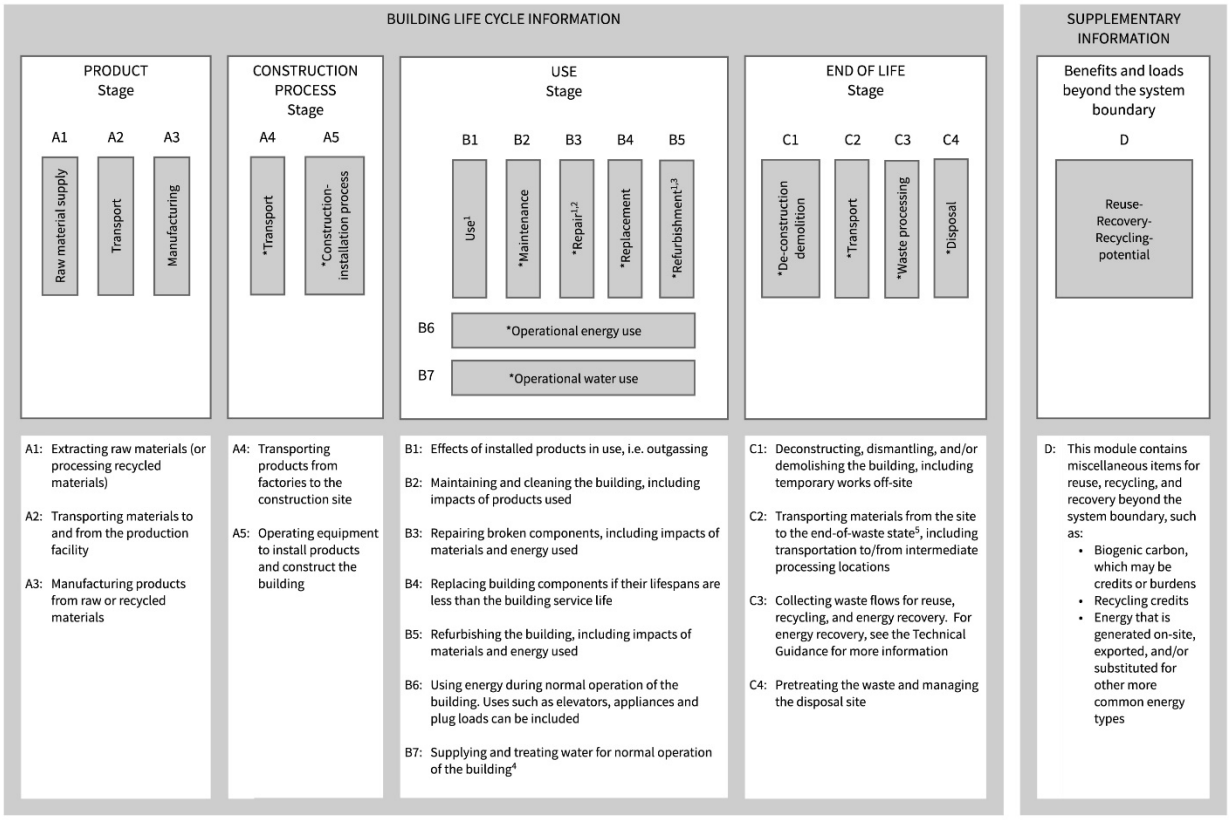

Figure 3.1. LCA stages and modules per EN 15978, reproduced from *Life Cycle Assessment of Buildings: A Practice Guide.* [3]

[3] Carbon Leadership Forum, "Life Cycle Assessment of Buildings: A Practice Guide," 2018, https://doi.org/http://hdl.handle.net/1773/41885.

ENVIRONMENTAL PRODUCT DECLARATIONS (EPDs)

EPDs are third-party verified LCA reports that follow a standardized accounting method (ISO 21930) outlined in a designated Product Category Rule (PCR), and are hosted by an EPD program operator. Program operators are organizations (independent companies, non-governmental organization, or trade organizations) that set up to oversee the third-party review of EPDs, as required by ISO EPD standards. There are multiple program operators in North America. A catalog of North America PCRs is being maintained by a group of North American EPD program operators and is available online.[4] While there are multiple EPD databases, no one single database includes all available North American EPDs.

Different materials and products report data at different levels of detail, which makes it difficult to compare EPDs because they have different underlying assumptions. Furthermore, as noted "EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds."[5] The comparability of EPDs (or lack thereof) is important consider when comparing the environmental impacts of products. Factors that impact the comparability of embodied carbon reported in EPDs include:

1. Methodology: Do EPDs follow the same PCR? The PCR author and version can have a significant impact on the methods used to calculate LCA impacts.
2. Upstream data: Do EPDs use aligned upstream data for significant impacts such as electrical generation or transportation? If upstream data (life cycle inventory datasets) are not aligned, variation in results can be significant.
3. Performance: Do the compared materials have the same performance characteristics? Two products of the same material category may have significantly different performance characteristics (e.g. 3,000 psi concrete for a foundation vs 5,000 psi concrete for a high-rise floor slab), which would make it inappropriate to compare their EPDs.
4. Installation, use, and end-of-life: If all life cycle stages after manufacturing are not identical, comparing embodied carbon alone is not appropriate and LCA data should be considered in the context of a 'whole-building' LCA.

The comparability of EPDs for each of the different material categories is addressed in more detail in Section 3.2.

There are different types of EPDs, affecting how EPDs are assessed in this review:

1. Facility-specific EPD: results for a specific product produced at a unique facility.
2. Product-specific or manufacturer-specific EPD: Results are representative of the processes for a specific product or family of products made by a unique manufacturer. This may be a weighted average of different production facilities.

[4] Program Operator Consortium, "North American PCR Catalog (Google Sheet)," accessed December 14, 2018, https://docs.google.com/spreadsheets/u/1/d/1lS7ukMUG1cAWnMGHKiqIvgcgeHQOeICIIH5t95InZy8/pubhtml.
[5] ULe, "Environmental Product Declaration Steel Deck," 2015.

3. Industry-average EPD: Results are weighted to reflect production method and proportion of a region. Sometimes only a sample of companies who elected to participate in the creation of the EPD and thus may not be truly representative of the average in the industry.

Of note, the dominant standard for creation of EPDs is ISO 21930, which was significantly updated in 2017. While updates of the material PCRs are in different levels of development, no EPDs on the market currently comply with this new standard. Key aspects of the new version of the standard include: more clarity regarding the carbon emitted in burning bio-fuels, and the requirement to report of variability of the results (e.g. standard deviation).

DISCUSSION

Given that structural materials within the same material category commonly have the same construction, use, and end-of-life impacts, comparing cradle-to-gate EPDs can be appropriate for comparing within the same material category (e.g. steel 'A' vs steel 'B'). Given that the installation, use, and end-of-life impacts vary by material, comparing cradle-to-gate EPDs of different material category (e.g. steel vs wood, or even precast concrete vs ready-mix concrete) is not appropriate without conducting a more detailed LCA. The intent of this technical review is thus to evaluate options for differentiating products of the same material category, e.g. selecting the 'cleanest' structural steel available. The purpose of this study is not to compare different material categories, such as steel versus concrete, and thus cannot answer questions such as, "Is a steel or concrete structure a lower-emission option for a building?"

Note that EPD results for one product can be the LCA impact for stage A1 of another product. For example, modules A1-A3 of cement production is included in module A1 of concrete because cement is an ingredient of concrete. A 'facility-specific' EPD typically refers to the facility responsible for the last stage of manufacturing (module A3) of the product. However, for some materials, the largest impacts and largest variability of impacts occur 'upstream' and are reported in LCA stage A1. Thus, identifying the 'facility' type most appropriate to evaluate different materials and products requires careful consideration. For many material categories, the most significant contributor to embodied carbon will be not the facility that fabricates the material but rather the facility(ies) that produce(s) the upstream materials. These upstream impacts are typically reported in life cycle module A1.

B. STRUCTURAL MATERIALS

The Washington State House Bill ESSB 6095 directed this study to "analyze existing embodied carbon policy and propose methods to categorize structural materials and report structural material quantities and origins." The materials analyzed herein are those identified on page 51 of ESSB 6095, which include "any of the following that function as part of a structural system or structural assembly":

1. Concrete, including structural cast-in-place, shotcrete, and precast
2. Unit masonry
3. Metal of any type
4. Wood of any type including, but not limited to, wood composites and wood laminated products.

The project team interpreted this list and focused on the primary structural elements as categorized below according to the standard classification method OmniClass Table 22 Work Results:[6]

- 03 Concrete
- 04 Masonry
- 05 Steel
- 06 Wood

Note that for each of these structural materials, additional components such as concrete formwork, reinforcing ties, steel bolts and connecting plates would be required. This technical review focuses only on the primary structural materials of the elements noted above.

Examples of the impact sources and their approximate percentage contributions of common structural materials by life cycle module is shown in Table 3.1. Section 3.2 will describe impacts of in greater detail.

Table 3.1. Summary of LCA impacts per LCA module and relative impact for common structural materials.

Material category	Property	A1	A2	A3
Structural steel[7]	Approx. % of impact: Source of impacts:	>90% Steelmaking (includes material mining, etc.)	<5% Transportation to fabricator	<10% Fabrication (cutting, welding, shaping steel)
Concrete[8]	Approx. % of impact: Source of impacts:	>90% Production of cement, aggregate, water and admixtures (including material mining, etc.)	<5% Transportation to concrete plant	<10% Mix design (recipe) and concrete mixing
Cement[9]	Approx. % of impact: Source of impacts:	<10% Raw material mining	<5% Transportation to cement kiln	>90% Manufacturing cement
Clay masonry[10]	Approx. % of impact: Source of impacts:	<5% Mining of clay	small Transportation and storage	>95% Firing and factory operations
Glue laminated beam[11]	Approx. % of impact* Source of impacts:	<10% Wood milling (includes forestry harvest and lumber shaping)	<5% Transportation to a fabrication facility	>90% Fabrication (drying, cutting, gluing, pressing)

*not including emissions from bio-fuel combustion or within the broader forest context.

[6] OmniClass, "Table 22 - Work Products," 2012, http://www.omniclass.org/.
[7] Ule, "Environmental Product Declaration Fabricateed Hot-Rolled Structural Sections," 2016.
[8] NSF, "NRMCA Member Industry-Wide EPD for Ready Mixed Concrete," 2016.
[9] Medgar L Marceau, Michael A Nisbet, and Martha G VanGeem, "Life Cycle Inventory of Portland Cement Manufacture," 2006.
[10] Christophe Rafenberg and Eric Mayer, "Life Cycle Analysis of the Newspaper Le MONDE," *International Journal of Life Cycle Assessment*, vol. 3, 1998, https://calculatelca.com/wp-content/themes/athenasmisoftware/images/LCA Reports/Brick_And_Mortar_Products.pdf.
[11] Ule, "Environmental Product Declaration North American Glued Laminated Timbers," 2013.

3.2 EMBODIED CARBON OF STRUCTURAL MATERIAL CATEGORIES

This section evaluates the availability and quality of current EPDs and PCRs for the structural material categories of interest. The first subsection evaluates the current status of EPDs in the industry and Washington State as a whole, and the remaining subsections evaluate each material category in more detail with regards to their embodied carbon characteristics and PCR/EPD status.

CURRENT STATUS OF EPDs

Table 3.2 uses OmniClass to expand the classification of structural materials to distinguish between different structural products or application of materials, and references a representative industry EPD if available. These categories were identified from a broader list within OmniClass Table 22 to be the most representative of structural materials in common use in Washington State. Input from industry stakeholders could refine this list.

From this table, several interesting observations can be made:

A. Methodology for different materials and products are not aligned.
    1. A single PCR exists for wood and steel products, while concrete and concrete masonry products utilize four different PCRs.
    2. None of the four material categories use the same program operator for PCRs or EPDs.
    3. All product types are currently in their 'first generation' of use following the initial PCR. (Typically, PCRs are set to expire every five years, and EPDs are valid for five years from their issue date, even if the PCR is updated. In the near future there will be valid EPDs for the same material category that follow different PCR versions and thus may not be comparable.)
B. EPD development is at different stages and levels of refinement depending on the industry.
    1. The wood and concrete industry trade organizations led the development of industry-average EPDs early this decade.
    2. The concrete industry has published regionally-specific benchmarks to highlight regional variation within industry average data.
    3. The industry average data for wood products represents a national average of forest production.
    4. Both steel and concrete representative EPDs are based on a weighted average of companies that participated in the study and thus may not capture the range of all manufacturers.
    5. Concrete masonry and clay masonry both have less LCA/EPD information available.

Table 3.2. Summary of representative EPDs and PCRs for eligible structural materials in North America. X = no representative EPD was identified in this study.

Product type (numbered per Omniclass)	PCR	Representative EPD	Issued	Country
03 Concrete				
03-20 Concrete Reinforcing				
Reinforcement Bars	SCS 2015	CRSI Fabricated Rebar	2017	US
Fabric and Grid Reinforcing	none	none		
Stressed Tendon Reinforcing	none	none		
Fibrous/Composite Reinforcing	none	none		
03 31 Structural Concrete	CLF 2013*	NRMCA Ready Mix Concrete Regional Benchmarks	2016	US
03 41 Precast Structural Concrete	ASTM 2015	Structural Precast Concrete Industry Wide EPD	2014	US, CA
04 Masonry				
04 05 13 Masonry Mortaring	ASTM 2014	none		
04 05 16 Masonry Grouting	ASTM 2014	none		
04 21 Clay Unit Masonry	ASTM 2016	Under development		
04 22 Concrete Unit Masonry	ASTM 2015	CMU in Canada	2016	CA
05 Metals				
05 12 Structural Steel Framing				
Hot rolled steel section	SCS 2015	Fabricated Sections	2016	US
HSS section	SCS 2015	Fabricated Hollow Sections	2016	US
Steel plate	SCS 2015	Fabricated Steel Plate	2016	US
Open web steel joist	SCS 2015	Open Web Steel Joists	2015	NA
05 31 Steel Decking	SCS 2015	Steel Deck	2015	NA
05 41 Structural Metal Stud Framing	SCS 2015	Steel Studs and Track	2016	US, CA
05 42 Cold-Formed Metal Joists	SCS 2015	none (similar to metal stud)		
05 44 00 Cold-Formed Metal Trusses	SCS 2015	none (similar to metal stud)		
06 Wood, Plastics, and Composites				
06 11 Wood Framing	FP 2013*	North American Softwood	2013	US, CA
06 12 Structural Panels				
Structural Insulated Panel	FP 2013*	none		
Cross Laminated Timber	FP 2013*	none		
06 16 Sheathing				
Plywood	FP 2013*	North American Plywood	2013	US, CA
Oriented Strand Board	FP 2013*	North American OSB	2013	US, CA
06 17 Shop Fabricated Structural Wood				
Laminated Veneer Lumber	FP 2013*	North American LVL	2013	US, CA
Parallel Strand Lumber	FP 2013*	none		
Wood I-Joists	FP 2013*	North American Wood I Joists	2013	US, CA
Metal-Web Wood Joists	FP 2013*	none		
Shop Fabricated Wood Trusses	FP 2013*	none		
06 18 Glue Laminated Construction	FP 2013*	North American Glu-Lam	2013	US, CA

* PCR update compliant with ISO 21930:2017 expected in early 2019

Table 3.3 summarizes the number of companies for various products types in Washington State. Most notable is that very few local companies currently have product or facility specific EPDs. As will be noted in the material-specific assessments in later sections of the report, the environmental impact of local fabrication or assembly can often be quite small compared to the environmental impact of the upstream material manufacturing. Therefore, even though few local companies currently have facility-specific EPDs for their products, this part of the supply chain is not always a major environmental concern. Instead, it may be more important to focus on gathering accurate (or regionally-specific) data for the upstream parts of the supply chain.

To summarize Table 3.3:

- Only 10% of ready mixed concrete suppliers have facility- or mix-specific EPDs. These facilities are located in urban markets near Seattle.
- Almost 80% of the structural steel fabricators contributed to the industry average EPD yet none were identified as having facility-specific EPDs.
- 50% of the rebar fabricators contributed to the industry-average EPD, and 30% have developed facility-specific EPDs, highlighting the low-carbon rebar available locally.
- No facility-specific EPDs in Washington were located for structural wood or clay masonry.

The numbers in Table 3.3 likely underestimate the total number of companies in each category, since these results are based upon membership counts in industry trade organizations, and not all companies are members of these organizations. However, some trends are evident:

- Some industries (cement, steel mills, masonry kilns) have only a few businesses in Washington.
- Some industries (steel fabricators, ready mixed concrete, sawmills) have dozens of businesses in Washington.
- Some structural materials have no local manufacturing base (structural steel, pre-stressing tendons) in Washington State.

Table 3.3. Estimate of number of companies for product types and EPD count in Washington State.

Product type	Estimated total number of companies in WA and number of companies with manufacturer specific EPDs			Estimated number of WA companies that participated in the industry average 'representative' EPD
	Data source	Total	w/EPDs	
03 Concrete				
03-20 Concrete Reinforcing				
Rebar fabricators	CRSI[1]	18+	6	9
Rebar steel mills	Search[2]	1	1	N/A[7]
PT Tendon fabricators	Search[2]	4+	0	0
PT Tendon strands	Search[2]	0	N/A	N/A
03 31 Structural Concrete				
Ready mixed concrete suppliers	NRMCA/WACA[1]	50+	3	3
03 41 Precast structural concrete				
Precast	PCI/NPCA[1]	15+	N.I.	5
Upstream Materials (select)				
Cement	PCA[1]	2	0	1
Aggregate	WACA[1]	20+[6]	N.I.	N/A
04 Masonry				
Masonry subcontractors	MCAA[1]	13+	0	0
Clay unit masonry manufacturers	Search[2]	1	0	0
Concrete unit masonry manufactures	NWCMA[1]	6+	1	N/A
05 Metals				
Structural Steel Fabricators	AISC[3]	34	N.I.	27
05 12 Structural Steel Framing				
Hot rolled steel section	AISC[3]	0	N/A	N/A
HSS section	AISC[3]	0	N/A	N/A
Steel plate	AISC[3]	0	N/A	N/A
Open web steel joist	SJI[1]	0	N/A	N/A
05 31 Steel Decking	SDI[2]	0	N/A	N/A
05 41 Structural Metal Stud Framing	SFIA[3]	2+	N.I.	2
06 Wood, Plastics, and Composites				
Sawmills	DNR[4]	37	N.I.	N.I.
Engineered wood products	APA[5]	9	N.I.	N.I.

[1]Industry trade association member listings
[2]Web and professional network search followed by phone interviews
[3]Email correspondence with trade association
[4]Washington State Department of Natural Resources, "Washington Mill Survey 2016," 2017, https://www.dnr.wa.gov/publications/em_obe_2016_mill_survey_final.pdf?9s0o1
[5]APA – The Engineered Wood Association, "Manufacturer Directory," accessed December 24, 2018, https://www.apawood.org/manufacturer-directory?c=292
[6]The National Stone Sand and Gravel Association identifies 118 member locations in WA.
[7]There is not an industry average EPD for rebar from mill, only of fabricated rebar.
N.I. = Not identified during study period
N/A = Not applicable. Either no EPD's exist or no manufactures in that category

03 CONCRETE

This section presents an overview, key facts, LCA issues, status of PCR/EPDs, and innovations for concrete.

OVERVIEW

Structural concrete typically consists of both concrete and steel reinforcement. This section focuses on concrete only, as the embodied carbon impacts of steel reinforcement are better categorized with other metal products.

Concrete is a material created by mixing together cement (the binding agent), coarse aggregate (rocks). Fine aggregate (sand), water, and admixtures, which modify performance, constructability, finish and color. Supplementary cementitious materials (SCMs) can be made from waste products of other manufacturing processes to reduce the amount of cement required to achieve desired performance. A batch of concrete varies by its recipe or *mix design*. The amount of cement is a primary contributor to the structural performance of the concrete mix – more cement often correlates to higher strength and faster curing times. However, the embodied carbon of concrete is driven primarily by the amount of cement in the mix because cement production requires significant energy input and releases CO_2 as a part of the cement-making process. Table 3.4 describes the processes, sources of emissions, and strategies for reducing the emissions of concrete through the early stages of its life cycle.

Table 3.4. Concrete processes, sources of emissions, and strategies for reducing emissions by life cycle stage.

	A1: Manufacturing	A2: Transportation	A3: Fabrication
Description of processes	Production of material inputs (cement, aggregate, water, admixtures (typically chemicals) and SCMs. Structural precast concrete includes reinforcing steel.	Cement is sourced from around the world, while aggregate tends to be sourced regionally. In WA, aggregate is produced locally or barged down the Pacific Coast from British Columbia.	Concrete is mixed on site and in trucks. For precast concrete and fabrication, this module also includes fabricating rebar, building formwork, and curing concrete.
Sources of emissions	• Fossil fuel combustion for cement kiln • Chemical reaction of turning limestone into cement • Fossil fuels used in mining/processing • Fossil fuels used in chemical admixture production	• Combustion of fossil fuels	Facility operations, which include: • Electrical use • Combustion of fossil fuels
Strategies to reduce emissions	• Increase plant efficiency • Innovate processes • Change electricity source • Capture emissions • Integrate SCM materials into cement production • Use more recycled materials	• Prioritize rail and water transport • Switch to electric vehicles	• Reduce the amount of cement used • Use cement from efficient kilns • Increase energy efficiency of equipment and facility • Change electricity source

CONCRETE KEY FACTS

- Producing 1 kg of cement results in approximately 1 kg of CO_2e, half of which are from a chemical reaction when transforming limestone into cement.[12]
- Typical 4,000 psi concrete in the Pacific Northwest can have a carbon footprint varying between 366 and 582 kg CO_2e/m^3.[3,13]
- Low-cement mixes tend to take longer to cure however full design strength is rarely needed as quickly as standard specifications require. Engineers can adjust these deadlines..
- High-strength aggregate can result in high-strength concrete with less cement.
- SCMs (fly ash or blast furnace slag) can increase concrete durability.
- Admixtures can help low-cement concretes meet placement and curing criteria.
- Facility-specific EPDs for more than 5,000 concrete mixes exist for approximately 17 companies in the US; three of these companies are in Washington.[14]

LCA ISSUES FOR CONCRETE

There is significant potential for reducing embodied carbon of concrete through optimization of concrete mixes. However, one of the most challenging aspects of concrete mix selection is connecting the actual performance needs of concrete to the mix design. Concrete mixes vary by strength (typically between 3,000 – 6,000 psi) and the strength is a critical aspect of the overall structural design. Additionally, the weather at the time of placement, the required finish quality, and construction schedule can impact which mixes will work and which will not. Setting limits to concrete embodied carbon without considering other performance criteria could result in significant construction challenges.

Ready-mixed concrete is an inherently local material because it cannot be transported far after mixing. This is because it begins to cure (harden) as soon as water is added to the cementitious materials. Additionally, aggregates (rocks and sand) are rarely transported long distances. Designing lower-carbon concrete can require more sophisticated concrete mix designs and additional materials which can require facilities to have additional equipment. Larger companies can more easily afford infrastructure for computer-controlled batching and on-staff engineering and testing teams. Smaller companies might have simple mixing facilities and commonly deliver a handful of standard mixes.

There are regionally-specific 'benchmarks' prepared by the National Ready Mixed Concrete Association (NRMCA). These benchmarks show significant regional variation. In this benchmark study, the Pacific Northwest Region includes Washington, Oregon, Idaho, and Montana. However, variation within this region is not known, and standard practice in Western Washington is not necessarily representative of the state as a whole.

As noted in Table 3.3, less than 10% of ready-mixed concrete producers in Washington State are equipped to deliver facility- or mix-specific EPDs at this time. All of these companies are in large urban

[12] Portland Cement Association and ASTM International, "Portland Cements Environmental Product Declaration," 2016, https://www.astm.org/CERTIFICATION/DOCS/295.EPD_for_Portland_Cements_-_Industry_Wide_EPD.pdf.
[13] Athena Sustainable Materials Institute, "NRMCA Member National and Regional Life Cycle Assessment Benchmark (Industry Average) Report-Version 2.0 Prepared for: National Ready Mixed Concrete Association (NRMCA)," 2016, https://www.nrmca.org/sustainability/EPDProgram/Downloads/NRMCA_BenchmarkReportV2_20161006.pdf.
[14] NRMCA, "NRMCA | Sustainability," 2017, https://www.nrmca.org/sustainability/EPDProgram/Index.asp#VerifiedEPDs.

markets. Although setting embodied carbon performance targets for concrete might be possible in areas where the EPD market is established, data on production opportunities and manufacturer capabilities across the state are not currently available to assess the feasibility of performance targets.

PCR/EPD STATUS FOR CONCRETE AND CONCRETE PRODUCTS

Ready-mixed concrete

The concrete PCR is unique in that it provides detailed specifications for the upstream data to be used within EPDs. The second version of the concrete PCR (due in early 2019) will provide additional prescriptive requirements to enable greater comparability.

EPDs are fairly mature in the concrete industry and are supported by the NRMCA and industry tools. However, there are many concrete suppliers who have not produced EPDs, and thus educating and supporting concrete suppliers may be necessary to create EPDs across the state for both large and small companies. Creating a Washington-specific EPD calculator could enable suppliers to create EPDs with lower threshold of cost and effort.

Upstream materials

Given that the production of upstream materials is a significant contributor to the total footprint of concrete, improving the quality of the upstream data would improve the precision of concrete EPDs. Imported cement is sometimes used in this region (commonly from Asia). The second version of the concrete PCR is expected to address this issue, and not equate imported cement to default US production averages as it currently does. While the Portland Cement Association (PCA) has published an industry-average EPD for cement, facility-specific EPDs for cement would improve the precision of concrete EPDs.

The default EPD for aggregate has relatively high LCA impacts. Developing facility-specific EPDs for aggregates is likely to enable concrete suppliers to produce lower-carbon concrete EPDs.

Precast concrete

The National Precast Concrete Association (NPCA) has developed an industry-average EPD for precast concrete. This effort could be leveraged to facilitate precast plants to create manufacturer- or facility-specific EPDs. Note that EPDs of precast concrete report average results per pound of concrete, not for a specific application. Plants could obtain facility-specific EPDs that align with the industry-average EPD, or alternately establish a system to generate project specific EPDs that reflect the actual design delivered.

INNOVATIONS IN CONCRETE

The following are some strategies available now that can lead to lower-impact concrete. These all would require training of architects/engineers/contractors and suppliers to implement at scale.

- Eliminate the use of prescriptive concrete specifications, which put limits on items such as a minimum amount of cement or maximum water to cement ratio. Often these standard prescriptive specifications remain unchanged year after year in companies and government agencies. Instead, performance-based concrete specifications, which define performance

attributes such as strength, durability, cure time, etc., should be used. See guidance from the American Concrete Institute (ACI).[15]

- Extend the curing time to longer than the historically specified 28 days for items such as slab-on-grade, foundations, and concrete shear walls if performance requirements permit. This could allow lower-cement concrete mixes to be used.

The following are carbon-related developments in concrete that have promise:

- The International Energy Agency (IEA) and the Cement Sustainability Initiative (CSI) have published a roadmap[16] which includes projections to achieve up to 24% CO_2 reductions by 2050. Key levers to carbon reduction include:
  - Improve energy efficiency
  - Switch to alternative fuels
  - Use innovative technologies, such as carbon capture
  - Develop alternative binders
- Innovative products that use CO_2 as a material resource include examples such as:
  - Utilizing CO_2 as an added ingredient to concrete reducing the amount of cement required (market-ready stage)[17]
  - 'Growing' aggregates via carbon capture mechanisms (prototype stage)[18]
  - Synthetic concrete aggregates using microbial calcium carbonate precipitation (research stage)[19]

[15] ACI, "329.1T-18: TechNote: Minimum Cementitious Materials Content in Specifications," 2018, https://www.concrete.org/store/.
[16] CSI & IEA, "Technolog Roadmap: Low-Carbon Transition in the Cement Industry," 2018, https://www.wbcsd.org/Sector-Projects/Cement-Sustainability-Initiative/Resources/Technology-Roadmap-Low-Carbon-Transition-in-the-Cement-Industry.
[17] CarbonCure, "CarbonCure," accessed December 19, 2018, https://www.carboncure.com/.
[18] Blue Planet, "Blue Planet | Economically Sustainable Carbon Capture," accessed December 19, 2018, http://www.blueplanet-ltd.com/.
[19] Srubar Research Group, "Living Materials Laboratory | University of Colorado at Boulder," n.d., https://spot.colorado.edu/~wisr7047/.

04 MASONRY

This section presents an overview, key facts, LCA issues, status of PCR/EPDs, and innovations for masonry.

OVERVIEW

Structural masonry consists of multiple components: masonry units (either precast concrete blocks or fired clay bricks), mortar (a water/sand/cement paste used to bind the units together when stacking), grout (a water/sand/cement fluid enough to cast into openings running vertically through the blocks or bricks), and reinforcing steel to provide tension capacity. See Section 03 Concrete for information on concrete. The environmental impact of grout and mortar will also be similar to that of ready-mixed concrete, with the amount of cement influencing both the strength as well as embodied carbon of these products. Unique issues for grout and mortar are discussed in this section. The impacts of reinforcing steel are covered in Section 05 Metals.

Clay masonry units or bricks are unique building materials made of quarried clay that is mixed, formed, and fired. A higher heat of kiln firing tends to correlate with higher-strength bricks, increased fuel use, and thus higher emissions.[20] Table 3.5 describes the processes, sources of emissions, and strategies for reducing the emissions of clay masonry through the early stages of its life cycle.

Table 3.5. Clay masonry processes, sources of emissions, and strategies for reducing emissions.

	A1: Manufacturing	A2: Transportation	A3: Fabrication
Description of processes	Mining, crushing, screening and storage of raw materials (primarily clay and shale)	Often, the kiln is located close to the mine, minimizing quarry-to-kiln transportation impacts	Clay is mixed, formed into bricks, coated or glazed for finish, dried, fired, and cooled.
Sources of emissions	• Combustion of fossil fuel to power mining equipment	• Combustion of fossil fuels	• Facility operations • Combustion of fuels to heat kiln. Natural gas is a common fuel source.
Strategies to reduce emissions	• Increase equipment efficiencies	• Switch to electric vehicles • Reduce transport distances	• Increase kiln efficiency • Change fuel source • Formulate brick that needs less energy to make

Alternative materials and assemblies can provide structural load bearing capacity similar to masonry and concrete, such as: straw bale, rammed earth, hempcrete, rammed earth walls, and blocks.

[20] BIM, "9 TECHNICAL NOTES on Brick Construction Manufacturing of Brick," 2006, www.gobrick.com.

MASONRY KEY FACTS

The following clay masonry facts have been extracted from industry publications[21] and a published LCA for bricks:[22]

- Markets for masonry are usually local and regional due to its high material weight. Masonry plants are commonly located close to mines.
- Structural brick has a documented long lifespan that is not captured in typical cradle-to-gate LCAs. However, if comparing two different brick products, their lifespans should be comparable.
- The embodied carbon impact of brick products is influenced by the availability of local materials (such as regional clay sources), appropriate waste and recycled material inputs, and the availability of landfill gas or other alternative fuels. This in turn can influence opportunities for innovation by manufacturers.
- A high percentage of bricks are re-used at end of life.

LCA ISSUES FOR MASONRY

Concrete masonry units

The LCA issues for CMUs are the same as for precast concrete. See Section 03 Concrete**.**

Clay masonry/bricks

The published LCA for brick and mortar products evaluated Canadian brick manufacturing highlighted that the majority of the energy use occurs during the drying and kiln firing of brick, and that supply is very local. No further LCA studies on clay or brick in North America have been identified besides that study in 1998.

Grout/mortar

The embodied carbon impacts of grout and mortar depend on the mix design of these products. Masonry grout and mortar are typically mixed at the building construction site, combining sand, masonry cement, and water in set proportions to meet strength requirements. Most grout and mortar are mixed using proportioning methods. The amount of cement used and impact of the cement production will be the primary driver of LCA impacts.

PCR/EPD STATUS FOR CONCRETE MASONRY AND CLAY MASONRY

Concrete masonry units

An industry-wide EPD for CMU's exists for Canadian producers but not for US producers. Some manufacturer-specific EPDs for CMU exist, one CMU producer with EPDs for seven products has been identified in Washington State.

[21] BIM; BIA, "Sustainability and Brick: Technical Note 48," 2015, www.gobrick.com.

[22] George J Venta, "LIFE CYCLE ANALYSIS OF BRICK AND MORTAR PRODUCTS," 1998, https://calculatelca.com/wp-content/themes/athenasmisoftware/images/LCA Reports/Brick_And_Mortar_Products.pdf.

Clay masonry/bricks

The Brick Industry Association is developing an industry-wide EPD for clay masonry. No US manufacturer-specific brick EPDs were found during the course of this study.

Grout/mortar

An industry-average EPD for masonry cement exists. The amount of variation between manufacturers is not known. Custom grout mix designs are rare and thus the variation in impact of grout and mortar would require careful study and implementation. Incentivizing the use of low-carbon masonry cement would be possible if manufacturer-specific EPDs for masonry cement were available.

Alternative materials

There are few LCA studies and no known EPDs for alternative materials. These materials are often locally produced and do not have large trade organizations to support the development of industry-wide LCA data. Information on low-carbon material options has been published by Architecture 2030 in their Carbon Smart Materials Palette,[23] which includes a qualitative assessment of the benefits of alternate materials.

INNOVATIONS IN MASONRY

The following are strategies that can lead to lower-impact masonry:

- For concrete masonry units:
  - Similar to concrete, eliminate the use of prescriptive concrete specifications in favor of performance-based specifications (see Section 03 Concrete).
  - Use alternative cementitious materials and methods to create lower-carbon concrete mixes.
- Source clay masonry from a producer with a low-carbon energy source.
- Source masonry locally. Some architectural bricks are traded internationally for desired colors and finishes, which are highly dependent of the clay materials available at a mine.
- Utilize alternative low-impact materials with similar functions (however, different performance characteristics would need to be addressed), such as:
  - Unfired clay/soil units
  - Units made of carbon sequestering materials such as straw/hemp
- Use low-carbon masonry cements in making grout and mortar.

[23] Architecture 2030, "Carbon Smart Materials Palette – Actions for Reducing Embodied Carbon at Your Fingertips," 2018, https://materialspalette.org/.

05 STEEL

This section presents an overview, key facts, LCA issues, status of PCR/EPDs, and innovations for concrete.

OVERVIEW

Steel is the primary metal used in structural applications in Washington State. For this reason, this technical review addresses only the structural steel components defined in (both 03-20 Concrete Reinforcement and 05 Metals), and does not address other metals such as structural aluminum or steel cable structures. Aluminum is commonly used for window systems and rarely as a structural element in buildings. Steel cables are primarily used in specialty tension roof structures and long-span suspension bridges, both of which are not common in current practice.

Steel is produced using two primary manufacturing methods in North America: 1) from a majority of raw material inputs in a basic oxygen furnace (BOF), and 2) from a majority of recycled steel in an electric arc furnace (EAF). Other production methods such as direct reduced iron (DRI) are being used increasingly in the US and are more frequently in India, the Middle East, and the Commonwealth of Independent (CIS) States, Russia included. Steel shapes are typically purchased by fabricators either directly from a steel mill or from a 'service center,' which is a regional facility that stocks common shapes for fast delivery. The discussions in this section apply to steel sections, sheet products, and rebar.

Table 3.6 describes the processes, sources of emissions, and strategies for reducing the emissions of steel through the early stages of its life cycle.

Table 3.6. Steel processes, sources of emissions, and strategies for reducing emissions.

	A1: Steelmaking	A2: Transportation	A3: Fabrication/Manufacturing
Description of processes	Creation of steel and rolling into generic sections such as wide flange beam or sheet steel	Steel is typically transported by rail or truck domestically and via boat internationally.	Fabricators transform steel material from generic section (e.g. 30 feet of steel beam) to the configuration needed for a specific building. This is typically done near the building site.
Sources of emissions	**BOF** • Chemical reaction between coke (coal) and iron ore • Combustion of fossil fuels • Upstream material mining and processing **EAF** • Electricity • Fossil fuel as energy • Upstream material processing	Combustion of fossil fuels	Facility operations: • Electrical use • Combustion of fossil fuels Project-specific impacts for fabrication (that do not require a furnace), such as: • Cutting • Drilling • Forming • Welding
Strategies to reduce emissions	• New/retrofit plants to increase plant efficiency and implement process innovations. • Change electricity source • Capture emissions • Recover and re-use steel shapes	• Prioritize rail and water transport • Use electric vehicles • Source locally	• Reduce intensity of fabrication effort (reduce welding and cutting) • Increase energy efficiency of equipment and facility • Change electricity source • Recover and re-use steel shapes

STEEL KEY FACTS

The following facts were extracted from a variety of publicly-available EPDs for steel unless otherwise noted:

- The embodied carbon of North American steel products for life cycle modules A1-A3 ranges between 0.6 and 2.4 kg CO_2e/kg steel. Steel sections produced in Chinese BOF mills is estimated at 2.9 kg CO_2e/kg steel.[24]
- The majority (over 90%) of emissions due to steel products occur during the steelmaking process (life cycle module A1).
- A smaller portion (less than 10%) of the GWP impact is attributed to transportation and fabrication (modules A2 and A3)
- EPDs of four rebar fabricators in Washington and Oregon report embodied carbon values ranging between 0.50 and 0.58 kg CO_2e/kg steel.

The following facts are from *Steel in Figures 2018* [25] unless otherwise noted (these relate to the global steel market, not just structural sections):

- Approximately 80% of US steel demand is met by US suppliers.
- The US is the largest global importer of steel, importing 25.2 million metric tons, (Mt).
- 68% of the 81.6 Mt steel produced in the US is via EAF.
- 83% of the 1,162 Mt of steel produced in Asia is via BOF.

Additionally, from interviews conducted with industry representatives during the course of this study, the following pieces of information are also important to note:

- As EAF's are powered by electricity, the emissions depend on the electrical grid carbon intensity.
- Some shapes (e.g. plates, pipes and large wide flanges) are not readily available from US EAF mills and are commonly imported or produced in US BOF mills.
- US sheet steel used in metal decks and studs are currently produced in a mix of EAF and BOF mills.
- US rebar is typically produced in EAF mills.
- The project team did not locate any EPDs or LCA data for pre/post-tensioned tendons. Some tendons are drawn from steel bar produced in US EAFs, while others are imported from unknown mill types.

LCA ISSUES FOR STEEL

Recycling

As global demand for steel exceeds the amount of steel available for recycling, a significant amount of 'virgin' steel must be produced. However, in the US, nearly 100% of US structural steel is recycled at end-of-life. The use of recycled steel as a material input can be seen as avoiding the production of virgin

[24] thinkstep, "China, Global Warming and Hot-Rolled Structural Steel Sections" (American Institute of Steel Construction, 2018), https://www.aisc.org/globalassets/aisc/publications/white-papers/global-warming-potential-of-chinese-and-domestic-hot-rolled-structural-steel.pdf.
[25] woldsteel, "World Steel in Figures 2018," 2018, https://www.worldsteel.org/en/dam/jcr:f9359dff-9546-4d6b-bed0-996201185b12/World+Steel+in+Figures+2018.pdf.

steel, referred to as an 'avoided burden' in LCA. However, not all LCAs report the impacts/benefits of steel recycling in the same manner. Some methods report this benefit as a negative (or reduced) impact or as credits for future recycling.

Allocation: Slag

During the purification process of steel production, impurities, known as slag, are removed from molten steel. Slag can have value; it can be ground and used as a cementitious material in concrete. Methods on how to allocate the impacts or benefits of slag vary. Some LCA studies treat this slag as a waste product (per the concrete PCR) while others (such as the aggregate PCR) treat it as a co-product. As a co-product, slag would take a share of the emissions of steel production, proportioning them by either mass or economic value, resulting in a reduced footprint for steel and an increased footprint for slag.

Grades of steel

LCA data for structural steel products do not commonly distinguish between different grades of steel. While steel is produced in different grades (denoting different strength and performance requirements), LCA results are not typically distinguished by grade. The differences in production relate to slight variations in chemical composition, and there is no known significant difference in energy requirements for these different grades. For mills that produce multiple grades of steel, plants do not typically track energy consumption separately by grade. Thus given current data using the same LCA results for different grades of steel appears to be appropriate.

PCR/EPD STATUS FOR STEEL

The steel PCR was published in 2015 by SGS Global Services.[26] It will not likely be updated to ISO 21930:2017 until 2020. This PCR covers the majority of steel products listed in Table 3.2. It excludes steel reinforcing bars with coatings, stainless steel reinforcing bars, and pre/post-tensioning strands.

Worldsteel collects LCI data for steel production globally. It also collects data from North American producers, and this data is used to estimate the production impacts (module A1) for North American industry average steel EPDs. Although not all steel manufacturers participated in the data collection to create this dataset, it is the highest quality LCA data currently available. The American Iron and Steel Institute (AISC) is in the process of updating the A1 steelmaking data, and new data should be available in 2019. Groups of fabricators have collaborated to produce average EPDs to integrate the average of upstream impacts (A1), transportation impacts (A2), and fabrication (A3) impacts. Four rebar producers in Washington have produced product-specific EPDs for their rebar production, including the mill-specific (A3) impacts. Notably, these EPDs report some of the lowest embodied carbon impacts reported for steel globally.

No EPDs currently exist for imported steel. Most whole building LCA tools use North American average data for steel production. Current LCA methods in practice do not effectively distinguish between the different production methods available for similar products. Unless steel EPDs are created using mill-specific data, or unless steel procurement is verified to match the local steel supply chain used in

[26] SCS Global Services, "North American Product Category Rule for Designated Steel Construction Products," 2015, https://www.scsglobalservices.com/files/standards/scs_pcr_steel-products_050515_final.pdf.

creating the EPD, using EPDs to distinguish between different fabricated steel products will not provide meaningful distinctions between products.

INNOVATIONS IN STEEL

The following are some strategies available now that can lead to lower-impact steel (these would require some deviation from the current practice of specifying and procuring steel):

- Procure steel from one of the mills included in the EPDs for steel products.
- Procure lower-impact steel with high-recycled content from regions with low-carbon electrical grids.
- Recover used steel and develop more robust and economical system for re-grading and re-warranting recovered structural steel.
- Encourage LCAs and EPDs for commonly used North American steel products that do not yet have them such as epoxy-coated rebar, pre/post-tensioning strands and stainless steel reinforcing bars.

The following are developing innovations in steel that have potential for lowering embodied carbon. These methods will require significant additional research and development investments:

- Process innovations for primary steel production as outlined in a steel industry fact sheet[27] include:
    - Redesigning the production process to integrate carbon capture and storage
    - Using hydrogen to replace carbon in chemical reactions during steelmaking
    - Using sustainably produced biomass as energy (or other low carbon energy sources)
    - Performing carbon capture and storage at the facility scale
- A Carbon Trust[28] report includes a list of actions that have the potential to reduce emissions per kg of steel by around 70 – 90% over the next 20 – 30 years.
- US industry and government bodies have invested in 'transformational technologies' such as Novel Flash Ironmaking.[29]

[27] worldsteel, "Fact Sheet: Climate Change Mitigation by Technology, Innovation and Best Practices," 2018, https://www.worldsteel.org/en/dam/jcr:0191b72f-987c-4057-a104-6c06af8fbc2b/fact_technology%2520transfer_2018.pdf.
[28] Carbon Trust, "International Carbon Flows Steel," 2011, https://www.carbontrust.com/media/38362/ctc791-international-carbon-flows-steel.pdf.
[29] DOE, "A Novel Flash Ironmaking Process | Department of Energy," 2016, https://www.energy.gov/eere/amo/downloads/novel-flash-ironmaking-process.

06 WOOD

This section presents an overview, key facts, LCA issues, status of PCR/EPDs, and innovations for wood.

OVERVIEW

Wood is used in building structures in many applications, such as dimensioned lumber (e.g. 2x4 stud wall), sheathing (e.g. plywood), shop-fabricated structural wood (e.g. wood I-Joists, etc.), and glued laminated (glulam) construction (beams, columns and cross-laminated timber (CLT)). Softwood lumber serves as both a finished product and a material input into fabricated elements known as *engineered wood products*. Table 3.7 presents the processes, sources of emissions, and strategies for reducing the emissions of wood products through the early stages of the life cycle.

Table 3.7. Wood processes, sources of emissions, and strategies for reducing emissions.

		A1: Manufacturing	A2: Transportation	A3: Fabrication
Description of processes	Softwood lumber	• Land preparation • Seedling preparation and planting activities • Thinning and harvest. Practices vary based on forest type and geography • Sawmilling activities	Via truck to mill	• Milling lumber to various sizes • Kiln-drying lumber (burning biomass and/or natural gas)
	Engineered wood	• Softwood lumber production (see above) • Adhesive manufacturing • Use of conveyor belts, fork lifts etc.	Raw materials (sawn lumber) is typically transported via truck from sawmills to manufacturing facility.	Wood members are shaped and fastened together using adhesives, heat and/or pressure.
Sources of emissions		• Fossil fuel as energy to power vehicles and other equipment • Biomass (wood chips etc.) as energy • Adhesive production • Production of fertilizers and other industry products, etc. • Waste disposal	Combustion of fossil fuels	• Burning wood chips • Burning fossil fuels • Electricity use.
Strategies to reduce emissions		• Increase plant efficiency • Better use of wood waste • Better wood recovery rates • Efficient/optimized resin use • Use of energy efficient drying and curing techniques.	• Prioritize rail and water transport • Streamline handling • Use electric vehicles	• Increase efficiency of equipment and facility • Capture emissions • Change electricity source • Efficient resource use
Pathway of biogenic carbon		• Carbon is converted to biomass via photosynthesis and stored in wood products • CO_2 is emitted (not reported in GWP) when biomass is combusted • Carbon remains in forest until wood residuals are burned, decomposed, or converted to soil carbon.	None	• Carbon remains in wood products, but is often emitted at end-of-life. • Carbon is emitted (but not reported in GWP) when biomass combusted.

WOOD KEY FACTS

Forest products and forests are part of a complex system that is difficult to model comprehensively using conventional LCA. Two open-access articles capture the complexities quite well addressing forest management and climate[30] and evaluating "tradeoffs in timber, carbon, and cash flow."[31] The following are some key facts about Washington structural wood and forests:

- Hardwood is not commonly used as a structural material.
- The most common species of structural woods grown in Washington State are Douglas Fir, Hemlock, and a Spruce-Pine-Fir (SPF) mix.
- Different woods have different performance characteristics and grow in different climates.
- Pacific Northwest structural lumber is typically higher in strength than the national average.
- Forestry practices vary significantly based on region, species, and forest type. In Washington State, there are two general regions separated by the Cascade Mountains: the Western forests, which tend to be wetter, and the Eastern forests, which are drier.
- The majority of wood that ends up in forest products produced in Washington is from private and state forests in Western Washington.
- Of Washington State's 43 million acres of land, approximately 22 million acres are forested.[32]

There are notable, publicly available LCA reports for wood products both as research[33] and as EPDs.[34] Some key facts from these publications include:

- At a national level, data shows an overall increase in the carbon stored in forests each year.[35]
- Current LCA practice treats all forest management practices as the same, using national data for forest management and harvest.
- Emissions from forestry practices account for less than 20% of typical wood product carbon footprint. Note that this does not model the carbon balance of the forest, just the emissions from harvesting wood.
- Wood production is often powered by a combination of burning wood waste (biomass) and fossil fuels with the majority of emissions related to drying lumber.
- Increasing the use of biomass as fuel can reduce product GHG emissions, since biomass emissions can be treated as carbon neutral. However, this policy only has grounds for as long as forest carbon remains neutral or is increasing in the region where the wood products are coming from.

[30] Stephen Fain et al., "Managing Moist Forests of the Pacific Northwest United States for Climate Positive Outcomes," *Forests* 9, no. 10 (October 9, 2018): 618, https://doi.org/10.3390/f9100618.
[31] David Diaz et al., "Tradeoffs in Timber, Carbon, and Cash Flow under Alternative Management Systems for Douglas-Fir in the Pacific Northwest," *Forests* 9, no. 8 (July 25, 2018): 447, https://doi.org/10.3390/f9080447.
[32] Washington Forest Protection Association, "Washington Forests," 2006, http://www.wfpa.org/our-forest-today/washington-forests/.
[33] CORRIM, "LCA's on Wood Products," accessed December 18, 2018, https://corrim.org/lcas-on-wood-products/.
[34] AWC, "Environmental Product Declarations (EPDs) for Wood," accessed December 18, 2018, https://awc.org/sustainability/epd.
[35] EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015," 2017.

LCA ISSUES FOR WOOD

Standard wood product LCAs track the impacts of managing forests and harvesting timber, and allocate these forest management emissions to wood products. LCA is well-suited to track the industrial emissions of harvest and manufacturing, but it is not as well-suited to track the impacts and benefits to the forest itself. The assumptions made in conducting forest-level assessments can have a significant impact on the results.[36] Forestry systems are frequently evaluated in LCA assuming *carbon neutrality*, which assumes that the release of carbon dioxide due to burning biomass (e.g. wood chips) for energy production (biogenic CO_2) is balanced by the carbon dioxide that is sequestered by growing the same amount of biomass. This carbon neutrality is not necessarily true in a global context. LCA does not commonly capture the carbon impact of treating forests for forest fire mitigation or retaining additional trees for stream protection or habitat preservation.

Production of wood products also generates co-products or waste (wood chips etc.). Depending on the LCA methods chosen, the impacts of producing a wood product can be allocated (by mass or economic value) to these co-products. Mass allocation is less conservative, in a way, resulting in a lower estimated impact of wood products. For example, this method reduces the product emissions by around 10% for a glue laminated beam.[37]

Wood products store the carbon that was removed from the atmosphere and converted into tree mass during photosynthesis, a process known as *carbon sequestration*. LCA often reports this quantity of carbon as a net negative impact or a "carbon credit." However, carbon removed from forest takes years to re-grow and at the end of life is often emitted in landfills or through combustion. The fact that the value of this credit varies depending on the temporal frame of reference is not commonly addressed.

Although the management of the forest has an impact on total carbon, there is no agreement on how to integrate these impacts into interpretation of LCA results. ISO does recognize that forest certification such as the Forest Stewardship Council (FSC) or Sustainable Forest Initiative (SFI) can be a measure of forest sustainability.

PCR/EPD STATUS FOR WOOD

The American Wood Council has published industry average EPDs for seven different structural wood products: softwood lumber, softwood plywood, oriented strand board, glued laminated timbers, laminated veneer lumber, wood I-joist and laminated strand lumber. This PCR conforms to ISO 21930:2017. The third version of the North American PCR for wood products is open for public comment as of the time of this publication and an update should be published in early 2019.

Current wood EPDs report industry average data for both the softwood lumber production and the manufacturing of engineered wood products. Mill surveys were collected in order to create these average datasets. Developing manufacturer-specific EPDs separately for mills (e.g. softwood lumber

[36] Stephen Fain et al., "Managing Moist Forests of the Pacific Northwest United States for Climate Positive Outcomes," *Forests* 9, no. 10 (October 2018): 618, https://doi.org/10.3390/f9100618.
[37] Tait Bowers et al., "Cradle-to-Gate Life-Cycle Impact Analysis of Glued-Laminated (Glulam) Timber: Environmental Impacts from Glulam Produced in the US Pacific Northwest and Southeast*," *Forest Products Journal* 67, no. 5–6 (September 2017): 368–80, https://doi.org/10.13073/FPJ-D-17-00008.

production) and engineered wood products (e.g. glue laminated beam production) would enable differentiation between similar wood products.

As highlighted in the development of the wood PCR: "EPDs do not address different forest management activities that influence wildlife habitat, endangered species, and soil and water quality, these potential impacts may be addressed thorough other mechanisms such as regulatory frameworks and/or forest certification systems which, combined with EPD results will give a more complete picture of environmental and social performance of wood products."[38]

INNOVATIONS IN WOOD

The following are some strategies available now that can lead to lower-impact wood products:

- Purchase wood products from efficient manufacturers using low-carbon or carbon-neutral fuels.
- Purchase wood products from local suppliers, thus reducing the transportation impacts.
- Recognize specific forest practices (e.g. by jurisdiction based on forestry regulations, by certifications, or from DNR fire-thinned forests) as 'carbon smart' to differentiate between products.

The following are developing innovations in wood that have potential. These methods will require research and development investments to implement effectively:

- Move toward longer rotation forestry (50–75 years) in the moist forest region based on regionally specific analysis rather than the current business as usual of 38-44 years[39].
- Establish methods to differentiate forest management and product pathways that increase the total carbon in forests and in long-life wood products and represent these differences within wood product LCAs.

[38] ULe, "Part B: Structural and Architectural Wood Products EPD Requirements," 2018, www.ul.com/businesses/environment.
[39] David Diaz et al., "Tradeoffs in Timber, Carbon, and Cash Flow under Alternative Management Systems for Douglas-Fir in the Pacific Northwest," *Forests* 9, no. 8 (July 25, 2018): 447, https://doi.org/10.3390/f9080447.

3.3 TECHNICAL SUPPORT OF EPD PRODUCTION

EPDs provide the essential information needed to comply with any Buy Clean regulation, but EPDs are not yet commonplace in the building industry. Most product manufacturers will have to create EPDs if they want their products to be used on Buy Clean projects.

In order to create an EPD, a supplier will usually commission a consultant to perform LCA calculations. A consultant with expert knowledge can ensure that the calculations and supporting data comply with ISO 21930. However, the creation of an EPD can be simplified with the creation and use of an LCA or EPD calculator that standardizes the common inputs (e.g. quantity of material, energy source type and use etc.). LCA standards permit the use of self-declared EPDs. A Washington Buy Clean policy could recognize self-declared EPDs produced using approved EPD calculators and documentation, saving time and money for product manufacturers. Furthermore, if these calculators are configured to assume conservative estimates of production variation, suppliers could still be motivated to commission manufacturer- or facility-specific EPDs in order to cast their products in a "better" light. Section 3.4 recommends development of Washington State-specific LCA studies for benchmarking purposes. These studies would be useful to inform EPD tool development. As mentioned in **Chapter 2: Policy Review**, some governments (e.g. Oregon and France) have provided technical support to help facilitate broader adoption of EPDs in their jurisdiction.

The following are suggestions that the State could adopt to facilitate the creation of EPDs for Washington businesses, and could help the industry adopt better-aligned LCA data.

ACTIONS TO IMPROVE EPDs

In order to improve the quality, availability, usability, and comparability of EPDs in general, the following technical issues should be addressed:

1. **Quality: Align LCI databases**. Life cycle inventory (LCI) databases provide the background data (e.g. emissions for power generation or truck transport) to generate the data used in an EPD. The US LCI database is not adequately supported. Two initiatives are underway that need additional support: a developing Canadian initiative to create a LCI database (see **Appendix C.2**) and an effort create a North American LCI database (see **Appendix C.3**). Ideally these two initiatives would be integrated for efficiency and alignment.
2. **Availability: Incentivize EPD production.** Providing technical and financial support for Washington structural material suppliers will help local manufacturers produce more EPDs. LCA consultants have developed customized EPD tools for different industries that could be customized for Washington producers. Both Oregon and California have provided education, technical, and financial incentives to help producers develop EPDs.
3. **Usability: Collect and compare EPDs.** As there are multiple EPD program operators hosting EPDs in different places, it can be difficult for consumers to find EPDs. Additionally, EPDs are complex and non-uniform documents. A searchable EPD database and material quantity reporting tool could help facilitate use of EPDs in design and procurement.
4. **Comparability: Develop benchmarking methodology**. As summarized below, different materials have different opportunities and challenges for embodied carbon reduction. Given that the average impact of current practice is not yet known, the project team recommends

developing data-driven benchmarking methodology for each material category, allowing for the incorporation stakeholder input and continuous improvement over time.

The following are actions to improve the quality of EPDs specific to each structural material category.

Concrete/CMU

Given that over 90% of the impacts of concrete can be attributed to the upstream material production, developing a Washington-specific concrete EPD calculator would be beneficial. This simplified EPD calculator could be customized to address regional variability in the supply chain for upstream materials. Specifically, this calculator could:

- Utilize conservative default values for mix design inputs. This would allow concrete suppliers to easily generate self-declared or third-party-verified EPDs from standard mix design specifications, which are included with all structural concrete specifications.
- Allow manufacturers who wish to capitalize on their own manufacturing efficiencies to produce a plant-specific EPD.
- Recognize known variability in the cement supply chain, as specified in the upcoming version of the concrete PCR (version 2). This can be done one of two ways: 1) cements that are not captured in US or Canadian industry-wide EPDs should produce facility-specific EPDs, or 2) conservative default values could be applied to all cements that do not report facility-specific EPDs. Given that the two Washington cement producers have not published facility-specific EPDs, the impact of this policy option on local companies is unknown.

Masonry

For concrete masonry units, see “Concrete/CMU EPDs” above. For clay unit masonry, given that there is only one structural clay masonry producer in Washington, developing an EPD calculator would not justified however support for EPD creation could be beneficial. Masonry grout and mortar could be integrated into a concrete EPD calculator.

Steel

Given that over 90% of the impacts in steel products can be attributed to steel production, refining Washington steelmaking data for steel used in Washington would be the most logical point of focus. The remaining impacts due to fabrication could be assumed using conservative estimates. Specifically, Buy Clean policy could:

- Specify that the facility of interest for steel products is the steelmaking facility (not the fabrication facility). Impacts for steelmaking could be obtained by one of several methods:
    - Obtain an EPD from the steelmaking facility or steel mill from which the steel product was sourced (The one steel mill in WA State has produced a facility specific EPD).
    - Require that a steel fabricator-specific EPD includes supply chain-specific estimates of the steelmaking impacts (as is currently done by multiple rebar fabricators for their facility-specific EPDs).
    - Create an EPD based on supply chain of a service center. Service centers are the primary distributors of steel for small to medium projects. The variability in service center supply chains has not been evaluated.

  - Assume conservative (high) default estimates of steelmaking impacts in order to incentivize the creation of facility-specific steelmaking EPDs.
- Develop a simple EPD calculator to estimate the fabrication impacts of different product types. Ideally, this would draw upon data that has already been collected for industry trade organizations. The data could be used to establish a conservative estimate of the embodied carbon impacts of current practice (e.g. greater than 80% of current producers).
- Allow manufacturers wishing to recognize their own manufacturing efficiencies to commission a facility-specific EPD.

Wood

The carbon impacts of forest products arise in three distinct phases of the wood supply chain: forest management, harvesting, and wood product production. To better capture the embodied carbon impacts of wood products, Buy Clean policy could:

- Provide standardized calculation methods to compute sawmill-specific EPDs. This would enable engineered wood product manufacturers to create supply-chain specific EPDs of their products.
- Create an EPD calculator for Washington State engineered lumber products, which could then be used to develop facility-specific EPDs.
- Establish methods to recognize 'carbon smart' forestry products in EPDs.

State support for these initiatives would help advance technically accurate Buy Clean practices

3.4 ESTABLISHING EMBODIED CARBON PERFORMANCE TARGETS

In order to reduce embodied carbon in procurement decisions, meaningful performance targets should be set. These performance targets would ideally be established based on benchmarks, estimates of current practice, and would vary depending on the material category. Considerations for establishing performance targets are numbered 1-3 as follows:

1. **Commission material-specific benchmark studies.** Developing supply chain-specific studies that include the evaluation of variability for materials used in Washington State would provide useful data to help establish reasonable benchmark values. National average data would not necessarily reflect the supply chain of Washington suppliers. Additionally, currently available industry data presents averages without information on the statistical distribution of the data. As noted in item 3 below, industry benchmarks may not be the most appropriate performance target. Material-specific considerations for benchmarking studies are as follows:
   - **A concrete/CMU benchmarking study** that divides the state into 6-9 regions, similar to the NRMCA Benchmark LCA report,[40] would enable better understanding of the current state of practice. This data could also support the development of an EPD calculator.
   - **A clay masonry benchmarking study** would not be meaningful nor economical given the goals of this Buy Clean study since there is only one structural clay masonry producer in Washington State. However, a study into clay masonry benchmarking could be valuable for non-structural (architectural) applications but beyond the scope of this study.

[40] Athena Sustainable Materials Institute, "NRMCA Member National and Regional Life Cycle Assessment Benchmark (Industry Average) Report-Version 2.0 Prepared for: National Ready Mixed Concrete Association (NRMCA)."

- **A steel benchmarking study** specific to Washington would add value. Many steel fabricators participated in the studies for the industry average/'representative' EPDs. The variation in embodied carbon would depend on different supply chain options for each of the different structural steel products.
- **A wood products benchmarking study**: The North American wood industry has supported significant surveys of production methods across the state and region, but it currently reports data as a national average and does not report variability. A Washington-specific study could be used to create regionally-specific LCA reports that address the varying effects of forest management, harvest, and production processes in Washington State. It might be appropriate to divide forests into different zones and could help inform simplified methods to recognize forest management in EPDs.

2. **Normalize material impacts to compare to targets.** Setting fixed performance targets for generic material categories (e.g. "all steel shall be less than *X* $kgCO_2e$/kg steel") risks limiting design and construction teams from meeting needed performance requirements at specific applications. Using weighted averages over a full building would allow flexibility to address design and construction issues. Additionally, tracking material impacts per unit area of construction could provide useful data. See discussion in **Chapter 5** and **Appendix C**.
3. **Set achievable performance targets and establish a roadmap for improvement:** Setting a target at industry average could discourage disclosure and result in cost increases if a limited number of suppliers meet the target. Rather, setting a target that is achievable today (e.g. by 80% of market) would likely help incentivize disclosure. Developing a timeline to reduce targets could then be developed tied to data-driven opportunity roadmaps specific to each industry.

3.5 DISCUSSION

It is essential to emphasize that the assumptions for this Buy Clean study is founded on procurement decisions to compare between materials of the nearly same performance characteristics. It is not appropriate to compare different material EPDs without integrating into a full LCA. Examples of issues that are not addressed by this study and that should be addressed at the whole building scale are:

- Impacts on operating energy (thermal mass, insulation).
- Impacts on building lifespan (seismic performance, durability)
- Scenarios for material re-use (circular economy)

When designing an effective Buy Clean policy aiming to reduce the embodied carbon of building materials, the following key issues should be considered:

- Different structural materials have different supply chain structures, different technical issues, different embodied carbon opportunities and operate at different scales. No 'one size fits all' policy will be equitable for all materials.
- Efficiencies of scale show up in both cost and carbon impact. Small and developing enterprises may inherently be less energy efficient per unit of product resulting in higher embodied carbon.
- Some products/processes are electricity dependent. Others depend on on-site combustion of fossil fuels. Some processes emit CO_2 during chemical reactions that take place during manufacturing. Decarbonizing the electrical grid is not sufficient to drive towards zero carbon manufacturing in Washington State.

CHAPTER 4:

PILOT STUDY

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CHAPTER 4: PILOT STUDY

4.1 OVERVIEW

A. INTRODUCTION

The Washington State Engrossed Substitute Senate Bill (ESSB) 6095[1] commissioned two scopes of work for the purpose of piloting the proposed Buy Clean Washington requirements:

1. **Buy Clean Washington Pilot (Sec. 1030)** authorized the Department of Enterprise Services (DES) to coordinate with five state-funded pilot projects and the University of Washington (UW) College of Built Environments to assess availability of facility-specific EPDs for eligible materials used on selected projects.
2. **Buy Clean Washington Study (Sec. 5014)** authorized an academic research team (UW, CWU, WSU) to develop pilot methods to support information collection. This resulted in a proposed system to categorize eligible structural materials and a method to report EPDs and structural material quantities and origins.

This chapter describes the proposed systems and methods for information collection, which includes model project specifications (formatted according to MasterFormat style of construction specifications) and a reporting template for reporting material quantity information. Also included in this chapter is a brief assessment of potential costs and next steps for the pilot projects. The pilot projects are still in the early stages of development and thus detailed feedback is not possible at this time.

B. PILOT PROJECTS

The Buy Clean Washington Study research team coordinated with DES to engage with pilot project managers and provide background on proposed Buy Clean Washington requirements and study goals. The research team assessed project schedules to understand the timeframe for testing pilot requirements. Initial engagement helped inform pilot methods developed during the study, described in Section 4.2. Table 4.1 provides an overview of the public works projects that participated in the pilot phase.

[1] Washington State Legislature, "SB 6095 - 2017-18 Concerning the Capital Budget," 2018, http://apps2.leg.wa.gov/billsummary?Year=2017&BillNumber=6095&Year=2017&BillNumber=6095.

Table 4.1. Pilot projects.

Project (project number)	Use	Current stage	Primary structural system	Project delivery method	Estimated bid date	Estimated construct-ion date	Estimated completion date
Washington State University Tri-Cities: new academic building (30001190)[2]	Instructional facility (laboratory and classroom space)	Design, construction document (12/2018 to 11/2019)	Unknown	GC/CM delivery	(design consultant contract – June 2018) (final construction contract – Oct. 2019)	Jan. 2020 - Feb 2021	Dec. 2020 (substantial completion)
Western Washington University: Life Sciences building addition and renovation (1730000768)	Instructional facility (laboratory and classroom space)	Schematic design	Unknown	GC/CM delivery	June 1, 2018	Dec. 20, 2019	Occupancy expected by Aug. 27, 2021
Shoreline Community College: Allied Health, Science, and Manufacturing Replacement (30000990)[3]	Multi-purpose instructional facility	Design develop-ment	Structural steel frame supporting concrete floors on metal deck and composite steel beams	Design-bid-build	July 2019	August 2019	June 2021
Secretary of State: Library-Archives Building (30000033)[4]	Office and public spaces, and storage	Pre-design funded but not completed	Unknown	GC/CM delivery	RFQ for architects due 2/12/19	N/A (est. 30 months duration)	Late 2021
Department of Transportation: SR9/Snohomish River Bridge Replacement (N00900R)	Transportat-ion (rural/ urban mobility)	Start pre-design in July 2019 (preliminary engineering Oct. 2019-June 2022)	(old bridge – steel thru truss, CIP conc. Deck steel floor beams/ stringers precast concrete girders	Design build	Mid-2021 (design build solicitation)	May 2022 – June 2027	Q4 2026 (operation-ally complete)

[2] Western Washington University Office of Facilities Development & Capital Budget, "Sciences Building Addition Request for Qualifications," 2018, https://www.wwu.edu/wwuarchitect/consultants/documents/PW733-Sciences-Building-Addition-RFQ.pdf.
[3] Shoreline Community College, "Health Science & Advanced Manufacturing Classroom Complex," 2017, https://des.wa.gov/sites/default/files/public/documents/Facilities/EAS/2018-102/HSAMCC Predesign.pdf.
[4] State of Washington Office of the Secretary of State, "2018 Supplemental Capital Budget," 2017, https://www.sos.wa.gov/_assets/office/2018_supplemental_capital_budget.pdf.

4.2 PROPOSED METHODS AND TEMPLATES

The purpose of the pilot phase is to assess the availability of current structural material EPDs and understand barriers that project teams may face when accessing EPDs. Additionally, the pilot phase aims to test methods developed by the study team supporting the collection of EPDs and other material information. Note that no penalization or additional effort would result to project teams if product suppliers were unable to provide EPDs during the pilot phase.

In the pilot phase, state awarding authorities will request the following information for eligible materials:

1) facility-specific EPDs
2) material quantity data (e.g. pounds of steel produced)
3) material origin data (e.g. supplier contact address)

To support this information gathering, the research team developed the following:

a) A general methodology to communicate and report requirements
b) A set of model construction specifications with language specifying these requirements
c) An Excel-based reporting sheet for pilot teams to record and submit information

A. GENERAL METHODOLOGY

This section outlines a general methodology for testing requirements on pilot projects. However, due to variances in pilot project schedules and delivery approaches, this is not a prescriptive procedure to uniformly apply across selected projects. Section 4.4 discusses this further and presents alternative options to reflect varying contexts.

The methodology consists of the following steps:

1. State awarding authorities shall reference Buy Clean Washington requirements in advertised RFQs for pilot projects, where possible (contingent on pilot project schedules – some may have already completed the bidding phase).The research team recommends that RFQs should be supplemented with a separate attachment specifying pilot clean requirements and guidelines for complying.

2. Buy Clean Pilot requirements shall be added to the specifications for the bid package. Model specifications are described in the next section.

3. Lead contractor(s) of awarded contracts shall communicate pilot requirements to product suppliers of eligible materials and assess availability of (or capability to provide) information before construction. Contractors would be responsible for reporting to the state project manager any foreseeable barriers using a reporting template.

4. Product suppliers shall complete a reporting template (presented in Appendix B2) to submit material quantity and origin data, and if an EPD is available, a link to the published PDF of the EPD and if no EPD is available, report barriers to obtaining an EPD

5. Contractors shall collect and report data to state project managers before eligible materials are installed.

B. MODEL SPECIFICATIONS

The research team reviewed documentation with model specification language for state-funded projects to assess options for incorporating Buy Clean requirements into current guidelines (e.g. online contract manuals and instructions to bidders). The research team recognizes that each state awarding authority has entity-specific guidelines and standard language that it applies across bid requests to award new public works contracts. Considering the time, coordination and resources needed to adapt and communicate changes to contracting manuals and other agency procurement guidelines, the project team aimed to develop a standard template that all awarding authorities could attach as a supplement to core documents commonly used to specify project requirements to potential bidders.

Appendix B.1 provides the proposed attachment specifying Buy Clean Washington pilot requirements in the form of OmniClass model construction specifications. The model specifications outline general requirements for the Buy Clean Washington pilot and specifies information needed to meet requirements. The University of Washington team will refine the recommended specifications with input from the pilot teams by June 2019 and post updates online at http://www.carbonleadershipforum.org/buy-clean-washington/.

C. REPORTING TEMPLATE

The reporting template is presented in the form of a table in **Appendix B.2**. Structural material quantity reporting focuses on constituent materials (e.g. steel and concrete) rather than structural type (e.g. steel framed building), since buildings of a primary structural material category typically include other materials (for example, a steel frame building typically includes foundations made of reinforced concrete). The University of Washington team will refine this template with input from the pilot teams by June 2019 and post updates online at http://www.carbonleadershipforum.org/buy-clean-washington/.

Structural material quantity reporting requirements for constituent materials, namely concrete (including grout), masonry, steel, and timber, are summarized in the following subsections.

CONCRETE (INCLUDING GROUT)

Structural material quantity reporting for concrete and grout shall include the material supplier and address, the specified compressive strength (psi), and the volume (cubic yards). Additional optional reporting includes the slump, the supplier mix designation, the structural component or components where the material is used, and whether the material is used precast or in-situ.

MASONRY

Structural material quantity reporting for masonry units includes the material supplier and address, the type of unit (concrete (CMU) or clay brick), the ASTM material designation, the specified compressive strength (psi), the unit weight (pcf), the unit dimension, and the number of units. Additional optional reporting includes the supplier mix designation.

STEEL

Structural material quantity reporting for steel includes the material supplier and address, the product type (structural steel, steel reinforcement (rebar), prestressing tendons, or steel decking), the ASTM material designation, and the weight (pounds). Structural steel includes steel plates and structural steel sections. Structural steel sections are typically selected from the shapes specified in the AISC Steel Construction Manual but may also include built-up or custom structural steel sections fabricated from plates (e.g., plate girders). Additional optional reporting includes the grade and whether the steel is coated or uncoated.

WOOD

Structural material quantity reporting for timber includes the material supplier and address, the product type (boards, plywood, oriented strand board (OSB), laminated veneer lumber (LVL), glued-laminated timber (GLT or Glulam), and cross-laminated timber (CLT)), the ASTM material designation, and the volume (cubic yards). Additional optional reporting includes the dimensions, the species, the grade, and the number of plies. For boards, the number of plies is one. For OSB the number of plies (layers) is not applicable and should be reported as "N/A" (not applicable).

4.3 POTENTIAL COSTS

The potential costs for the pilot projects are projected to be as follows:

1. **Costs to design teams to implement specs**: This is estimated to be low. Following recommendations developed as part of the California Buy Clean implementation, the project team recommends not modifying the standard construction specification process. Rather, teams shall attach an additional document to the standard specifications. The estimated time requirements of implementing the specifications by design/construction team are as follows:
    a. Introductory discussions: 4 hours
    b. Evaluation of process and filling survey: 8 hours
    c. Writing specifications, including back-checking requirements: 8 hours
2. **Effort to collect and report data**: The cost for this is unknown. However, the work of collecting and reporting EPD data can be facilitated by developing EPD datasets. Estimate between 2 days and 2 weeks of a project engineer to complete.
3. **Impact on construction costs**: Cost unknown-expected to be low. Without mandating EPDs or setting any performance targets, no change to costs of materials or produces would be expected. Construction estimates might increase to absorb both the effort identified in item 2 above and to cover any perceived risks of complying with the pilot project.

4.4 PILOT STUDY NEXT STEPS

As shown in Table 4.1, there is notable variance between pilot project schedules and delivery approaches. Therefore, it is challenging to propose a uniform approach and timeline to test requirements across selected projects. Further, DES is required to complete the Pilot Phase by June 2019, and the supplementary Buy Clean Washington Study (this report) is final in December 2018. A timeline extension would be needed to support state agency personnel and/or external researchers to test methods developed by the study and collect information from pilot project teams.

The research team recommends using a simplified approach to pilot methods that limits any disruptions to current project schedules and work streams, especially since several consultants and contractors have already been selected for some projects (design stage underway), whereas other projects are not scheduled to advertise contracts in the near-term. Further, no additional support is currently provided to support contractors to work with product suppliers to collect or generate EPDs.

Given that the different projects are in different stages of development, the research team recommends the following steps to assist pilot teams in implementing the pilot project. The University of Washington project team members will be able to convene and coordinate these efforts with DES through June of 2019 given the current project funding and timeline for UW.

Jan. 2019	**Introduction:** Present the proposed framework to pilot teams via web conference and solicit feedback via discussion.
Feb. 2019	**Stakeholder discussions:** UW CLF to host discussions to evaluate reporting method.
March 2019	**Collect feedback:** Distribute pilot specification language and reporting methods to pilot teams and interested stakeholders and solicit feedback through a survey.
June 2019	**Refine:** Update pilot specifications and reporting template and distribute to pilot project teams.
June 2019	**Report:** DES to provide preliminary reports to legislature fiscal committees
2019 - on	**Implement:** The requirements of the specifications will be met by construction teams and material suppliers as the construction process unfolds. **Evaluate:** DES to collect reports and survey teams to evaluate the impacts of the process.

As the pilot projects are on differing schedules, the project team recommends that DES staff check in with project teams in September of 2019 and in subsequent years track the project development through final construction and reporting. The Buy Clean Washington Study team recommends that the reporting template be integrated into an organized data collection method to ensure that the results can be analyzed to inform future policy.

CHAPTER 5:

POLICY EVALUATION

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CHAPTER 5: POLICY EVALUATION

5.1 INTRODUCTION

This chapter presents an analysis of a general Buy Clean policy framework (based on the Buy Clean California Act[1] and HB: 2412 - Creating the Buy Clean Washington Act[2]), outlines a pathway to develop Buy Clean policy and supporting standards, discusses potential impacts of policy implementation, and identifies investments that could help support embodied carbon policy implementation.

5.2 BUY CLEAN POLICY FRAMEWORK

This section describes key components underpinning Buy Clean policy, providing a basis to assess policy options, approaches and potential impacts, described in more detail in later parts of this report chapter. The 'Buy Clean' framework is based on 1) the current Buy Clean California Act - signed into law in October 2017, 2) the originally proposed HB: 2412: Creating the Buy Clean Washington Act - introduced to the Washington State legislature in January 2018, and 3) lessons learned from evaluation of global embodied carbon policies (see **Chapter 2: Policy Review**). Key components of Buy Clean policy include:

1. **GOAL:** Policy addresses two goals to reduce the carbon impact of construction:
   - Incentivize disclosure of embodied carbon
   - Set performance targets to measure and reduce embodied carbon
2. **SCOPE:** The scope of policy mandates is limited to:
   - Procurement of construction materials for state-owned facilities and infrastructure
   - Enable product choices within a material type, rather than between material types
   - A selected list of 'eligible materials'
3. **METHOD:** Policy uses life cycle assessment (LCA) to disclose and evaluate embodied carbon.
   - Use of EPDs to evaluate embodied carbon
   - Setting a global warming potential (GWP) performance target based on LCA
   - Demonstrating compliance as part of construction process
   - Establish reporting mechanisms and methods to establish conformance/exemptions.
4. **TIMELINE:** Policy establishes an appropriate timeline to build industry capacity:
   - Voluntary submission of EPDs and/or testing with pilot projects
   - Mandatory submission of EPDs
   - Performance targets established and mandatory
   - Performance targets reviewed and updated as appropriate
5. **IMPLEMENTATION/EVALUATION:** Effective implementation and evaluation should include:
   - Support for local manufacturers to develop EPDs
   - Education and outreach to design, construction and facilities professionals
   - Creation of a centralized database of material quantities, origin and EPD results
   - Regular evaluation of progress connected to global material de-carbonization roadmaps

[1] California Legislative Information, "Buy Clean California Act [3500 - 3505]," 2017, https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5.
[2] Washington State Legislature, "HB 2412 - 2017-18 Creating the Buy Clean Washington Act," 2018, https://app.leg.wa.gov/billsummary?BillNumber=2412&Year=2017.

Based on assessment of selected US-based and global embodied carbon policies, the following guiding principles can inform best practices for policy development and potential implementation. The potential investments listed in Section 5.6 would support broad application of guiding principles, but they are not necessarily contingent on supplemental funding. The guiding principles include:

1. Establish clear and consistent messaging around policy goals and key components; e.g. emphasize that policy aims to compare related material types vs. make comparisons between different material types.
2. Provide opportunities or mechanisms for feedback from stakeholder groups. Consult (and consider input from) industry representatives from both the supply-side (manufacturers) and demand-side (architects, building owners), as well as technical LCA experts in order to reflect material-specific nuances in policy language and/or implementation guidelines.
3. Identify potential resources (e.g. organizations, people, professional reports, etc.) that decision-makers can leverage during policy development, particularly when and where there are technical complexities and issues related to supply chains and environmental LCA reporting.
4. Assess the timeline of potential implementation and pilot projects against the timeline of upcoming large state-funded projects.
5. Where possible, develop policy that encourages innovation and provides benefit to product manufacturers who meet compliance standards.

5.3 GENERAL ANALYSIS OF BUY CLEAN CALIFORNIA

The Buy Clean California Act addresses components noted in the Buy Clean Policy Framework (Section 5.2). There is no pre-established roadmap, tested framework or formal evaluation of Buy Clean policy. Case studies from individual construction projects and international policies with similar standards provide lessons learned, but there is no comparable model of US state-level procurement policy that establishes standards for environmental disclosure and performance targets.

California will incrementally introduce Buy Clean standards, starting in January 2019. The research team has gathered information and lessons learned from Buy Clean California policy development and implementation planning, but there are many unknowns that could take several years to understand and evaluate. Based on qualitative evaluation of the Buy Clean California Act, this section provides further analysis of its key components against the policy framework outlined in Section 5.2.

GOALS

The original Buy Clean California Act (which informed bill language proposed by Washington) was intentionally simplified and tied to high-level goals, such as reducing global carbon emissions through encouraging low carbon manufacturing practices. Shaped by brief language to define standards, the original bill was moved forward by policymakers and advocates motivated to pass it into law in the near-term legislative cycle. Its simplicity was intended to allow clear and digestible communication of standards, which by nature, are complex and technical, particularly since requirements would apply across product markets with varying supply chains and material-specific nuances.

Succinct bill language helps ensure legislative and other stakeholders (whose endorsement is key to move regulation forward) can understand policy and communicate its broad goals and parameters. Detailed, exacting language can lead to rigid standards unresponsive to continually evolving product markets, whereas broad, simplified language allows potentially flexibility to interpret and adapt guidelines as needed. However, brevity and limited detail – especially related to standards that would require a depth of technical knowledge from affected industry groups – can risk confusion, concern and differing interpretations of requirements, and may not reflect the complexities and variances unique to each product market.

The goals underpinning the Buy Clean California Act are two-pronged: 1) Disclosure: through the EPD requirement, policy aims to accelerate adoption of reporting practices that improve product transparency, and 2) Performance: through the pre-calculated GWP thresholds, policy aims to limit levels of embodied carbon emissions, and thereby, move product suppliers to adopt 'low carbon' manufacturing processes (relative to respective product markets).

While the bill itself is not explicit on broader policy vision, content developed by advocates for the bill provides insight. Overall, the Buy Clean policy vision aims to accelerate the reduction of embodied carbon emissions attributed to construction materials through using purchasing power to address the 'carbon loophole'. Recent press articles[3,4] support other reports[5] that clarify and assess the carbon loophole issue.

SCOPE

The scope of Buy Clean policy shaped by California enables state government to consider environmental performance of facilities and infrastructure it *owns,* and thereby, directly position state awarding authorities to address embodied carbon attributed to public procurement. In the broad landscape of both public- and private- funded construction projects, the immediate impact that state-level procurement policy would have on transforming industry-wide practice and realizing large emissions savings may be limited, but it could accelerate incremental shifts and provide a roadmap for commercially-focused policies, resulting in cumulative benefits over time.

As described in **Chapter 3: Technical Review**, construction materials result in carbon emissions and other environmental impacts throughout all the main lifecycle stages of a building: (A) production and construction, (B) use, (C) end-of-life, and (D) impacts beyond the system boundary. LCA is typically applied to assess impacts occurring throughout all stages (cradle-to-grave) or occurring during one defined stage (e.g. cradle-to-gate). The scope of Buy Clean policy considers cradle-to-gate impacts, and does not necessarily assess the holistic picture of environmental impacts incurred by a material over its lifecycle phases (e.g. maintenance, repair, replacement, or end-of-life disposal).

The defined scope of Buy Clean does not account for potential emission 'trade-offs' of material types. For instance, a material may result in high emissions during manufacturing, but in other life cycle phases, it could contribute to significant emissions savings (e.g. energy efficiency gains and/or

[3] Brad Plumber, "You've Heard of Outsourced Jobs, but Outsourced Pollution? It's Real, and Tough to Tally Up," *The New York Times*, September 4, 2018.
[4] Ali Hasanbeigi and Daniel Moran, "The Glaring Loophole in Our Climate Policies," *The Washington Post*, September 13, 2018.
[5] Daniel Moran, Ali Hasanbeigi, and Cecilia Springer, "The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products," 2018, https://buyclean.org/media/2016/12/The-Carbon-Loophole-in-Climate-Policy-Final.pdf.

reuse/recycling benefits). Furthermore, the scope does not consider other environmental impact categories (e.g. acidification, eutrophication, ozone depletion, smog formation) beyond GWP used to provide a holistic assessment of lifecycle environmental impacts. For these reasons, it is critical to emphasize that Buy Clean policy is only appropriate to compare materials with nearly identical performance variables and types of life cycle impacts. The policy is not an appropriate mechanism to compare performance between different materials (e.g. steel vs. concrete).

The Buy Clean California Act includes four 'eligible material' categories: carbon steel rebar, flat glass, mineral wool board insulation, and structural steel, which were material types policy advocates identified as 'high impact/trade exposed'. The proposed Buy Clean Washington bill initially included an expanded version of this list, which was refined to limit the eligible categories to structural materials. The focus on structural materials helps address industry concerns that 'competing' material types would have similar reporting requirements under Buy Clean regulation, even though the policy does not intend to compare between material categories.

METHOD: MANDATORY ENVIRONMENTAL DISCLOSURE STANDARD – FACILITY-SPECIFIC EPDS

The Buy Clean California policy requires product manufacturers of each eligible material to report embodied carbon using a facility-specific EPD or 'similarly robust LCA method.' Successful bidders would need to submit EPDs before installing products on state-funded projects.

Governments and firms require or publish three common types of EPDs: (1) industry-average (in which the average commonly only represents sample datasets from participating product manufacturers), (2) product-specific (which may be an average of several facilities producing the same product), and (3) facility-specific. EPDs can be third-party verified or 'self-declared.'

Facility-specific EPDs provide the most direct, detailed and potentially accurate assessment of environmental impacts attributed to a specific product. However, generating facility-specific EPDs is often more resource intensive than publishing other types of EPDs, and some product manufacturers perceive that facility-specific EPDs could be used by competitors to glean propriety information.

The Buy Clean requirement of facility-specific EPDs is not a common specification in other programs or policies with EPD-specific guidelines. For instance, the LEED EPD credit establishes a pathway that allows for the use of industry-average or product-specific EPDs in its credit calculation. While collecting granular data at the facility level could provide a more direct assessment of impacts of a specific product, the additional challenges and barriers to product manufacturers are worth noting, particularly concerning small, local firms with no prior experience or limited budgets to incorporate new reporting practices into current business models.

METHOD: MANDATORY ENVIRONMENTAL PERFORMANCE STANDARD – GWP THRESHOLD

Buy Clean California intends to establish a pre-calculated GWP threshold (or limit) for each material category to measure and compare environmental performance of eligible materials. GWP is a standardized metric that reports greenhouse gas (GHG) emissions, an environmental impact category specifically targeted by Buy Clean goals. Buy Clean California will require state awarding authorities (beginning in 2021) to assess whether or not embodied carbon emissions fall below the threshold to verify if compliance is met. At this time, the policy would not recognize or attach weighting to varying

levels of performance below or above the limit. This potentially limits opportunity to motivate continual improvement beyond the threshold and thereby, realize significant emissions reductions over time.

California intendeds to establish GWP thresholds for each product category based on average environmental performance calculated by available facility-specific, product-specific and industry-average EPDs. However, since thresholds would only represent a sample of publicly available EPDs from each product market, they may not accurately reflect the true average of market-wide performance, especially in contexts with sparse datasets and/or inconsistent methodologies, tools and sources to generate data. See Section 3.4 of the **Chapter 3: Technical Review** for detailed description on challenges related to setting performance targets for material categories.

The Buy Clean California Act outlines the process to establish GWP thresholds, stating "the department [the Department of General Services (DGS)] shall set the maximum acceptable global warming potential at the industry average of facility-specific global warming potential emissions for that material with a phase-in period of not more than two years. The department shall determine the industry average by consulting recognized databases of environmental product declarations. When determining the industry averages pursuant to this paragraph, the department should include all stages of manufacturing required by the relevant product category rule. However, when setting the initial industry average, the department may exclude emissions that occur during fabrication stages, and make reasonable judgments aligned with the product category rule."

Subsequently, the state defined a prescriptive method to calculate a baseline based on a weighted calculation of EPDs from single suppliers with single production facilities, single suppliers with multiple production facilities and industry-wide EPDs[6]. However, this approach does not account for two important factors - (1) not all product suppliers will issue EPDs (e.g. there are no EPDs currently available for steel commonly imported to the US West coast), and (2) ideally, performance results should be weighted based on production capacity, and not all facilities produce equal volumes of materials. Additionally, upcoming EPDs (per the new ISO 21930:2017 EPD standards) will require product suppliers to report variability (e.g. standard deviation); however, the current policy method does not anticipate how to integrate new EPD data into evaluation.

METHOD: DEMONSTRATING COMPLIANCE

State agencies and public entities (e.g. state universities) awarding construction contracts will be required to communicate Buy Clean policy requirements in their bid specifications (i.e. instructions to bidders). Bidders do not need to provide EPDs during the bidding process; the bidder awarded the contract would need to report EPDs provided by product manufacturers before a project team can install eligible materials.

California amended the policy to include options for noncompliance. If the requirements "[are] technically infeasible, would result in a significant increase in the project cost or a significant delay in completion, or would result in only one source or manufacturer being able to provide the type of material needed by the state."[7]

[6] https://www.documents.dgs.ca.gov/pd/engineering/AB%20262/GWP_Method_Doc.pdf
[7] California Legislative Information, "Buy Clean California Act [3500 - 3505]."

The language does not specify penalties or recourse if product manufacturers do not meet requirements without providing justification, but it infers that selected product manufacturers would no longer be eligible to provide construction materials, and assuming there is a competitive pool of manufacturers who could meet requirements, the project team would select another option. This uncertainty poses risk to the construction team as they attempt to evaluate project impacts such as: How much will this requirement impact material costs? How will non-compliance justification be established? How much time will the documentation and justification cost?

TIMELINE

The bill timeline is summarized below:

1. Buy Clean California Act signed into law (October 15, 2017)
2. Amendment passed – updated implementation timeline and added justifiable exemptions (June 27, 2018)
3. Voluntary submission of facility-specific EPDs requested (starting January 1, 2019)
4. Mandatory submission of facility-specific EPDs required (starting January 1, 2020)
5. DGS to establish GWP maximum (by January 1, 2021)
6. Performance reported in EPDs must fall below maximum GWP (starting in July 1, 2021 – applies to contracts 'entered into' on or after that date)
7. DGS to submit a report to the CA Legislature (by January 1, 2022)
8. DGS to review GWP maximum and adjust downward as appropriate (by January 1, 2024 and every three years thereafter)

The incremental timeline to implement Buy Clean California presents potential benefits. It could provide additional time for affected product markets to improve understanding of environmental reporting, labels and performance measures, and build capability to access or apply the tools, data and software needed to track and quantify environmental impacts. Furthermore, by including an initial trial phase that encourages voluntary participation, the government positions itself to build internal capability to regulate policy, establish a standard delivery approach, and assess and refine policy details based on lessons learned during the first phase of implementation.

However, time alone may not ensure that affected industry groups become equipped to meet compliance standards in the future. Depending on the context (especially in regions with small businesses), firms may not have the financial ability to access technical and educational resources to build internal capability. In this context, an extended timeline risks delaying the issue of non-compliance. Where possible, government should supplement an incremental timeline with education and training resources for manufacturers. **Chapter 2: Policy Review** provides examples of support programs administered by the USGBC-LA and Oregon DEQ (see **Chapter 2 Section 2.3**).

IMPLEMENTATION

The California Department of General Services (DGS) implements state regulation. DGS staff developed their expertise in the eligible material categories and evaluated the state of EPDs across affected

product markets. Further, DGS has developed implementation procedures, made publicly available on the department website.[8] As part of this process, DGS has:

1. Hosted a public event (6/26/2018) with stakeholders to share information about implementation including:
    - Proposed language to include in state contract specifications
    - Presentation slides from the stakeholder event with background on LCA/EPDs
    - Proposed methodology for calculating 'Global Warming Potential Baseline'
    - A summary of calculation data available (as of June 2018)
    - External stakeholder comments and DGS responses
2. Posted resources including:
    - The incentive program administered by the USGBC Los Angeles chapter[9]
    - A list of the accepted PCRs for each eligible material category
    - The EPD program operator responsible for the majority of EPDs (for each material)
3. Hosted a meeting with awarding agencies (9/26/2018) to 'discuss acceptable documentation for AB 262 compliance, standardized language for requesting EPDs in solicitations, industry compliance concerns and next steps.'[7]

As noted, the bill requires DGS to establish maximum GWP thresholds for eligible material categories and update these values every three years. DGS is also required to assess barriers to implementation and effectiveness of GWP thresholds through a report due six months after legislation becomes mandatory. This timeframe could challenge ability to collect and compile sufficient data to assess the policy, unless DGS establishes a standardized method to collect, compile and evaluate data from participating construction projects.

5.4 PATHWAY TO DEVELOPING BUY CLEAN WASHINGTON POLICY

This section presents a step-by-step pathway for Washington State to consider upon developing Buy Clean policy standards. Under each step (where appropriate), the research team presents 'key considerations' – strategies or approaches that the state could adopt to potentially mitigate potential risks, impact effectiveness of policy, influence complexity and cost of policy implementation, and/or provide additional flexibility for policy to meet the needs of different industry groups (e.g. complex product markets, small businesses, etc.).

The recommended steps in this Section are as follows:

STEP 0: Evaluate policy context

STEP 1: Establish policy goals

[8] DGS, "Buy Clean California Act (AB 262)," accessed December 30, 2018, https://www.dgs.ca.gov/pd/Programs/Engineering/AB262.aspx.
[9] USGBC-LA, "Buy Clean California – USGBC LA," accessed December 12, 2018, https://usgbc-la.org/programs/buy-clean-california/.

STEP 2: Establish policy scope
- 2.1 Select eligible materials
- 2.2 Select type of policy standards
- 2.3 Select type of compliance guidelines

STEP 3: Establish Methods
- 3.1 Select disclosure method
- 3.2 Select method to report material quantities
- 3.3 Select method to establish performance targets
- 3.4 Select method to assess environmental performance

STEP 4: Establish Timeline
- 4.1 Consider construction industry practices
- 4.2 Select time to evaluate embodied carbon (if appropriate)
- 4.3 Select method to update embodied carbon targets (if appropriate)

STEP 5: Implement and Evaluate

STEP 0. EVALUATE POLICY CONTEXT

As a starting point, policymakers should assess factors unique to local context and assess state 'readiness' to meet policy standards. Key factors to consider include: (1) prevalence of related policies and initiatives targeting the building sector, (2) prevalence and level of environmental reporting practices by product market, (3) availability and quality of EPDs and LCA data sources, (4) availability of accessible, standardized software, tools and methodologies, and (5) availability of government resources to support education, training, and incentive programs to support policy.

Chapter 3: Technical Review evaluates the context of embodied carbon reporting for structural materials in Washington State. While many of these recommendations could be generalized for other building materials, care should be taken to evaluate material-specific impacts if Buy Clean policy is developed for materials other than those evaluated in this report.

STEP 1. ESTABLISH POLICY GOALS

The Buy Clean Washington Study starts with the presumption that policymakers have established broad goals related to carbon reduction throughout the supply chain of building materials. Governments often consider embodied carbon procurement policies to achieve two high-level goals: (1) Disclosure**:** To accelerate the adoption of reporting practices that disclose the environmental impacts of construction materials and (2) Performance**:** To accelerate the reduction of embodied carbon by improving the environmental performance of construction materials.

While both goals are not mutually exclusive (governments often develop standards targeting both goals within a single policy), policymakers may choose to develop policy around a dominant goal based on policy context. For instance, a government body may shape near-term standards around disclosure goals, in order to build industry capability to meet performance goals in the future.

STEP 2. ESTABLISH POLICY SCOPE

When establishing the scope of Buy Clean policy three aspects are critical to consider, the eligible materials to be eligible for the program, the type of policy (disclosure or performance-based) and the type of compliance (mandatory or voluntary).

2.1 SELECT ELEGIBLE MATERIALS

The basis of Buy Clean policy is a pre-determined 'eligible materials' list, which defines specific product categories required to comply with policy standards. The Buy Clean Washington Study assessed material types based on the eligible materials list identified by the Pilot Project (per bill language in ESSB 6095); however, the state could consider adopting other approaches to defining a list of eligible materials:

Option 1: Adopt list defined for the Pilot Project, which specifies structural materials for four categories

Option 2: Modify selection criteria for the eligible materials list, considering factors such as trade-exposed products, materials that result in the highest emissions during the manufacturing phase

Option 3: Do not establish a prescriptive list. Rather, apply Buy Clean requirements to *all* construction products used for public-funded projects.

2.2 SELECT TYPE OF POLICY STANDARDS

As identified in description of Step 1: Establishing the policy goals, there are some key aspects to consider when establishing the scope of Buy Clean policies. This section outlines and provides examples against two high-level options for type of standards to develop: 1) disclosure-based and 2) performance-based.

Option 1: Disclosure-based policy

Under Option 1, Washington State could develop policy with disclosure-based reporting standards in order to improve transparency of environmental impacts across product markets. Standards would require or incentivize product manufacturers selected for state-funded construction projects to publish environmental impacts of 'eligible products'. State awarding authorities would collect environmental impact data from product manufacturers but would not assess or compare performance of products. Therefore, WA State would not penalize or reward product manufacturers for level of reported embodied carbon emissions. This would function similarly to the first stage of the Buy Clean California project before GWP limits are established.

Example A: *A state government requires manufacturers to publish EPDs for select product categories in order for eligible installation on public-funded projects.*

Example B: *A state government provides its environmental agency supplemental funding to establish a voluntary EPD program for local manufacturers including tools such as LCA/EPD Calculators. Manufacturers apply to participate in the program and receive financial, technical and educational support to generate EPDs.*

Option 2: Performance-based policy

Under Option 2, Washington State would develop standards for environmental performance thresholds or targets pre-calculated by the Department of Enterprise Services (DES) for each product category identified as an 'eligible material'. Standards would incentivize or require manufacturers to meet a level of environmental performance relative to a pre-calculated value that reflects an embodied carbon performance target for each product type. This could function similarly to the final stage of the Buy Clean California project or be applied differently depending on the methods selected in Step 3.

Example 2A: *a state government pre-calculates mandatory GWP thresholds for each product category defined as 'eligible' under policy. Through published facility-specific EPDs, product manufacturers must demonstrate that products fall below the GWP limit before installing materials on public-funded projects.*

Example 2B*: A federal government implements a national voluntary rating system, providing points and certifications aligned with pre-established targets for global warming potential (GWP). The system awards points proportional to the level of environmental performance demonstrated by product manufacturers. Developers obtain incentives such as certification (e.g. green product label), financial bonuses, additional construction rights (e.g. density bonuses), or technical, education and financial support that helps manufacturers meet targets.*

Example 2C: *a state government sets performance targets for each product category. Contractors commit to meeting performance targets at bidding with outcomes linked to prescribed bid award criteria such as 'sustainability points' or connected to an overall project carbon target that must be met.*

2.3 SELECT TYPE OF COMPLIANCE GUIDELINES

Governments can apply either mandatory (noncompliance is penalized) or voluntary (requirements are optional) compliance guidelines to underpin policy standards. As a general observation, the research team recognizes that providing benefits to product manufacturers for meeting policy standards (vs attaching penalizations or disadvantages to non-compliance) can lower the risk of inadvertent, negatives impact to local businesses.

Option 1: Mandatory

Product manufacturers must comply with standards in order to install construction materials on state-funded projects. Noncompliance would result in a form of penalization determined by WA State – for instance, the state could refuse to permit installation of non-compliant materials on the awarded project, or WA State could require product manufacturers of non-compliant materials to pay a fine or follow additional recourse procedures.

Further, WA State could establish exemption criteria to waive compliance for product manufacturers who meet pre-determined requirements. WA State could adopt similar exemption criteria included in the amended Buy Clean California Act, which states justifiable exemptions could be made if the requirement is found technically infeasible, likely to incur significant cost increases or schedule delays to the project, or where no other manufacturer could provide the type of material needed by the state. Or, WA State could consider other exemption criteria specific to firm-level attributes. For instance, exemptions could be made for

firms that meet WA State definition for small businesses or that meet similar criteria (e.g. operating budget or number of full-time employees).

Instead of waiving compliance completely, WA State could consider providing an alternative pathway to exempt product manufacturers that encourages them to adopt other approaches to improve reporting practices and environmental performance. For example, the pathway could require completion of a regimented curriculum around environmental impact reporting (e.g. EPDs and LCAs), so that at the very least, firms are familiarized with practices and positioned to adopt them in the long-term (see Recommended Investment #4 on page 5-21 for more information on this pathway).

Option 2: Voluntary

In requests for proposals (RFPs) to potential bidders, state awarding authorities would include a request for optional compliance with policy standards. This would allow WA State to formalize a process for collecting environmental impact data that is already available; however, without incentives, it is unlikely that the optional request would result in generation of new environmental impact data or improved performance from product markets not already carrying out reporting practices.

STEP 3. ESTABLISH METHODS

Establishing the methods for implementing Buy Clean policy is a critical step as it sets forward technical details that can significantly impact the outcomes of the policy.

3.1 SELECT DISCLOSURE METHOD

EPDs are a widely-adopted and well-established standard for reporting environmental impacts/performance. EPDs provide GWP values that directly correlate with the Buy Clean goal to reduce embodied carbon emissions. For several product markets, EPDs may be the preferred and most sensible reporting standard for eligible materials, since they are already prevalent in practice. However, other product markets may carry out alternative product-specific reporting standards responsive to the specific nuances of a material supply chain (e.g. FSC certification for wood products). See **Chapter 3: Technical Review** for more description and analysis of EPD availability and supply chain characteristics of each product category. Options available include:

Option 1: Standard EPDs. Market-driven development of third party verified EPDs.

Option 2: Supported EPD Development. Support EPD production as outlined in **Chapter 3 Section 3.3**.

Option 3: Alternate Methods. Accept alternate reporting methods including but not limited to self-declared EPDs.

3.2 SELECT METHOD TO REPORT MATERIAL QUANTITIES

Collection and analysis of material quantities data in addition to EPDs (note, EPDs only provide values per unit quantity) can be valuable in meeting the goals of Buy Clean policy. This data would help WA State determine if Buy Clean policy resulted in a total embodied carbon reduction over time (i.e. *X* tons

over *Y* years). Additionally it enables evaluation based on relative impact of different materials used on a project.

> **Option 1: Detailed Reporting.** Report material quantities in a standardized way to facilitate data aggregation and comparison, following the template developed for **Chapter 4: Pilot Study**, which can be found in **Appendix B.2: Structural Material Quantity Reporting Template**.
>
> **Option 2: Simplified Reporting.** Report material quantities in aggregate (e.g. total cubic yards of concrete used not differentiated by mix type used. This might be simpler to implement than Option 1 but would produce significantly less data on material use and selection.
>
> **Option 3: No Reporting.** Do not require reporting of material quantities. This is the easiest to implement.

3.3 SELECT METHOD TO ESTABLISH PERFORMANCE TARGETS

If a performance-based policy is selected, this section provides guidance on establishing a methodology to calculate performance targets (GWP values) specific to each product market eligible under Buy Clean. **Chapter 3**: **Technical Review** outlines critical issues when establishing methods to identify performance targets for embodied carbon. WA State could consider two approaches to establishing performance targets.

> **Option 1: Average EPD Method**. Collect available EPDs and calculate benchmarks using methods similar to those described in the California Buy Clean Policy. This method has the advantage of enabling calculations to occur based on prescriptive formula without requiring significant interpretation to implement. Given this method's dependence on published EPDs (generally produced voluntarily) it risks not adequately representing the range and distribution of current practice nor the regionally specific nature of the supply chain that can exist for structural materials.
>
> **Option 2: Benchmark Study Method:** Conduct regionally specific embodied carbon benchmark studies to establish estimates of material embodied carbon representative of the range of materials currently available in Washington State. This method is described in **Chapter 3 Section 3.4**. This method has the advantage of more accurately reflecting current practice and would be more likely to identify meaningful yet achievable performance targets. This method likely requires more investment of State resources to develop the benchmark studies. Prescriptive targets could be set such as embodied carbon within the bottom 80% of current practice in year 1 ratcheting to improved performance in subsequent years.

3.4 SELECT METHOD TO ASSESS ENVIRONMENTAL PERFORMANCE

WA State could consider two approaches to assess environmental performance of eligible materials:

> **Option 1: Single Threshold:** Establish a single GWP threshold for each structural material type and apply a binary approach to assess environmental performance for compliance standards – does the reported GWP value fall above or below the pre-established threshold? Similar to Buy Clean California, the cut-off is binary, either a product is below the target and thus permitted or above the target and not permitted (unless an exemption is granted). This approach does not

incentivize or reward radically low carbon solutions and may thus have difficulty actually impacting material production markets.

Option 2: Tiered System: Establish a tiered system for each structural material type that assesses degree of performance relative to GWP benchmarks. This would position WA State to recognize (and potentially reward) products with the lowest emissions and could motivate product manufacturers to continually improve beyond the GWP threshold. WA State could assess reported GWP values against pre-established performance rates relative to a baseline (e.g. a product's GWP is 30% lower than the baseline) or pre-establish a set of targets that range in ease/difficulty to meet. Products at the high end of tiers (or exceeding targets) could potentially pay a penalty to be considered for purchase. This option has the advantage of enabling easy phase in with achievable targets while incentivizing innovation.

STEP 4. ESTABLISH TIMELINE

4.1 CONSIDER INDUSTRY PRACTICES

When establishing an implementation timeline the following issues should be considered:

1. The extended timeline of construction: it can be years from when a project is initiated until it is bid and then additional years from start to end of construction. Project costs can increase if requirements changes after contracts awarded. Set timeline to give sufficient time for design and construction teams to implement and test methods.
2. How long it takes manufacturers to obtain EPDs: depending on the sophistication of the company or industry this can range from several months to years.
3. Analysis of the effectiveness of policy takes data and time. Providing mechanisms to automatically track and evaluate data will facilitate evaluation and reporting.

4.2 SELECT TIME TO EVALUATE EMBODIED CARBON (IF APPROPRIATE)

Select the optimal time to evaluate EPD data. Requiring EPDs and establishing performance thresholds at bidding could potentially influence procurement more than at construction.

Option 1: At Bid. If EPDs and embodied carbon performance is integrated into bidding requirements, Buy Clean Policy has the potential to have higher impact on product selection. Using a tiered system as described in Step 3.4 could be used to establish quantitative measures of product sustainability to be evaluated as part of a comprehensive bid package. Final installation of materials could be verified to meet bid statements with financial penalties applied for non-conformance.

Option 2: At Construction. When EPDs are evaluated just prior to construction there is risk that the conformance with Buy Clean Policy will be an afterthought and any non-compliance identified as worthy of exemptions. While time of construction is an ideal time to verify the actual materials used, this is a phase of construction where schedule is often the dominant driver of decisions and a difficult time to identify alternate sourcing options.

4.3 SELECT METHOD TO UPDATE EMBODIED CARBON TARGETS (IF APPROPRIATE)

Option 1: Automatic Updates. Automatic update of performance targets (such as decreasing annually to 50% of a current benchmark by 2040) have the advantage of forcing improved performance targets without continued negotiation. However, automatic updates may not be technologically feasible.

Option 2: Responding to Material Updates. If the Average EPD method is used to establish targets (Option 1 of Step 3.3) then the target would be updated to reflect the gradual shift in industry (or perhaps just the average shift in products reporting EPDs). Given that high carbon products will be less likely to report impacts using EPDs, this method risks skewing the estimates to reflect a self-selecting subset of industry.

Option 3: Material Specific Roadmaps. Setting achievable performance thresholds and obtaining industry input to establish a roadmap and timeline for improvement will help develop meaningful targets that inspire improvement over time and that are technologically feasible. As noted in **Chapter 3: Technical Review**, many industries already create roadmaps and performance targets for their industry. These could be leveraged to align with Buy Clean policy target timelines.

STEP 5. IMPLEMENT AND EVALUATE

In order to effectively implement and evaluate Buy Clean policy, staff at divisions such as California's DGC, Oregon's DEQ or Washington's DES need to have unique knowledge and skills and time and resources to support the policy. Section 5.6 outlines a range of potential investments that the state could consider to support the goals of Buy Clean policy.

5.5 POTENTIAL OUTCOMES

Since Buy Clean policies are relatively new, predicting outcomes requires qualitative assessment and application of professional judgement. Table 5.1 presents opportunities and potential outcomes related to embodied carbon policy options explored in this chapter, while Table 5.2 presents challenges and respective potential outcomes. These opportunities and challenges could be evaluated and elaborated upon through formal stakeholder engagement.

Table 5.1. Assessment of opportunities and potential outcomes related to embodied carbon policy

OPPORTUNITIES	POTENTIAL OUTCOMES
1. The policy can bring attention to established environmental reporting standards and green product labels (e.g. EPDs), and life cycle analysis approaches (WBLCA, LCA)	1.1 Increased awareness and knowledge of disclosure standards and life cycle thinking
	1.2 Increased uptake of environmental reporting practices, particularly in product markets with limited prevalence of (or nonexistent) environmental reporting practices
2. A disclosure-based policy could lead WA State to establish a system for data collection	2.1 WA State can evaluate current availability of (and willingness to provide) environmental impact data and identify (1) product markets where environmental impact data collection and EPD publication is prevalent or mature, (2) product markets with data gaps that could use support to fill and (3) potential opportunities and barriers to EPD collection

OPPORTUNITIES	POTENTIAL OUTCOMES
3. WA State could supplement policy with education and training resources for product manufacturers	3.1 State-funded education and training could build industry capability to adopt environmental reporting practices into standard business processes
4. Product manufacturers could use environmental/green product labels for business purposes	4.1 Product manufacturers would be able to use labels as marketing tools, and for other purposes (e.g. LEED points) which could provide a competitive edge to local firms
	4.2 Carrying out environmental reporting could provide valuable information to guide firm-level investments that reduce energy consumption and achieve cost savings
5. A performance-based policy could position WA State to directly measure and compare environmental performance results, and set a baseline for 'acceptable' maximum levels of embodied emissions	5.1 Targets and collected data can be used for comparative assessment, positioning WA State to select best options for embodied carbon reduction
	5.2 WA State can develop performance targets balanced between ambitious and achievable, which could lead businesses to adopt sustainable manufacturing practices that reduce embodied carbon
	5.3 Electricity dependent product manufactures benefiting from Washington State's low carbon electrical grid would be recognized when competing with products made in regions with higher carbon electrical grids
6. WA State could develop compliance exemptions to mitigate risk and provide flexibility	6.1 Compliance exemptions could avoid delays to project schedules and prevent additional financial costs to project teams
	6.2 Compliance exemptions could mitigate potential consequences to small firms
	6.3 Compliance exemptions could ensure policy is responsive to specific complexities of affected product markets
7. WA State could incentivize voluntary submission of environmental impact data,	7.1 Incentives can further motivate product manufacturers to participate and thereby, spur generation of EPDs

Table 5.2. Assessment of challenges and potential outcomes related to embodied carbon policy

CHALLENGES	POTENTIAL OUTCOMES
1. A disclosure-based policy would not position state officials to assess and compare environmental performance	1.1 Without environmental performance requirements or incentives, product manufacturers may not have an imperative to adopt or improve practices to reduce embodied carbon
2. Environmental reporting could pose additional costs to businesses. Costs may incur from personnel time (internal FTE and/or external consultants), third-party verification, and publication of label. Cost would vary by product market and type of EPD required.	2.1 Additional costs could burden small businesses (or firms with tight operating budgets) with limited flexibility to absorb the added financial burden of environmental reporting
	2.2 Additional costs could result in "unfair" advantage to large businesses with more flexibility and resources (financial, staff, software, technical skills, past experience, etc.) to adopt environmental reporting standards

CHALLENGES	POTENTIAL OUTCOMES
3. WA State would need to develop disclosure-based standards that (1) government can feasibly implement, and (2) are responsive to specific variances of supply chains	3.1 WA State does not have the staff expertise or time to develop effective policy resulting in failed implementation.
	3.2 WA State develops standardized requirement(s) that may not be realistic or achievable for some product markets, resulting in additional burden to product manufacturers.
	3.3 WA State develops requirements specific to each product market, resulting in additional time, cost and complexity to implement, resulting in additional burden to state officials.
4. Establishing a method to shape performance-based targets for each product category would require rigorous data collection and verification, a defined calculation methodology, and government access to vetted software and tools.	4.1 WA State may not have (or is unable to procure) the resources needed to pre-calculate measures, including staff time and expertise, technical systems and budget
	4.2 Methods to establish targets are overly simplified resulting in ineffective policies
	4.3 Depending on product market, there may be data limitations due to availability, sample representation, quality and consistency in tools, methods and sources. This could lead to development of unfair or ineffective measures (e.g. the bar is set too high or too low).
5. Level of penalization for non-compliance may not strike the right balance (i.e. it's too severe or not severe enough).	5.1 'Harsh' penalizations (e.g. disqualifying noncompliant materials) could result in delays to project schedules or incur additional costs to project teams, particularly if the noncompliant material is from a product category with limited competition
	5.2 Product manufacturers could find penalizations too severe and decide to no longer consider state-funded projects as a revenue stream. This could limit competitive procurement options to WA State and result in a missed opportunity – the government-led imperative to improve transparency and reduce environmental impacts is no longer a driver to the product manufacturer who does not pursue state contracts
	5.3 Alternatively, less severe penalizations (e.g. a nominal fee) could undermine effectiveness of policy. Manufacturers may assess that the time, cost and technical resources needed to meet compliance outweigh the cost of non-compliance
6. Policymakers would need to avoid developing exemption guidelines that are too broad or too easy to meet.	6.1 Compliance criteria could make policy ineffective if it provides too much flexibility in how exemption rules can be interpreted (or it includes too many criterion that most firms could meet)
	6.2 Exempt product manufacturers may not have an imperative to carry out effort aligned with meeting standards. Further, this could disadvantage exempt businesses in the long-term, in a context where standards are mandatory or the 'norm' for commercial projects
7. Optional standards could result in lack of participation (i.e. low levels of compliance)	7.1 Lack of product manufacturers pursuing compliance standards would not generate new environmental impact data nor support improved environmental performance of products
	7.2 Lack of compliance could send message to industry and other governments that policy is ineffective, and thereby this discourages future effort to build upon policy or replicate elsewhere

5.6 POTENTIAL INVESTMENTS

The following section provides investments for Washington State officials to consider to support potential Buy Clean Washington regulation and/or to support goals related to Buy Clean policy. Investments are not contingent on legislators passing a regulatory Buy Clean Washington Act. These investments could support non-regulatory programs or initiatives that accelerate adoption of transparent manufacturing practices and reduction of embodied carbon. They can also mitigate potential risks or negative impacts of any potential Buy Clean regulation.

The investments are based on lessons learned from other governments with established embodied carbon policies (discussed in **Chapter 2: Policy Review**). This section includes descriptive sub-sections on the following recommended investments:

1. Support continual evaluation of Buy Clean policy and Pilots
2. Develop a standardized delivery approach
3. Build internal capability to implement policy
4. Lead ongoing industry engagement and workforce development
5. Use technical infrastructure to support policy
6. Align with existing policies, programs, and initiatives
7. Establish program to manage policy

1. SUPPORT CONTINUAL EVALUATION OF BUY CLEAN PILOTS

The Buy Clean Washington Study has been conducted in parallel to (and supports) the Pilot Phase evaluation led by DES. The study identified several research areas that would benefit from extended time and an updated scope of work, described further in Table 5.3.

Table 5.3. Investment #1: Support continual evaluation of Buy Clean policy.

RECOMMENDATION	DESCRIPTION
1.1 Extend Pilot project phase	Additional time would enable DES to coordinate with the pilot project managers and research team to share study methods and templates, collect feedback and refine as needed. Further, extension provides more time for pilot projects to apply methods to test ability to meet Buy Clean Pilot requirements.
1.2 Solicit industry feedback	Formalized stakeholder feedback of this Study would be valuable in order to assess the analysis and methods proposed. This could be done via online comment period, establishment of a technical advisory committee and/or public presentations and workshops.
	Key stakeholder groups should include: Product manufacturers, Trade associations, Architecture, engineering, and construction (AEC) representatives, and Academic and nonprofit groups with technical/subject expertise and who have established relationships with industry groups.
1.3 Conduct an economic impact analysis	For quantitative assessment of potential economic impacts, WA State could benefit from conducting an economic analysis (potentially through an environmental policy lens). The economic study could assess several potential impact areas, including local company revenue and profits, employment, and gross regional product (GRP).
1.4 Support ongoing data collection on delivery of Buy Clean California	California will trial Buy Clean policy standards beginning in January 2019 (voluntary EPD collection). Information and lessons learned gathered from public officials and affected industry stakeholders would supplement data collection from the WA Pilot Phase.

Overall, additional time is needed for pilot research teams to trial the methods and templates developed in this study (see **Chapter 4: Pilot Study**). Furthermore, we highly recommend that any additional evaluation should include formal industry consultation.

2. DEVELOP A STANDARDIZED DELIVERY APPROACH

Buy Clean policy would require participation of personnel from multiple awarding authorities (state government agencies and public entities, e.g. universities) managing construction contracts. Awarding authorities would need to adapt their department-specific procurement processes to reflect new standards and develop new or update accompanying guidelines (e.g. contracting manuals). State agencies and public entities would need to coordinate early and consistently to align efforts and establish a consistent delivery approach.

Table 5.4 presents recommendations to ensure a standard delivery approach that would avoid duplication of effort, confusion of varying processes, and potential burden to product manufacturers.

Table 5.4. Investment #2: Develop a standardized delivery approach.

Recommendation	Description
2.1 Identify funding priorities for policy delivery and assess availability of state resources (financial and staff time)	Assess (1) amount of additional financial resources needed to supplement and deliver policy (and identify funding priorities), and (2) availability of government funding in the near-term and long-term to support policy implementation. Understanding funding opportunities or barriers could help guide and prioritize investments needed to support policy delivery.
2.2 Establish cross-agency/entity implementation team or workgroup	Formalize a workgroup comprising procurement decision-makers and key personnel representing each awarding authority. DES could convene and coordinate meetings, work activities, etc.
2.3 Develop standardized procedures/processes	State agencies and public entities collaborate to establish standard procedures for managing compliance and develop Buy Clean procurement guidelines with consistent language.
2.4 Establish a phased approach to implementation, starting with a voluntary/trial phase.	Deploy an incremental, extended timeline to test requirements, assess industry readiness to comply, and provide flexibility to refine standards and procedures where appropriate. This could also provide affected industry groups more time to understand requirements and build capability to meet standards, especially if supplemented by investments under Recommendation #4.
2.5 Design a component of policy implementation that reduces potential burden or disadvantage to product manufacturers	Develop compliance exemption(s) and/or alternative pathway(s) aimed at firms from product markets with limited or no availability of EPDs, and/or state/regional firms considered “small businesses”
2.6 Provide ongoing, publicly accessible communication on policy implementation	Provide communication resources and forums to update industry stakeholder groups and the general public on status of policy implementation. Where possible, use fact-based messaging to demonstrate policy impact.

3. BUILD INTERNAL CAPABILITY TO IMPLEMENT POLICY

Environmental performance reporting and pre-calculating measures are practices underpinned by a complex system of overlapping (and sometimes inconsistent) technical standards and guidelines, software and tools, quantitative methodologies, and a myriad of initiatives and research (often spanning international borders). The technical complexity of establishing and regulating embodied carbon standards requires a level of expertise that many government bodies do not have within existing programs. Table 5.5 presents recommendations that would help build internal capability to implement Buy Clean policy.

Table 5.5. Investment #3: Build internal capability to implement policy.

RECOMMENDATION	DESCRIPTION
3.1 Provide high-level education and training to current personnel	Identify and/or create educational/training course(s) or other resources focused on green building labels (e.g. EPDs), embodied carbon, building products and related supply chains, and lifecycle analysis.
3.2 Establish and employ new staff positions to fill skill and knowledge gaps	Fund creation of new position(s) to employ staff with appropriate knowledge and skillsets. Ideal candidates could meet most or all of the following selection criteria: • Understanding and prior experience working in the building industry • Expertise in lifecycle analysis and environmental product declarations • Higher education degree related to environmental science • Knowledge of environmental policies, particular related to embodied carbon or materials management • Demonstrable aptitude in verbal and written communications • Experience engaging multiple external stakeholder groups
3.3 Establish a panel of on-call consultants qualified to provide technical services	Establish a formal list of qualified firms and professionals that could provide technical, administrative and training support to government personnel and industry stakeholders as needed. Recommended expertise areas include: • Tool/software development and management (particularly tools related to product environmental impact metrics) • Green building labels (e.g. EPDs) • Developing and delivering professional educational/training curriculum • Engagement with industry and product market stakeholders • Quality assurance • Program design (and policy mechanisms) related to building materials • Technical knowledge of embodied carbon, building materials and supply chains, lifecycle analysis

4. LEAD ONGOING INDUSTRY ENGAGEMENT AND WORKFORCE DEVELOPMENT

Table 5.6 presents the recommendations to help the building industry and workforce engage in Buy Clean practices. This involves engaging building industry and product market stakeholders through communication forums, education and training, and incentives; increasing industry awareness and valuation of environmental reporting and performance; and engaging with external consultants to provide technical assistance and develop tools to support compliance.

Table 5.6. Investment #4: Lead ongoing industry engagement and workforce development.

RECOMENDATION	DESCRIPTION
4.1 Facilitate ongoing stakeholder engagement	Stakeholder engagement needs facilitation to occur throughout the policy development process. Develop and execute a plan for stakeholder engagement, identifying key groups and mechanisms for engagement. See Recommendation 1.2 in Table 5.3. Examples of potential mechanisms for engagement: • Workshop or focus group sessions (by invitation) • Public informational sessions • Dedicated website to post documentation and updates, and to provide a channel for written feedback • Educational communication materials, e.g. brochures, fact sheets, online videos
4.2 Provide incentives	Invest in state-led, or identify/invest in externally managed incentives, at least in the initial phases of policy implementation. Incentives could include: • Awarding points or credits that could lead to certification or an environmental marketing claim • Financial incentives to support manufacturers collect and report environmental performance data • Reimbursements for educational or technical support • Cash bonuses for compliance • Additional construction rights (e.g. density bonuses)
4.3 Provide professional education and training opportunities	Provide education and training to build knowledge around green building labels (EPDs) and underpinning systems (LCA methodology, software, data), and improve awareness of environmental impacts attributed to construction materials. Further, identify established education and training courses or work to develop and deliver educational program specific to Buy Clean policy. Leverage courses that offer continuing education credits or certifications recognized by industry associations.
4.4 Online educational resources/directory	Sponsor or host an open-source resource library that includes case studies (success stories), news, reports, policies (model templates), brochures, videos, briefs, RFQ announcements.

5. SUPPORT TECHNICAL INFRASTRUCTURE

Governments often invest in databases, software/tools and standardized methodology that aligns with policy standards and supports implementation. Such technical resources help government agencies manage information and streamline reporting processes. Multiple technical investments can be aligned to provide a standardized system for ensuring compliance. Technical resources also help build industry capability to report environmental impacts, and where policy establishes performance targets, government can use data and tools to calculate values that accurately reflect baseline performance of product markets. Further, as discussed in **Chapter 3: Technical Review**, robust technical infrastructure is needed in order to improve the quality, availability, usability, and comparability of reported EPDs.

Table 5.7 presents recommendations to support technical infrastructure.

Table 5.7. Investment #5: Support technical infrastructure.

RECOMMENDATION	DESCRIPTION
5.1 Support development of a North American LCI database that integrates EPD results	WA State partners with others (government, NGOs and industry) to co-sponsor and provide leadership to advance emerging data initiatives such as: • National or regional Life Cycle Inventory data centers as outlined in Appendices C.2 and C.3. These initiatives are critical to enabling comparable LCAs and EPDs. • An open access EPD database, the Embodied Carbon in Construction Calculator (EC3). The EC3 tool is hosted at the University of Washington's Carbon Leadership Forum and could provide a mechanism to find and report EPDs for Buy Clean Policy
5.2 Commission embodied carbon benchmark studies specific to Washington State	As outlined in **Chapter 3: Technical Review**, commissioning material and regionally specific embodied carbon benchmark studies would provide valuable insights into current industry averages and variability in Washington State. Note that for each material category, a different organization(s) has established expertise and have already created the LCA models that would streamline the creation of these studies.
5.3 Identify LCA software and tools that could be used to create WA specific EPD calculators	LCA consultants have developed customized EPD/LCI software and tools for different industries that could be customized for Washington-based product manufacturers. Further, modeling software could be integrated with the benchmark studies and database (recommendations 5.1 & 5.2) to support comparisons and decision-making.
5.4 Develop a standard manual that provides guidance on technical infrastructure	WA State develops formal documentation that includes step-by-step guidance on database, methodologies, and general requirements and processes related to Buy Clean policy.

6. ALIGN WITH EXISTING POLICIES, PROGRAMS AND INITIATIVES

There are several programs and initiatives with similar goals and standards that product manufacturers and other industry groups are already familiar with or follow. **Chapter 2: Policy Review** outlines a suite of aligned activities Table 5.8 presents this recommendation in detail.

Table 5.8. Investment #6: Align with existing policies, programs, and initiatives.

RECOMMENDATION	DESCRIPTION
6.1 Partner with green building rating programs (national or local chapters)	Recommend WA state work with NGOs to align new policy standards with existing programs (see **Chapter 2: Policy Review**) such as: • LEED EPD credits • LEED pilot credits possible through demonstrating compliance with WA State policy. • ILFI Zero Carbon Certification. • ILFI Living Building Challenge Material Petal. • Architecture 2030's Carbon Smart Material Palette and the 2030 Challenge for Products.
6.2 Lead or participate in a collaborative regional work group focused on embodied carbon policy	WA state could lead or support (through direct funding or participation) regional policy collaboration with government, industry, NGO stakeholders across region (e.g. California, Idaho, Oregon, Washington, British Columbia). Public officials, industry leaders and researchers across states/provinces and cities in the region are pursuing or evaluating policies with similar goals and standards around embodied carbon, but there is no formal structure or mechanism to bring stakeholders together to share updates, exchange lessons learned, and identify barriers and opportunities to implementation.

7. ESTABLISH PROGRAM TO MANAGE POLICY

Each recommended investment above has greater potential for effectiveness and impact when complimented by other investments, especially if brought together under a single, harmonious system. Dependent on funding availability, WA State could establish and fund an ongoing program or public agency to develop and introduce multiple investments that address all of the recommended areas. The most effective example the project team identified was the system that is in place in France that connects between advancing the quality of data, promoting the generation of EPDs, testing tools and implementation pathways and developing reporting mechanisms including building rating systems rewarding low carbon building options.

Table 5.9 outlines recommended services that such a program could provide.

Table 5.9. Investment #7: Establish program to manage policy.

RECOMMENDATION	DESCRIPTION
7.1 Professional education and training	Administer a structured education and training program that includes online and in-person sessions
7.2 Online portal of collated, open-source resources	Manage a web-based, searchable platform that provides access to open-source resources provided by external organizations (e.g. recorded webinars, professional reports, research studies, technical guidance, etc.)
7.3 Establish and manage stakeholder work group(s)	Bring together organizations and professionals with similar work objectives to: • Understand landscape of local industry and product markets • Identify barriers and opportunities facing industry groups • Formulate a consensus-based roadmap for continual improvement
7.4 Policy design and planning	Lead implementation planning and delivery for potential Buy Clean policy. Over time, translate lessons learned from Buy Clean policy into best practices and delivery models for other governments and organizations to apply (e.g. cities, counties and companies)
7.5 Provide incentives and research grants	• Provide financial support and incentives to local product manufacturers to meet compliance standards • Administer research grants to nonprofits and small businesses to support projects that result in case studies, generation of more data, understanding effective practices and approaches at facility-level
7.6 Formalize technical infrastructure and manage systems (e.g. database, software/tools)	Bring together technical resources under a shared, open-source platform with accompanying guidelines, methodologies, etc. Lead ongoing maintenance and refinement of technical systems.
7.7 Evaluate policy outcomes	Establish performance indicators for policy and evaluate progress on a systematic, consistent basis. Develop a process to analyze and reflect evaluation in continual updates to policy.

5.7 POTENTIAL COST IMPACTS

This section presents four policy scenarios that could lead to cost impacts to product suppliers and WA State Government. It identifies key dependencies that could impact cost amount.

Table 5.10. Cost assessment and dependencies.

	Cost Assessment	Dependencies
Scenario 1: Environmental reporting standards are implemented.		
Product Suppliers	EPD development costs range from $5,000 for materials with established datasets, tools and technical infrastructure to over $50,000 for materials with complex manufacturing processes and/or data and technical resources. Costs may incur from personnel time (internal FTE and/or external consultants), third-party verification, and publication of label.	• Type of EPD and material categories. • Reporting method (e.g. simplified vs detailed) to collect required structural material data. • Organization size, e.g. those with high net income and large staff size may easily absorb costs. • Organization past experience/capability. • Time, i.e. how long it takes manufacturers to obtain EPDs. • State supplemental investments to support compliance, e.g. financial incentives or technical education.
State Gov.	Costs to state government would depend on whether it uses existing resources to implement new policy or if it provides supplemental funding.	• Budget availability/amount. • Current state agency personnel expertise/capability. • If (and by what degree) state adapts procurement systems and processes. • Types of investments made.
Cost Mitigation	1. Promote benefits of using EPDs to support long-term revenue growth. EPDs can be used to: • Provide verified results to support green marketing claims. • Provide competitive advantage with clients/markets focused on environmental sustainability. • Communicate with clients and investors. • Inform business changes to improve operational efficiency and reduce energy costs. 2. Support development of EPD datasets and industry resources. 3. Partner with industry associations to procure externally provided financial, technical and educational incentives. 4. Set compliance exemption criteria for local small businesses.	
Scenario 2: Environmental performance standards are implemented.		
Product Suppliers	Similar to disclosure standards, cost of meeting performance targets could incur from staff time, reporting, verification, etc. Standards could require some firms to change or adopt new manufacturing practices to improve performance.	• Rigor of standards (i.e. targets are simple or difficult to meet). • Availability of WA funding/incentives. • Organization experience/ability. • Prevalence/sophistication of firm's low carbon manufacturing practices.
State Gov.	WA State would need to develop disclosure-based standards that it can feasibly implement, and that are responsive to specific variances of supply chains. Costs could incur to the state due to data collection and verification, defining a calculation methodology, and getting access to vetted software.	• State resources to pre-calculate and implement targets. Includes personnel time and expertise, technical systems, budget. • Availability of regional, product-specific data to calculate measures. • Method used to establish and assess targets.
Cost Mitigation	1. Set achievable targets. 2. Consider product specific performance criteria to develop targets. 3. Invest in technical resources (e.g. state/regional-specific EPD calculator, material-specific benchmark studies).	

Scenario 3: Noncompliance guidelines include penalties.

	Cost Assessment	Dependencies
Product Suppliers	State could refuse permit installation of non-compliant materials or require product manufacturers of non-compliant materials to pay a fine or follow additional recourse procedures.	• Type of compliance penalties. • Exemption criteria.
State Government	Costs depend on type of penalties and potential impacts to project schedules. Noncompliance fees could generate modest revenue for state. 'Harsh' penalizations (e.g. noncompliant product supplier no longer permitted to install materials) could result in delays to project schedules and incur additional construction costs to state and their design and construction teams.	• Type of compliance penalties. • Exemption criteria. • Impacts to project schedules. • Competition in product markets.

Cost Mitigation

1. Consider incentivizing compliance over penalizing noncompliance.
2. Establish exemption criteria to waive compliance, e.g. requirements likely to incur significant cost increases or project delays.

Scenario 4: Implementation timeline and delivery.

	Cost Assessment	Dependencies
Product Suppliers Project Teams	The extended timeline of construction: it can be years from when a project is initiated until it is bid and then additional years from start to end of construction. Project costs can increase if requirements change after contracts awarded.	• Project delivery model. • Project schedules.
State Gov.	Buy Clean policy would affect multiple awarding authorities managing construction contracts. Awarding authorities would need to adapt their department-specific procurement processes to reflect new standards.	• Level of coordination effort needed between awarding authorities. • Approach to updating procurement processes and guidelines.

Cost Mitigation

1. Set timeline to give sufficient time for design and construction teams to implement and test methods.
2. State agencies and public entities coordinate early and consistently to align efforts and establish a consistent delivery approach.
3. Use model specification template as an attachment to existing construction contracting manuals and standard specs to decrease time and effort of updating existing guidelines to reflect new policy requirements.
4. Create and maintain an EPD database and reporting method.

APPENDIX A: BUY CLEAN WA LEGISLATION

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Appendix A.1

Original Buy Clean Washington Bill: HB 2412

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H-3037.4

HOUSE BILL 2412

State of Washington 65th Legislature 2018 Regular Session

By Representatives Doglio, DeBolt, Macri, and Ormsby

Prefiled 01/05/18. Read first time 01/08/18. Referred to Committee on Capital Budget.

AN ACT Relating to creating the buy clean Washington act; and adding a new chapter to Title 39 RCW.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

NEW SECTION. **Sec. 1.** The legislature finds and declares the following:

(1) Climate change will have devastating global impacts.

(2) All scientific evidence points to the need for Washington and the world to reduce greenhouse gas emissions to avert the worst effects of climate change. Climate change impacts are already apparent in Washington, where scientists have determined that annual temperature increases and a long-term drought are consequences of human-induced climate change.

(3) The legislature has committed to reduce greenhouse gases, through numerous statutes requiring regulatory and other action by public agencies. Those regulations and actions do not currently encourage public dollars for infrastructure projects to be spent in a way that is consistent with the state's goals to reduce greenhouse gas emissions.

(4) State agencies must take climate change into account in their planning and investment decisions and employ full life-cycle cost accounting to evaluate and compare infrastructure investments and

alternatives. Full life-cycle cost accounting in this instance also refers to accounting for the impacts across the life cycle of a product, or life-cycle assessment.

(5) Great quantities of emissions are released during the manufacture and transport of products used in public infrastructure projects.

(6) Washington, through its extensive purchasing power, can improve environmental outcomes and accelerate necessary greenhouse gas reductions to protect public health, the environment, and conserve a livable climate by incorporating emissions information from throughout the supply chain and product life cycle into procurement decisions, and using that information to help direct expenditure.

(7) Incorporating emissions information will acknowledge those companies that have invested in emissions reduction technologies and practices. It will encourage other companies to take action to reduce emissions to become more competitive in the Washington bidding process.

NEW SECTION. **Sec. 2.** The definitions in this section apply throughout this chapter unless the context clearly requires otherwise.

(1) "Awarding authority" includes any of the following:

(a) The department of enterprise services;

(b) Institutions of higher education, including state universities, regional universities, The Evergreen State College, and community and technical colleges;

(c) Natural resource agencies, including the department of natural resources, the state parks and recreation commission, and the department of fish and wildlife;

(d) Any other state governmental entity that receives funding from the omnibus capital appropriations act for a public works project; and

(e) Any nonprofit organization receiving funding from the omnibus capital appropriations act for a public works project.

(2) "Department" means the department of enterprise services.

(3) "Eligible materials" include any of the following:

(a) Carbon steel rebar;

(b) Flat glass;

(c) Mineral wool board insulation;

(d) Structural steel;

(e) Cement;

(f) Structural timber;

(g) Solar panels;

(h) Refrigerants in new equipment;

(i) Aluminum;

(j) Gypsum; and

(k) Concrete.

(4) "Eligible project" means: (a) A construction project larger than five thousand gross square feet of occupied or conditioned space as defined in the Washington state energy code; or (b) a building renovation project when the cost is greater than fifty percent of the assessed value and the project is larger than five thousand gross square feet.

(5) "Greenhouse gas" has the same meaning as defined in RCW 70.235.010.

NEW SECTION. **Sec. 3.** (1) By January 1, 2019, the department shall establish and publish a maximum acceptable global warming potential for each category of eligible materials in accordance with both of the following requirements:

(a) The department shall set the maximum acceptable global warming potential at the industry average of facility-specific global warming potential emissions for that material. The department shall determine the industry average by consulting nationally or internationally recognized databases of environmental product declarations.

(b) The department shall express the maximum acceptable global warming potential as a number that states the maximum acceptable facility-specific global warming potential for each category of eligible materials. The global warming potential shall be provided in a manner that is consistent with criteria in an environmental product declaration.

(2) By January 1, 2019, and in conformance with RCW 43.01.036, the department shall submit a report to the legislature that describes the method that the department used to develop the maximum global warming potential for each category of eligible materials pursuant to subsection (1) of this section.

(3) By January 1, 2022, and every three years thereafter, the department shall review the maximum acceptable global warming

potential for each category of eligible materials established pursuant to subsection (1) of this section, and may adjust that number downward for any eligible material to reflect industry improvements if the department, based on the process described in subsection (1)(a) of this section, determines that the industry average has changed, but the department may not adjust that number upward for any eligible material. At that time, the department shall update the requirements to reflect that adjustment.

(4) The awarding authorities may amend their fee schedule to accommodate this chapter.

NEW SECTION. **Sec. 4.** (1) An awarding authority shall require the successful bidder for a contract described in subsection (3) of this section to submit a current facility-specific environmental product declaration, type III, as defined by the international organization for standardization standard 14025, or similarly robust life-cycle assessment methods that have uniform standards in data collection consistent with international organization for standardization standard 14025, industry acceptance, and integrity, for each eligible material proposed to be used.

(2) An awarding authority shall include in a specification for bids for an eligible project that the facility-specific global warming potential for any eligible material does not exceed the maximum acceptable global warming potential for that material determined pursuant to section 3 of this act. An awarding authority may include in a specification for bids for an eligible project a facility-specific global warming potential for any eligible material that is lower than the maximum acceptable global warming potential for that material determined pursuant to section 3 of this act.

(3) A successful bidder for a contract described in subsection (2) of this section may not install any eligible materials on the project until that bidder submits a facility-specific environmental product declaration for that material pursuant to subsection (1) of this section.

(4) This section only applies to a contract entered into on or after July 1, 2019.

NEW SECTION. **Sec. 5.** In carrying out its duties under this chapter, an awarding authority shall strive to achieve a continuous reduction of emissions over time.

NEW SECTION. **Sec. 6.** By January 1, 2022, and in conformance with RCW 43.01.036, the department shall submit a report to the legislature on any obstacles to the implementation of this chapter, and the effectiveness of this chapter to reduce global warming potential.

NEW SECTION. **Sec. 7.** This chapter may be known and cited as the buy clean Washington act.

NEW SECTION. **Sec. 8.** Sections 1 through 7 of this act constitute a new chapter in Title 39 RCW.

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Appendix A.2

ESSB 6095 Signed legislation page

CERTIFICATION OF ENROLLMENT

ENGROSSED SUBSTITUTE SENATE BILL 6095

Chapter 298, Laws of 2018

(partial veto)

65th Legislature
2018 Regular Session

CAPITAL BUDGET--SUPPLEMENTAL

EFFECTIVE DATE: March 27, 2018

Passed by the Senate March 8, 2018
Yeas 49 Nays 0

CYRUS HABIB

President of the Senate

Passed by the House March 6, 2018
Yeas 96 Nays 2

FRANK CHOPP

Speaker of the House of Representatives

Approved March 27, 2018 3:17 PM with the exception of Sections 3011(2), 3011(3), 3011(4), 4002, 7018, and 7019 which are vetoed.

JAY INSLEE

Governor of the State of Washington

CERTIFICATE

I, Brad Hendrickson, Secretary of the Senate of the State of Washington, do hereby certify that the attached is **ENGROSSED SUBSTITUTE SENATE BILL 6095** as passed by Senate and the House of Representatives on the dates hereon set forth.

BRAD HENDRICKSON

Secretary

FILED

March 29, 2018

Secretary of State
State of Washington

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Appendix A.3

ESSB 6095 Sec. 1030: Buy Clean Washington Pilot (91000447)

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NEW SECTION. **Sec. 1030.** A new section is added to 2018 c 2 (uncodified) to read as follows:

FOR THE DEPARTMENT OF ENTERPRISE SERVICES

Buy Clean Washington Pilot (91000447)

The appropriation in this section is subject to the following conditions and limitations:

(1) By June 15, 2018, the department must coordinate with the following projects: (a) Washington State University Tri-Cities academic building, project number 30001190; (b) Western Washington University sciences building addition and renovation, project number 30000768; (c) Shoreline Community College allied health, science, and manufacturing replacement, project number 30000990; (d) secretary of state library archive building, project number 30000033; and (e) the department of transportation SR9/Snohomish river bridge replacement, project number N00900R. The awarding authorities for these projects must collaborate with the University of Washington college of built environments study in section 5014 of this act to test proposed methods and availability of environmental product declarations.

(2) An awarding authority for the projects listed in subsection (1) of this section shall require the successful bidder for a contract to submit current third-party verified environmental product declarations for the eligible materials used if available and currently utilized.

(3) The awarding authority shall report to the department the quantities and any environmental product declarations collected in this section.

(4)(a) The department shall provide a preliminary report to the fiscal committees of the legislature by June 30, 2019, of the findings in subsection (1) of this section, and on any obstacles to the implementation of this section, and the effectiveness of this section with respect to reducing carbon emissions.

(b) The department shall report any positive or negative impacts to project costs, based on the requirements in this section.

(c) The department shall report on any positive or negative economic impacts to Washington state based on where the eligible materials are purchased.

(5) For the purposes of this section:

(a) "Eligible materials" include any of the following that function as part of a structural system or structural assembly:

(i) Concrete, including structural cast in place, shotcrete, and precast;

(ii) Unit masonry;

(iii) Metal of any type; and

(iv) Wood of any type including, but not limited to, wood composites and wood laminated products.

(b) "Environmental product declaration" means a facility-specific type III environmental product declaration, as defined by the international organization for standardization standard 14025, or similarly robust life-cycle assessment methods that have uniform standards in data collection consistent with international organization for standardization standard 14025, industry acceptance, and integrity.

(c) "Structural" means a building material or component that has, but is not limited to having, the following properties: Supports gravity loads of either building floors or roofs, or both, and is the primary lateral system resisting wind and earthquake loads, such as shear walls, braced frames, or moment frames, and includes foundations, below-grade walls, and floors.

Appropriation:

State Building Construction Account—State. $65,000

Prior Biennia (Expenditures). $0

Future Biennia (Projected Costs). $0

TOTAL. $65,000

Appendix A.4

ESSB 6095 Sec. 5014: Buy Clean Washington Study (91000022)

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NEW SECTION. **Sec. 5014.** A new section is added to 2018 c 2 (uncodified) to read as follows:

FOR THE UNIVERSITY OF WASHINGTON

Buy Clean Washington Study (91000022)

The appropriation in this section is subject to the following conditions and limitations:

(1) The University of Washington, led by the college of built environments, in collaboration with the Central Washington University construction management program, the Washington State University architecture and engineering school and the department of enterprise services, shall analyze existing embodied carbon policy and propose methods to categorize structural materials and report structural material quantities and origins.

(2) The colleges shall report to the legislature the methods developed in this section by December 31, 2018. The report must include potential impacts to project costs, both positive and negative, that use the proposed methods in subsection (1) of this section, and potential economic impacts, both positive and negative, to Washington state based on the origin of material purchased.

Appropriation:

State Building Construction Account—State. $100,000

Prior Biennia (Expenditures). $0

Future Biennia (Projected Costs). $0

TOTAL. $100,000

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APPENDIX B: PILOT SUPPLEMENTARY MATERIALS

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Appendix B.1

Model specifications

To download the latest version of the model specifications, go to the Carbon Leadership Forum's Buy Clean web page:

http://www.carbonleadershipforum.org/resources/buy-clean-washington/

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Add to new section X:
***[as appropriate for project type and specification standard]*:**

X-1. BUY CLEAN WASHINGTON PILOT

X-1.1 General

A. This section includes general requirements and procedures for facility-specific Environmental Product Declaration (EPD) Submittals of "eligible materials" subject to the Buy Clean Washington Pilot (91000447) per the Engrossed Substitute Senate Bill 6095 (Sec. 1030).

1. The awarding authority for state-funded building projects shall require the successful bidder for a contract to submit current third-party verified EPDs for the eligible materials used if available and currently utilized.

2. The awarding authority for state-funded building projects shall require the successful bidder for a contract to submit the quantities (in mass or volume), cost and origin for the eligible materials used.

3. The awarding authority shall report to the State of Washington Department of General Services (DGS) the quantities and any EPDs collected.

B. The following materials are subject to the Buy Clean Washington Pilot. "Eligible materials" include any of the following that function as part of a structural system or structural assembly:

1. Concrete, including structural cast in place, shotcrete, and precast
2. Unit masonry
3. **Structural steel** of any type including reinforcing steel
4. Wood of any type including, but not limited to, wood composites and wood laminated products.

C. "Environmental product declaration" means a facility-specific type III EPD, as defined by the defined by the International Organization Standardization (ISO) standard 14025 or similarly robust life cycle assessment methods that have uniform standards in data collection consistent with ISO standard 14025, industry acceptance and integrity for each eligible material proposed to be used.

D. "Structural" means a building material or component that has, but is not limited to having, the following properties: Supports gravity loads of either building floors or roofs, or both, **or** is the primary lateral system resisting wind and earthquake loads, such as shear walls, braced frames, or moment frames, and includes foundations, below-grade walls, and floors.

X-1.2 Submittals

A. For products requiring an Environmental Product Declaration (EPD) as stated in the applicable specification section, the EPD must conform to one of the disclosure types listed in below, in descending order of preference:

1. Facility-specific Environmental Product Declaration, Type III (i.e., conforms to ISO 14025 and 21930 and has at least a cradle to gate scope).
2. A publicly available, critically reviewed life-cycle assessment conforming to ISO 14025 (i.e., has at least a cradle to gate scope).

B. For products requiring an Environmental Product Declaration (EPD) as stated in the applicable specification section, use reporting template found at http://www.carbonleadershipforum.org/resources/buy-clean-washington/ to provide a link to the published EPD, and to complete fields to report origin and quantities data of the eligible material.

C. Submit the completed reporting template with EPD, origin and quantities data to the state agency (awarding authority) commissioning the construction project and the University of Washington's Carbon Leadership Forum. The report must be submitted before product installation.

Appendix B.2

Structural material quantity reporting template

To download the latest version of the structural material quantity reporting template, go to the Carbon Leadership Forum's Buy Clean web page at:

http://www.carbonleadershipforum.org/resources/buy-clean-washington/

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For each item in the spreadsheet (concrete, masonry, steel, and timber), create additional rows for each different combination of variables for which a quantity is used.
Indicates optional entry (provide if known).

Concrete (Including Grout):

Supplier Name	Supplier Address	Specified Compressive Strength (ksi)	Volume (yd^3)	Slump (in.)	Supplier Mix Designation	Stuctural Component(s)	Precast or In-Situ?

Masonry:

Supplier Name	Supplier Address	Type	ASTM Material Designation	Specified Compressive Strength (ksi)	Unit Weight (pcf)	Unit Dimensions (inch x inch x inch.)	Number of Units	Supplier Mix Designation

Steel:

Supplier Name	Supplier Address	Type	ASTM Material Designation	Weight (lbs)	Grade	Coating Type or Uncoated

Timber:

Supplier Name	Supplier Address	Type	Volume (yd^3)	Dimensions	Species	Grade	Number of Plies

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APPENDIX C: RESOURCES

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Appendix C.1

Policy resource collection

Note:

For a list of additional external resources (not specifically related to policy) compiled by the Carbon Leadership Forum, go to:

http://www.carbonleadershipforum.org/resources/external-resources/

For a sortable database of these resources, go to:

CLF's Embodied Carbon Resources Database (Google Sheet)

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Appendix C.1
Policy Resource Collection

OVERVIEW

This Appendix is a collection of educational information, which the research team collated to provide high-level resources targeted to US-based policy professionals. Resources include official legislation and policy documentation, professional reports and whitepapers, research studies, recorded webinars, websites of programs and groups focused on embodied carbon and/or related policy, and more.

This document presents resources within four tables:

C1 - Official documentation related to current US-based policies and programs
C2 - High-level information on embodied carbon context and policy
C3 - Tools and resources for general decision-making and technical support
C4 - National and regional collaborations

RESOURCE TABLES

TABLE C1 – OFFICIAL DOCUMENTATION RELATED TO CURRENT US-BASED POLICIES AND PROGRAMS

1.1 Buy Clean California Act			
Title and link	**Type**	**Source**	**Overview**
AB 262: Buy Clean California Act	Official legislation (2017)	CA State Legislature	Original bill signed into law on October 15, 2017
AB 1817: Amendment to Buy Clean California Act	Official legislation (2018)	CA State Legislature	Signed into law June 27, 2018 - amends existing language and implementation dates
Proposed State Contracting Manual language	Government document (2018)	CA Department of General Services (DGS)	Proposed language developed to provide policies, procedures and guidelines to CA state agencies when implementing law
Proposed Global Warming Potential (GWP) methodology	Government document (2018)	CA DGS	Proposed methodology for calculating the GWP for the eligible materials
External Stakeholder Comments	Government document (2018)	CA DGS	Comments submitted in response to the AB 262 External Stakeholder Outreach Event held by DGS on June 26, 2018
2016 California Green Building Standards Code (CALGreen)	(2016)	CA Building Standards Commission	Includes two voluntary tier measures for LCA and WBLCA credits similar to LEED v4
1.2 Buy Clean Washington			
Title and link	**Type**	**Source**	**Overview**
HB 2412: Creating the buy clean Washington act	Proposed legislation (2018)	WA State Legislature	Original bill introduced in the House Committee on Capital Budget in January
SHB 2412: Creating the buy clean Washington act	Proposed legislation (2018)	WA State Legislature	Substitute bill introduced in February
House Capital Budget Committee - public hearing on HB 2412	Video recording (2018)	WA State Legislature	Recorded public hearing held by House Capital Budget Committee. HB 2412 discussion/ testimonies begin at 44:45 of recording

Engrossed Substitute Senate Bill 6095	Official legislation (2018)	WA State Legislature	Sec. 1030 and Sec. 5014 define scope and allocate funding for: (1) Buy Clean Washington Pilot (led by DGS) and (2) Buy Clean Washington Study (led by UW)
EO 1801: State efficiency and environmental performance	Executive order (2018)	State of Washington Office of the Governor	Mandates state agencies to consider and account for GHS emissions
1.3 Oregon			
Title and link	**Type**	**Source**	**Overview**
HB 3161 and HB 3162	Proposed legislation (2017)	Oregon State Legislature	Proposed requirements for Oregon Department of Transportation to establish pilot program to assess how procured products affect emissions of carbon dioxide
EO NO. 17-20: Accelerating efficiency in Oregon's built environment to reduce greenhouse gas emissions and address climate change	Executive order (2017)	State of Oregon Office of the Governor	Outlines a number of energy efficiency measures for Oregon's building sector, including a directive for Oregon state agencies to analyze feasible options for lowering embodied carbon of building materials
Oregon Concrete EPD Program	Official website	Oregon Concrete & Aggregate Producers Association	Supports concrete manufacturers to measure and report environmental impacts of concrete mixes through EPDs. Includes a web-based tool, a reimbursement incentive, and direct technical assistance to manufacturers
1.4 US-based green building rating systems, codes and programs			
Title and link	**Type**	**Source**	**Overview**
LEED v4.1	Rating system/certification program	USGBC	Provides certifications at different levels based on number of points awarded for green building features
Living Product Challenge	Certification program	International Living Futures Institute (ILFI)	Assesses products from cradle-to-grave, taking into account product's impact on energy consumption, water use and human health
Zero Carbon Certification	Certification program	International Living Futures Institute (ILFI)	Requires projects to offset 100% operational carbon through renewable energy, and the total embodied carbon impact of construction
2030 Challenge for Products	GWP reduction targets	Architecture 2030	Performance targets set for every decade leading to 2050 to realize zero product emissions
Green Globes	Rating system/certification program	Green Building Initiative (GBI)	Uses an ANSI-approved consensus development process, in which energy performance is measured against regional performance data instead of baseline data from a typical building
B3 - Buildings, Benchmarks & Beyond	Government program	State of Minnesota	Includes an LCA component (Guideline M.1), requiring WBLCA for state-funded new building and major renovation projects
2012 International Green Construction Code (IgCC)	Model code	International Code Council	A regulatory framework for new and existing buildings, establishing minimum green requirements for buildings and complementing voluntary rating systems

TABLE C2 – HIGH-LEVEL INFORMATION ON EMBODIED CARBON CONTEXT AND POLICY

2.1 Embodied Carbon Context			
Title and link	**Type**	**Source**	**Overview**
The Built Environment and Embodied Carbon Emissions	Webinar (2017)	West Coast Climate & Materials Management Forum	Speakers explain the context of embodied carbon impacts, why they matter, and how they can be reduced (includes policies)
The Urgency of Embodied Carbon and What You Can Do about It	Web article (2018)	Building Green	Describes the context of embodied carbon and issues around tracking, reporting and reducing its impact
USGBC LEED v4 Education Series: Materials and Resources	Portal of educational resources (e.g. webinar courses)	USGBC	Educational courses presented in multiple formats. Relevant resources include "Demystifying EPDs" and "Whole Building Life-Cycle Assessment Basics"
Whole Life Carbon Assessment for the Built Environment, 1st edition	Professional guidance report (2017)	Royal Institution of Chartered Surveyors	Guidance mandating a whole life approach to reducing carbon emissions within the built environment
2.2 Embodied Carbon Policy			
Title and link	**Type**	**Source**	**Overview**
The Embodied Carbon Review	Report (2018)	OneClick	Reviews global certifications and regulations addressing embodied carbon emissions from construction materials
Embodied Carbon of Buildings and Infrastructure: International Policy Review	Report (2017)	Forestry Innovation Investment	Reviews policy approaches by 'leading' countries addressing embodied carbon and best practices that could be considered in the development of a carbon framework
Embodied Carbon in the Built Environment: Change Through Policy	Webinar (2018)	Embodied Carbon Network	Speakers presents knowledge, strategies and case studies related to policies addressing embodied carbon
The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products	Report (2018)	KGM & Associates, Global Efficiency Intelligence	Provides updated analysis on the 'carbon loophole', a term to describe global imported consumption-based or embodied carbon levels
Buy Clean CA webinar	Webinar (2018)	Thinkstep	Overviews law requirements and considerations/recommendations from an industry/LCA expert group perspective
IPCC Special Report – Summary for Policymakers	Report summary (2018)	IPCC	Presents high-level findings of the IPCC Special Report (assessment of global warming research)
2.3 Case Studies			
Building Project	**Key Details**	**Source**	**Overview**
Helen Sommers Building	Measuring and Reducing Embodied Carbon in Concrete	Sellen Construction	In-depth information on how the Sellen project team reduced the embodied carbon in concrete for the state-funded Helen Sommers Building
University of British Columbia Brock Commons Tallwood House	Brock Commons Time Lapse	Naturally:wood	Overview of building project and estimated GHG emissions saved due to low carbon materials selection

TABLE C3 - TOOLS AND RESOURCES FOR DECISION-MAKING

3.1 RESOURCES TO SUPPORT DECISION-MAKING BY POLICY/GOVERNMENT PROFESSIONALS			
Title and link	**Type**	**Source**	**Overview**
Climate Friendly Purchasing Toolkit	Toolkit	West Coast Climate & Materials Management Forum	Resources to help policymakers target the most significant GHG emissions in a public institution's supply chain, or the production of goods and services
Circularity in the Built Environment: Opportunities for Local Government Leadership	Primer report (2018)	StopWaste, Arup	Presents government officials a high-level circular economy framework for the built environment at the community, neighborhood and building scales
3.2 TECHNICAL RESOURCES TO SUPPORT POLICY STANDARDS			
Title and link	**Type**	**Source**	**Overview**
Embodied Carbon in Construction Calculator (EC3)	WA-based pilot program	Skanska USA, Carbon Leadership Forum, C-Change Labs	Collaborative project hosted at the University of Washington to develop an open-source EPD database sortable based on embodied carbon. Designed to align with and support building sector initiatives needing integrated data and tools to implement embodied carbon targets
Carbon Smart Building Materials Palette	Interactive web-based tool	Architecture 2030	Provides designers with attribute-based guidelines for (1) designing buildings with low- or zero embodied emissions, and (2) specifying construction materials with low- or no-embodied carbon
Embodied Carbon: Developing a Client Brief	Professional guidance report (2017)	UK Green Building Council	Provides industry professionals knowledge and resources to use when working with clients to request embodied carbon measurements
LCA Model Specifications V1	Model specification templates (2017)	Carbon Leadership Forum	Provides editable model specification language for EPD/LCA data collection
LCA Practice Guide	Professional guidance report (2018)	Carbon Leadership Forum	Introduces life cycle assessment concepts to building professionals and explains how to determine the environmental impacts of a building
LCA Technical Guidance	Professional guidance report (2018)	Carbon Leadership Forum	Provides technical recommendations to support applying LCAs to buildings in North America. Supplements the *LCA Practice Guide* and intended for LCA experts

TABLE C4 - NATIONAL & REGIONAL COLLABORATIONS

4.1 Sources	
Title and link	**Overview**
Embodied Carbon Network	WA-based initiative convened by the UW Carbon Leadership Forum that brings together building sector professionals, researchers, and environmental advocates. Members focus on tracking/measuring/reducing embodied emissions. Network comprises ten topical groups focused on subjects related to embodied carbon, including a Policy Focus Group. Currently, there are over 360 members based throughout the world.
West Coast Climate and Materials Management Forum	Collaboration of state, local, and tribal governments that develop ways to push sustainable materials management into standard practice. The forum identifies and shares effective greenhouse gas emission reduction strategies that also improve the way communities source, use, and recover materials throughout life cycle.
Bay Area Materials Working Group – Low-Carbon Concrete Codes Project	Project consortium working to produce model code language for local governments to adopt low embodied-carbon concrete specifications for residential and non-residential applications. Project will provide technical assistance to four pilot projects to apply the specifications.
Structural Engineers (SE) 2050 Commitment Initiative. Supported by ASCE SEI Sustainability Committee	Challenges structural engineers to meet embodied emissions benchmarks and increasingly higher reduction targets by 2050. The initiative aims to enlarge the collection of structural material quantities data from buildings projects to help determine an embodied emissions baseline.

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Appendix C.2

Low Carbon Canada Initiative

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NRC·CNRC CONSTRUCTION

Developing a Low-Carbon Canada through Life Cycle Assessment in Infrastructure Projects – A National Low Carbon Infrastructure Initiative

A proposal for discussion

National Research Council Canada | Conseil national de recherches Canada

Canada

Authors: Geoffrey Guest, Ph.D., National Research Council of Canada
Trevor Nightingale, Ph.D., National Research Council of Canada
Jason Urquhart, P.Eng., National Research Council of Canada
Jieying Zhang, Ph.D., National Research Council of Canada

Selected list of key supporting organizations:

- Athena Sustainable Materials Institute
- Atlantic Woodworks
- B.C. Climate Secretariat
- C-Change-Labs
- Canadian Cement Association
- Canada Green Building Council
- Canada Precast Pre-stressed Concrete Institute
- Canadian Standards Association Group
- Canadian Wood Council
- Clean Energy Canada
- Environment Climate Change Canada
- International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG)
- National Research Council of Canada
- Natural Resources Canada
- Public Services and Procurement Canada
- The Forest Products Association of Canada
- Treasury Board Secretariat of Canada
- University of Calgary
- University of Sherbrooke
- University of Toronto
- Zizzo Strategy

Report Date: 5 November 2018

Proposal Summary

Motivation: In the absence of climate action, climate change is estimated to cost Canada $21-$43 billion per year by 2050.[1] To address this pressing issue, the Federal, Provincial and Territorial governments have committed to reducing their greenhouse gas (GHG) emissions by 30% by 2030, and the Government of Canada (GoC) is also committed to 80% reductions of its operational GHG emissions by 2050. Current GoC pilot projects have focused on reducing the GHG operational emissions of GoC buildings as buildings account for 90% of its carbon footprint. Canadian industry experts have also joined the GoC in starting to develop procurement policy recommendations that will support the Pan-Canadian Framework objectives of GHG emissions reduction as well as spur innovation and build a robust economy based on clean growth.[2] These are all steps in the right direction; however, to realistically and efficiently achieve these ambitious goals will require a more holistic and coordinated approach, and perhaps more importantly, need sophisticated tools and quality databases to ensure robust results and facilitate quick adoption on a broader scale.

Public and private sectors in support of the implementation of LCA: The use of the relatively new practice of life cycle assessment (LCA) promises a greater and more integrated approach by going beyond operational GHG emissions reduction and addressing carbon emissions in all four stages of a built asset:

- emissions linked to the manufacture, transport and construction of building materials;
- emissions due to asset construction;
- emissions/sinks associated with asset operation; and,
- emissions during the de/re-commissioning of the asset.

For many years in Canada, focus has been on GHG emissions associated with asset operations. This has resulted in a robust green construction industry valued at $23.5 billion in 2014 while also generating nearly 298,000 direct jobs that produced green materials and technologies, and contributed to designing and constructing low-carbon buildings. [6] This industry now recognises the importance of addressing carbon emissions in the other stages of a built asset and is showing growing interest in the Canada Green Building Council's Zero-Carbon Building Standard [7] which requires estimating the total carbon footprint using LCA.

Several provincial and municipal initiatives requiring LCA

The Ministry of Infrastructure Ontario recognizes the importance of integrating environmental LCA into their infrastructure planning, procurement, business case development and decision-making processes and they plan to use LCA in the near future.[3] The province of Quebec developed an initiative to increase the use of wood in construction, requiring a comparative analysis (LCA-based) of life cycle GHG emissions for structural materials in provincially funded projects.[4] Both Alberta and Nova Scotia are presently establishing similar Wood Charters as Quebec which will also require life cycle emissions data at the funding application stage. Municipally, Vancouver is taking the lead, introducing a new low-carbon rezoning policy with a compliance path that requires the reporting of embodied emissions using a whole-building LCA perspective.[5] Beyond these examples it is evident that the LCA tool is playing an important role in GHG reporting and mitigation in various jurisdictions across Canada.

Integrating LCA into decision making will ensure that climate change mitigation is fully considered during the planning process, and thus support selection and use of lower-carbon materials and services during procurement and construction. When LCA is coupled with life cycle cost assessment (LCCA) it becomes

[1] Assumes no adaptive action taken: National Round Table on the Environment and the Economy (2011) Climate Prosperity: Paying the price: The Economic Impacts of Climate Change For Canada. Report 04. http://nrt-trn.ca/wp-content/uploads/2011/09/paying-the-price.pdf

[2] Clean Energy Canada (2018) The Power of Procurement: Cutting the federal government's carbon emissions. http://cleanenergycanada.org/report/procurement-federal-emissions/http://cleanenergycanada.org/report/procurement-federal-emissions/

[3] Ministry of Infrastructure Ontario (2017) Building better lives: Ontario's long-term infrastructure plan 2017. https://www.ontario.ca/document/building-better-lives-ontarios-long-term-infrastructure-plan-2017/chapter-2-planning-future#section-2 .

[4] Government of Quebec (2017) The Wood charter. https://www.mffp.gouv.qc.ca/publications/forets/entreprises/charte-du-bois-anglais-Web.pdf.

[5] City of Vancouver (2017) Green buildings policy for rezoning. http://guidelines.vancouver.ca/G015.pdf

[6] In 2014: DelphiGroup (2018) Green building in Canada – Assessing the market impacts & opportunities. https://www.cagbc.org/CAGBC/Advocacy/Green_Building_in_Canada_Assessing_the_Market_Impacts_Opportunities.aspx.

[7] CaGBC (2017) Zero carbon building standard. https://www.cagbc.org/cagbcdocs/zerocarbon/CaGBC_Zero_Carbon_Building_Standard_EN.pdf.

possible to assess the total cost of ownership (TCO) which now enables asset owners to make a fully informed financial decision when adjudicating construction bids for private and public sector projects.

Enabling reliable assessment of emissions and ownership cost: The NRC's *National Low-Carbon Infrastructure Initiative* will provide enhanced and integrated tools, guidelines and databases to empower Canadians to take carbon-based decision-making actions:

A first of its kind centralized and validated national Life-Cycle Inventory (LCI) database is required to unleash the full potential of LCA and allow for fair comparison of tendered projects both in terms of life-cycle GHG emissions and in the total cost of asset ownership over its lifespan. Robust, defensible, and meaningful evidence-based carbon decision-making requires high-quality LCI data. The core of this initiative therefore revolves around establishing a publicly accessible, transparent, scientifically robust, regionally relevant, and ever-growing national LCI database where the onus will initially be placed on construction materials and followed by transportation, fuel pathways and beyond.

Whole-infrastructure LCA guidelines and enhanced LCA tools (infrastructure-specific) will further assist in providing the step-by-step approach needed to measure, evaluate, and track the full life-cycle of carbon emissions of buildings and infrastructures. The tools and guidelines will leverage the LCI database, stimulate innovation in low-carbon materials, technologies and design, and contribute to aligning capital investment decisions with sustainability policies at all jurisdictional levels across Canada. This will be reinforced by changes to the National Master Construction Specifications.

The development of both will require close partnership with a consortium of stakeholders from across industry, government and academia to ensure equal opportunities and innovation is stimulated throughout the low-carbon supply chains and infrastructure design.

Economic and Innovation Outcomes: The global market for low-carbon goods and services is worth over $5.8 trillion, and it is projected to grow 3% per year.[2] Canada's green building industry is worth $23.5B in GDP and directly supports an estimated 298,000 jobs[8]. Embedding LCA in the infrastructure procurement decision making process will accelerate the growing trend of Canadian companies developing advanced green materials and energy efficient technologies, increase their competitive edge and access to both domestic and foreign markets like Europe, Asia and the United States.[9] Open and transparent requirements in the LCA guidelines and tools will enable all construction material segments to participate in the development of materials, systems, and designs selected for projects based on their performance. This non-prescriptive approach will stimulate innovation by being democratic and inclusive and will enable informed financial decisions that will lower the TCO of Canada's built assets.

Deferred maintenance (DM) is a large and growing problem in Canada because operating budgets do not accommodate the high back-end cost of low-up-front construction bids. Municipal governments have seen a 10-fold growth in their deferred maintenance since 1985, the university sector more than doubling since 2000 and estimates of accumulated DM costs for hospitals ranging between $15B and $20B.[10] This project will benefit Canada as a whole by developing the tools needed to curb this trend and to systematically address this DM in a methodical and most cost effective manner.

Willing Consortium of Support: The *National Low-Carbon Infrastructure Initiative* will require a total of four years to establish all elements to full operational readiness. The estimated $7-9M of funding required will be delivered through a consortium of stakeholders each being a member of the Steering Committee that will set the overall direction and priorities, oversee and direct the Initiative projects, each designed to deliver one or more outputs defined by the Steering Committee. Projects will be delivered by Technical Teams working collaboratively, comprised of Canada's leading talent from industry, academia, and government labs, and making use of existing knowledge and data, where possible.

Critical mass has been achieved with commitments or expression of strong interest to join (by NRC, NRCan, TBS, PSPC, Canadian Wood Council, Cement Association of Canada, and others). The Initiative will launch in

[8] Canada Green Building Council, "NATIONAL GREEN BUILDING ECONOMIC IMPACT"

[9] *See footnote 2.*

[10] Deferred Hospital Maintenance in Canada. http://www.healthcarecan.ca/wp-content/themes/camyno/assets/document/Reports/2015/HCC/EN/Deferred%20Maintenance_EN.pdf

January 2019 with the first Steering Committee meeting. Meantime, consultation of over fifty other stakeholders from across Canada is underway.

Please contact Marcel Lavoie for more details: Marcel.Lavoie@nrc-cnrc.gc.ca .

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Appendix C.3

North American Data Center Overview

A North American life cycle inventory data center

Jeremy Gregory, Massachusetts Institute of Technology
Debbie Steckel, American Center for Life Cycle Assessment
April 2017

Summary

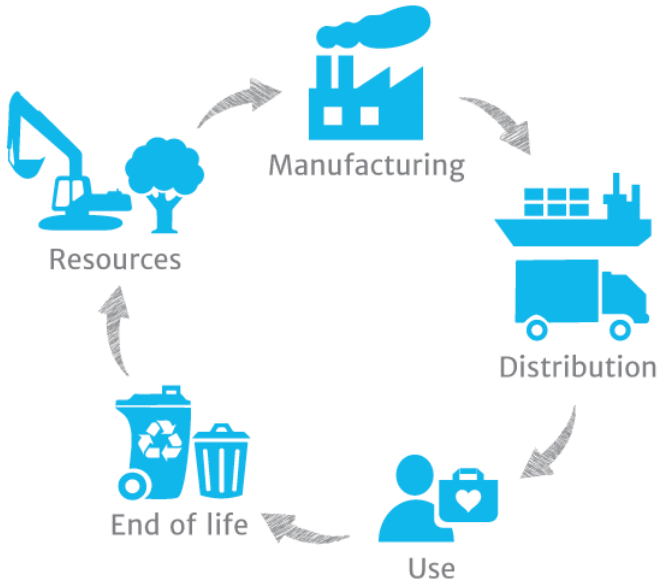
We are seeking $3M in funding over a four-year period to seed the creation of a center to manage North American life cycle inventory data. Such data is critical for conducting life cycle assessments, which are increasingly used to support government and industry policy and design decisions that involve product environmental footprints. High-quality and transparent data will increase the confidence in and use of these important analyses, which are starting to be used in many economic sectors.

We have assembled a diverse set of stakeholders to support the development of the data center. These stakeholders come from a broad array of sectors including government, academia, industry, academia, and consulting. A primary objective of the group is to establish a business model that ensures the long-term viability of the center.

Motivation

Quantitative assessments of products' life cycle environmental footprints are increasingly used to support decisions in policy and government arenas. For example, the US EPA requires an assessment of the environmental footprint of renewable fuels before they can be approved under the Renewable Fuel Standard. The US Green Building Council provides points in its LEED building standard for the use of building products that have a quantified environmental footprint.

Life cycle assessment (LCA) is the methodology used to quantify a product's environmental footprint throughout its entire life cycle from cradle to grave. Life cycle inventory (LCI) data is used in every LCA. It includes information on material and energy inputs for each process in the life cycle, along with emissions to air, land, and water. LCAs rely on databases that include LCI data for thousands of processes such as transportation, electricity generation, and material production.



http://www.ecoentreprises.qc.ca/innovate-and-optimize/business/life-cycle-assessment

High quality LCI data is a critical component of a reliable LCA. Most of the best LCI data comes from Europe. While there have been some efforts to create an LCI database for the US, efforts have stalled due to a lack of reliable funding sources. There are numerous gaps in existing US LCI data, the data are not updated, and there is no consistent format.

There is broad consensus that there is a need for high-quality, transparent life cycle inventory data applicable to North American industry.

Vision

We are creating a center to cultivate and maintain transparent LCI data that support North American industry and policy decisions and that are interoperable with data from other regions. A top priority for the center is a business plan that ensures its long-term viability.

Creation of the Center

A coalition of partners interested in creating the center will assemble and create a request for quotes (RFQ) targeting an organization that will operate the center. The coalition will establish the terms of the RFQ, evaluate the quotes submitted, and select an entity to run the data center. Key considerations in the RFQ would include scope of the center's activities (e.g., LCI data only, or consulting as well), tax status (e.g., profit or non-profit), and details expected in the proposed center's business model.

Coalition partners will contribute funds that will be used to seed the data center in its start-up phase before subscription fees could fully fund the center, similar to a start-up business with investors. Terms will be established for what partners would receive in exchange for seed funding (e.g., access to LCI data for a certain period of time without paying fees).

An advisory board will also be created that includes stakeholders who would like to contribute to the process of creating the center, but are not able contribute financially to be a member of the coalition. Advisory board members will not have voting status for decisions related to the creation of the center.

The American Center for Life Cycle Assessment will act as the legal entity that manages the creation of the center, including writing contracts for each coalition partner, receiving fees from the partners, managing selection of the entity chosen to run the center, creating a contract for the entity, and distributing fees to the entity. However, it is important to note that this would purely be an administrative role. This effort will be truly collaborative and it is in our interest to ensure that a broad range of stakeholders are engaged in the creation of the center.

Stakeholders engaged in the process

A stakeholder group has begun to shape the vision for the center and define the terms of coalition and advisory group members. The group has had numerous web and in-person meetings over the course of several months and includes representatives from a wide variety of entities listed here.

- **Government:** FHWA, National Energy Technology Laboratory, NIST, National Renewable Energy Laboratory, Natural Resources Canada, USDA, USEPA, USFS, US Green Building Council
- **Industry:** American Chemistry Council, Apple, Chevron, Dow, Dupont, Eastman, GE, Interface, International Copper Association, National Asphalt Paving Association, National Ready Mixed Concrete Association, P&G, Portland Cement Association, Sabic, SETAC, Siemens, Steel Recycling Institute, The Aluminum Association, The Sustainability Consortium, US Green Building Council
- **Academia:** Arizona State, Carnegie Mellon, Harvard, MIT, Michigan Tech, Northeastern, Polytechnique Montréal, UC Santa Barbara, UC Berkeley, UC Davis, U of Illinois-UC, U of Pittsburgh, U of Washington, Yale
- **LCA Consulting:** CADIS, EarthShift Global, ERG, Pre, Quantis, thinkstep, WSP

Seed Funding

We are seeking $3M in seed funding to support the initial creation of the center over a four-year period. $2M will be used to support the first two years of the center while it is creating its database. At the beginning of year three support will decrease to $750k as the center starts to receive revenue from other sources (e.g., subscription fees for the database, or additional longer-term investment). Support will decrease further in year four to $250k as the center receives increased revenue. No further seed funds will be provided after year four.

Funds from coalition partners will be used as seed funds. A maximum of $250k is expected from coalition partners. We are seeking the remaining $2.75M from other partners.

Timeline

Activities to-date:

- May 2, 2016: Kick-off web meeting with stakeholders
- Summer 2016: stakeholder survey
- September 30, 2016: stakeholder meeting at LCA XVI
- Fall 2016: two web meetings about value proposition and coalition membership

Next steps:

- Develop contract for coalition members
- Recruit coalition and advisory group members
- RFP development
- Obtain seed funding
- Once seed funding is obtained:
    - Distribute RFP
    - Select entity
    - Open NA LCI Data Center

Appendix C.4
Normalization method

As described in Chapter 3 and Chapter 5, in order to permit design and construction flexibility, could permit use of weighted average calculations to enable 'outlier' high carbon options for select applications provided that other low carbon options can offset impacts above a performance threshold.

In order to compare performance results, project teams could normalize their embodied carbon values in each material category by dividing the total embodied carbon (in kg CO_2e) by the total material weight in each category. An example of this calculation is shown as follows:

Assume that a project has:

- *1000 kg of Type 1 steel with an embodied carbon impact of 1.0 kg CO_2e/kg steel*
- *2000 kg of Type 2 steel with an embodied carbon impact of 2.0 kg CO_2e/kg steel*

The total weighted embodied carbon impact is calculated as

= (Embodied carbon of Type 1 steel) + (embodied carbon of Type 2 steel)

= (1000 kg x 1.0 kg CO_2e/kg) + (2000 kg x 2.0 kg CO_2e/kg)

= (1000 kg CO_2e) + (4000 kg CO_2e)

= 5000 kg CO_2e total

Dividing by the total weight of steel:

= (5000 kg CO_2e) / (1000 kg Type 1 steel + 2000 kg Type 2 steel)

= 1.67 kg CO_2e/kg steel

Thus, the normalized embodied carbon result for steel is 1.67 kg CO_2e/kg steel.

Using a normalized embodied carbon measure for each material, the resulting values should be equal to or less than the suggested benchmark value for that material category in order to meet Buy Clean requirements. In the example, if the benchmark value for steel is 2.0 kg CO_2e/kg steel, then the result from the result from the example (1.67 kg CO_2e/kg steel), being lower than the benchmark value, satisfies the benchmark requirements for steel.

If the results do not meet the benchmark requirements, then projects should select different material choices and re-perform the calculation. If projects are unable to meet the Buy Clean requirements, then the research team should seek special consultation with the Buy Clean program operators to explore alternative pathways to compliance.