LCA for WA

Life Cycle Assessment (LCA) and Buildings Research for WA State

University of Washington (UW) and Washington State University (WSU)

Research in Support of SB 5485

Contents

Life Cycle Assessment and Buildings Research for WA State: *Report to State*

A Review of Resources on LCA and Embodied Energy and Carbon in Building Materials: *Attached Reference Document*

Research Leads

Kathrina Simonen, RA, SE, LEED AP
Assistant Professor Architecture
College of Built Environments, UW

Liv Haselbach, PE, PhD, LEED-AP
Associate Professor Civil and Environmental Engineering
College of Engineering and Architecture, WSU

Research Team

Elaine Oneil, PhD
Research Scientist, School of Forest Resources
College of the Environment, UW

Joyce Cooper, PhD
Associate Professor Mechanical Engineering
College of Engineering, UW

David Fish
Graduate Research Assistant
College of Built Environments, UW

Bailey Brown
Graduate Student Participant
Civil and Environmental Engineering, WSU

Mazohra Thami
Graduate Student Participant
College of Built Environments, UW

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LCA for WA

Life Cycle Assessment and Buildings Research for Washington State

Note, for additional information please see the Attached Reference Document: A Review of Resources on Life Cycle Assessment and Embodied Energy and Carbon in Building Materials dated August 31, 2012.

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ES ESSB 5485: LCA for WA Executive Summary

UW-WSU Life Cycle Assessment and Buildings Research for Washington State (LCA for WA)

ES0 Introduction

There is growing national and international interest in integrating the methods and data of Life Cycle Assessment (LCA) into the evaluation of the environmental impacts of building materials and products, as well as those of whole buildings, considering their complete life cycle (construction, operation, maintenance and end of life). This report is based upon the charge to the University of Washington (UW) and Washington State University (WSU) by the Washington State Legislature, outlined in ESSB5485, to explore the potential of integrating LCA methods, data or tools into the State Building Code. The report is comprised of two documents, the main report and a reference document. The recommendations by UW and WSU based on ESSB5485 are further summarized in the final report.

Life Cycle Assessment and Buildings Research for Washington State, this main report includes:

- Background information on Life Cycle Assessment (LCA) as it relates to building practice to provide context to evaluate the report,
- A review of the studied items which are being recommended for future review, and
- Recommendations to the state on methodologies to integrate LCA into state code.

A Review of Resources on Life Cycle Assessment and Embodied Energy and Carbon in Building Materials, (Satisfies ESSB5485 section 1. (a) and (b)), this reference document includes summaries or listings of the following items:

- Text of ESSB5485 and Analysis by state staff.
- LCA based Codes and Legislation
- LCA based Rating Systems and Metrics
- LCA based Standards
- Models: LCA methods, data and impacts
- Tools: building industry specific LCA tools
- LCA and buildings research

LCA provides promise as a method to track and reduce the environmental impact of buildings. Every building product and system has some environmental impact. Applied correctly, LCA could enable a systematic review of buildings and help to evaluate environmental impacts as one of the multiple building performance criteria that must be assessed when making design decisions. Emerging methods to use building codes and regulation to promote the development of LCA data and integrate LCA methods into the design process are occurring in both the US and in Europe. The research team identified several methods already in (or nearly in) the structure of codes, such as the IgCC and ASHRAE 189.1 which provide recommendations for whole building LCAs when

evaluating high performance buildings, and leadership standards such as LEED V4 EPD credit and Architecture 2030 which provide incentives for the development of product-specific Environmental Product Declarations (EPDs). The French government has developed databases, regulations and tools that demonstrate methods to integrate LCA into manufacturing, design and construction practice. We believe that these are promising methods to provide information for effectively integrating LCA into the state building code and are worthy of further study to determine the potential impacts (cost, time, complexity) and benefits (environmental, economic, social) to the state.

As European efforts began years ahead of the US, they provide excellent case studies to evaluate the opportunities and challenges in implementing these policies. In developing methods to assess if LCA should be integrated into codes or regulation (in addition to evaluating the LCA code itself), care should be taken to evaluate the tools used to implement the code, the standards and analysis methods the tool uses to compute LCA results as well as the availability and quality of the data used as input to the tool.

ES1 Recommendations

Based on **ESSB 5485 Sec. 1.(2)(a) (i)**, in order to fulfill the charge to provide recommendations to the legislature for methodologies to '*determine if a standard, model or tool using life-cycle assessment can be sufficiently developed to be incorporated into the state building code,*' the LCA for WA research team recommends the following:

An evaluation of a LCA standard model or tool using LCA should contain the following three stages:
Goal: Clearly articulate the goals of incorporating LCA Methods into the state code.
Scope: Identify the LCA Methods which could be applied in the code and determine how and in what applications these methods might be integrated into code.
Evaluation: Evaluate if the LCA Methods can be (or already are) adopted into code language, and evaluate the effectiveness and impact of adopting the LCA methods into code.

Given the current state of LCA practice and tools as well as the capabilities of the building industry, the research team recommends that a modest goal such as *increasing awareness* would be currently most appropriate. Additional potential goals are outlined in section B1.1 of the report. The LCA for WA research team outlined an assessment methodology to narrow the scope of items to be reviewed in detail and identified critical factors that the state might consider when evaluating the LCA methods outlined in section B1.2 of the report. Based upon our preliminary implementation of this methodology, the LCA for WA research team has identified two general methods worthy of further consideration: whole building LCA and encouraging the development and use of Environmental Product Declarations (EPDs) to motivate transparency and improvement. This methodology could be refined and expanded upon by the state in order to finalize these conclusions.

Additional study is required to assess the impact adopting these methods would have throughout the building industry. Section B1.3 of the report outlines a proposed methodology in detail. The French HQE program administered by the CTSB has been testing EPD standards, data repositories and whole building LCAs in use by actual practitioners and checked by LCA experts. This comprehensive effort might be appropriate to emulate.

Based on **ESSB 5485 Sec. 1.(2)(a) (ii)**, in order to facilitate the effort to '*develop a comprehensive guideline using common and consistent metrics for the embodied energy, carbon and life-cycle accounting of building materials,*' the research team recommends supporting the development of emerging national and international standards related to LCA and EPDs. EPDs are developed with the LCA assumptions unified through the creation of Product Category Rules (PCRs), which facilitate the reporting LCA data in a consistent manner. Supporting the development of recognized consensus-based standards is important to help advance LCA practice. Section B2 of the report outlines our recommendations in more detail. Funding from the state (to account for staff time, fees for membership in standards bodies and help advancing these efforts [drafting standards, attending consensus meetings, etc.]) could help to advance the development of standards.

Based on **ESSB 5485 Sec. 1.(2)(a) (iii)**, in order to facilitate the effort to *'incorporate into every project the ongoing monitoring, verification, and reporting of a high performance public building's actual performance over its life cycle,'* the state should consider supporting two efforts currently underway: advance a proposed metering rule currently under review by the Technical Advisory Group (TAG) for proposal to the State Building Code Council; and fund efforts already designed by the States' Department of Enterprise Services (DES/formally General Administration) to track the actual operational energy of select state high performance buildings. The metering rule would legislate that buildings be equipped to measure, monitor, record and display energy consumption data for each energy source and end use category to enable effective energy management. Additionally, the state should fund a comprehensive LCA of these DES selected buildings to test different methods and tools for analyzing the impacts related to materials, construction and demolition integrated with the use phase impacts. Section B3 in the report outlines these recommendations in more detail.

In **ESSB 5485 Sec. 2.(1)(a) & (b)**, the bill requests that the Department of General Administration (now DES) develop recommendations to the legislature for '*streamlining current statutory requirements for life-cycle cost analysis, energy conservation in design, and high performance of public buildings'* and make '*recommendations on what statutory revisions, if any, are needed to the state's energy life-cycle cost analysis to account for comprehensive life-cycle impacts of carbon emissions'* and that DES should '*use the report prepared by the University of Washington and Washington State University under section 1*' of ESSB 5485. Based on the research conducted to date, the research team does not recommend making substantive changes to any of the items listed.

We believe that additional data, research and industry expertise is needed in order to effectively integrate LCA and carbon accounting into state code directly as requested by this section of the bill.

ES2 Conclusions

Life Cycle Assessment data and methods show great potential to improve our ability to evaluate, and thus reduce, the environmental impacts of building materials, products and systems as well as whole buildings. Both better data (more complete and comparable) and more expertise (by professionals and code officials) are needed to enable sophisticated use of LCA in building design and construction practice. Implementing any such requirements could result in substantial unintended consequences. Thus, we recommend that the more promising methods be evaluated in more detail and that the State of Washington actively support their development in a manner that could be applied in the near future. The State should consider taking a step-by-step approach to integrating LCA into building codes or green rating systems. This research team has identified several potential research projects that could provide 'first-steps' for integrating LCAs into state code and motivate the development of better LCA data and LCA expertise in the industry. These include:

- Whole Building LCA: Testing and evaluating emerging code based methods.
- Rewarding transparency through promoting the use of multi-attribute EPDs.
- Supporting standards development.
- Using LCA to evaluate the actual performance of high-performance buildings.

With better data and a more educated industry, the next stages of integrating LCA into code and practice can be better evaluated. The research team believes that better data and a more educated industry are critical to enabling the use of LCA to evaluate and reduce the total life cycle impacts of buildings.

I Introduction

I0 Background

Effective July 22, 2011, Engrossed Substitute Senate Bill 5485 (ESSB 5485) charged the University of Washington (UW), led by the College of Built Environments, and Washington State University (WSU), led by the College of Engineering and Architecture, to perform research and make recommendations to the State assessing methodologies for integrating life cycle assessment (LCA) into the state building standards or codes. Note that life cycle assessment can be written with or without a dash between the word 'life' and the word 'cycle'. For consistency, the dash is not used herein, although it does appear in the legislation. The final text of the legislation can be found at: http://apps.leg.wa.gov/documents/billdocs/2011-12/Pdf/Bills/Session%20Law%202011/5485-S.SL.pdf. The exact language of ESSB 5485 and the final bill report can also be found in the attached reference document. When exact language is used from ESSB 5485 within this report, it appears in quotes.

ESSB 5485 is divided into two primary sections. Section 1 identifies research and reporting to be prepared by UW/WSU. Section 2 identifies recommendations that the Washington State Department of General Administration (now re-named and re-organized under the Department of Enterprise Services[DES]) shall make to the Legislature to streamline the statutory requirements for life cycle cost analysis and energy conservation in the design and high performance of public buildings, and shall include recommendations on what statutory revisions, if any, are needed to account for the comprehensive life cycle impacts of carbon emissions using the report prepared by UW/WSU.

Specifically, Section 1, Subsection (1) of ESSB5485 charged UW/WSU to:
'Conduct a review of other states' existing building codes, international standards, peer-reviewed research, and models and tools of life cycle assessment, embodied energy, and embodied carbon in building materials. This review must identify:

(i) If the standards and models are developed according to a recognized consensus-based process;
(ii) If the standards and models could be implemented as part of building standards or building codes; and
(iii) The scope of life cycle accounting that the standards and models address.

By September 1, 2012, the University of Washington and Washington State University shall submit a report to the legislature consistent with RCW 43.01.036.' Herein, the response to Section 1 Subsection (1) of ESSB 5485 is called "Task A."

Section 1, Subsection (2) of ESSB 5485 charged UW/WSU to:
'In addition to providing the data required in subsection (1) of this section, the report must include recommendations to the legislature for methodologies to:

(i) Determine if a standard, model, or tool using lifecycle assessment can be sufficiently developed to be incorporated into the state building code;
(ii) Develop a comprehensive guideline using common and consistent metrics for the embodied energy, carbon, and life cycle accounting of building materials; and
(iii) Incorporate into every project the ongoing monitoring, verification, and reporting of a high performance public building's actual performance over its life cycle.'

Herein, the response to Section 1 Subsection (2) of ESSB 5485 is called "Task B."

I1 Terminology: Rating Systems, LCA, Impacts, EIO-LCA, EPDs, Embodied Carbon, Embodied Energy and LCCA

ESSB 5485 states that the research team shall focus on 'life cycle assessment, embodied energy, and embodied carbon in building materials.' ESSB 5485 also references life cycle cost analysis (LCCA) in Section 2,which defines the charge of the Washington Department of General Administration (now the DES). This section summarizes the clarifications of these terms and also provides additional background into these topics to give context for the reporting and evaluation that follow.

In Subsection (3) of Section 1 of ESSB 5485, the bill specifically states that:
'"Life cycle assessment" means manufacturing, construction, operation, and disposal of products used in the construction of buildings from cradle to grave.'

Life cycle assessment (LCA), embodied energy and embodied carbon are not further defined in ESSB 5485, but the **Final Bill Report ESSB 5485, C341 L11, Synopsis as Enacted** provided additional clarification as:

'Life cycle assessments review every impact associated with all stages of a process from extracting raw materials through manufacturing, distributing, using, repairing, maintaining, recycling, or disposing. Life cycle assessment can provide a broader review on the environmental, social, and economic concerns related to a product.

Embodied energy is the amount of energy needed to extract, transport, manufacture, install, and recycle or dispose of a product or service. Methodologies to determine embodied energy vary as to the scale and scope of the use and type of embodied energy.'

It is generally accepted that LCA, embodied energy, and embodied carbon are methodologies or metrics that are used in part to analyze various subsets of the sustainability of a product or process. The aforementioned clarifications in ESSB 5485 and its Final Bill Report appear to be very consistent with accepted interpretations of these terminologies.

For a good overview of LCA and LCCA in buildings we recommend the text: 'A life cycle approach to buildings: principles, calculations, design tools' (Konig et all, 2010). The following is additional text provided for further clarification as interpreted by UW/WSU.

I1.0 Background on rating systems, guidelines, regulations, codes and standards.

The following background on the different sustainability rating systems has been adapted with permission by the author from an article accepted for publication in the Journal of Green Building (Thompson et al., 2013).

There are many tools related to sustainability. These include rating systems, guidelines, codes, standards and regulations.

Green rating systems are tools that are used to confirm that a building or infrastructure project is being designed and built sustainably. They provide a metric to assess how sustainable a building or project is by assigning a representative value. The value of this metric is typically assigned based on how many credits or criteria the project meets. These credits often fall into a wide range of categories including site selection, water conservation, energy use, materials selection, and operations and maintenance. Each credit implemented earns points towards the value, which represents a sustainability measure for the project.

One of the best-known green rating systems is Leadership in Energy and Environmental Design for new construction and major renovation (LEED NC), which has been developed by the US Green Building Council (USGBC 2009). Green rating systems are typically voluntary; however, laws can reference them, and thus they become regulation (WA, 2009).

Guidelines differ from green rating systems. For guidelines, there is no metric established to rate the sustainability of the project. Guidelines are in place simply to establish guiding principles and suggest courses of action to meet the goal of building more sustainably. These guidelines typically assist an organization in achieving their sustainability goals by identifying preventative or corrective measures in areas where sustainability can be improved.

Building codes provide rules that establish the minimum standards for building performance. While historically, building codes have focused on protecting the health and welfare of the public, more recent codes have expanded to include minimum energy efficiency requirements. 'Green Codes' include additional requirements to improve the environmental performance of buildings over a broad range of impacts. Codes can be adopted and amended at both the state and local jurisdiction level.

Consensus standards such as the American Standards for Testing and Materials (ASTM) or International Organization for Standardization (ISO) are sometimes referenced by green rating systems such as LEED to establish methods for assigning credits. These standards may be procedures used for quantifying measures of sustainability (e.g. energy use, carbon emissions, etc.) and are used to ensure that the common methods are universally employed. ISO has created series of environmental standards directly related to LCA. (ISO, 2006 a,b,c).

Regulations are laws established by the government and must be followed regardless of the green design tools implemented. Sources of regulations may be imposed by the Counties, such as the

Surface Water Design Manual (King County 2009). Design standards such as applicable sections of the Washington State Public Building Requirements (SBCC 2009), the International Building Code (ICC 2009), and the International Green Building Code (ICC 2012) must be followed as mandated by the State.

I1.1 Life Cycle Assessment (LCA)

The following introduction to LCA was adapted with permission from an introduction to Life Cycle Assessment prepared for another publication, (Simonen, 2011).

Life cycle assessment (LCA) is a method for estimating the environmental and resource impacts of a product or process throughout its full life cycle including material extraction, manufacturing, distribution, use and disposal (See Figure I1.1). The assessment process begins with the specification of the study goal and scope. Based on the goal and scope, an emissions and resource accounting tracks inputs (e.g. water, crude oil) and outputs (e.g. carbon dioxide, methane and particulate matter emissions). Finally, impacts are estimated by translating inputs and outputs to environmental impacts such as climate change or acidification.

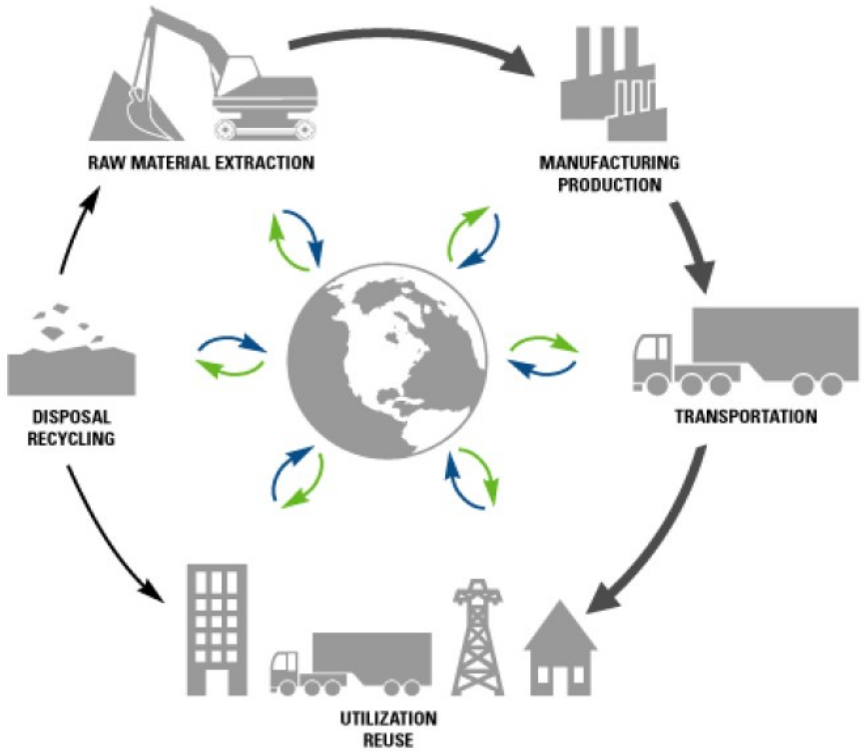

Figure I1.1: Tracking input *from* nature and output *to* nature across a product life cycle, (NIST, 2011)

The International Organization for Standardization (ISO) has standardized LCA. Their standards are internationally accepted as the primary life cycle assessment standards. ISO 14044 (ISO 2006c) details the technical requirements for an 'ISO-compliant LCA'. A summary of critical issues related to LCA is provided by Reap et al. (2008a, 2008b) and includes:

Assessment Goals: The fundamental first step of an ISO-compliant LCA is to identify the 'goal' (why the study is being done). Different goals may produce different assessment results. For example, an LCA compiled with the goal of identifying and reducing environmental impacts in a manufacturing process will likely produce different results than an LCA compiled to capture the total environmental impacts attributed to producing a product type.

Functional Units: LCA data are normalized to a functional unit (some basic common unit or size for comparison) of a material, product or process. Because the functional unit is defined for each LCA considering the quantity, quality and duration of the product or service provided, LCA results may or may not be comparable. For example, a building LCA quantifying the life cycle impact of 100sf of floor to support a live load of 100psf with maximum ¼" deflection for 50 years may or may not be comparable to a building LCA quantifying the life cycle impact of some other 100sf of floor space with undefined performance criteria. If looking to compare results of different analyses, care should be taken to ensure that equivalency of function is maintained.

System Boundaries: LCA requires a clear definition of the system boundaries (what industrial and natural processes are included and excluded). While the results of an LCA are theoretically comprehensive, in practice the preparation of an LCA requires the practitioner to make assumptions about what to include, what impacts to measure and what data sources to use. Based upon the goal of the study, the analysis may exclude some of the life cycle phases, resulting in data that is not comparable. Often studies will exclude contributions from phases such as fabrication and construction based both on a belief that the contributions are minimal and also on the difficulty of attaining data. When developing an analysis to compare materials, products or systems, defining the system boundary to effectively capture comparable components is critical to obtaining meaningful results.

Byproduct and Co-product Modeling: Co-products are life cycle byproducts that are useful elsewhere. There are multiple valid methods to allocate environmental impacts to the product of interest, and selecting among them requires some judgment in interpretation. Predicting recycling and re-use rates and the role of co-product markets, as well as determining what processes should 'bear' which portion of the environmental burden (how impacts are allocated), can significantly alter LCA results. Thus, understanding the methodology behind these decisions is critical to understanding and interpreting the impacts.

Life Cycle Inventory Data: The LCA of a building material or product is created by aggregating the life cycle impacts of all of the different processes required to extract raw materials and transform them into the product. The Life Cycle Inventory (LCI) data for each of these processes is termed the unit process LCI data. Unit process data is a list of all of the inputs from nature and emissions to

nature. A comprehensive LCI can track hundreds of different emissions. In order to create a high quality LCA, high quality LCI data for all of the unit processes are required. As there are limited US-specific LCIs published, many LCAs are created using either primary data or modifications of LCI data collected for a similar process or from a different region. Higher quality LCI data for a greater range of building materials, processes and products is needed to improve the quality of LCA analysis for buildings.

Variability and Uncertainty: An ISO-compliant LCA must include an assessment of data quality. Data is typically assessed in terms of age, technical and geographic relevance, completeness and consistency. LCI data includes aspects of uncertainty (that which is not known) and variability (known variation). Most LCI and LCA results are published as average data without information on the statistical variation of the data. The types of variability that are typical for building LCAs include: geographic variability – buildings have different requirements for different regions; technology variability – manufacturers can use distinctly different processes such as steel in basic oxygen furnace or electric arc furnace; use phase variability – user behavior impacts energy use and maintenance schedules; and methodological differences – choices in how the LCA was performed including system boundary, allocation decisions, impact assessment methods and LCI data sources. Interpreting LCA results thus requires a sophisticated understanding of the underlying variability and uncertainty of the data. LCA practitioners caution against assigning statistical relevance to LCA results with less than 10-20% difference between two options.

Environmental Impacts: LCIs report a wide range of emissions. In order to translate these to a smaller number of more tangible environmental impacts, the emissions that contribute to a specific environmental impact category (e.g. greenhouse gasses contribute to climate change) are multiplied by characterization factors that establish the equivalency of impact to a reference emission (e.g. global warming potential in proportion to carbon dioxide). However, climate change is not the only environmental impact category possible, and decisions related to the environmental preferability of products or processes should not be made based on a single impact category alone, or one risks other potential unintended negative environmental impacts. There are many different environmental impact categories and also different methods for characterizing them. For instance, the IPCC provides generally accepted methods for characterizing contribution to climate change in terms of carbon dioxide equivalents (CO_2e) for a wide range of emissions and resource use. Care should be taken to ensure that carbon footprints are reporting CO_2 equivalents for this wide range of contributors, rather than only air emissions and uptake of carbon dioxide. In addition, European and US standards have different methods of tracking and reporting environmental impacts such as smog formation and human health effects, making these results not always comparable. Additional information on environmental impact categories appears in the next section.

I1.2 Environmental Impacts of LCA

What environmental or resource impact categories should be included in a comprehensive LCA? There is no single answer to this question. In fact, there are many impacts that are difficult to include in LCAs due to the lack of supporting LCI or characterization data, developing science for environmental impacts or many other reasons. However, in order to portray a broader picture of the impact categories that are being considered for LCAs, the impacts assessed by different LCA tools and standards are explored in this section.

A list from Building for Environmental and Economic Sustainability (BEES), which is one of the LCA programs developed at the National Institute for Standards and Testing (NIST), follows in Table I1.1.

Table I1.1: Impact Categories Listed in BEES 4.0

IMPACT CATEGORY	BRIEF DESCRIPTION
Acidification Potential	A measure of air releases that acidify rain
Criteria Air Pollutants	Particulate matter
Ecological Toxicity	Various chemical releases to the environment
Eutrophication Potential	A measure of nutrient loadings to waterbodies from air and water pollutant sources
Fossil Fuel Depletion	See *Overall Energy* later in the list
Global Warming Potential	A measure of GHG emissions
Habitat Alteration	A measure of the loss of threatened and endangered species habitat
Human Health	Two categories of cancerous and noncancerous impacts of chemical releases
Indoor Air Quality	Mainly volatile organic compounds
Overall Energy	Multiple measures of energy use, or embodied energy, sometimes segregating fossil fuel and other sources
Ozone Depletion Potential	A measure of the potential for depletion of ozone in the stratosphere, which is important for ultraviolet light protection at the Earth's surface
Smog Potential	A measure of air emissions that promote smog development. This is commonly the development of ozone in the air we breathe in the troposphere
Water Intake	Typically the consumption of potable water

The list can further be subdivided by first itemizing those impact categories more readily incorporated or more commonly incorporated into LCAs, followed by those which are under development at this time. ASTM Committee E60 on Sustainability has a working group, WK28938, which is working on a draft of a 'Standard Practice for Minimum Criteria to Ensure Fair Comparisons When Performing Life Cycle Assessment of Whole Buildings'. The environmental and

resource impact categories included or not included in an earlier draft are itemized in Table I1.2. Note that the current draft no longer contains any listing of impact categories, but instead requires including those required by regulation or by similar request.

Table I1.2: ASTM E60 WK28938 Draft Impact Categories, March 2012

Draft Inclusion Status	**IMPACT CATEGORIES**
Impact Categories Which are Suggested to be Included for Comparative Assessments	Climate Change (greenhouse gases)
	Depletion of the Stratospheric Ozone Layer
	Acidification of Land and Water Sources
	Eutrophication
	Formation of Tropospheric Ozone (photochemical oxidants) – aka smog
	Depletion of Non-Renewable Energy Resources
Impact Categories Which May be Required by an Enacting Code or Rating System	Depletion of Non-Renewable Material Resources
	Use of Renewable Material Resources*
	Use of Renewable Primary Energy*
	Consumption of Fresh Water
	Solid Waste
Impact Categories Currently Outside Its Scope	Indoor Air Quality
	Social Impacts
	Monetary Assessments Such as Life Cycle Costing
	Human Health and Ecotoxicity Risk Assessment Related to Toxic Releases
	Biodiversity

*Note that impact categories are not necessarily negative.

These lists of impact categories in no way indicate a ranking of importance, nor do they represent a recommended order for this report. They are included herein to provide information as to the

scope of what LCAs may entail and to demonstrate that reporting environmental impacts requires decisions on which impacts to report and which methodologies to use in computing the impact measures. Although there is a need for continued development of methods to report environmental impacts, care should be taken to ensure that impact categories are well understood and the calculation methods enable consistent results. (Baitz et al, 2012)

Finally, there needs to be a discussion of the outcomes of an LCA. Current international standards, particularly ISO, dictate that the results list each impact category analyzed. BEES and other programs may have options for integration of the results from each impact category into compiled or single number overall rankings. However, these are not recommended to be part of an LCA report, nor are they recommended in this report. Rather, the compiled rankings are user-specific tools for decision makers to use based on weighting other factors of importance to them.

I1.3 Economic Input Output (EIO) LCA

The LCA evaluated in the majority of this report refers to the more typical 'process'-based LCA where individual unit process data is evaluated and aggregated to attain a final LCA for the multi-process manufacturing of a material or product. However, an alternate method of LCA, Economic Input Output LCA (EIO-LCA), builds upon government databases that report economic activity and environmental emissions per industrial sectors of the economy (Suh, 2009, Hendrickson, Lave & Mattews, 2006). LCA analysts develop databases that correlate data related to economic activity in each sector to environmental emissions in those sectors to create EIO databases that can enable an LCA to be performed based on dollars spent rather than quantities of material used.

I1.4 Environmental Product Declarations (EPDs)

Environmental Product Declarations (EPDs) use an ISO standardized (ISO 14025) method to report the 'environmental footprint' of a material or product and can be conceptualized as equivalent to an environmental 'nutrition label' for products. An EPD reports the results of an LCA in a consistent manner following agreed-upon rules. These standards are being designed to be general enough to apply to all products from clothing to curtain walls (ISO 14025, ISO 21930, CEN 15804). Rules specific to the building industry (Product Category Rules/PCRs) are required to refine the EPD reporting and LCA calculation standards to address unique manufacturing, use and end-of-life conditions. In order to compare the environmental footprint of a material or product, one must be sure that consistent assumptions are made when the footprint is evaluated. Without 'category'-specific PCRs, it is not possible to create comparable EPDs. PCRs are in effect environmental accounting standards. If developed and used properly, EPDs may be appropriate to use when comparing products if developed using the same product category rules.

fig I1.4 EPDs are based on LCA. EPD data could be used to develop project specific building LCAs.

I1.5 Embodied Carbon

Embodied carbon is an estimate of the contribution to climate change made by the production (rather than use or disposal) of a product. Thus, it represents a portion of an LCA that estimates only the contribution to climate change and only through certain initial phases of its life. The IPCC Global Warming Potential (GWP) is a widely recognized environmental impact metric. It is measured in units of kilograms of carbon dioxide equivalents and includes contributions from multiple greenhouse gasses (GHG) such as carbon dioxide, methane, nitrous oxide and others. The mass of each of these GHGs is converted to represent the equivalent impact of a kilogram of carbon dioxide and thus summed to an equivalent mass of carbon dioxide or CO_2e .

Standards for tracking and reporting the carbon footprint of companies, organizations and products have been/are being developed. The Greenhouse Gas Protocol (GHG Protocol) is a widely used greenhouse gas emission accounting standard that has been developed in cooperation between the World Resource Institute and the World Business Council for Sustainable Development (WRI/WBCSD). WRI/WBCSD divides GHG emissions into categories referred to as scopes (See FigureI1.2.)

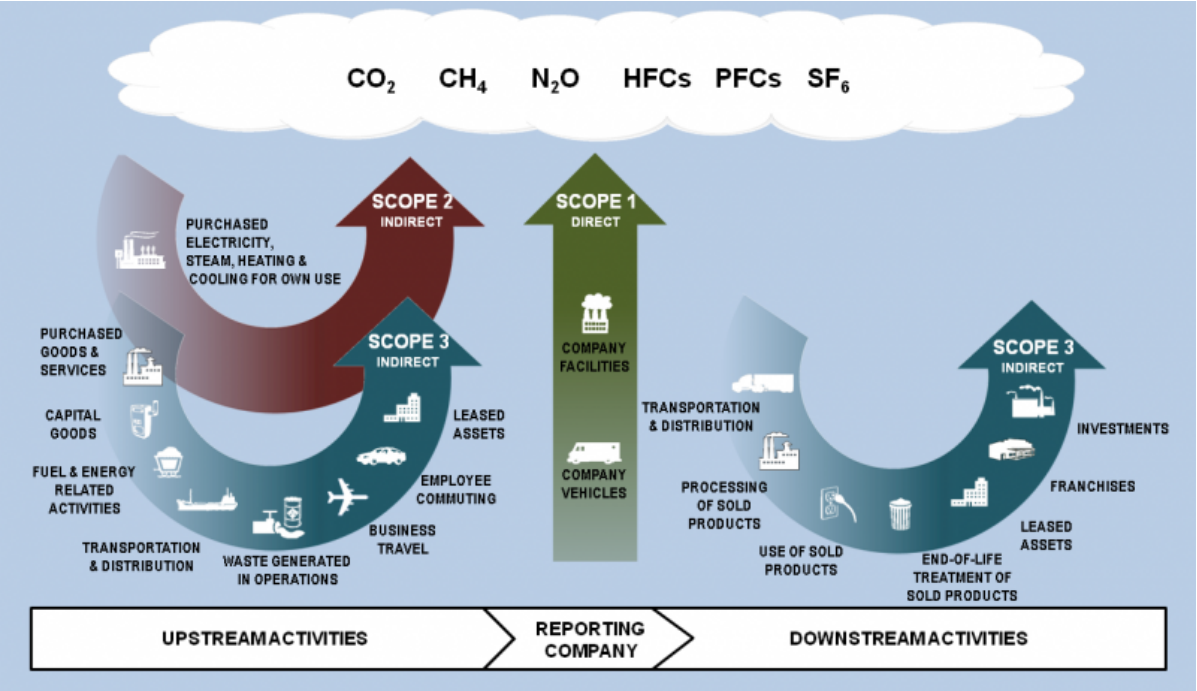

Figure I1.2. Defining GHG emissions by source type (scope), (WRI/WBCSD, 2011)

Scope 1 defines the emissions directly under the control of the company that are related to the generation of energy used to power facilities and vehicles. These are categorized as direct emissions because the company reporting the emissions directly controls them. Scope 2 defines those emissions related to the generation of energy purchased by a company. These are categorized as indirect as the company only has indirect control over the process. Scope 3 defines the emissions related to other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc. Upstream activities of Scope 3 are those that are purchased by a company and used in the primary activities of the company (or production of a product). Downstream activities of Scope 3 occur after the product leaves the company 'gate' and include use and disposal impacts.

While initial standards focused on reporting corporate carbon footprints, in October of 2011, the WRI/WBSCD released a Product Standard (WRI/WBCSD, 2011). This standard, which is based on LCA methodology, articulates methods appropriate for evaluating and tracking the carbon footprint of a material or product. Efforts to harmonize these standards with ISO are underway.

I1.6 Embodied Energy

Embodied energy reports the total energy (typically in kilojoules) used to produce and (usually) install a product (or install and replace a product component). Total energy use is different and is a typical output of a comprehensive LCA. Total energy use should reflect all life cycle phases

including use and disposal, but embodied energy does not include use and may or may not include disposal.

Although products with higher embodied energy often have higher embodied carbon, the two are not always proportional as carbon emissions depend upon the energy source. For example, an energy-intensive production process that used mostly renewable or low carbon fuel sources could have a very small embodied carbon footprint yet a high embodied energy. Furthermore, some processes release or sequester greenhouse gases as part of a chemical reaction (such as cement production) and thus have proportionally higher or lower embodied carbon than other materials. It is also important to remember that the primary means of electricity generation varies in different regions, leading to regionally-variable energy and emissions baselines. Energy use is a direct measure of manufacturing energy needs combined with energy efficiency. A carbon footprint, on the other hand, measures a combination of energy use efficiency and fuel source emissions.

I1.7 Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis (LCCA) is a different analysis than LCA that takes into account all monetary costs involved in acquiring, owning and disposing of a building or building system (WBDG, 2010). Energy lifecycle cost analysis (ELCCA) is a decision-making tool used in assessing energy-using systems (heating, cooling, lighting, building envelope, and domestic hot water) that enables the comparison of present values for two or more design options and accounts for both the first costs and the operational energy costs of the alternatives (WA GA, 2011). Since 1975, the State of Washington has required that an ELCCA be performed during the design of all publicly owned or leased facilities (WA GA, 2005). Evaluation of LCCA or ELCCA is not part of the UW/WSU research charge. The State's current ELCCA procedure is at the WA State Department of Enterprise Services' ELCCA page, http://www.ga.wa.gov/EAS/elcca/home.html. We have suggested opportunities to integrate an accounting of carbon emissions into the State's energy life-cycle cost analysis in section B4 in support of ESSB 5485's Section 2.(1).b which charges the Department of General Administration to make recommendations on any statutory revisions that are needed to enable one to account for these carbon emissions.

I2 Use of LCA Data in Design Decision-Making

In order for environmental footprint (a summation of a building or product's contribution to a particular environmental impact) data to be used in procurement decision-making and/or product certification and labeling programs, the GHG (Greenhouse Gas) Protocol Product (WRI/WBCSD, 2011) and ISO standards such as ISO 14025 and ISO21930 require that the reporting conform to industry-specific 'product rules' or guidelines which are commonly called product category rules (PCRs). PCRs typically include the quantification of a list of many commonly recognized environmental and resource impacts. Thus consideration of climate change alone is not considered adequate to establish if a product or process is 'environmentally preferable'. For example, a

product with a small contribution to climate change might be a very poor performer in another environmental category (e.g. smog potential, ozone depletion, water use, etc.).

ISO standards (ISO 2006a) provide guidance for developing and reporting the environmental footprint of products in what are called environmental product declarations (EPDs). Developing standards by the European Committee for Standardization (CEN, 2012) are providing additional clarification to help ensure uniformity for building products.

Additionally, when looking to compare between similar products, verifying that the full life cycle impacts are considered is essential to ensure that one is comparing 'apples-to-apples'. Two different options must be functionally equivalent in order to comprehensively compare environmental footprints. Thus, the life of the product, the maintenance, use and end of life phase impacts must be evaluated in addition to the 'cradle-to-site' embodied impacts. For example, one should not select a window based only on the impacts related to its manufacture and construction, as the thermal performance of a window is critical to the use phase impacts of a building. Furthermore, if the glass seal lasts ten years instead of twenty, the glazing will need to be replaced more frequently. Thus, a complete LCA comparison of windows would include the impact on operational energy as well as the required maintenance and refurbishment over the full life of the building.

Sustainability includes environmental, economic and societal issues for present and future generations. Thus, both LCA and LCCA are important to sustainability. However, there are many societal issues not addressed in either. Some societal issues such as the availability of resources like water or energy and some environmental health impacts are increasingly becoming important parts of LCAs. Other societal issues such as ‘access to’ versus ‘availability of’ resources are not yet included nor are other issues such as education or health care. This report will focus on the typical issues currently being considered or under development for consideration in LCA practice, including environmental and resource impacts. Although important, integrating social aspects of LCA remains a developing discipline.

I3 Project Process

A primary goal of this project is to ensure the development of content that is of greatest value to the Washington State Legislature and the building industry as a whole. Therefore, multiple opportunities for input and feedback from interested stakeholders were provided. The following is a summary of the research team's outreach efforts:

- Developed a website to summarize the research project and post progress updates: http://courses.washington.edu/lcaforwa/wordpress/.
- Solicited interest and developed an email list (currently >140 participants) to distribute announcements of research progress (typically, monthly emails have been distributed).
- Held a stakeholder workshop on September 14-15 at the University of Washington (the 32 participants including engineers, architects, state employees and industry trade organization representatives) to help identify an appropriate direction and content for this work. A summary of key points addressed in the meeting was posted on the research website.
- Developed documentation in the following steps:
  - Prepared a list of relevant standards, codes, models and tools. The preliminary list of items to study for Task A was posted on the research website on Nov 1, 2011 for stakeholder input: http://courses.washington.edu/lcaforwa/wordpress/?page_id=58. During November of 2011, input and feedback were received from 12 different stakeholders identifying additional items to study and providing comments on the progress to date.
  - Compiled a list of peer-reviewed research in early 2012.
  - Prepared descriptions of relevant standards, codes, models and tools, and peer reviewed research, pursuant to Task A.
  - A 50% draft of Task A was presented for public review in January 2012, and the comments received from that review were incorporated into an 80% draft.
  - Prepared recommendations based on the Task A descriptions of relevant standards, codes, models and tools, and peer reviewed research, pursuant to Task B. A 50% draft of Task B was issued simultaneously with the 80% Draft of Task A on May 1, 2012.
- Held a stakeholder workshop on May 7th, 2012 which included educational presentations by invited experts. Video of these presentations can be found at the LCA for WA website: http://courses.washington.edu/lcaforwa/Video_12-05-07/.
- Revised Task A and B documentation based on the May 7 stakeholder workshop and individual reviewer comments resulting in the document here presented. The 90% document was issued for stakeholder feedback by July 2012.
- Stakeholder comments to the 90% draft are included with responses in appendix C2.

A Task A: Review of Available Resources

A0 Introduction

Per Washington ESSB 5485, this is a Final Report to the State of the 'Task A' requirement to:

'Conduct a review of other states' existing building codes, international standards, peer-reviewed research, and models and tools of life cycle assessment, embodied energy, and embodied carbon in building materials' (Sec. 1. (1)(a)). This review must identify:

(i) *'If the standards and models are developed according to a recognized consensus-based process';*

Recognized consensus-based processes include processes followed by international standards organizations such as ANSI, ASTM, ISO and ICC.
For the purposes of this report, peer-reviewed research is research that is published in a peer-reviewed journal or which has met the LCA peer review requirements of ISO 14044. (ISO, 2066c)

(ii) '*If the standards and models could be implemented as part of building standards or building codes';*

Task B of the research requires the team to develop recommendations on how to determine if the standard or model 'can be sufficiently developed to be incorporated into the state building code'.
For the Task A phase of the research, the potential of implementation into code language is rated by prioritizing the relative importance of each standard and model for evaluation using the following metrics:

1 ***Applicable***
Already being developed in code-based language or easily adoptable.
Most directly related to linking LCA and building practice.
1A ***Highest importance***
Shows highest potential for integration into the state building code.
1B ***Important***
Supplemental to the effort, but not sufficient on its own. Examples include:
a. A standard that could be referenced by the code.
b. A tool that could be used to comply with certain code requirements.
c. A database or tool that would need to be updated with regionally-specific information.

2 ***Possibly Applicable***

May be worthy of future study.
Shows potential but would require additional development.

3 ***Low applicability***
Out of date.
Only tangentially related to LCA and construction.

(iii) The scope of life cycle accounting that the standards and models address.

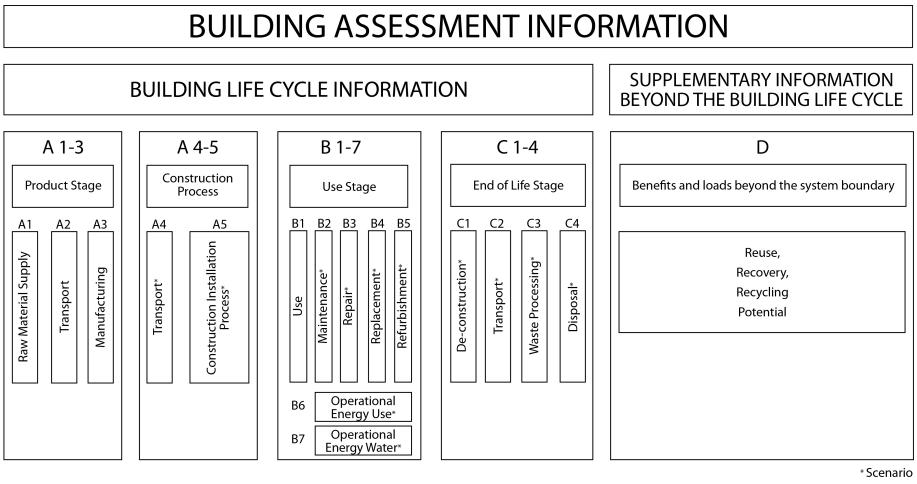

Figure A0.1: Modular development of building life cycle stages, (adapted from CEN, 2011)

In evaluating the scope of life cycle accounting that the standards or models address with respect to the life stage or phase of a product or process, the organizational structure developed by the European Standard for LCA and buildings in CEN 15978 has been slightly modified to simplify the stages to more accurately reflect the information in the documents we reviewed (not all studies included the detailed information included in the CEN life stages) and as no current U.S. standard is complete. The general categorization in CEN 15978 (Figure A0.1) and the modified categorization used herein are summarized as follows:

CEN Life Stage

A1-3: Material Extraction and Product Manufacturing Stage
A4-5: Construction Stage
B1-7: Use Stage
C1-4: End of Life Stage
D: Reuse, Recovery, Recycling Stage

Modified Life Stages for Categorizing in this Report

A: Product/Manufacturing and Construction Stages (cradle to gate)
B: Use Stage
C: End of Life Stage
D: Reuse, Recovery, Recycling Stage

A1 Organization of the Review

Figure A1.1 presents the wide array of potential connections between tools, data, and methodologies. As shown, standards provide protocols for collection of LCI data: first for production (i.e. building construction), use, and end-of-life stages and next for the materials and energy used in each. These data are combined with impact characterization methods in software tools used to prepare the LCA. Finally, the LCAs are used in the development of codes and rating systems.

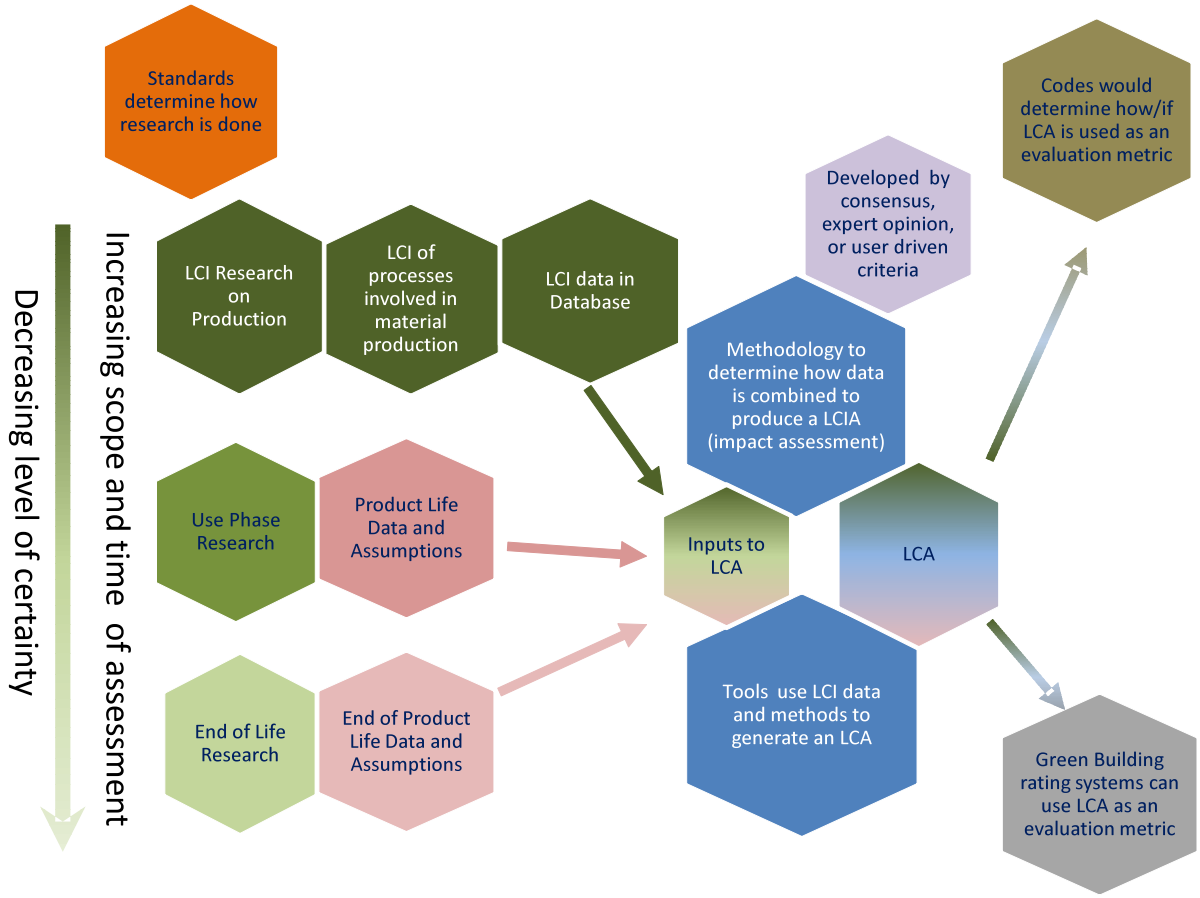

Figure A1.1: Flow from life cycle research to application in rating systems and codes.

The specific LCI data for each of the materials and processes that are combined to develop the full life cycle inventory for a given product are typically built from some combination of survey data and engineering process models. Such data can be verified, and uncertainties can be quantified. However, when practitioners are unable to perform surveys or develop process models, data are available in databases and/or from published LCAs.

An LCA can be developed using any tool and impact estimator from the potential list in Figure A1.2, and carried through to whatever time dimension of inventory data is desired (i.e. to the end of

construction, use phase, or end of life phase). LCA results will vary based on the specificity and extent of inventory data chosen and by the impact assessment method used to conduct the analysis. The tool choice should not affect the outcome.

Using LCA data in green rating systems or codifying them in the building code would necessitate developing methods to address the uncertainties inherent in moving down the building's time line from construction through the use and end-of-life phases.

An example of the many intricacies of the LCA process is evident in Figure A1.2, which was developed by a consulting engineering firm, Arup, to portray the connections between various groups of products and the resources that might be used in some of their life cycles, as well as the associated analyses. This figure shows the relationships between the existing tools, methodologies, databases, and design guides that can be used to develop LCAs for buildings and building products worldwide. The relationships that are most relevant for purposes of this study are those that utilize North American data or data that would be relevant for North American construction. For example, if a product such as steel is imported, data on the life cycle of imported steel would be relevant for evaluation purposes.

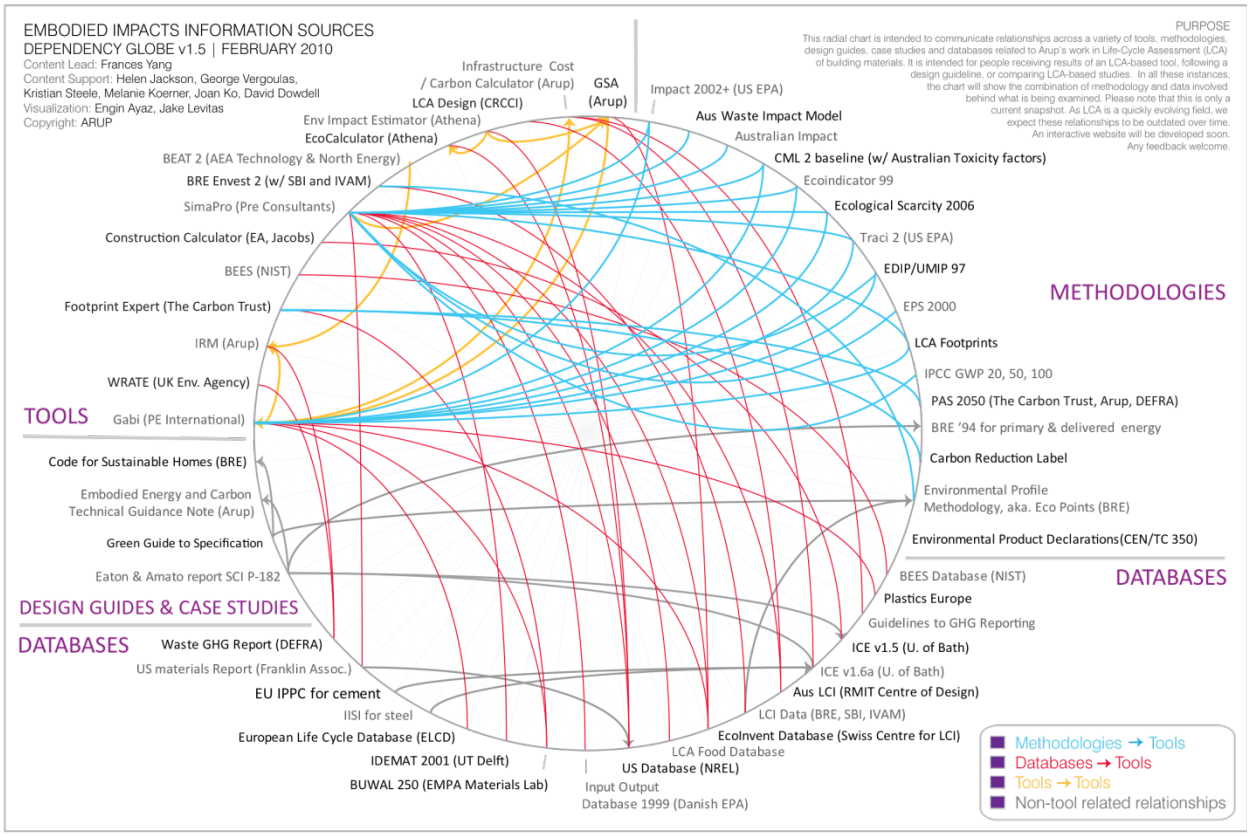

Figure A1.2: Embodied Impacts Information Sources Dependency. (Image courtesy of: Dowdell, D., Jackson, H., Ko, J., Koerner, M., Steele, K., Vergoulas, G., & Yang, F. (ARUP) (2010). *Embodied impacts information sources: Dependency globe* (v. 1.5). Arup, San Francisco, CA.

Given the start provided by Arup (2010), there are also many standards that are used in data development or to guide the use of the models, tools, databases and environmental methodologies listed in Figure A1.2. Thus, in the initial portion of this research, information concerning various groupings of standards, models and tools are compiled and summarized for applicability.

In identifying the items for review, the research team performed the following:

1. Contacted the major US code development organizations to attain updates of current codes.
2. Contacted the major US and international standards organizations and reviewed lists of current and developing standards.
3. Conducted a literature review for LCA standards and tools for the building industry.
4. Contacted developers of LCI data and LCA tools to understand the status of these models and identify other potentially relevant models or research.
5. Solicited input from stakeholders and other industry experts.
6. Compiled LCA studies recommended by research team and stakeholders.

A more detailed analysis of the studied codes, international standards, peer-reviewed research, and models and tools of life cycle assessment, embodied energy, and embodied carbon in building materials is contained in the attached reference document. Table A1.1 presents the organization of this reference document.

Table A1.1: Organization of the Reference Document with Detailed Analysis

Report Section	***Grouping***	***Brief Description***
Attachment A1	ESSB 5485	ESSB 5485, House and Senate Bill Report, Environmental Committee Bill Analysis, and the Final Bill Report
Attachment A2	LCA Codes	Local, national and international building codes with environmental LCA considerations
Attachment A3	LCA Rating Systems	Use of LCA in 'green building' rating systems and performance metrics. Potential to integrate into code
Attachment A4	LCA Standards	ASTM, ISO and other standards
Attachment A5	LCA Models	Life Cycle Inventories: public and proprietary
Attachment A6	LCA Tools	Building industry specific tools linking LCA data to construction practice
Attachment A7	Research	LCA research related to building materials

A2 Summary of the Review

The following is a summary of the number of items reviewed in the reference document.

Table A2.1: Summary of Reviewed Items

Grouping	*Number of Items Reviewed*	*# of Items Reviewed that were Developed According to a Recognized Consensus-based Process*	*# of Items Reviewed that Consider the Production/ Manufacturing & Construction Stage (Cradle to Gate) [A]*	*# of Items Reviewed that Consider the Use Stage [B]*	*# of Items Reviewed that Consider the End of Life Stage [C]*	*# of Items Reviewed that Consider the Reuse, Recovery, & Recycling Stage [D]*
A2: Codes &Rating Systems	11	1ǂ(2)	9ǂ (1)	6	5	2
A3: Rating Systems & Metrics	9***	3ǂ (1)	9	4	4	2
A4: Standards	20**	20	19	19	17	10
A5: LCA Models & Databases	8	3ǂ (1)	2ε	2ε	1ε	1ε
A6: Building Industry LCA Tools	25	1ǂ (4)	19ǂ (5)	17	14	5
Total	**73**	**28**	**58**	**48**	**41**	**20**

ǂ Not all items fully analyzed (*number not analyzed*)

ε Most vary in terms of LCA stages (A-D) covered depending on the product analyzed

** An additional 19 items were provisionally reviewed and not included in the final report as they were not related to the study topic.

*** An additional item was provisionally reviewed and not included in the final report as it was not related to the study topic.

A3 Review and Recommendations

The research team has grouped the items reviewed into the following categories in order to summarize the results of our research:

1. LCA Codes and Rating Systems
2. LCA Standards
3. LCA Models (analysis methodology)
4. LCA Models (data)
5. LCA Tools for the Building Industry
6. Research Review: LCA and Building Codes

What follows is a summary of key issues identified in each category reviewed and a summary of the research items evaluated as having the 'highest importance' (rated 1A, and reviewed in more detail in the attached reference document) and thus most applicable for further review. This list has evolved over three public comment periods.

A3.1 LCA Codes, Legislation and Rating Systems

There is currently significant effort, both nationally and internationally, being undertaken to develop means of integrating LCA-based environmental assessment into building codes and green building rating systems. There are two general approaches being taken: a whole building LCA approach that looks to compare a proposed building against a 'benchmark building' of some sort; or a method focused on rewarding public declarations of environmental impacts through the use of EPDs. Table A3.1 summarizes the codes and rating systems that the research team recommends evaluating in further detail as outlined in the Task B recommendations of this report.

Table A3.1: Existing codes and rating systems of 'highest importance' /worth further study
Listed in alphabetical order

Code	***Brief Description***
ANSI/ASHRAE/ USGBC/IES 189.1 (ASHRAE 189.1)	ASHRAE 189.1 was adopted in 2011 as the Standard for the Design of High-Performance Green Buildings (excluding low-rise residential buildings). It is an alternative to the IgCC 2012 and is published together with that document. Adoption of this code is limited (see attached reference document). Municipalities have the option of adopting either or both of these codes. If both are adopted, practitioners must select one of the codes to follow. The optional LCA section (Section 9.5) outlines a procedure for a whole building LCA that provides a standard for a performance-based assessment method for material environmental impacts between at least two building alternatives and must show at least a 5% improvement in at least two impact

	categories (land use (or habitat alteration), resource use, climate change, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, or eutrophication). The LCI includes accounting for various national ambient air quality standard emissions, greenhouse gases and hazardous air pollutants as listed in the Clean Air Act. This optional LCA method would replace a prescriptive option for material selection (Section 9.4) for increased recycled content, regional materials, bio-based products and wood building material certification.
CalGreen	Whole building LCA section A5.409.2 is a voluntary whole building LCA. Requires at least a 10% improvement for at least three impact categories, one of which must be climate change.
IgCC 2012	Released in March 2012, Section 303 Whole Building LCA covers only climate change and a choice of two or more additional environmental impacts (choice of: primary energy use, acidification, eutrophication, ozone depletion or smog). This section specifies the creation of a whole building LCA to compare against a (not defined) baseline building and demonstrate reductions of at least 20% reduction in the identified impact categories. Adoption of this code is limited. See attached reference document. If followed, then projects do not need to abide with Section 505, Material Selection, which covers a combination of reused, recycled, recyclable, bio-based and indigenous materials. In addition, the IgCC 2012 has a comprehensive Chapter 6 on Energy Conservation, Efficiency, and CO_2e Emission Reduction for the effective use of energy in a building.
Legislation	
Dutch LCA analysis	Starting in 2013, the Dutch building code may require LCA of all new buildings (per verbal discussion with researcher-awaiting confirmation).
Exec. Order 13514 Sec. 13 Interagency Group	(IN DEVELOPMENT). Proposed guidance for 'green' purchasing standards for the US Government. The draft for public comment has repeatedly been delayed. It is expected to serve as a model for states and agencies in the US.
French EPD& LCA legislation	French legislation mandating the creation of Environmental Product Declarations (EPDs) for all products sold in France that are published with any environmental claim. In development over the past several years, the legislation has prompted the creation of data used to develop an LCA database

	for building products in France. The deadline for implementation is 2013. Multiple federal and state ordinances have also been passed mandating whole building LCA. Tests of some of these methods have recently been published (HQE, 2012) and multiple tools and datasets have been developed to support the LCA analysis.
German & Swiss LCA Certification	Both Germany and Switzerland have adopted whole building LCA as part of their green building certification systems. Regionally specific tools and databases have been developed and are currently being tested to determine if appropriate baselines can be developed to proposed buildings against standard metrics (based on discussions with practitioners, pending details and references).
Rating Systems	
2030 Challenge for Products	This is a voluntary system to reward the use of products with EPDs that document improvements in climate change impacts relative to an industry baseline. Developed by a nonprofit, Architecture 2030, the 2030 Challenge for products provides motivation and recognition for manufacturers who develop EPDs and reduce their carbon footprint compared to an industry average baseline (most of which still need to be developed). They are also advocating the development of multi-attribute EPDs. Note: Architecture 2030 is not quite a rating system but rather a 'leadership standard'. Rather than identify a separate category we have kept it within the rating systems section.
LEED V4	Draft revision to LEED proposed rewarding the use of products with ISO compliant EPDs. Note: LEED is in the updating process and this section is uncertain. However, the State should know that these options might soon be available. As was written in the 4th draft (of what was then titled LEED 2012), buildings would receive credits in the materials and resources section if documentation was provided that a certain percentage of the building materials (both structural and non-structural) used have EPDs. Note that this proposal does not require that the EPDs demonstrate any improvement over a bench-line but rather are rewarding product transparency. Additional points are awarded for the use of products that document that chemicals on a "chemicals of concern" list are not used.
Living Building	Green building rating system that integrates LCA through the requirement to

Challenge	purchase carbon offsets to compensate for the embodied impacts of materials. In order to estimate the total carbon footprint of the building, users are directed to use simple LCA-based approximation methods. This results in the magnitude of impact being dominated by the square footage of the building being analyzed, and a more detailed LCA is not required.
PAS 2050	U.K.-based method for reporting the carbon footprint of products.

A3.2 LCA Standards

Both National and International standards bodies have been developing LCA Standards over the past 20 years. ISO standards 14040 and 14044 are internationally recognized as the foundation standards of LCA and are typically referenced by other standards, models and tools as well as LCA studies. ISO 14025 provides the guidance for reporting environmental performance claims as EPDs. The recently adopted European Standard CEN 15804, as well as ISO 21930, provide additional clarification for the preparation of EPDs for building materials and products. All of these standards provide some flexibility in adoption, and thus additional clarification by national standards or guides will be useful.

Table A3.2 shows LCA standards which have been identified as appropriate to reference in support of developing code. These items were all identified as having a 1B-rating in the task A reference document.

Table A3.2: LCA standards appropriate to support development of LCA into the building code

Standard or Proposed Standard	***Brief Description***
ASTM D7075-04	Standard Practice for Evaluating and Reporting Environmental Performance of Bio-based Products
ASTM WK23356	Proposed New Practice for PCRs for Use in Development of Environmental Declarations for Building Products and Systems
ASTM WK28938	*New *Guide* or *Practice* for Whole Building LCA (title under development)
ASTM WK31993	*New Practice for Communication of Sustainable Attributes of Products
EN 15643-1:2010	Scw-Ab - Part 1: General framework
EN 15643-2:2011	Scw-Ab - Part 2: Framework for the assessment of environmental performance
EN 15804:2011	Scw-Epd - Core rules for the product category of construction products

	(Product Category Rules)
EN 15942:2011	Scw-Epd - Communication Format - Business To Business
EN 15978:2011	Scw- Assessment of environmental performance of buildings - Calculation method
ISO 14020:2000	Eld – General principles
ISO 14021:1999	Eld – Self-declared environmental claims (Type II environmental labeling)
ISO 14025:2006	Eld – Type III environmental labeling- Principles and procedures
ISO 14040:2006	Em – Life cycle assessment -- Principles and framework
ISO 14044	Em -Life cycle assessment -- Requirements and guidelines
ISO 15392:2008	Sbc -- General principles
ISO 15686-6:2004	Buildings and constructed assets -- Service life planning -- Part 6: Procedures for considering environmental impacts
ISO 21930:2007	Sbc -- Environmental declaration of building products
PD CEN/TR 15941:2010	Sustainability of Construction Works – Environmental Product Declarations - Methodology for selection & use

*Nomenclature:

SG	Standard Guide
SP	Standard Practice
PCR	Product Category Rules
Scw	Sustainability of construction works
Ab	Assessment of buildings
Epd	Environmental product declarations
Eld	Environmental labels and declarations
Em	Environmental management
LCA	Life cycle assessment
Sbc	Sustainability in building construction
PAS	British Standards Institution's (BSI) Publicly Available Specification

A3.3 LCA Models (analysis methodology)

As discussed earlier in the document, there are different models by which LCI data is analyzed and different models for characterizing environmental impacts resulting from a wide range of emissions. The models listed here are all respected and tested methods. However, the results of analyses completed based on different modeling assumptions will have different results. Thus, review of LCA results must consider the models and assumptions used in creating the LCA. Models must be identical if results of LCAs are to be compared. Table A3.3 outlines the primary analysis and impact models adopted in US LCA practice.

Table A3.3: LCA models rated of 'highest importance'/worthy of further evaluation

Models	***Brief Description/Analysis***
CML	The CML-IA is a database that contains characterization factors for life cycle impact assessment published through the Institute of Environmental Sciences (CML) as part of the Faculty of Science at the University of Leiden.
Eco-Indicator 99	An impact assessment method developed by Pre consultants and integrated into SimaPro software.
EIO-LCA	Method of linking environmental and economic activity based on industrial sector designations. Requires manipulation of data reported separately to the Federal government to create the EIO databases. Uses national average data and thus is best for general evaluation of Life Cycle Impacts. Does not require or permit detailed evaluation of supply chain or material choices.
Hybrid LCA	Method of integrating EIO-LCA with more detailed process-based LCI data.
Process LCA	Use of LCI data to develop LCA of building products, materials and whole buildings. Environmental impacts are tracked per individual 'unit processes' and compiled to determine LCA results. Requires detailed data on material types, quantities and manufacturing process.
TRACI	US EPA-published recommended characterization factors for translating emissions to environmental impacts.

A3.4 LCA Models (data)

The underlying LCI data used in an LCA can either be specific (data collected at the manufacturing site) or generic (based on data from another study). As many building industry products are made through the assembly of different materials and products, a high quality, US-specific LCI database is critical to enabling the production of LCAs and EPDs for the US market. Other regionally specific LCI databases exist, and a summary of the most relevant databases is shown below in table A3.4a.

Table A3.4a: LCA models/databases rated of 'highest importance' by the research team
Listed in alphabetical order

Databases (Unit Process Data)	
BATH ICE	UK-based Inventory of Carbon and Energy that provides benchmarks and summaries of the embodied energy and carbon of over 200 materials.

BEES	Sponsored by US NIST, this database includes a tool to assess environmental and economic impacts. Future development of this database is uncertain.
ecoinvent	The ecoinvent Center supports the development of the ecoinvent LCI database which currently includes more than 4000 industrial life cycle inventory datasets. Based in Switzerland, the database does include international LCI data.
INIES	Database for EPDs developed by the French EPD mandate. Note that not all of these EPDs have been third party verified. More than 700 EPDs cover more than 7,000 products on the French market. www.inies.fr.
LCA Digital Commons	An open access LCI database sponsored by the US Department of Agriculture. The US LCI database developed by NREL is currently being hosted by this system. https://www.lcacommons.gov/nrel
Proprietary Datasets	LCA consultants (e.g. PE International, Franklin Associates) have internal proprietary LCA databases that are used in LCA consulting and can be integrated into commercially available database tools.
US LCI Database	Publically accessible database of US LCI data originally sponsored by NREL. Although missing critical unit process data, supporting the development and enhancement of publically accessible, US-specific LCA data is critical to advancing our ability to use LCA effectively.
Databases (EIO Data)	
CEDA	A private EIO database that includes data for US, UK and China. Used as background data for NIST-sponsored BIRDS tool under development (see below).
EIO-LCA	EIO dataset developed by the Green Design Institute at Carnegie Mellon University that is publically available for non-commercial use and can be licensed for commercial use.
LCA Database Tools	
Gabi	Commonly used LCA software with detail and complexity appropriate for LCA practitioners, not typical building industry professionals.
SimaPro	Commonly used LCA software with detail and complexity appropriate for LCA practitioners, not typical building industry professionals.

The US LCI database provides freely accessible unit process data for US manufacturing supported by the National Renewable Energy Lab (NREL). NREL does not generate the data but rather posts data submitted by individual industries. Often this data is generated by industry organizations that collect LCI data from their member organizations and publish industry average results. Not all industries have provided data to the US LCI database. See Table A3.4b for a summary of the LCI data that currently exists for building materials and products. Of note, of the nearly 500 entries in the US LCI database, approximately 40% of the entries are related to energy use and transportation. Of the remainder, wood products provide approximately 50% of the total LCI data submitted. All industries should be strongly encouraged to submit and update LCI data to the US LCI database. Additionally, better quality information about the variability and uncertainty of the LCI data needs to be collected.

The Swiss government has supported the development of a very comprehensive LCI database, eco-invent. Its data thus represents national Swiss manufacturing processes and Swiss electrical energy consumption, but by using LCA database tools, users can substitute local electrical mixes to help regionalize the data. LCA practitioners typically use LCA database tools such as Gabi or SimaPro that can access multiple databases.

The NIST-sponsored BEES database provides a centralized location to publish product-specific LCI data. Although the research team understands that the database will continue to accept additional data, there will be limited support for updating the interface and foundation methodology. A government agency such as NIST could develop a tool similar to BEES that could provide a national platform for publishing product EPD results similar to the database INIES. This would provide valuable data for the building industry. No such tool development is known at this time.

Table A3.4b: Summary of materials/products with US LCI/LCA data
(notes for table on next page)

	US LCI Database (# unit processes)	Date of LCI data	BEES	Published ISO LCA	US EPD	PCR Development	Eco-Invent (Swiss) database
MATERIAL							
Aluminum	17	2005-07	1[G]				19
Aggregate	0		0	N			7
Cement	2	2004-06	1[H]	Y		D	20[L]
Concrete	0		0[I]	Y		D	16[M]
Glass	0		1[J]				~40[N]
Gypsum wall board	0		3				9
Masonry (general)							
Brick masonry	0		3				6
Concrete masonry units	0		0				7
Natural stone	0		2				4
Steel (general)	9[A]	2003-07					~50[O]
Galvanized sheet steel	1	2003	1[K]				0
Vinyl	16[B]	2010	4				19
Wood (general)	154	95, 04-08				Y	~110[P]
Rough Lumber	14	2004-08	3				~25
Composite I Joist	2	2004	0				0
Glue Laminated Beam	4[C]	2004	0				4
Plywood/other sheet goods	15	2004-10	2				11
PRODUCT							
Carpet/Floor Coverings	5[D]	2008-10	4		7		11[R]
Ceilings	0		2		1		0
Insulation	1[E]	2008	1				17
Plumbing	7[F]	2010	1				29[S]
Roofing	0		7				6[T]
Siding (general)	0		1		1	D	0[U]
Walls (steel or wood framing)	7	2003-08	3				0[V]
Windows	0		0			D	20[W]

Table A3.4b: Continued

[A] US LCI – Steel (General) includes two listing for Zinc, which contains ~46% iron ore
[B] US LCI – "Vinyl" is not listed direct in the database, its major constituent part, Ethylene, is listed in high percentage in 16 vinyl related listings
[C] US LCI – Includes Laminated Veneer Lumber (LVL)
[D] US LCI – Wood flooring products only, no carpet or other listings
[E] US LCI – EPS Insulation Board
[F] US LCI – No listings for copper or PEX piping, only PVC and ABS
[G] BEES – Aluminum listed pertains to Aluminum Siding
[H] BEES – Cement includes products with cementitious bases, e.g. stucco
[I] BEES – Various cement listings are the only products listed in reference to Concrete
[J] BEES – Glass listed pertains to a glass tile product
[K] BEES – Sheet steel shaped into Steel Studs
[L] EcoInvent – Cement listing count does not include 'fibre cement' products, e.g. cementitious fiber siding (James Hardie Brand) and other similar products
[M] EcoInvent – Does not include listings pertaining to lime or limestone or similar
[N] EcoInvent – 'Glass' listings include float glass products, fiber glass product, foam glass products and other similar
[O] EcoInvent – Steel listings include steel fittings and fasteners as well as EAF and similar productions
[P] EcoInvent – Includes a large variety of wood product including those with mix materials, also includes wood fuels
[R] EcoInvent – Zero listings for 'Carpet' but numerous listings for textiles and weaving to manufacture carpet, also includes listings for tiles, ceramic and natural types
[S] EcoInvent – Few listings of 'piping,' most are for the material and processing, i.e. copper or polyethylene production and copper rolling and plastic extrusion
[T] EcoInvent – Included are listings for 'roofing tile' of various materials, not included are the numerous listings for chemicals and polymers used to make the roofing membranes
[U] EcoInvent – Zero listings for 'siding' in terms of the US construction technique, various products are listed that could be used as siding, e.g. Fibre Cement Board or various Sawn Lumbers
[V] EcoInvent – Listings do not pertain to use, in the case of 'Steel or Wood Studs' the user could use a listing for the process of making the steel stud or manufacturing the wood stud
[W] EcoInvent – Three parts of the window listed in various ways: Frame, Glazing, Rubber gasketing

The research team believes that populating the US LCI database with high quality data for building materials and products will enable meaningful LCAs of buildings and products. The previous table demonstrates how a government-sponsored effort can lead to the development of a more comprehensive LCI database. Thus efforts to motivate the publication of LCI data on this freely accessible database should be supported and prioritized. The USDA's LCA Digital Commons has provided an expanded platform to support the collection of LCI data and has provided an enhanced framework to report variability and data uncertainty. Understanding the variability of LCA results is critical to understanding the statistical relevance of differences between options and the appropriateness of using LCA data in procurement decisions.

A3.5 LCA Tools for Building Industry

In order to implement LCA in construction practice, users typically use an LCA tool to provide a user-friendly interface to integrate LCA data according to a specific model or methodology (see Figure A3.1). General LCA tools typically provide more detail and flexibility for a comprehensive analysis but are more complex than is appropriate for use by general practitioners. Building industry LCA tools can vary in detail and complexity from quite simple and intuitive (e.g. Build Carbon Neutral or the Green Footstep) to more complex and detailed (e.g. Gabi or Build it). In France, where LCA mandates have been in development at both the federal and regional level for some time, there are multiple nationally-specific LCA tools developed to respond to slightly different regulatory requirements and objectives. These LCA tool developers have organized to develop a consistent LCA database for use in France and are working to harmonize analysis models/methodology so that the underlying assumptions of the tools are consistent and what differs is the user interface for collecting and reporting data.

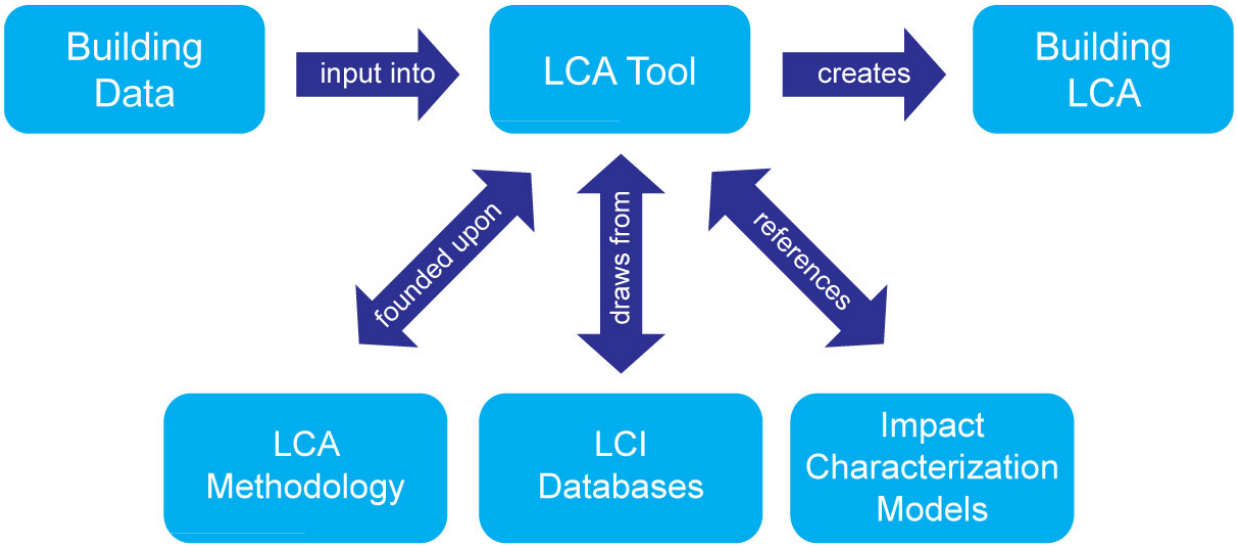

Figure A3.1 Diagram of LCA requirements

Currently the Athena Institute produces the largest US-specific building industry LCA tools (Eco Calculator and Impact Estimator). One should be careful not to limit possibilities based on the tools currently available. As demonstrated throughout Europe, multiple LCA tools are being developed in multiple regions. Adapting these tools to the US or developing new tools could be a possibility. Note that regional variations in construction assemblies, thermal and seismic requirements, manufacturing processes and energy sources necessitate the use of regionally -specific LCA data. In particular the development of benchmarks must carefully consider regional conditions.

Table A3.5 summarizes the LCA models, databases and tools rated as worthy of further study as part of our Task A research.

Table A3.5: LCA Tools for the Building Industry rated of 'highest importance'/worthy of further evaluation *Listed in alphabetical order*

LCA Tools for Buildings	
Athena Eco Calculator	Simplified US and Canadian building industry-specific LCA tool to calculate the embodied impacts of building construction based on standard building assemblies. (free)
Athena Impact Estimator	US and Canadian building industry-specific LCA tool to model building construction and calculate the embodied impacts of building construction.
BIRDS	(IN DEVELOPMENT) by US government/NIST, this tool is proposed to develop a hybrid LCA method for whole building assessment.
Build Carbon Neutral	A very simple carbon calculator for buildings that addresses: building area, stories above and below ground, primary structural system, eco-region, and landscape disturbances.
B-Path	Developed by researchers at Lawrence Berkeley National Laboratory (LBNL), the Berkeley Lab Building Materials Pathways (B-PATH) Model aims to enhance environmental decision-making in the commercial building LCA, design, and planning communities. Per LBNL website http://bpath.lbl.gov/ accessed August 28, 2012. Spreadsheet with LCI data for primary structural materials. Worthy of further evaluation-not reviewed in depth in time for final report publication.
e-Licco	Developed to support requirements for whole building LCA established by the Bourgogne region. Used modified eco-invent data (not the EPD data). http://e-licco.cycleco.eu
Elodie	A whole building LCA tool developed by the CSTB in France to support the HQE Performance program to advance environmental performance and indoor air quality of low energy consumption buildings. This tool has been tested by building industry practitioners (Association HQE, 2012) to assess the potential of more wide-spread adoption in practice. This tool uses both generic data (eco-invent data modified for French electrical grid) and product-specific data collected by the French EPD system. http://www.elodie-cstb.fr/
Equer	A whole building LCA tool that is linked to an energy simulation tool COMFIE, enabling links between operational and embodied impacts. www.izub.fr .
Gabi Build-it	Gabi-Build it is a building industry-specific interface to Gabi that is designed for the German market in response to German green building rating systems.

GPR	GPR is an LCA tool developed in the Netherlands that is based upon a harmonized Dutch LCI database and methods. http://www.gprgebouw.nl
Green Calc	Green Calc is an LCA tool developed in the Netherlands that is based upon a harmonized Dutch LCI database and methods. www.greencalc.com
Green Footstep	A building carbon footprint calculator developed by the Rocky Mountain Institute that addresses: location, regional electricity emissions, net carbon storage of the native site due to landscape, the option of using EIO data or user supplied data for the embodied impacts, and the option of using baseline or user supplied data for the operational impacts and building lifespan. The online tool provides some suggestions on how to increase site carbon storage and increase operational efficiency.
LCB Method	The Low Carbon Building Method is based on PAS 2050 standards and is a spreadsheet-based method for estimating the GHG Emissions and emission reduction performance for buildings. Developed in the UK, it includes a database of default emission factors (kgCO2e/kg material) for most typical building materials.
LEGCP	German whole building LCA tool that builds upon a German construction specification system used by cost estimators. This tool has been tested in use in attempts to develop whole building LCA benchmarks. (Lutzkendorf, Kohler & Konig, 2012)

The use and interpretation of the tools' outputs should be conditioned by a data quality analysis as described by the ISO standards as well as consideration of variables such as:

- Do the input data accurately reflect the product of interest?
- Is regional variation accounted for with respect to production processes and emissions?
- Have all upstream factors been accounted for?
- Are the comparisons being made using the same impact estimators?
- Are the impact estimators transparent?
- Do the impact estimators adequately capture emissions to the environment that are likely to be detrimental?

Additionally, the research team would like to caution the state against using either a single environmental impact (such as climate change) or weighted single indicators (combining multiple environmental impacts into a single 'Eco-Score') as metrics to inform design decisions as these methods may lead to unintended consequences and can be subjective/not reflective of the goals of the end users.

A3.6 Buildings and LCA Research

Research related to LCA and building materials and construction can be categorized into two primary categories: (1) research into the methods and standardization of LCA, and (2) research that uses LCA to evaluate building materials, products and/or complete buildings. We have organized our review of LCA research accordingly and have focused our assessment on research related to methodologies to implement LCA into regulatory frameworks, and design and construction practice-based LCAs. The attached reference document contains a review of LCA research identified by stakeholders.

IMPLEMENTING LCA

Typically, designers and regulators looking to reduce the environmental impacts of buildings have focused on reducing the operating energy use of buildings. Many LCA studies that include all life cycle phases of buildings show that over a typical life span, the operational impacts represent 70-90% of the total impacts, which supports this focus. However, with increasing energy efficiency and on site generation, net-zero operational energy buildings are becoming more common and thus the impacts of materials, construction and demolition become relatively more significant. Thus LCA should include material impacts as well as operational impacts. Policy makers and industry non-profits (Architecture 2030, USGBC, Governments of France, Germany, Switzerland, Netherlands & Washington State) are beginning to look to LCA as a method to track and reduce the environmental impacts of materials and products used in the built environment.

Relevant US codes and ratings systems are either still developing (USGBC) or were updated/ published recently (ASHRAE 189.1, IgCC). We have identified little significant research that studies or tests these methods. Joshi (Joshi, 2009) provides overviews of LCA tools, outlines seven different scenarios to help identify the different potential users of LCA tools and provides case studies of LCA used in design and construction practice. An article by Ortiz et al. (Ortiz, 2009) outlines use of LCA in the construction industry, and the American Institute of Architects (AIA) developed a guide to Building LCA in practice (Bayer et al, 2010). Studies that reference the recent standards have been limited to reports on the state of code development and position pieces advocating the integration of LCA to improve the 'Rational Framework' for evaluating green building construction (Contreras, Roth, Lewis, 2011 & Simonen, 2011).

Research is being undertaken to test simplified methods of integrating LCA into construction practice (Bribian, 2009, Malmqvist et all, 2010, Lasvaux et al, 2012a&b, Ventura, 2012, Kohler, 2012). Additional research is needed to test the validity of simplified methods when used to implement LCA standards in practice-particularly in the US context. Case studies of practice-based LCA analysis have been reported (Annemans, Verhaegen & Debacker, 2012). An interesting multi-authored editorial (Baitz et al, 2012) outlines critical issues that must be addressed in order to translate the theory of LCA to practice.

Established regulations in both France and Germany have prompted the development of research projects that attempt to develop whole building LCA benchmarks (Lutzkendorf, Kohler and Konig, 2012, Lebert, et al, 2012 & Preservation Green Lab, 2012). Of particular note is the French HQE study in which 74 buildings (20 single family residences, 19 multi-family residences, 21 office buildings and 14 academic or research buildings) were assessed during the design process using the building LCA software Elodie, which was developed by the French research organization CSTB. In this study, the LCA efforts were simultaneously checked by LCA experts, and the time and difficulty of implementation recorded. A summary of this research was published in English (HQE, 2012). This study would be an appropriate model to use in formulating a study to assess the implementation impacts and benefits of integrating LCA into the Washington State building code.

BUILDING INDUSTRY SPECIFIC LCA OVERVIEW

There are many different building industry specific LCAs published that range from LCAs of building materials or components (e.g. Kline, 2005, Marceau et al., 2007, Athena 2002) to whole building systems (e.g. Collinge et al, 2012, Pinto 2011). Results from different studies can come to contradictory conclusions relating to the environmental preference of building materials or systems. In order for LCAs to be comparable, the underlying data, system boundaries, analysis and impact assessment methods must be identical (see Introduction and Terminology section I-1 thru I-9 of this report). These assumptions are rarely consistent across studies.

In the attached reference document, we have summarized a sampling of building industry specific LCAs as submitted to us by industry stakeholders.

Of particular note is the challenge of defining functionally equivalent materials or assemblies (Lavagna, 2012). The different LCA studies evaluated below use different methods for determining functional equivalence. For example:

1. (Wisitorfer et al, 2005) Compared residential structures of the same size and configuration designed to have the same thermal insulation values. Thus these buildings were assessed to have equivalent use phase impacts.
2. (Ochsendorf et al, 2011) Compared residential structures using typical code minimum construction for the systems studied (wood frame construction vs. insulated concrete formwork (ICF) walls). This study modeled the resulting differences in use phase impacts and considered the difference in thermal mass of the two systems.

Given the variability in LCA methods and building construction, great care should be taken when attempting to use the results of a specific LCA to make generalized conclusions for the building industry as a whole.

A4 Conclusions

LCA provides promise as a method to track and reduce the environmental impact of buildings. Emerging methods to use building codes and regulations to promote the development of LCA data and integrate LCA methods into the design process are occurring in both the US and in Europe. Many European efforts began years ahead of the US and thus provide excellent case studies to evaluate the opportunities and challenges in implementing these policies.

The codes, rating systems, standards, models and tools identified in this report are worth further investigation as outlined in the Task B section of this report. LCA tools are required in order to implement LCA into design and construction practice. These tools need to be based upon consistent standards/models and high quality LCI data, designed to be readily used by building industry professionals, and ideally synchronized with existing building information modeling (BIM) tools or industry practices such as material scheduling and cost estimating. The US LCI database and many LCA tools require sophisticated understanding of LCA methods to be used effectively. The US LCI database does not yet have sufficient LCI inventory for US production. EPDs provide a mechanism to report product specific LCA results. A US database to compile EPDs would also provide a needed source of LCA data for use in building design and construction.

In developing methods to assess if LCA should be integrated into codes or regulation, in addition to evaluating the LCA code, care should be taken to evaluate the tools used to implement the code, the standards and analysis methods the tool uses to compute LCA results and the LCI data used as input to the tool. Additionally, in reviewing a proposed code, one must determine if new tools, methods or data is required to implement the code in practice and the extent of training and/or additional industry expertise that will be required to implement the code requirements.

B Task B: Methodology Recommendations

B0 Introduction

Per Washington ESSB 5485 Sec. 1.(2)(a), this is the final report of the 'Task B' requirement to prepare a report that "must include recommendations to the legislature for methodologies to:

(i) Determine if a standard, model or tool using life cycle assessment can be sufficiently developed to be incorporated into the state building code;
(ii) Develop a comprehensive guideline using common and consistent metrics for the embodied energy, carbon and life cycle accounting of building materials; and
(iii) Incorporate into every project the ongoing monitoring, verification, and reporting of a high performance public building's actual performance over its life cycle."

Thus, this document includes three sections to address these three requirements of the legislation:

B1 Incorporating LCA into the State Building Code
B2 Developing Consistent Metrics to Assess Building Materials
B3 Monitoring, Verification and Reporting of Actual Performance

Additionally, in ESSB 5485 Sect. 2.(1)(a), the "department of general administration shall make recommendations to the legislature, consistent with RCW 43.01.035, for streamlining current statutory requirements for life cycle cost analysis, energy conservation in design, and high performance of public buildings. "

And section 2.(1) (b), "recommendations on what statutory revisions, if any, are needed to the state's energy life-cycle cost analysis to account for comprehensive life-cycle impacts of carbon emissions." Thus, this document includes a fourth section to provide guidance on how the research completed by the UW/WSU team per section 1. (2)(a) addresses some of these additional requirements of the legislation:

B4 Integrating LCA and Life Cycle Costing.

In developing these recommendations, the research team built upon the data and evaluation included in Task A (see attached reference document: *A Review of Resources on Life Cycle Assessment, and Embodied Energy and Carbon in Building Materials*); incorporated existing knowledge and expertise of the research team; integrated stakeholder comments from the September and May workshops and two open comment periods; and conducted additional research including discussions with stakeholders and other professionals and academics.

B1 Incorporating LCA into the State Building Code

In developing methodologies to "determine if a standard, model or tool using life-cycle assessment can be sufficiently developed to be incorporated into the state building code", the research team recommends that evaluation contain three stages:

B1.1. Goals
   a. Clearly articulate the goals of incorporating LCA Methods into the state code;
B1.2. Scope
   a. Identify the LCA Methods which could be applied in the code and determine how and in what applications these methods might be integrated into code.
B1.3. Evaluation
   a. Evaluate if the LCA Method(s) can be (or already are) adopted into code language; and
   b. Evaluate the effectiveness and impact of adopting the LCA methods into code.

B1.1 GOALS

As in an ISO-compliant LCA, the first key step of integrating LCA should be in identifying the goal. What is the perceived benefit of incorporating LCA into the state building code? Clear goals are required in order to effectively develop and evaluate LCA methods. The research team has identified the following potential types of goals relevant to this study that may or may not be adopted for this integration:

1. Reduce specific total life cycle impacts (e.g. embodied carbon/global warming potential) of buildings, building products and construction materials;
2. Increase awareness and understanding of total life cycle impacts of buildings, building products and construction materials;
3. Motivate designers to innovate towards the reduction of total life cycle environmental impacts of buildings;
4. Motivate manufacturers to improve manufacturing processes to reduce environmental impacts;
5. Motivate owners, designers and specifiers to include environmental impacts as an additional criterion to evaluate in decisions about building materials, products and systems;
6. Enable LCA based 'green' procurement standards;
7. Prioritize the use of locally-produced materials and products if possible;
8. Incentivize the development of local business production of high performance/low embodied impact building products;
9. Prioritize specific environmental and resource impacts to be studied in greater detail;
10. Identify other environmental and resource impacts that are not currently prioritized while state agencies fulfill mandated carbon footprint (and other environmental performance) reporting requirements (evolving state and federal agency rules); and

11. Reduce manufacturing and construction waste.

Recommendations

Different stakeholders will see different values and risks with meeting the aforementioned goals. For example, while the first goal of reducing specific total life cycle impacts (e.g. reducing the 'carbon footprint') of buildings is clear and compelling, the analysis is difficult to verify and focusing on a single environmental impact risks significant negative impact to others. Care should be taken to ensure that the knowledge and capability exists to achieve stated goals.

Given the current state of LCA practice and tools, as well as the capabilities of the building industry, the research team recommends that a more modest goal such as 2. *Increasing awareness*, would be currently most appropriate. Increased awareness has the potential to motivate improvements (Items 1, 3, 4 & 5) without prescriptive requirements and additionally helps improve industry knowledge and capabilities, setting the foundation for more ambitious strategies in the future.

B1.2 SCOPE: IDENTIFICATION OF BUILDING CODE RELEVANCE

Of the multiple codes, standards, models and tools of LCA identified and studied, not all are appropriate for integration into the building code. The research completed in Task A evaluated codes, standards, models and tools against a criteria ranking systems. Items ranked as '1-Applicable' from the Task A research should be evaluated to narrow down the options to a short list of proposed methods to study in more detail. This section, B1.2, proposes a rubric to identify these methods against objective criteria and to provide a framework for decision-makers to prioritize the identified codes, standards, models and tools.

Codes and Rating Systems

As part of task A, we preliminarily identified nine codes and rating systems as worthy of further review. Some stakeholders have also identified other rating systems such as Green Globes and NGBS as also worthy of further review. This list has evolved over three public comment periods; stakeholder requests to add or delete items that have not been adopted by the research team are identified in appendix C2.

In order to narrow down these methods to a shorter list for more detailed study, the research team has outlined an assessment methodology to identify critical factors that the state should consider when evaluating LCA methods for adoption into the building code. Table B1.2 outlines criteria by which these codes and rating systems can be evaluated. Note that the state could add or subtract criteria for evaluation prior to selecting methods for further study and that some of the developing standards might also be evaluated in similar fashion.

Table B1.2: Example of analysis of some existing and developing LCA-based codes and green building rating systems (can be expanded for final review by state)

Note, a preliminary review of the items noted has been provided for example purposes only.

	ASHRAE 189.1 Whole Bldg LCA	Exec. Order 13514 Sec. 13	French EPD Legislation	IgCC 2012 Whole Bldg LCA	2030 Challenge for Products	Living Building Challenge	LEED V4: Materials Disclosure/EPDS	LEED V4: Whole Building LCA	Other Items TBD by WA State
Is it developed through a consensus-based process?	Y	N	N	Y	N	N	N	N	
Is it peer reviewed? (not always appropriate)	N		D	N	N	N	N	N	
Includes Life Cycle Stage A: Manufacturing/Construction	Y		Y	Y	Y	Y	Y	Y	
Includes Life Cycle Stage B: Use and Maintenance	Y		D	Y	P	A	A	?	
Includes Life Cycle Stage C: End of Life	Y		D	Y	P	N	A	?	
Includes Life Cycle Stage D: Reuse, Recovery, Recycling	Y		D	Y	P	N	A	?	
Written in code language?	Y		Y	Y	N	N	N	N	
Can be a standard referenced in a code?	Y								
Full building LCA?	Y								
Promote product specific EPDs?	N								
References/uses LCA data?	Y								
Does it need a reference baseline?	N								

If so, do those baselines exist?	N								
Does it require user to generate a reference design?	Y								
Does it generate new LCI data?	P								
Does it generate new LCA users?	Y								
Does it include climate change?	Y								
How many environmental impacts considered? (List them)	9								
Do training/reference documents exist?	N								
Does it evaluate social impacts?	N								
Does it evaluate economic impacts?	N								
Does it document improvements?	Y								
Does it require the purchase of software tool or LCI databases?	Y								
Is the background data/method open and transparent?	P								
Does system exist for evaluating and improving the method?	Y								
Does it comply with ISO 14044?	Y								
Will method prioritize local products?	P								
Is regional variability of climate, seismicity and methods addressed?	P								
Goal 1: Reduce environmental impact (EI) of buildings.	P								
Goal 2: Increase awareness of EI of buildings/materials/products.	Y								
G3: Motivate designers to innovate & reduce EI	Y								
G4: Motivate manufactures to innovate & reduce EI	P								
G5: Motivate users to use EI as assessment criteria.	Y								

G6: Enable LCA based 'green' procurement standards.	N								
G7: Prioritize the use of local products/materials.	P								
G8: Incentivize the development of high performance products.	P								
G9: Prioritize specific EI to reduce/study.	N								
G10: Identify EI of concern for more study/reporting.	N								
Other criteria established by state/stakeholders TBD.									

Key for Responses to table B1.1

Y Yes

P Perhaps. Possible yes, possible no.

N No

D Depends upon which user. Requires manufacturers to prepare LCA of products which typically would be done by a LCA practitioner.

A Additional components (not the LCA section) enable a Y answer to this question.

Recommendations

The research team recommends that the state sponsor research to evaluate systems using a matrix such as the one listed above to identify a short list of 2-4 methods for more detailed evaluation as outlined in the following section. Alternatively, based upon preliminary review of the above evaluation criteria, the research team has identified that there are two general methods worthy of further consideration:

1. Whole building LCA (as outlined by ANSI 189.1 and IgCC, etc.); and
2. Use of multi-impact EPDs for motivating transparency and improvement (French EPD, CEN15804, 2030 Challenge for Products, LEED V4 etc.).

Although the details of how these methods are motivated/rewarded/executed are slightly different by different codes and green building rating systems, a detailed study into these methods would enable an evaluation of the effectiveness of the different codes and rating systems. With additional evaluation criteria established by the state, these methods might be expanded upon or refined for the next stage of analysis.

B1.3 EVALUATION

Although the analysis set out in B1.2 will help identify potentially valuable and appropriate methods to integrate LCA into the building code, additional study is required in order to assess the impact and effort adopting these methods would have throughout the building industry.

This analysis will require testing the methods in practice to assess implementation details and effort and should include input from expert stakeholders. We propose that 2-4 methods (dependent upon available funding) first identified through the aforementioned initial vetting process in Phase I should be assessed on projects of varying scale (from single family homes to larger institutional and public projects).

Models and Tools

In order to implement LCA based codes or rating systems, building industry and US-specific LCA tools (software and/or databases) would enable building industry professionals to analyze and assess both proposed and constructed buildings. Ideally different tools would be tested for each of the different rating systems evaluated in more detail, as the challenge and benefit of implementing proposed codes or rating systems depends both upon the code requirements as well as the design and detail of the evaluating tool. As noted in the Task A report, LCA tools can be defined by their underlying data, the methodology to combine and report the data and the user interface. As part of Task A, the research team identified multiple models and tools ranked as 'Important'. The state might expand or contract this list based on their additional criteria. Although not all of these tools have been developed based on data, practices, preferences and codes, their methodology and interface might be worth investigating for possible adaptation.

The research team recommends that the criteria in Table B1.3 be evaluated for each of the different methods, using different tools and for different scales of buildings.

Table B1.3: Proposed Example Evaluation Matrix for LCA Methods in practice.

EVALUATION OF LCA METHOD IMPLEMENTATION: **Single Family Residence/Small Commercial Construction** **(one of multiple bldg. types to be studied)**					
	Method 1 – Tool A	Method 1:- Tool B	Method 1- Tool C	Method 2: Model A	Method 2: Model B
Priority from Phase I?					
Time for design team (hr)					
Time for construction team (hr)					
Time for plan check (hr)					
Time for manufacturer (hr)					
Cost for design team ($)					
Cost for construction team ($)					
Cost for plan check ($)					
Cost for manufacturer ($)					
Cost implications of NOT implementing ($)					
Evaluate tool's appropriateness for building type and construction method. (data sources and methodology)					
Implementation time (mo)					
Quantification of environmental impacts possible?*					
Identification of potentially relevant environmental impacts not quantified.					
Qualitative review of the methodology. (Written review of the methodology)					
Input from stakeholder expert survey (summary of quantitative survey results)					

Input from stakeholder expert survey (summary of qualitative comments)					

*May need to be segregated by impact as identified by the goals.

The evaluation criteria should be evaluated quantitatively as noted in the aforementioned table. Quantification of costs and times should be defined by either prescriptive estimated methods or by actual measurement of time and cost as performed by building industry professionals.

Additionally, the research team should write a 2-3 paragraph qualitative evaluation of the method/model/tool for this scale of buildings.

In addition, as noted in the last two rows of Table B1.3, there is a proposed expert survey to solicit input from a diverse group of stakeholders to provide additional input to aid in the evaluation of these methods. Items to be covered might include:

1. Benefit to the state of adopting methods (Based on list of typical benefits and include line for 'other')
2. Environmental impact of methods (Based on list of typical impacts and include line for 'other')
3. Difficulty to implement (rank from 0 low to 5 high)
4. Cost to implement (rank from 0 low to 5 high)
5. Complexity (rank from 0 low to 5 high)
6. Value (rank from 0 low to 5 high)
7. Written comments and suggestions on how to improve tools and methods.

The stakeholder survey should also solicit 1-2 paragraphs of written comments that can be included in the assessment report as an appendix.

Recommendations

In order to assess the criteria noted above a research study should be developed to either:

A. Develop test projects to evaluate the methods as prototypes conducted by the research team on case study projects (less effort, however less informative than option B);

B. Test the methods and tools in practice. Ideally the LCA studies should be conducted in parallel with actual projects under development. The study should include a research team as well as support for building industry professionals (designers, manufactures, contractors and plan check professionals) as needed to implement and test the LCA methods in practice. This method was used by the French research organization CSTB in evaluating methods to integrate full building LCA into French building code regulation. It provided an opportunity to test the challenge and effectiveness of actual practitioners applying LCA per these regulations. Note: methods should be tested to assess applicability for regional variation and should be able to adapt to state and national conditions.

C. Alternately, the state could take a wait and see approach and see how the voluntary LCA sections of emerging green building codes get implemented in practice (CalGreen, IGCC, ASHRAE 189.1). Research would then focus on evaluating the voluntary codes in practice rather than applying the methodologies to test buildings.

B2 Developing Consistent Metrics to Assess Building Materials

"Develop a comprehensive guideline using common and consistent metrics for the embodied energy, carbon and life-cycle accounting of building materials;"

International standards organizations (ASTM, ISO, WRI/WBCSD, etc.) have been working to develop guidelines that use common and consistent methods for reporting the life cycle impacts of materials and products. Within these standards, methodologies are presented outlining the reporting of LCA results such as resource use (e.g. embodied energy/total energy consumption in KJ), potential to impact the environment (e.g. global warming potential (GWP) or equivalent CO2 emissions (CO2e)) or other data such as including chemicals of concern (COC) or other reported emissions (e.g. mercury emission quantities) that are not analytically tied to a potential environmental impact.

Certain environmental impacts such as global warming potential and ozone depletion potential are developing, but have taken many years to get to their current state, whereas the development of accepted metrics for other environmental impacts such as land use change or water footprint are not nearly as established. Through the Intergovernmental Panel on Climate Change (IPCC) there is (near) international consensus on the methodology to characterize global warming potential (GWP) as equivalent CO_2 emissions (CO2e). Methodology to track and report embodied energy is relatively straightforward as computing this is a required as part of developing an LCA.

In order to use LCA to make 'comparative assertions' (asserting that one product is definitively better than another), standards (ISO, CEN,) have very prescriptive criteria that must be met. These include (among others):

a. The description (function, performance and use) must be identical.
b. The ISO 14040 goal and scope are equivalent.
c. The data collection methods, calculation procedure and allocation methods are equivalent.
d. The impact categories and calculation methods are identical.

Note that the requirement for 'functional equivalence' is a critical point (Lavagna, 2012). One cannot compare a cubic foot of one material to another unless the materials are functionally equivalent (same strength, durability, thermal properties, etc.). And while it is theoretically possible to compare functionally equivalent assemblies (such as a residential wall), it is quite difficult in practice to design two truly functionally equivalent systems using the multiple criteria by which a wall performance can be analyzed (cost, construction ease, thermal and acoustic performance, water permeability, durability, thermal mass, VOC emissions, etc.).

Examples to illustrate this point:

- One cubic foot of concrete cannot be compared to a cubic foot of wood, steel or aluminum.
- One cubic yard of concrete could be compared to another provided all other key performance criteria are the equivalent or exceed the minimum criteria (strength, permeability, workability, etc.).
- Material strengths can vary based on regionally available materials.
- Comparing the LCA impacts of two different roof systems must consider the relative life of each of the roofs.

In practice, designers and specifiers will be able to use LCA data as another metric by which to evaluate the multiple criteria that must be considered when making material and product design choices. In the context of specific problems, the LCA data reported with the 'consistent metrics' of LCA following ISO standards as LCA reports and/or EPDs will be able to be used within a whole building life cycle approach to determine environmentally preferable options. However, generalized recommendations based on select LCA studies risk missing nuanced and significant variations in performance requirements between different projects.

Recommendations

We recommend that the State of Washington support the development and advancement of these growing consensus standards. As part of Task A, 18 standards were identified as 'Important' and worthy of further consideration. These standards are registered under three standards organizations: ASTM, ISO and CEN. In particular (as noted in section B1.2), we see that Environmental Product Declarations (EPDs) have the potential to advance the state of LCA practice, develop a culture of transparency and continuous improvement, and recognize the environmental benefit of local manufacturing. Additionally, US standards have begun developing in parallel to established international efforts. Harmonization of national and international standards is important to enable clear and consistent use of LCA. It is important to consider the regional aspects as more detailed LCA standards develop. Methods to support the development of these consensus standards include:

1. Providing funding to have WA state representation at standards development bodies. This could be through state staff or subcontracted to others. Funding is also needed to support membership fees, procurement of standards, travel to consensus meetings and reporting to the legislature and state staff.
2. Rewarding, prioritizing and/or preferring products that ***report*** LCA data per EPD standards;
3. Referencing these standards when integrating LCA data into government policies and procedures;
4. Avoiding development of parallel (potentially conflicting) standards; and
5. Supporting research into the efficacy of developing metrics for the various environmental impacts not yet established.

B3 Monitoring, Verification and Reporting of Actual Performance

"Incorporate into every project the ongoing monitoring, verification, and reporting of a high performance public building's actual performance over its life cycle."

Currently most building code requirements are either prescriptive or performance-based. Performance-based designs are typically verified through modeling the building before construction. Emerging codes and leadership standards (ASHRAE, LEED) require some post-occupancy evaluation, typically focused on verifying operational energy efficiency. Research (UW-Integrated Design Laboratory) and policy (City of Seattle) efforts have begun developing databases to track the operational energy use of buildings of specific types (IDL/Hospitals) or regions (Seattle). The State Building Code Council is considering a proposal that would require energy metering for all building codes over 20,000sf (per email communication with Duane Jonlin, City of Seattle). The purpose of this requirement is to integrate current metering and monitoring technology (including submetering of significant energy consuming systems), so that the effects of regulations can be known and understood.

Washington State, in the newly renamed Department of Enterprise Services or DES (formerly General Administration), is already charged with the collection of energy performance information on several types of public buildings. The current scope of this charge is, however, limited by both the users in collecting the data and the resources at DES for compiling, evaluating, disseminating and furthering education from information gleaned from the data.

The benefit of monitoring, verifying and reporting the actual performance of high performance public buildings over their life cycles could be that, with sufficient data, the actual benefits of code standards could be evaluated and potentially improved, and proposed efficiency measures could be ranked for their reliability and sustainability. In order to track performance over the 'life cycle,' data should be collected during all life cycle phases from manufacturing, construction, maintenance, use and demolition. LCA methodology is appropriate to use in developing this analysis. As this data would most easily come from different sources and over a significant period of time, we propose the following methodology:

1. Develop organizational framework to identify key data, sources and timeline;
2. Establish appropriate time/format/mechanism to collect the data;
3. Establish method and structure to evaluate and interpret the data; and
4. Utilize results of analysis to assess needs to improve/modify code requirements.

Table B3.1 Example outline of data which might be collected in order to assess full life cycle impacts *(initial assessment might provide information on relative impact of data and establish data collection priorities)*

LCA Phase	***Who***	***Goal***	***What***
Design	Arch/Eng	Estimate/reduce Influence choices	Operational Energy Use Est/year Embodied LCA based on estimates
Manufacturing/ Construction	General Contractor	Report actual use Compare to estimate	Embodied LCA based on quantities Manufacturing and construction waste
Use: Energy	Bldg Mngr Utilities	Report use Tune/optimize system	Operational Energy Use/year (avg?) Water use Fuel sources
Use: Maintenance	Bldg Mngr	Report use Minimize impacts Influence choices	Material use Ongoing maintenance, repair and replacement of major building systems. Cleaning (if significant)
Demolition	General Contractor	Reduce waste Encourage re-use Report practices	Waste disposed Method of disposal Travel distances

Recommendation

We recommend that the state provide resources to enhance the existing programs at DES to collect, compile, evaluate and disseminate data on the energy use of public buildings, with an initial focus on educational facilities, as these will have the dual benefit of educating and demonstrating to our youth and educators these important issues. Then, in support of this enhanced program at DES, the next step would be to support the development of a pilot project to test the effort and value of collecting operational energy data for existing high performance buildings. Additionally, we recommend that the state commission a LCA study of select buildings to integrate more comprehensive life cycle impacts throughout the buildings' life cycles (embodied, operational and end of life). This LCA should include an evaluation of total life cycle costs as well as environmental impacts. We recommend that the LCA be performed using a range of models and tools in order to evaluate the complexity and value of integrating these methods into practice. This analysis could potentially be performed in tandem with the analysis of LCA methods defined in section B1.

Alternately or additionally, the state might further evaluate the proposed metering and monitoring legislation, weighing the costs of implementation against the benefits that increased knowledge would provide.

B4 Integrating LCA and Life Cycle Costing

BACKGROUND

Information regarding the State of Washington's Energy Life Cycle Cost Analysis (ELCCA) was obtained by the Washington State Department of Enterprise Services (formally General Administration, GA) web page www.ga.wa.gov/EAS/elcca/home.html. The following is a summary of what is currently required.

Currently all new public construction design is mandated to meet the United States Green Building Council (USGBC) LEED-NC Silver Rating (per RCW 39.35D High-performance public buildings, apps.leg.wa.gov/RCW/default.aspx?cite=39.3D).

The 2005 ELCCA guidelines lay out a four-step process for ELCCA. In schematic design, green building options are considered and evaluated by the architect and client using the LEED-NC checklist and an Environmental Design Considerations form. Also in schematic design, a work plan is developed by the ELCCA analyst for review before beginning the ELCCA. This plan outlines the scope of the ELCCA: which systems will be analyzed, which alternatives will be considered, and which systems use prescriptive versus unconventional strategies. During design development, the ELCCA analyst runs the ELCCA and prepares a report with all the findings including alternative strategies and rationale for the chosen option. Finally, in early CDs, an addendum is prepared by the ELCCA analyst, who details and analyzes any value-engineered or client-mandated changes from the original recommendations.

The major categories for the ELCCA are heating, cooling, lighting, domestic hot water, and building envelope, which are all evaluated in terms of occupant comfort, health, and productivity.

In 2001, the Legislature added language requiring that ELCCAs analyze a system "which shall comply at a minimum with the sustainable design guidelines of the U.S. Green Building Council's LEED NC Silver Standard or similar design standard as may be adopted by rule by the department RCW 39.35.030(11)(a.). Of a total of 69 possible points on the LEED NC Checklist, 33 to 38 are required for a Silver rating. In these guidelines, the GA adopts use of the LEED Silver rating by requiring analysis of what will be known as a "High Performance" alternative. To meet the legislative intent for energy efficiency and renewables, GA further requires that the "High Performance" alternative earn a minimum of four of the required points from the LEED "Energy & Atmosphere (7-8).

The analysis of life cycle costs is completed within a published spreadsheet (5.1-energy-life-cycle-cost.xls) that gives standard assumptions for cost variables such as fuel cost escalation and discount rates and guidance as to what should be included in the cost analysis.

OPPORTUNITIES

The UW/WSU research did not evaluate the opportunities to streamline existing statutory requirements. In our research to evaluate the integration of LCA into the State Building Code, stakeholders consistently cautioned against developing requirements that would add burden to the process of designing, building and evaluating buildings to current codes.

LCA does provide a method to account for environmental impacts and using LCA to track only climate change impacts is often termed 'Carbon Accounting'. Using LCA methods, it would be possible to track CO_2e/Carbon impacts over the life of building options explored in the ELCCA methodology in two methods:

1. Track embodied and operational CO_2e within an expanded ELCCA. Embodied impacts would be the 'first cost,' with additional costs coming from maintenance impacts associated with manufacturing the equipment or component and maintaining and replacing it as required. Operational impacts would be related to the emissions generated by the energy used during the life of the system. Two options could be compared on cost as well as carbon footprint.

   Note that the research team supports ISO and WRI/WBCSD recommendations that single impact environmental reporting not be used to make procurement decisions. Thus in order to evaluate environmental impacts in addition to cost impacts, the evaluation should evaluate more than just CO_2e and report additional environmental impacts for consideration. Expanding the existing spreadsheet to provide default impacts per unit of fuel used and guidance on how to estimate impacts of embodied materials such as mechanical equipment and building materials would enable this more detailed comparison to be completed.

2. Assign a dollar amount to carbon and account for it in the cost analysis. If there were a carbon tax, the cost for fuels would reflect their carbon emissions. Washington State could adopt a price model to prioritize low carbon options. However, setting the cost of carbon would likely be a challenging and contentious process.

Recommendations

At this time we do not recommend changing the state's energy life-cycle cost analysis to account for the comprehensive life-cycle impacts of carbon emissions. We believe better data and industry expertise related to LCA is needed to more comprehensively integrate and assess environmental impacts in this manner. We believe that recommendations made in sections B1, B2, & B3 have the potential to advance the state of the practice so that, at a future date, these issues could be considered within analyses such as the ELCCA.

B5 Conclusions

There is growing national and international interest in including LCA-based metrics into building codes and green building rating systems. These efforts can be generalized as focusing on whole building LCA and promoting material transparency through the use of EPDs. In regions of France, Germany and Switzerland, codes and legislation mandating LCA practices have been or are in the process of being implemented. As identified by the LCA for WA research team and others working to implement the European regulations, the primary objective of these evaluation efforts should be to gain knowledge about the embodied impacts of building materials within a comprehensive life cycle evaluation of buildings. While these European examples can be used to explore different methods of integrating LCA into practice, the details of their implementation must be customized to US regions. The research team has identified research projects that would evaluate LCA codes and rating systems that show potential to increase awareness of the LCA-based impacts of building materials and products, generating new LCA data and helping designers and builders evaluate and reduce the environmental impact of the buildings they design and build. The following is a summary of the four potential research studies identified in sections B1-B3 above.

1. Whole Building LCA in Practice:
    a. Test whole building LCA methods prescribed by IgCC/ASHRAE 189.1 & CalGreen.
    b. Investigate French HQE research in more detail to determine if conclusions can be translated to US practice.
    c. Evaluate adoption of voluntary methods outlined in the whole building LCA codes.
2. Rewarding Transparency through Multi-attribute EPDs:
    a. Evaluate the impact of rewarding projects that use products with ISO-compliant EPDs per Architecture 2030/LEED V4.
    b. Evaluate the effectiveness of the French EPD system for applicability in Washington State and/or US.
    c. Research the efficacy of developing metrics for the various environmental impacts not yet established.
3. Supporting Standards Development:
    a. Support the development of internationally harmonized standards for whole building LCAs and EPDs.
    b. Reference established standards when integrating LCA data into government policies and procedures.
    c. Avoid development of parallel (potentially conflicting) standards.
4. Actual Performance of High Performance Buildings:
    a. Develop a pilot project to evaluate methodology to track and report the actual performance of high performance buildings through the collection of data during construction and operation, and integrate embodied and operational impacts through performing an LCA of these buildings.
    b. Evaluate the impacts of integrating metering and reporting requirements for new building construction.

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LCA for WA 90% Draft
Stakeholder Comments
Review Comments Tracking Spreadsheet
31-Aug-12

STAKEHOLDERS WHO COMMENTED ON 90% Draft

Name (alphabetical by first name)	Affiliation	email contact
Bruce Chattin	Washington Aggregates & Concrete Associat	bchattin@washingtonconcrete.org
Duane Jonlin	City of Seattle	Duane Jonlin <duane.jonlin@seattle.gov>
Edie Sonne Hall	Weyerhaeuser Company	Edie Sonne Hall <edie.sonnehall@weyerhaeuser.com>
Emily Lorenz	self- employed Consulting Engineer	Emily Lorenz <emilyblorenz@gmail.com>
Erik Kneer, Kyle Steuck, Luke Ruggeri, Matthew Comber	Degenkolb Engineers, SEAOC Sustainable Design Committee, SEAONC	ekneer@degenkolb.com, ksteuck@degenkolb.com, lruggeri@degenkolb.com, mcomber@degenkolb.com
Frances Yang	Arup	Frances Yang <frances.yang@arup.com>
Jordan Palmeri	Oregon Department of Environmental	PALMERI Jordan <palmeri.jordan@deq.state.or.us>
Rob Brooks	ICC Evaluation Services	Rob Brooks <rbrooks@icc-es.org>
Sue Lani Madesn	The Madsen Group	Sue Lani Madsen <suelani@centurylink.net>
Tien Peng	National Ready Mixed Concrete	tpeng@nrmca.org
Wayne Trusty	Wayne B. Trusty & Associates Limited	wtrusty@sympatico.ca
Martha VanGeem	self- employed Consulting Engineer	martha.vangeem@gmail.com

STAKEHOLDER COMMENTS

	Stakeholder	Document	Page	Line	Comment	Action	Response
	Bruce Chattin		2-Jan	19	Bill definition of life cycle assessments. Throughout the document, this definition is stretched and in some cases departed from. LCA as defined per the language and scope of the Bill as passed should be the standard in which this research and report is presented.	Noted: See respone	Baed on Final bill report we believe that we have interpreted the scope of the sudy as requested.
	Bruce Chattin		2-Jan	21	The synopsis as enacted should not be used as additional clarification as the language in the bill is the definition is clear and requires no additional clarification, The Bill does not contemplate social concerns in any context in the final Bill language. References as such should be deleted.	Future Consideration	This is a direct quote from the clarification provided in the final bill report. We have not included social or economic LCA at this time. Leaving reference to final bill report in document although no additional anlysis completed related to social LCA at this time.
	Bruce Chattin		2-Jan	34	The following additional text described as permissible clarification; (1.1 LCA from the Carbon Leadership Forum CLF). The CLF is not authorized to provide additional clarity to a clearly written definition as it is not consistent with the direction and scope of the bill. The CLF is a body directly tied to the research team and a) should be fully vetted as having a vested interest and integral to the research and b) is offering guidance of self interest as it relates to other research team member efforts. This discussion abbreviates the scope of the bill definition and contemplates cradle to gate, which is NOT the definition of LCA in 5485.	Modified	The reference to the CLF document was to provide approriate reference for a previously published document created by K. Simonen. Clarified in text. Multiple stakeholders asked for the report to include additional educational materials related to LCA. The introduction section provides this added guidance but is not the actual review or recommendations provided to the state.

	Bruce Chattin		1/3/05	14	Use of a recognized or standardized protocol such as ISO is a sound premise. However, so that others that actually read the report also come away with the sense of difficulty this concept entails. The well identified the limitations contained throughout should be equally stressed or summarized in the whole as a separate section of discussion neatly summarizing consequences. Any next steps as a function of this report will have to take into account the ability to take further actions based on very real and tangible factors such as; many elements remain underdevelopment, targets are not finalized, overall complexity and complexity of integrating multiple models, outcomes, values, functions, implementation limitations and overall LCA economics.	Future Consideration	Needs to be highlighted as we move forward with this research.
	Bruce Chattin		11-Jan	13,14	The use or discussion of cradle to site is not within the scope of the Bill. Introducing it as a separate element comprises the scope of the bill as originally written. The bill requires full apples to apples consideration in a cradle to grave scenario and does not suggest any dissection of incremental life cycle staging or periods.	Modified	That is explicitly what we are stating in this section. Clarified to include end of life impacts.
	Bruce Chattin		11-Jan	22	"encouragingly" is a research team editorial comment and is not warranted. The Bill does not contemplate "impacts" beyond the scope of LCA as defined. Section should be deleted.	Accept	Deleted word
	Bruce Chattin		A-5	8-Mar	Good description of limitations as it relates to the consideration of multiple models tools, etc. It would seem best to highlight limitations as presented (italicized) so the reader will get the full perspective of the model or tool suggested.	Future Consideration	No time to implement emphasis in this report.
	Bruce Chattin		A-8	19-21	This is an excellent statement that should be included in any opening introduction outlining the premise of the report. In previous comments we recommended the inclusion of the statement; (previously found on page A3-9 in the 50% Report) : *"Every building product and system has environmental impacts".* This is a very balanced, fair, objective and grounding statement that should be a signature recommendation of the research team. It should also present a focus on criteria to ensure fair and reasonable comparisons across building systems, codes and designs irrespective of the LCA model used and applied at full service life stages.	Accept	see added note to exectuive summary introduction
	Bruce Chattin		A8-A9	Table A3:1	If these are ranked in a descending order of priority (if not, may be perceived to be) IGCC should rank higher in the priority of recommendations given its release date, and current usage within municipalities within nationally and WA state correctly. Continuing development products such as procurements, Dutch analysis, should be rated lower until content and parameters can be fully evaluated.	Accept	Clarified these are intended to be in alphabetical order. Edited where discrepancies found
	Bruce Chattin		A8-A9	Table A3:1	This would equally true of rating systems that are currently in use and tangible data is likely available. The ability of a performance based rating system such as 2030 should be the standard in which measurements can be achieved and verified per future monitoring and verification.	Future Consideration	Needs to be highlighted as we move forward with this research.
	Bruce Chattin		A-13	Table A3-4a	US LCI Database section: quality US based databases that are compiled independently and relevant to national construction practices, designs and materials (natural and otherwise) should accentuated as being the most relevant, especially if they are already considered credible. These should take precedence over other data forms.	Accept	Clarified these are intended to be in alphabetical order. Edited where discrepancies found
	Bruce Chattin		A-14	5-Feb	Supported by above comment. NREL is an example of an often cited credible database.	Accept	Matches current text
	Bruce Chattin		A-16	4-Feb	The team recommendation of data base building is fine, however, it relates only to products and not the analysis of the full LCA cycle as outlined in the Bill. The Bill calls for consideration of building materials not "primary" building materials and as such would limit the scope of all materials used in high performance buildings. Delete the word primary. Populated data should be independently gathering and compiled and the recommendation should stress that important perspective.	Accept	deleted word.
	Bruce Chattin		A-17	Table A3.3	Some tools, models, calculators are funded, constructed and implemented by a variety of specialty self interest products or groups. So the state can truly evaluate independent rating systems or calculators, if a calculator, etc. is the product of a specially building / construction material, aligned with a building material trade organization / association or received or is funding by a specialty product. It should be clearly identified as having a specific origin and alliance.	Accept	Added as an evaluation criteria into section B: Evaluate tools appropriateness for building type and construction method. (data sources and methodology)

	Bruce Chattin		A 17-18	Table A3.3:	A number of resources are international and are built on their national standards or materials etc. *It should be the strong recommendation of this report that Washington should consider US standards, be engaged in national standard of databases, and or wait to be part of any national code, rating system etc.* To have multiple states go off in multiple directions uncoordinated will simply undermine any consistent outcomes. To built a data base off international benchmarks, incorrectly makes the assumptions that all inputs are equivalent and, precludes the use of national / local qualities, and disenfranchises national products and manufacturing systems.	Accept	See section B2. Recommendations. We believe international ISO standards remain the leadership standards related to LCA. Not always appropriate for US standard to duplicate others already in existance. ADDITIONALLY see added sentence right before table A3.3 regarding regional specificity.
	Bruce Chattin		A-18	14-Oct	A good example of expressing limitations in future tools the report has identified. Such limitations should be emphasized throughout or a summary of limitations expressed at the end of the report.	Future Consideration	Good suggestion unfortunately no resources to complete at this time.
	Bruce Chattin		A-19	8-19:	The legislature specifically defined LCA parameters to recognize the full cost of ownership in high performance public buildings. The bill did not say to look toward other areas if the research suggests a level of attainment already exists. Line 12-13 are the primary premise in which the bill was authored, passed and should be respected.	Noted: See respone	We believe we are addressing the requirements of the bill to look at the comprehensive LCA impacts from cradle to grave.
	Bruce Chattin		A-20	18-Sep	Could be simply presented in the references section along with the multiple wood based studies already provided. Fiq. A3-6 as presented is out of context with the scope of the report and it references specific building materials. It is inflammatory regardless of the source based on the known special interests that originated this legislation and the CORRIM report it was built upon. The Bill does not call out or highlight any specific building materials and references construction materials generically. Figure should be deleted. Lines 20-22 does a very good job of summarizing this section as presented and is all that is necessary.	Accept	diagram deleted from final report
	Bruce Chattin		A-21	26	Properly suggests the early stages of LCA applications while recognizing more data and validity of outcomes will require additional research, new tools, methods and data.	Accept	we agree
	Bruce Chattin		B-2	B1.1 Goals:	In short, this section does a good job of putting all of this research in context by encouraging the state to define achievable outcomes while accentuating; awareness, motivations, incentives and priorities.. Performance standards such as 2030 strive to allow the market place, engineers, designers, and owners to define what they want, how to get it there, let building materials be used to contribute their maximum attributes in the whole building design and document incremental accomplishments over time.	Accept	
	Bruce Chattin		B-3	9-Jun	We would agree with this statement. State considerations and direction should not impose self inflicted limitations in achieving the best LCA outcomes (as defined by the Bill) for the full cost ownership. Per the previous section, B1.1 Goals, the state should follow performance based outcomes that can be documented and verified. How they get there is the incentive to realize the objectives. Prescription based outcomes assumes functional equivalence and will limit outcomes and provide constraints.	Accept	
	Bruce Chattin		B-6 13,14		We do not concur with recommendation of a customized version of the matrix. Per past experience, when the state customizes a program, it exponentially expands the degree of difficulty, impedes ability to efficiently implement , limits function and increases costs. We strongly encourage the report recommend to be part of a well developed national standard, model and system. The dismantling of the western climate initiative is a good example of many participants trying to customize their own outcomes. Typically individual sate efforts fail under their own weight.	Modified	Recommendations modified. Provide alternative to review based on preliminary findings of research team.
	Bruce Chattin		B-7	8-Jun	Supports comment above	Modified	
	Bruce Chattin		B-9	18-Nov	A good synopsis of limitations and factors to be considered in any effort. It should be promoted in the report as a primary aspect of measurement when considering any new approaches.	Future Consideration	Not sufficient time to reorganize but appreciate the input. Will highlight for next stage development
	Bruce Chattin		B-9	23-32	Our concerns already expressed about using international or non US based standards. With state law already requiring state silver LEED standards, (ELCCA and RCW 39.35) any additional consideration of tools or models once vetted and in successful practice elsewhere, should be used within exiting state parameters. There are numerous existing state and county projects that can be evaluated and should have in place outcomes that can be measured and verified in the current built environment.	Accept	Added note about regional variation.

	Bruce Chattin		B-10 26		Functional equivalence is not only a critical point in the comparison of contrasting materials but is also critical when comparing like building materials; regional, nationally or internationally. Component products such as glass, steel, concrete and wood and are not universally the same as resources and processes are local, material characteristics are different and do not provide equivalent performance characteristics, (often performance limitations), manufacturing processes are different, raw material and finished product costs, and consideration of relevant cost to benefit ratios.	Accept	Note added: • Material strengths can vary based on regionally available materials.
	Bruce Chattin		B-11 13-21		Supporting standards by consensus if it is US based on US data. "Parallel development" suggests they will never meet, which suggests differences or "conflicting standards".	Accept	clarified wording. Want to discourage creation of US specific standads when International standards are adequate. LCA standards typically require regionally specific data.
	Bruce Chattin		B-13	19-Mar	As the state is already charged with collecting, monitoring and verifying energy performance we strongly recommend an audit be conducted by the state auditor as an independent analysis and public report on how existing high performance public buildings are performing based on current RCW criteria and policy . This should also identify any additional costs borne in funding and construction to achieve these outcomes and identify a clear cost benefit ratio to the public. This should be completed and published before any additional consideration of LCA studies are conducted. If we can not accurately summarize now what we have already built (per RCW 39.35) and identify the benefits of state practices and policies, then additional discussion may be necessary. It is reasonable recommendation to make and insist upon in the public interest and communicate compliance and predicted outcomes have been realized.	Modified	We belive that the LCA propsed in the research report would help to address this issue. Added comment to include costs into that analysis.
	Bruce Chattin			B5 Conclusions	As previously stated, we would not support the adoption or consideration of European evaluations. As indicated; "a growing national and international interest", we strongly suggest WA and other interested states act and participate nationally to identify, models, tools data and calculation methods that properly pertain to US construction materials, methodologies, practices and interests.	Modified	Added text to conclusions to confirm we would not recommend adopting EU models or codes. Need US customization.
	Bruce Chattin		B-15	28-31	While additional research is clearly needed, the clear definition of anticipated, tangible and realized outcomes must equally be defined concurrently. Without clearly identified outcomes that CAN be realized, WA will continue to chase deliverables that may be more relevant to international criteria.	Future Consideration	No action possible at this time to address this coment directly. We have outlined research work we believe can help provide actual outcomes.
	Bruce Chattin		B-16	1	This is why we strongly suggest a full audit of a select group of in place buildings built per existing state high performance building standards. This existing benchmark will help collect state specific data, identify performance and economic achievements, verify anticipated performance and economic achievements were met and if not, what did not contribute to those outcomes.	Future Consideration	As proposed in section B3 this would be the first step in this research.
	Bruce Chattin		X7-2	1-15:	We stated in the 50% draft comments that legislation failed or otherwise has no place in this report. Other than the underlying and authorizing Bill 5485, other state legislation does not contribute to this report. If it remains to be included, Bill references should be qualified (even 5485) by clearly identifying the self interests and sponsoring groups affiliated in supporting and perhaps drafting the legislation.	Noted: See respone	Identifying items provided by stakeholders. See added comment at introduction to research section.
	Charlie Solverson, PE	1			As Background, the Northwest Power Act directs the Northwest Power and Conservation Council to prepare a plan to assure the Pacific Northwest region an adequate, efficient, economical, and reliable power supply. A key component of their plan is energy conservation, this includes energy efficiency conservation as well as efforts to reduce carbon footprint. The Council's 2007 paper entitled Carbon Dioxide Footprint of the Northwest Power System explores how future growth in CO2 production would be affected by various resource development scenarios and other policies of interest. Reasonably, policies to integrate LCA and embodied energy analysis into state and local building codes should be considered polices of interest of to the Council.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies.

	Charlie Solverson, PE	2			Northwest Power and Conservation Council methodologies for energy conservation are incorporated into Washington State law through the The Energy Independence Act , commonly known as I-937. Under the I-937, utilities are required to use methodologies consistent with those used by the Northwest electric power and conservation planning council. This includes energy efficiency acquisition. As an example of how this is applied at the program level, the Tacoma Public Utilities Conservation Market Plan offers design assistance and incentives for new construction and major remodels. Under the program, utility incentives may pay up to 100% of the incremental cost of efficiency measures.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies.
	Charlie Solverson, PE	3			The UW – WSU Life Cycle Assessment Building Research should recognize the nexus between I-937 and Senate Bill 5485, as they both seek to promote high performance development as a means to conserve energy and reduce our carbon footprint. A key recommendation of the research should be that alignment occur between methodologies for life cycle assessment and the evaluation of environmental impacts 'embodied' in building materials and methodologies used by the Pacific Northwest electric power and conservation planning council, as they relate to energy conservation and carbon footprint reduction.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies.
	Charlie Solverson, PE	4			At a practical level, this could be as simple allowing LCA and analysis of embodied energy to be included in the design assistance component of utility conservation market plans for new construction and major remodels. Utility incentives for this would serve as a catalyst for the evolution and integration of of life cycle assessment methods, data and/or standards into state and local building codes.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies.
	Charlie Solverson, PE	5			Tacoma is interested in participating in piloting the integration of LCA and embodied energy analysis into our building codes, particularly, as it relates to the adaptive reuse of existing buildings.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies.
	Duane Jonlin	LCA for WA	General		It takes a lot of reading, essentially reading all 57 pages, and reading between the lines, to find the real bottom line here: "Although LCA methodologies show great promise for understanding and managing the overall energy consumption of buildings, we find that the existing LCA knowlege base, software tools and analytical structure are not yet well-enough developed to be mandated in codes or building evaluations. Implementing any such requirements prematurely could result in substantial unintended consequences. However, we recommend that the most promising of the available standards and software be evaluated in detail, and that the State of Washington actively support their development in a manner that can be applied in practise in the near future. " ...or words to that effect.	Accept	Executive summary provided
	Duane Jonlin		I-1	20	garbled sentence	Accept	comma added
	Duane Jonlin		A-8	26	Mention for both Standard 189 and IgCC that their actual use as code requirements is extremely limited. Also, last sentence in LEED V4 description is garbled.	Accept	
	Duane Jonlin		A-16	2	Paragraph is somewhat irrelevant. The legislature didn't ask about a very large volunteer opportunity to populate national databases.	Modified	
	Duane Jonlin		A16	27	Not clear what the diagram is supposed to connect to. Does not seem useful, but if retained it should be reversed to read left to right.	Modified	Updating diagram/adding others
	Duane Jonlin		A21	34	garbled sentence	Accept	sentence modified
	Duane Jonlin		B12	1	I think you missed the point of the legislative requirement. The main part of performance is the operational energy efficiency during the building's lifetime. This is a golden opportunity to advocate for metering and monitoring technology (including submetering of significant energy and water-consuming systems) to be built into all buildings, so that the effects of our regulations can be known and understood.	Modified	Added content relating to the net metering requirements
	Duane Jonlin		B12	5	Sentence not true, and not really sensible. Larger buildings are often modeled, but the idea with a prescriptive requirement is that it does not require verification or modeling.	Accept	sentence modified
	Duane Jonlin		B12	32	Under use-energy, add "utilities" under the "who" column	Accept	
	Duane Jonlin		B13	3	Paragraph is nearly identical to another paragraph on the previous page, line 12	Accept	
	Duane Jonlin		General		This has been a lot of work - congratulations!	Accept	Thank you.

	Edie Sonne Hall	LCA for WA	I-8	30	add "using the same product category rule" after compare products. This is to clarify that Product Category Rules will dictate the rules for what should be in an environmental product declaration and how it should be accounted for, but a fruit and a building product EPD may have totally different functional units etc...	Accept	
	Edie Sonne Hall	Reference Doc	I-11	6	Would clarify that ISO 14025 is the standard providing guidance on EPDs.	Accept	
	Edie Sonne Hall		A-4	9 to 11	I'm unclear what standard you are referring to in the top left. For example, LEED and Green Globes are standards but those are identified in bottom right. Are you talking about ISO 14044 standard?	Accept	LEED and Green Globes are rating systems not standards. ISO, ASTM, CEN, ANSI are standards
	Edie Sonne Hall		A-9 to A-10	Rating syste	The National Green Building Standard (NGBS) and the Green Globes standard should both be included as they both include Life cycle assessment. They are also both ANSI based green building rating systems. 2008 National Green Building Standard (NGBS) includes LCA for individual products and whole buildings. The 2012 NGBS adds LCA for assemblies, which will allow use of the EcoCalculator. Green Globes has two provisions for the use of LCA. Assemblies, which include the structural system and building envelope, can use Green Globes LCA Credit Calculator for Building Assemblies. This performance approach is an alternative to the prescriptive material selection provisions. For Furnishings, Finishes and Fit-outs a few points can be earned by using Bees or another ISO 14044 compliant, but it is concurrent with other prescriptive point opportunities.	Future Consideration	Green Globes is included in the reference document. Not sufficient time to include into final report
	Edie Sonne Hall		A-15	3	What does D stand for in PCR development? "in Development"? If so, wood should be clarified as there is a North American Wood PCR that was issued in fall 2011. There may be a version 2 issued soon but version 1 is already out	Accept	Changed
	Edie Sonne Hall		A-16	30	I believe the EcoCalculator also has modules for Canada.	Accept	
	Edie Sonne Hall		A-17	Table A3.3.	Again, Ecocalculator also for Canada	Accept	
	Edie Sonne Hall		B-4	Table B1.2.	Changed ASRAE to ASHRAE. I believe there are other times throughout document this comes up	Accept	
	Edie Sonne Hall		B-4	Table B1.2.	Green Globes and NGBS should also be included in this table.	Modified	See text on previous page
	Emily Lorenz	LCA for WA	B-6	18-19	I would reference CEN 15804:2012 because it is a more-comprehensive method for creating EPDs. Architecture 2030 only looks at carbon (single attribute), and LEED PV4 is not yet finalized. If we are encouraging the adoption of multi-attribute-based LCAs (which we should), then I would not include the single-attribute methods	Accept	
	Emily Lorenz	LCA for WA	B-15	39	I would reference CEN 15804:2012 because it is a more-comprehensive method for creating EPDs. Architecture 2030 only looks at carbon (single attribute), and LEED PV4 is not yet finalized. If we are encouraging the adoption of multi-attribute-based LCAs (which we should), then I would not include the single-attribute methods	Accept	
	Frances Yang Arup	LCA for WA	A-18	3	If not too large a section, can the ISO data quality analysis be copied here?	Noted: See respone	Can't copy a standard into our text.
	Frances Yang Arup	LCA for WA	A-19	4-5	Recommend change to: "Research into (1) the methods and standardization of LCA and (2) research that uses LCA to evaluate building materials, products and/or complete buildings."	Accept	
	Frances Yang Arup	LCA for WA	A-20	Figure A3.6	Needs a legend. Not clear why some data points are copied into the bar portion and some are not. What to the two different shades of bars represent?	Modified	Chart is deleted
	Frances Yang Arup	LCA for WA	A-21	2	"appear to be *as* significant… than" should read "appear to be *more* signficiant... than"	Accept	
	Frances Yang Arup	LCA for WA	A-21	38	Expected a statement about how the data is also not easily used by those who use the building codes. Interface for using the US LCI is for LCA practioners using tools like GaBi and SimaPro. There needs to be a bridge to those who design to the building codes if the codes are going to be prescribing the LCA.	Accept	
	Frances Yang Arup	LCA for WA	B-6	17	Why is LEEDv4 Whole Building LCA not among the ones listed? How is it so different from the ASHRAE and IgCC methods?	Accept	Document updated to include LEEDV4 whole building LCA
	Frances Yang Arup	LCA for WA	B-8	Table B1.3	Not clear what "cumulative ranking of importance" means.	Accept	changed wording
	Frances Yang Arup	LCA for WA	B-9	1	"both quantitatively *[and qualitatively]* as noted.."	Accept	
	Frances Yang Arup	LCA for WA	B-9	20	Suggested add to the qualitative portion of the evaluation: "Solicit for a prioritized wishlist of enhancements to tool/methodology to meet Goals." It is likely more helpful to hear from the test groups what minor/major changes could be made to the tools to enable them to do what they needed, rather than simply what the tools are/are not able to do.	Accept	

	Frances Yang Arup	LCA for WA	B-10	33	Replace "so thus:" with "Examples to illustrate this point:" The list is only a sampling of the considerations functional units deserve and should not allow misinterpretation that it is an exhaustive list.	Accept	
	Frances Yang Arup	LCA for WA	B-11	12	Could reference the BRE "Green Guide to Specification" here as an example of an approach with this shortcoming, which limited the success of LCA in BREEAM.	Noted: See respone	We are not able to comment on this issue.
	Frances Yang Arup	LCA for WA	B-13	3 to 7	Repeat of B-12 Lines 12 to 16. Delete.	Accept	
	Frances Yang Arup	LCA for WA	B-13	20	Idea: how about setting up a program where any university student could conduct the LCA (and LCCA?) for state-funded projects in their thesis work, choosing only amongst the models and tools identified as "applicable" in this study? What if they also had to run two analysis for each project, and compare and report difference in results and experience from the two different tools/methodologies, and submit the data to the testing program?	Noted: See respone	This is possible but funding can not be guaranteed nor consistent oversite provided.
	Frances Yang Arup	LCA for WA	A-21	32 to 38	A diagram would help to clarify different references and recommended paths for whole bldg LCA vs. EPDs	Accept	We will be inserting a new figure to clarify this.
	Frances Yang Arup	LCA for WA	B-12	Fig B3.1	Recommend assigning priorities to the data collection. Maintenance and cleaning can go in the lowest priority due to difficulty in collection and correlation to environmental impacts. The data collected is typically cost which is predominantly labor and very large material replacements. Likely hard to separate out housekeeping and small repair products from labor. A healthy building approach is probably more suitable way to deal with these than LCA for the time-being.	Modified	modified table title to clarify
	Frances Yang Arup	Reference Doc	A6-17		Why is there not a summary analysis of Elodie?	Noted: See respone	Not sufficient time. Potential development in future research
	Frances Yang Arup	Reference Doc	A6-28		As pointed out in the analysis of LCADesign, tools tied to BIM may offer greater viability in the future. May be worth mentioning in the Report somewhere.	Accept	See conclusions to section A
	Frances Yang Arup	Reference Doc	A7-2	9 to 18	Not clear how the French HQE was successful. It sounds great in the amount of study generated, but what have been the outcomes? Has there been successful feedback that has continually improved the tools, methods and regulations? Why would WA/US need to run a new test (case study) program? How much can be directly copied from the HQE program, lessons learned, and tools? Where does their program not meet needs or context in the US/WA?	Future Consideration	Needs further study-potentially a good model to emulate. Changed section B5 to represent this.
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	General Comment		We agree with the approach, conclusions, and recommendations that encourage further development of the science of LCA and applications to building construction & use. We also agree with the encouragement of measurement & verification of life-cycle building performance as it will aid the industry in both verifying common design/modeling practices and establishing baseline performance.	Accept	Thank you
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report & Reference Doc	Report: B-4 & B-15; Reference Doc: A2-7		Table B1.2: Recommend consideration of the draft 2013 CALgreen Section A5.409 "Life Cycle Assessment," which expands upon the LCA section from the 2010 CALgreen document that was reviewed and is summarized in the LCA for WA reference document. Largely similar to LEED's requirements, but worth evaluating implementation into a similar code document. Though LCA is in the voluntary provisions, many local jurisdictions in California are implementing the CALGreen Voluntary provisions as mandatory. Recommend including case studies and lessons learned from California in addition to European examples cited.	Accept	
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-4	2	Table B1.2: The Living Building Challenge has been listed as referencing a baseline that exists (bottom of p. B-4). The Living Building Challenge sets an objective of net-zero impacts. We feel that referring to this net-zero objective as a "baseline" is inaccurate, as the term baseline is typically used to define a "typical" building over which to improve performance.	Modified	Modified chart as we do not have resources to complete evaluation at this time
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-8	1	Table B1.3 "Quanitfiable Reduction of Environmental Impacts Possible:" The objective in selecting a tool should be whether or not the tool is capable of quantifying the impacts of any given building system in a manner that is usable and transparent. The responsibility of reducing those impacts rests on the design team and is not something that the tool can accomplish. We recommend rewording this line to exclude the word "reduction" and simply focus on quantifiable impacts.	Accept	Good point

	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-8	1	Table B1.3 "If (Y) to [quantifiable reduction] how much?" We recommend deleting this line per comment above. We also feel that the magnitude of "reduction" across multiple tools (as the table is intended to evaluate) is simply a reflection of different assumptions made in the various tools, is not necessarily a reflection of accuracy or desirability of the tool, and should therefore be excluded when comparing alternative tools.	Accept	
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-12	32	Fig B3.1: Recommend adding "Reduce Manufacturing and Construction Waste" as a goal for collecting full life cycle impacts.	Accept	
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-13	1	Fig B3.1: Recommend reporting ongoing maintenance for major building systems (Mechanical, Electrical, Plumbing, Structural, Exterior Cladding, Interior Partitions, etc.)	Accept	Thank you.
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-13	1	Fig B3.1: Recommend including method of disposal. This would capture information regarding materials re-used or recycled in "What" of demolition reporting	Accept	
	Kneer, Steuck, Ruggeri, Comber	LCA for WA 90% Draft Report	B-13	1	Fig B3.1 Use-Maintenance phase: recommend excluding items such as cleaning, focus on major renovations- perhaps set a benchmark as a cost percentage of building value??	Modified	
	Lionel Lemay		A-20		There is a graph on page A20 that indicates it is adapted from Ochsendorf et al. First, the way the graph is presented out of context and with no legend and explanation is not helpful and misleading and frankly not very scientifically presented. Second, I tried to find the graph in the referenced report but could not find it (if I overlooked it then please let me know). I suspect someone on your team took data from the report and constructed the A20 graph. The problem is the way the A20 graph is presented it really is an apples to oranges comparison of LCA studies, the very thing you are trying to avoid based on other statements in the LCA for WA report.	Accept	Deleted chart
	Lionel Lemay		A-20		Also, there is a sentence just above the graph that indicates the report was done for National Concrete Ready Mixed Association. First the report was not done for NRMCA and second, the name of our association is wrong…it should be National Ready Mixed Concrete Association. I suggest the A20 graph be removed from the report since it does not add anything except confusion and certainly if you are going to reference the Ochsendorf report, make sure it's referenced correctly.	Accept	Deleted chart
	Lionel Lemay		A-20		Also, I think it might make sense to discuss what the author of this section of the LCA for WA report was trying to accomplish with the A20 graph directly with the MIT authors of the Ochsendorf report. If you let me know who the LCA for WA author was, I could arrange for a meeting with MIT people to help clarify.	Accept	Deleted chart
	Lionel Lemay		A-20		What would probably be more useful to have in the LCA for WA report are graphs from the Ochsendorf report that show the variation in LCA studies as they are presented in the report (Fig. 5.1, 5.2, 5.3) since these are apples to apples comparisons as opposed to the way the A20 graph was presented which is an apples to oranges comparison. But also show the importance of full life cycle assessment versus embodied life cycle (Fig. 3.10, 3.26, 4.8). I've copied John Ochsendorf and Franz Ulm at MIT as well as leaders from RMC Research & Education Foundation, PCA, NRMCA and Washington Aggregates and Concrete Association so they are aware of how the MIT report is being used and perhaps elicit input from them.	Future Consideration	Worthy of future study
	Martha VanGeem	LCA for WA	I-6, I-7		ASTM draft standards cannot be used or cited per ASTM, " Ballot item documents are not ASTM standards, and shall not be reproduced or recirculated in whole or in part without written authorization from ASTM." Delete all references to ASTM draft standards.	Noted: See respone	Liv had conversation with Steve Mawm. He allowed OK to quote scope that is online and small synopsis of key points.
	Martha VanGeem	LCA for WA	A-9	IgCC	If you include the impact categories in the IgCC, you should also include the ones in ANSI/ASHRAE/USGBC/IES Standard 189.1 on High Performance Green Buildings and its LCA section. Standard 189.1-2011 is a compliance path within the International Green Construction Code (IgCC) as stated in Section 301.1.1 of the IgCC, "… these buildings shall meet either the requirements of ASHRAE 189.1 or the requirements contained in this code." The LCA critera are in section 9.5.1 of Standard 189.1. Also, Standard 189.1 is referenced many times later in this document so should also be included in this table.	Accept	

	Martha VanGeem	LCA for WA	A-10	LEED v4	Take out references to draft versions of LEED. Draft versions of any standard should not be cited since they have not completed their review and approval process.	Modified	Noted as a draft and worthy of discussion. Test modified.
	Martha VanGeem	LCA for WA	A-15	Table 3.4b	I cannot review this important table without an indication of what the symbols and footnotes are.	Accept	Sent table with symbols and footnotes to VanGeem for review 8/8/12 will integrate into final document.
	Martha VanGeem	LCA for WA	A-16	35	Add this text: To be in compliance with ISO standards, tools must include all of the relevant impacts, not just the ones that are easy to develop into tools. The impacts of biodiversity, land use, ecotoxicity, and human toxicity are a little more challenging to implement in a simple tool yet are significant and relevant.	Modified	Will integrate a variation on suggested text
	Martha VanGeem	LCA for WA	A-19	22	ASHRAE 189.1 was first published in 2009.	Accept	
	Martha VanGeem	LCA for WA	A-20	Fig. A3-6	Delete this figure since it is from an unpublished report.	Accept	
	Martha VanGeem	LCA for WA	A-21	17	Take out references to unpublished documents	Accept	Re-word this section to provide alternatevie methods
	Martha VanGeem	LCA for WA	B-5	Item G-6	Architecture 2030 answer should be N. The Architecture 2030 challenge is only carbon and not full LCA.	Accept	Chart modified.
	Martha VanGeem	LCA for WA	B-5	18-19	The Architecture 2030 challenge is only carbon and not full LCA. Reference to it here should be deleted.	Accept	Chart modified
	Martha VanGeem	LCA for WA	B-15	39	Architecture 2030 specifies only carbon impacts and therefore is not ISO compliant because it does not include all relevant impacts.	Accept	Chart modified
	Martha VanGeem	LCA for WA	A7-1, A7-3		Take out references to unpublished documents: Dowdell et al, and ASTM WK23356.	Noted: See respone	Dowdell, crediting image in document. Change reference. In progress listed for those interested in standards development
	Martha VanGeem	LCA for WA	X7-2	1-2	Remove all references to New York City Initiative 0577-2011. It was found to not have merit and was nothing more than a draft. Information from a wide range of stakeholders (Building Owners, Contractors, Engineers, Manufacturers) was presented to the Council Task Group on the proposed green code amendment. The Council's opinion was that this was not a "one size fits all" solution and the proposal has been removed from consideration. If this is included, then all proposals from Urban Green and all proposed city council resolutions from all cities should be included and of course this is unreasonable. This proposal does not have merit and could be detrimental if copied by others. An approach to optimize cement content based on concrete performance objectives is much more reasonable. In addition, what does this have to do with LCA? - a third order effect if any.	Noted: See respone	We are including items that are determined not relevant but identified as potentially relevant by stakeholders to ensure that this document accurately represents research reviewed. Note this section to be clarified to address this concern.
	Martha VanGeem	LCA for WA	X7-2	33-34	Remove reference to CLF Concrete PCR as this is still a draft document. Also, the link does not work.	Modified	Web link to be fixed.
	Martha VanGeem	Reference Doc	A2-2	item 17	Remove reference to NYC draft doc, "NYC INT 0577-2011". It was found to not have merit and was nothing more than a draft. Information from a wide range of stakeholders (Building Owners, Contractors, Engineers, Manufacturers) was presented to the Council Task Group on the proposed green code amendment. The Council's opinion was that this was not a "one size fits all" solution and the proposal has been removed from consideration. If this is included, then all proposals from Urban Green and all proposed city council resolutions from all cities should be included and of course this is unreasonable. This proposal does not have merit and could be detrimental if copied by others. An approach to optimize cement content based on concrete performance objectives is much more reasonable. In addition, what does this have to do with LCA? - a third order effect if any.	Noted: See respone	We are including items that are determined not relevant but identified as potentially relevant by stakeholders to ensure that this document accurately represents research reviewed.
	Martha VanGeem	Reference Doc	A2-16	7-35	Remove reference to NYC draft doc, "NYC INT 0577-2011". See above comment.	Noted: See respone	We are including items that are determined not relevant but identified as potentially relevant by stakeholders to ensure that this document accurately represents research reviewed.
	Martha VanGeem	Reference Doc	A2-17	1-17	Remove reference to Oregon first. It was only a proposal, as you state. It is not applicable, as you state.	Noted: See respone	We are including items that are determined not relevant but identified as potentially relevant by stakeholders to ensure that this document accurately represents research reviewed.

	Martha VanGeem	Reference Doc	A4-24	29	No one is a member of the subcommittee except ANSI, which delegates the work to ACI. ACI then appoints delegates just prior to each meeting and for review purposes.	Accept	
	Martha VanGeem	Reference Doc	A7-3	Table A7-3	Delete this table since it is from an unpublished report.	Accept	
	Martha VanGeem	Reference Doc	A7-4	section A7-4	This is a very limited set of references.	Modified	See added coment at introduction to research section plus expanded references included in final report
	Martha VanGeem	Reference Doc	A7-5	third row	Where is this report from Brown cited in the references?	Modified	See added coment at introduction to research section.
	Martha VanGeem	Reference Doc	A7-6	last 2 rows	Please make "VanGeem" one word	Accept	
	Martha VanGeem	Reference Doc	A7-10	2-10	Delete unpublished reference by Akbarien et al. There are plenty of published reports to reference.	Modified	link to published report provided
	Martha VanGeem	Reference Doc	A7-11 thru A7-19	30-39	Delete all unpublished references. Unpublished report frequently have not gone through their final reviews. There are plenty of published reports to reference.	Noted: See respone	Identifying items provided by stakeholders. See added comment at introduction to research section.
	Martha VanGeem	Reference Doc	A7-14		Add reference to LCA comparing ICF to wood frame walls: Marceau, M. L., and M. G. VanGeem. 2006. "Comparison of the Life Cycle Assessments of an Insulating Concrete Form House and a Wood Frame House." Paper ID JAI13637. Journal of ASTM International Vol. 3, No. 9, American Society for Testing and Materials, West Conshohocken, Pennsylvania, October. Also, Marceau, M. L., and M. G. VanGeem. 2002. Life Cycle Assessment of an Insulating Concrete Form House Compared to a Wood Frame House. PCA R&D Serial No. 2571, Portland Cement Association. Let me know if you would like a copy.	Future Consideration	References added to list. No time to review- included for future reference
	Martha VanGeem	Reference Doc	A7-17	25	Stadel et al. This is an unpublished report and should not be referenced. There are plenty of published reports to reference.	Noted: See respone	Identifying items provided by stakeholders. See added comment at introduction to research section.
	Oregon Department of Environmental Quality (P	LCA for WA			I'd like to offer a peer reviewed whole building LCA Oregon DEQ commissioned as a source of information for "Appendix 7 - Research" or any other appropriate reference. I noticed similar studies to ours such as the recent National Trust on Historical Preservation LCA study of material reuse and thought is would be an appropriate reference for your work. Our LCA was critically reviewed according to ISO 14044 standards and was deemed ISO compliant. You can view the full report directly at: http://www.deq.state.or.us/lq/sw/wasteprevention/greenbuilding.htm. Our LCA research has been used to help inform changes to Oregon's REACH building code, which is an aspirational and optional energy efficiency code. DEQ has also used this research to help educate the building community on where the environmental impacts of building products occur (mostly in production - not disposal). We've helped the Earth Advantage rating system align the ultimate benefits of home size with other practices and have worked on aligning incentives that reward using less energy and fewer materials. DEQ has found LCA research to be helpful to inform policy decisions and is interested in tracking the progress of this workgroup and WA legislative efforts.	Future Consideration	These are interesting points. Unfortunately we do not have the resources and time to evaluate effectively in time for the final report. Will consider in future studies. Report added to reference list
	Rob Brooks	LCA for WA	ES-2	32	Why not suggest a third method which is to proceed with voluntary adoption of green building codes (IgCC, ASHRAE 189.1) that would drive the use of whole building LCA? The likelihood of funding additional studies to test different methods and tools would increase once the framework is in place to potentially use the tools.	Modified	The state of WA could do nothing and alow voluntary adoption of green building codes. Given that some of these include LCA, LCA may become integrated into practice.
	Rob Brooks				RESPONSE FROM ROB in follow up email: There are a number of jurisdictions currently evaluating the adoption of the IgCC. ICC is developing support systems (product evaluation, training, accreditation, tools, etc) to support this new code, so expect that some of the code official concerns will be addressed in the near future.	Future Consideration	
	Rob Brooks				I think there is a need for universities to provide supporting investigations/ studies that address some of the complexities such as LCA within the green codes. My thoughts are that your recommendations should be more of a push strategy (help push the adoption of an existing document) rather than a pull strategy (study/develop - new/improved - ideas/documents for future adoption).	Future Consideration	

	Rob Brooks				The push strategy seems more of a win-win-win for universities, the design community, and code development organizations and provides an immediate deliverable to the marketplace.	Future Consideration	
	Rob Brooks				I am copying Dave Walls who is our Executive Director of Sustainability and oversees the development of the IgCC. He can provide more information about adoptions and activities outside of Washington. His number is (562) 699-0543 ext 7732 and he works out of Sacramento.	Future Consideration	
	Sue Lani Madson				There was no outline included in the email, I skimmed through the documents. You have clearly delved deeply into the subject, and worked hard to pull it all together. However, without at least an outline of the Executive Summary it is difficult to provide feedback.	Accept	Ex Summary Inclouded
	Sue Lani Madson				I did search to see if some of the references I had suggested were evaluated, and could not find the BOMA International challenge included. It would be useful to know if they met their challenge to reduce energy consumption in commercial buildings by 30% between 2007 and 2012. I still see no evidence of input from the public or private building operators viewpoint.	For Future Consideration	Related to energy use during operations. Not a focus of this report.
	Sue Lani Madson				I am including my original comments from November 2011 as a memory jogger for you of the kinds of questions potential users of this document will have as you prepare your Executive Summary sections.	For Future Consideration	Related to energy use during operations. Not a focus of this report.
	Sue Lani Madson				RE: Criteria that should be used "to determine if a standard, model, or tool using life-cycle assessment can be sufficiently developed to be incorporated into the state building code". Add to the list: how do they balance with the costs and consequences of implementing as part of building codes?· Cost of NOT implementing, i.e. what are the costs and consequences of NOT implementing and · Define impacts that cannot be objectively or readily quantified.	Accept	Integrated into section B of document
	Sue Lani Madson				RE: Suggestions to improve research product: Consider in relation to different baseline conditions, variations across the state in economic and development pressures and opportunities. E.g. availability	Accept	Integrated into section B of document
	Sue Lani Madson				Provided additional references related to life cycle costing	Modified	References included in attached reference documents for future evaluation. Most related to life cycle costing which is outside the primary scope of the UW/WSU research effort
	Tien Peng		1-2	36	Many legislative members do not know the difference between a code, a standard, a rating system, a LCA tool, a LCA database or a metric. As a former Code Council member, I would say the same goes for that body as well. This introduction to Terminology would be a great place to briefly describe and list all the ones used in this document. GABI, ANSI, CEN, LEED, NREL, ASHRAE, TRACI, etc	Accept	Added section in definition section re codes/rating systems
	Tien Peng		A-8	18	Should separate Codes vs Rating Systems. One is mandatory, the other voluntary. One is baseline requirement, the other is aspirational.	Modified	Not separating but adding additional information at front of document to clarify
	Tien Peng		A-8	26	I underestand that the USGBC had a hand in the development, but it should just be "ASHRAE 189.1" to avoid confusion from the USGBC's LEED rating system.	Accept	
	Tien Peng		A-10	1	Clarify Architecture 2030 for Products is focused primarily on embodied carbon footprint.	Accept	
	Tien Peng		A-14	9	Change "Wood" to "All" Industries should be strongly encouraged…	Accept	***
	Tien Peng		A-21	2	Tough to understand this sentence. Is this meant to say, "The difference in Global Warming Potential vary as much in different studies as the variation from on ematerial to another". That's not even much better. Some other way?	Modified	paragraph modified
	Tien Peng		B-13	3-7	Delete - Duplicate from previous page.	Accept	
	Tien Peng		B-13	29	Change to "all new, public construction is mandated…"	Accept	
	Tien Peng		B-15	22	Would a recommendation to update the 2001 ELCCA language in the RCW 39.35.030 to reflect the current LEED rating sytem be appropriate as reported on B-14? That is, LEED has, at every revision, increased its stringency, therefore the original intention may not have the same effect.	Future Consideration	Worth further study. Beyond the scope of this research project to evaluate.

	Tien Peng		B-16	5	Would it be beyond the scope to include a matrix of the economic impact of the summary of recommendations from this report? I can see that a number of provisions will require additional expenditures by building owners/devlopers. Also, some costs by the State. Understandably, these future construction costs will typically be offset by either energy savings during the life of the building or have some other economic benefit.	Future Consideration	Worth further study. Beyond the scope of this research project to evaluate.
	Wayne Trusty	Reference Doc	A2-7	29-30	Says CalGreen has no explicit LCA standards included, which is incorrect. Whole building LCA is in Section A5.409	Accept	Update document.
	Wayne Trusty	Reference Doc	A3-1	13	The Green Buiding Initiative is not a Canadian entity as stated here. It is a US not-for-profit, headquartered in Portland OR, which acquired the US rights to Green globes.	Accept	deleted reference
	Wayne Trusty	Reference Doc		16	LEED only used the EC as a pilot credit and it is not in the drafts for LEED v4	Accept	
	Wayne Trusty	Reference Doc	A3-7	2	Add ICC-Evaluation Services to the list. It is becoming a key player re US EPDs. Also, the list is a mix of Program Operators and standards orgs and that should be made clear for those who don't know anything about EPDs.	Accept	
	Wayne Trusty	Reference Doc	A3-9	28-29	Saying GBI is supported by ANSI is misleading, if not totally incorrect. Green Globes is an ANSI standard, but ANSI does not bring together stakeholders to comment and steer technical aspects of the system as stated here.	Accept	
	Wayne Trusty	Reference Doc		33-35	Use of the word 'This' at start of last sentence makes this a misleading statement re the Athena EcoCalculator. Could say: The tool used in Green Globes is the Athena EcoCalculator, which is further reviewed in Section A5.3.	Accept	
	Wayne Trusty	Reference Doc	A3-10	16-22	The wording is generally off re LCA in the last published version of LEED v4, including incorrect names of the credits that involve LCA and failure to mention the whole building LCA credit.	Accept	Updated in final report
	Wayne Trusty	Reference Doc	A4-5	na	I would not include SCS proposed standard in the table -- it is being fought by all LCA practitioners that I know as well as those involved in EPDs and is inconsistent with the ISO standards for EPDs.	Modified	See intro to this document. Plus added text this section. Included at request of other stakeholders
	Wayne Trusty	Reference Doc	A4-6	11	This implies that ISO 14044 is not relevant and is not further evaluated since it is designated with na in the table. The same is true of ISO 21930, which is highly relevant to the use of LCA for buildings.	Accept	Will be updated in final document
	Wayne Trusty	Reference Doc	A4-11	14-30	This description is out of date; version currently out for vote should be consulted.	Accept	Updated
	Wayne Trusty	Reference Doc	A4-27	1–26	Suggest deleting in entirety. It is more than "fairly controversial".	Accept	Added note to clarify concern. This is included a summary of items reviewed. Many at direct request from stakeholders.
	Wayne Trusty	Reference Doc	A5-8	6	Is it rreally a consensus standard, e.g., ANSI or ASTM?	Accept	Corrected mistake
	Wayne Trusty	Reference Doc	A5-8	13-18	BEES uses out-dated TRACI, and the emphasis here on SETAC somewhat distorts the reality. The latest version of TRACI does not include many of the measures cited.	Accept	
	Wayne Trusty	Reference Doc	A5-10	30	The last sentence is incorrect because it implies only European data is being used for such comparisons. Ecoinvent has data from various contries with local editors who make sure it is OK.	Accept	section deleted
	Wayne Trusty	Reference Doc	A6-5	1	Why evaluate tools that are not available or appropriate for use in the US, some not even in English while others in the list no longer exist. The last para actually highlights this issue and then opens the door to the idea that tools can be adapted – a very difficult and potentially time consuming and costly effort. I don't think it helps the State much.	Noted: See respone	We were asked to review broadly.
	Wayne Trusty	Reference Doc	A6-6	14-15	This is the most appropriate way to calculate effects of columns and beams because it directly affects the sizing and use of rebar in concrete cols and beams. Also, the data is generated taking account of the floor live load, not just its size. Not something that should be implicitly criticized like this without discussion of why.	Accept	Deleted sentances
	Wayne Trusty	Reference Doc	A6-7	16-17	This is presumably referring to operating energy and that should be made explicit. Other use phase effects re maintenance and replacement cycles are included.	Accept	
	Wayne Trusty	Reference Doc		29	PV normally stands for photovoltaics and is not typically considered to be a cladding material. Vinyl cladding is included and I think AI is also included.	Modified	PV is used in buildings and is of interest to designers
	Wayne Trusty	Reference Doc	A6-29	1	I don't think LCAid exists any more; if confirmed, this should be deleted.	Noted: See respone	Reference document includes all items reviewed, may be outdated.

	Wayne Trusty	Reference Doc	A7-4	12	The Athena steel data was updated since 2002 with input from the US steel industry. The reference here implies that the old data is still used. Also, the fact that the tool is Canadian does not mean the data is only for Canada as implied in the 'Location' column.	Accept	
	Wayne Trusty	LCA for WA	I-6	8 – 9	BEES uses an out-dated version of EPA's TRACI system and some of the impact measures listed are no longer supported. The list should be taken from TRACI 2 v.4. Habit Alteration is especially misleading.	Noted: See respone	We are listing different impacts as refernce to help users understand that there are different interpretations of applicable environmental impacts.
	Wayne Trusty	LCA for WA		12 – 17	This list is from an earlier draft of the ASTM standard and has been deleted from the most recent version. The best current breakdown of accepted measures is ISO 21930, Section 8. Portions of that list have been used in the IgCC, LEED v.4, and CalGreen.	Accept	Modified to reflect this change
	Wayne Trusty	LCA for WA	I-8	14	Spelling of 'annalists' is incorrect.	Accept	
	Wayne Trusty	LCA for WA		14 – 16	It is misleading to refer to EIO data as "…presented in slightly different forms by the government...". A more detailed explanation should be provided regarding how EIO data is converted to support EIO-LCA.	Accept	
	Wayne Trusty	LCA for WA		24 – 28	This implies there are no rules, or that rules are insufficient for building products. ISO 21930 should be cited as the standard for building product EPDs.	Accept	
	Wayne Trusty	LCA for WA		32	I think this description confuses the carbon footprint concept with GWP estimation in an LCA, which takes into account the full life cycle of the product. Also the reference to "carbon footprint" is misleading in that it too will cover a full life cycle as indicated in Figure I1.2.	Accept	deleted sentence re carbon footprint
	Wayne Trusty	LCA for WA	I-10	2 – 3	This first sentence is a weak and misleading definition of embodied energy, which can include initial and recurring embodied energy over the full life cycle – e.g., transportation, maintenance, etc.	Accept	
	Wayne Trusty	LCA for WA	I-11	6 – 9	Again ISO 21930 should be cited.	Accept	
	Wayne Trusty	LCA for WA	A-8 & A-9	Table A3.1	There are some problems with Table A3.1, as follows: ASHRAE 189 only requires improvement in 2 impact categories; CalGreen, which includes whole building LCA is missing; Exec. Order 13514 and French EPD & LCA legislation are not codes or rating systems; not sure about German& Swiss LCA Certification. Suggest these items be in a separate category so as not to confuse codes and rating systems with other initiatives. The IgCC description is somewhat mislead in that the IgCC says 20% reduction in GWP and at least two of the other listed measures. The table write reads as if only two should be chosen in addition to GWP.	Accept	Codes, Legislation and Rating systems are separated. IgCC, CalGreen and ASHRAE updated.
	Wayne Trusty	LCA for WA	A-10	Table A3.1	I do not believe 2030 Challenge and Living Building Challenge should be classified as rating systems. The LEED v4 description does not mention whole bulding LCA, which is included in the draft, and does not fully cover the ways in which LCA is included. Green Globes, the first US rating system to introduce LCA, is not even listed in the table. PAS 2050 is not a rating system.	Accept	Living Bld Challenge is rating system. 2030 is clarified to be a 'leadership standard' Difficult to categorize.
	Wayne Trusty	LCA for WA	A-10	6 – 7	ISO 21930 should be included in the para along with 14025 (I note that it is included in the table that follows).	Accept	
	Wayne Trusty	LCA for WA	A-12	Table A3.3	Very weak and potentially misleading descriptions of EIO-LCA and Hybrid LCA.	Modified	Text modified in attempt to clarify
	Wayne Trusty	LCA for WA	A-13	Table A3.3	I believe ecoinvent includes direct access to U.S. data through agreement with US LCI Database (NREL)	Modified	Text updated to clarify issue
	Wayne Trusty	LCA for WA	A-14	9 – 10	If wood already provides 50% of non-energy/transportation data, why the statement saying the wood industry should be encouraged to submit and update LCI data? What about the industries that have not submitted?	Accept	Correct. Meant to say 'all' Thank you for catching that.
	Wayne Trusty	LCA for WA	A-14	22 – 23	Has this suggestion been discussed with NIST since publishing EPDs is a role for the organization that has nothing to do with the BEES tool as currently structured?	Accept	Modifed recommendation
	Wayne Trusty	LCA for WA	A-16	32 – 35	The sentence "When looking to assess…." seems garbled. The first half says limit to tools currently available and the second half seems to say the reverse.	Accept	
	Wayne Trusty	LCA for WA	A-19	9 – 10	If this first sentence means LCA has not been used in the design stage of buildings then it is incorrect. LCA has been used for years in Norht America in design decisions, to assess alternatives at the whole building level, and to set environmental benchmarks for new buildings.	Accept	Sentence deleted
	Wayne Trusty	LCA for WA	A-19	17	Architecture 2030 and USGBC are not policy makers as indicated here.	Accept	
	Wayne Trusty	LCA for WA	A-19	22	Include CalGreen	Accept	

	Wayne Trusty	LCA for WA	A-19	30 – 41	Not sure exactly where this fits, but the government of Canada has commissioned whole building LCA for 10 to 15 years using the Athena Impact Estimator. The Estimator has also been used in design of notable Canadian and US private sector buildings, etc.	Future consideration	Did not receive information in time to include in the report. Worthy of future evaluation
	Wayne Trusty	LCA for WA	A-21	29	3 to 5 years is a gross understatement - the Netherlands and UK are just two examples of LCA being applied for at least 10 to 15 years.	Accept	
	Wayne Trusty	LCA for WA	B-2	34	LCA does not necessarily support locally-produced materials and products. Transportaiton is taken into account in LCA, but other impacts could overwhelm any benefits of shorter transport distances. This should not be included as a perceived benefit of using LCA.	Clarification	This is a potential goal, may not be the actual result.
	Wayne Trusty	LCA for WA	B-4	Table B1.2	This table contains erros and misleading indicators -- more than can be readily covered here. Just two examples: the combining of ANSI/USGBC/ASHRAE in one column; and even suggesting that codes like IgCC should be peer reviewed. In addition, this table and other written matieral in the report displays a lack of understanding of the 'reference design' required in codes and LEED v4 to demonstrate improvement.	Accept	Table simplified and clarified.
	Wayne Trusty	LCA for WA	B-7	15	Data is not the only consideration because tools for use by design teams as opposed to LCA practitioners have embedded algorithms that reflect regional or national building practices, material preferences, and building codes.	Accept	
	Wayne Trusty	LCA for WA	B-15	37	Add CalGreen	Accept	