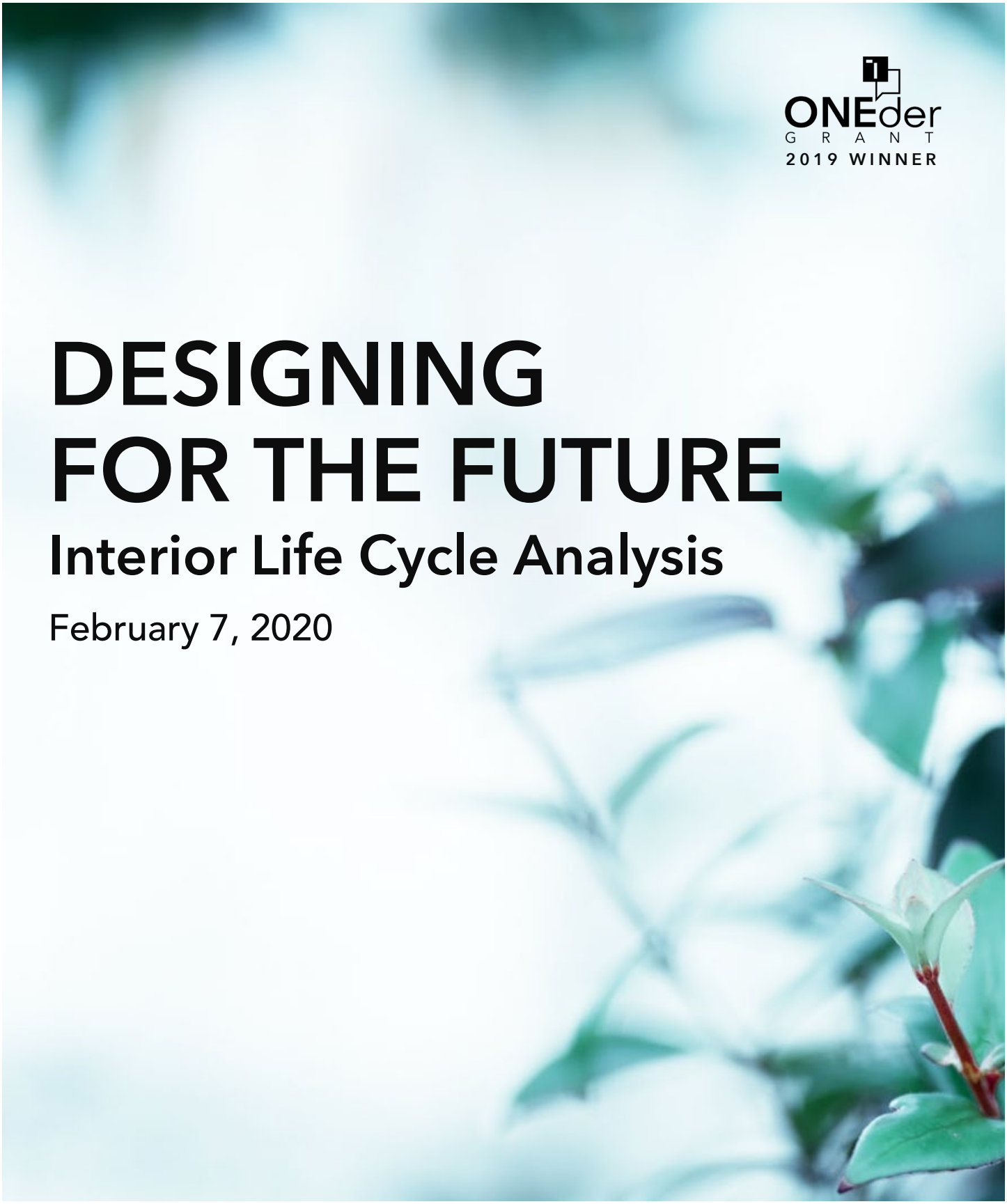


ONEder GRANT 2019 WINNER

DESIGNING FOR THE FUTURE

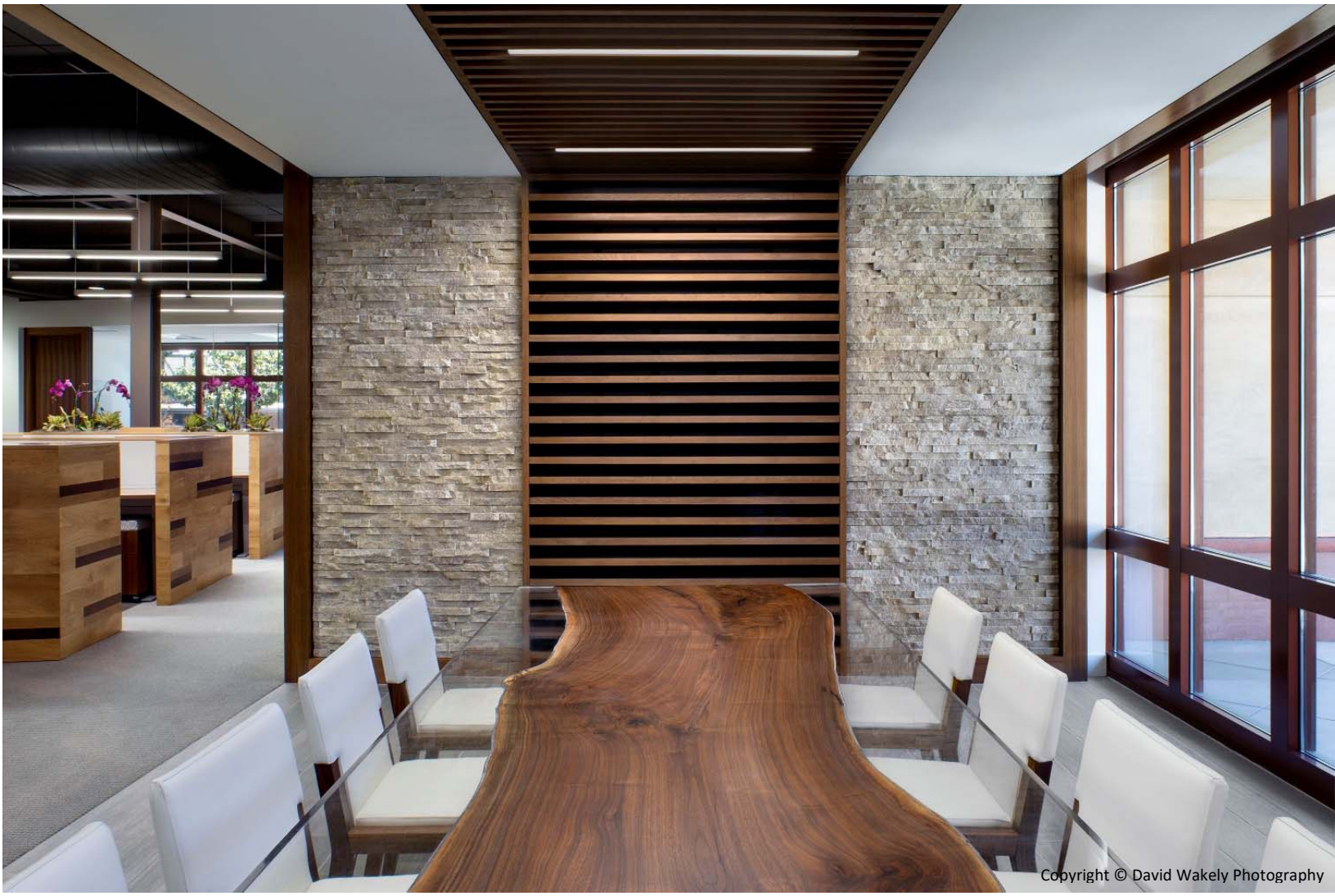
Interior Life Cycle Analysis

February 7, 2020

HPS

Designing for the Future

Interior Life Cycle Analysis



HPS HAWLEY PETERSON SNYDER

design . contribute . elevate

February 7, 2020

ABSTRACT

This study looks into how the growing knowledge base and selection of tools related to Life Cycle Analysis (LCA) and carbon can be utilized more effectively in the interior design process. The goal is to identify promising bridges between LCA criteria and the decision making process for interior design practice, as well as next steps to help move the industry forward.

Materials selected during design and used in construction have an immediate embodied carbon footprint and impact on the environment. Thoughtful selection of those materials presents an opportunity to influence outcomes in a positive and instrumental way.

According to Architecture 2030, 75% of annual global greenhouse gas (GHG) emissions are attributable to the urban built environment and buildings alone account for 39% of the emissions. Eliminating dependence on fossil fuels is an important part of the solution and key to addressing climate change and meeting the Paris Climate Agreement targets. As energy and operational efficiencies continue to improve in the building sector, embodied emissions play an increasingly significant role.

The embodied carbon of building core and shell construction represents 11% of global GHG emissions. Life Cycle Analysis software has begun to support conscientious design decision making relative to the base building with increasing robustness. This is key, because once “spent” the embodied carbon in a building is fixed in place. However, the impact of interior finishes and design decisions are greater than might otherwise be expected. Because interiors are often replaced multiple times over the life a typical 60 year building, their cumulative impacts frequently outstrip those of the base building, sometimes significantly.

Although progress has been made in Building Life Cycle Impact Reduction (LCIR), interior design analysis tools and strategies are lagging. The purpose of this research is to investigate LCIR opportunities for interior design and propose a way forward through a collection of pathways that link the growing LCIR knowledge base and tools with practice-based strategies that support more sustainable outcomes.

This research seeks to identify barriers and avenues for interior design Life Cycle Impact Reduction through literature review and interviews with design professionals, manufacturers, software providers, and topic experts. The Strategies and Solutions section outlines findings and proposed ways forward for designers, manufacturers, and LCA software providers that will facilitate a designer’s ability to be part of the solution. This integrative study provides multiple perspectives on the potential future use of LCIR strategies in the interior design process, while adding to a larger conversation and movement within the design field.

By identifying the environmental effect of interior design decisions through analysis of data, the development of better tools, and modified design processes, there exists a greater potential to create positive change

TABLE OF CONTENTS

ABOUT THE TEAM

Hawley Peterson Snyder (HPS) combines over 60 years of architectural and design experience with a thoughtful collaborative approach to craft dynamic spaces that engage the senses and delight the imagination. HPS is a place where designers can design, contribute, and elevate.

In 2019, One Workplace, a local, family owned AV, design, furniture, and workplace consulting company, launched the ONEder Grant pilot program. Their goal was to invest in their relationships with local architecture and interior design firms by challenging them to innovate. HPS took that challenge by submitting a proposal to expand on research into Life Cycle Analysis for interiors.

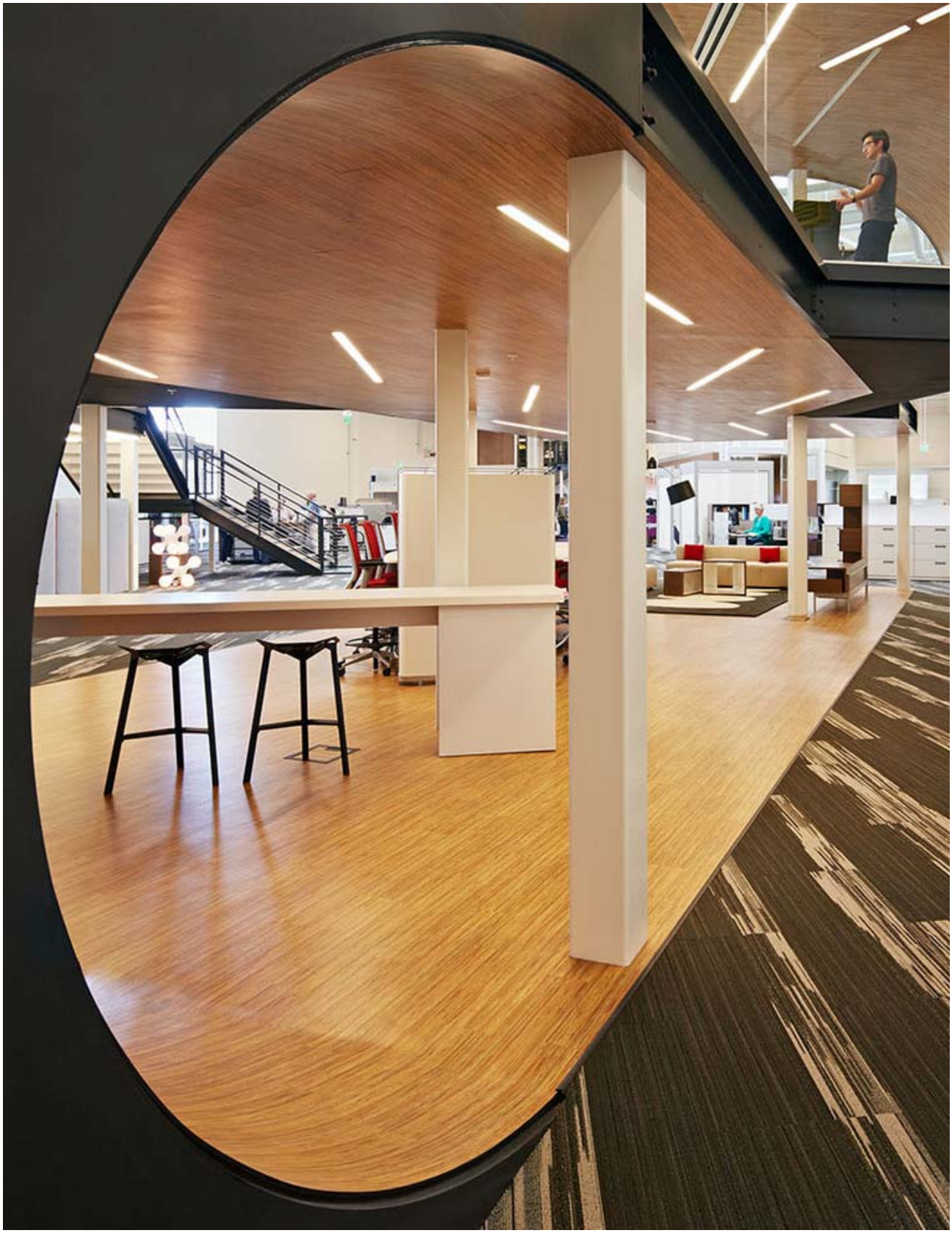
Karen Glaser, IIDA, LEED AP, Senior Interior Designer, Associate, has 35+ years of experience in the design field. Prior to HPS, she worked as a Professional Associate at HDR for over 21 years doing projects in the Healthcare, Corporate Workplace, and Government segments. She also has been a Healthcare Design Conference Nightingale Awards Juror for five years.

Nic Kaspereen is a Sustainability Research Assistant at HPS and Teaching Assistant at San Jose State University where they are completing a Bachelor of Fine Arts in Interior Design. Nic's passion for design and the environment have led them to focus on environmental solutions to design that will help improve the built environment while addressing the looming impacts of climate change.

Mercedes Ramirez, Associate IIDA, is an interior designer with experience in residential, commercial, institutional, and healthcare design. She has a Bachelor of Arts in Interior Design with a concentration in Interior Architecture from Sacramento State University. Her design approach is focused on holistic healing in the healthcare world with a particular attention to efficient work flow that keeps each person in mind, whether it is staff, patients, or visitors. She envisions that with each project the carbon impact should decrease to create healthier environments for all.

Sharon Refvem, FAIA, LEED Fellow, Director Sustainability Resource Group, Senior Associate, has served as Project Architect and/or LEED Administrator on many of the firms' projects. She also provides green building consulting services for cities, organizations, and other architectural firms. Before joining HPS, she practiced architecture in Switzerland and taught at the Swiss Federal Institute of Technology (ETH) in Zurich. She is a member of AIA California Committee on the Environment, past President of AIA Silicon Valley, and a founding member and past President of the U.S. Green Building Council's Northern California Chapter.

Denise Tom-Sera, IIDA, LEED AP BD+C, EDAC, CEAS, Senior Interior Designer, Associate, has extensive experience in visioning, planning, and designing healthcare, workplace, and community projects. Her background in Design and Kinesiology (science of human movement) is combined with over 25 years of commercial design experience. Her creative problem-solving approach is based on a deep dive into the client's core values, culture, and ways of working. Her unique approach to visioning strives to ensure that the people using the space are recognized and celebrated.



One Workplace

ACKNOWLEDGEMENTS

The journey started with curiosity and a headfirst dive. We could not have completed this study without the myriad of experts, cheerleaders, sounding boards, brainstormers, reviewers, challengers, friends, and family members who helped us along the way.

Thank you to One Workplace for investing in the design community. We want you to know how grateful we are for receiving a ONEder grant.

Thanks to Dave and Liz Ferrari at One Workplace for affording us the opportunity to do research in the field of sustainability and design. Also, Mark Baker, Carolyn Clark Beedle, Dave Bryant, Leigh Knight, Amy Nieva, Kelly Steitz, and the rest of the ONEder grant team, especially our coach Theresa Behdjet, for their support and guidance, and for being so helpful throughout this process.

Thanks to the Principals at Hawley Peterson Snyder and all of our colleagues at HPS for their support and encouragement, always checking in to see how things were going, and offering their help. Thanks to the whole firm for cheering us on!

Through connections we were introduced to a group of experts who graciously gave their time and shared their passion and expertise. It has been a gift to learn about what others are pursuing in sustainable design and hear about their efforts to create a better built environment, and in so doing, actively address climate change.

Thanks to those we interviewed who shared their time and insights with us for this report:

Roderick Bates, Clinton Boyd, Eden Brukman, Jenn Chen, Lisa Conway, Karen Glaser, Dr. Joshua Kneifel, Morana Medved, Liesl H. Morell, Kim Pham, Kirsten Ritchie, Anita L. Snader, Larry Strain, Denise Tom-Sera, and Robert Wendoll.

Thanks to our families for their support through this process, especially to Missy Satterberg for her help and support on the editing of this paper.

The commitment and passion of everyone involved inspires us. We hope that reading this gets others excited as well, and encourages them to take positive action as we all design for a better future.

Karen Glaser
Nic Kaspereen
Mercedes Ramirez
Sharon Refvem
Denise Tom-Sera

February 7th 2020, Sunnyvale, California

John Spotorno, HPS

INTRODUCTION

This study looks into how the growing knowledge base and tools related to Life Cycle Analysis (LCA) and carbon assessment can be utilized more effectively in the interior design process. The goal is to identify promising bridges between LCA criteria and the decision making process for interior design practice, as well as next steps to help move the industry forward toward lower carbon solutions.

> *"There are two types of carbon emissions with respect to a building, operational carbon and embodied carbon. Operational carbon refers to carbon dioxide emitted during the life of a building, emissions from heating, cooling, lighting, etc. Embodied carbon refers to carbon dioxide emitted during the extraction, manufacture, and transport of building materials."*
>
> MaterialsCAN, Carbon Action Network

As important as continued progress on energy and operational efficiency in the built environment are in the effort to reduce carbon emissions and counter climate change, the challenge of addressing embodied carbon is at least as urgent. While the impact of operational carbon accrues over time, the impact of embodied carbon is immediate. According to the United Nations Environment Programme, the manufacturing of building materials makes up 11% of total greenhouse gas (GHG) emissions. While that is less than the 28% of global GHG emissions attributed to operational energy, its impact is nevertheless large and immediate.

Traditionally interior design professionals have had to consider multiple, sometimes conflicting, criteria in their design process, including: aesthetics, program, durability, cost, maintenance, and other factors. Sustainability and occupant wellbeing have become increasingly prominent design criteria over the last couple of decades thanks to the emergence of LEED, WELL, and other programs that have improved the general understanding of the relationship between design decisions and good outcomes. It has become clear that in order to successfully address environmental considerations, this broader criteria needs to inform early decision making, not just represent an accounting of results at the end of a project.

The impact of embodied carbon on the environment has garnered increasing attention over the last several years, because buildings make up such a large share of greenhouse gas emissions. This realization made it clear that the carbon impact of design decisions, including interior design choices, needed more attention. A 2019 study by the Carbon Leadership Forum, investigated the impact of tenant improvements (TI) and MEP (mechanical, electrical, and plumbing) systems relative to the carbon profile of buildings, concluded the following:

> *"…The results identified high-impact TI components as: office furniture (offices, cubicles, chairs, tables), ceiling panel suspension systems, carpet, doors, glazing, and acoustical panels."*
>
> *Life Cycle Assessment of Tenant Improvement in Commercial Office Buildings*, The Carbon Leadership Forum, Department of Architecture, University of Washington, April 2019.

Architecture 2030 reports that, 75% of annual global greenhouse gas (GHG) emissions are attributable to the urban built environment and buildings alone account for 39% of the emissions. Eliminating dependence on fossil fuels is an important part of the solution and key to addressing climate change and meeting the Paris Climate Agreement targets. While operational emissions are important, their impact takes place over time. The embodied carbon represented by the material in a building is present and irreversible immediately. As energy and operational efficiencies continue to improve in the building sector, embodied emissions take on increasing significance. This report takes a closer look at embodied carbon and how the design community can make more informed selections using carbon reduction as a design criterion.

The embodied carbon of building core and shell construction represents 11% of global GHG emissions. LCA software has begun to support conscientious design decision making relative to the base building with increasing robustness. This is key, because once "spent" the embodied carbon in a building is fixed in place. However, the impact of interior design and finish decisions are greater than might otherwise be expected. Because interiors are often replaced over the life a typical 60 year building, the cumulative impact of serial renovation projects often outstrips that of the base building, sometimes significantly.

Goals

The goals of this report are to:

- Provide an entry point for interior designers and other stakeholders who want to better understand life cycle analysis, why it is an important factor in interior design, and how they can utilize it to make better material selections
- Offer feedback to LCA software providers about what interior designers need to inform decision making during the early stages of design and throughout the process
- Encourage manufacturers to participate by providing LCA and EPD data about their products and using it to improve the footprint of their products
- Distill a set of next steps and best practices for all the stakeholders to enable forward progress and improved environmental outcomes

Methodology

To achieve the goals of this research project, the following three step approach was taken:

Understanding: Initial efforts were made to understand current thinking and research on the impact of building material selection on the environment. Particular attention was paid to whether or not data supporting considered interior material selection is available and if so, how accessible it

is. Life cycle analysis was investigated, including what kind of data is available and how it is collected, evaluated, and accessed. Some existing LCA tools were explored and tested. In addition, common interior design practices were reviewed, including work flow, selection criteria, approval processes, budget considerations, and scheduling.

Identifying: The initial research began to reveal the myriad of challenges associated with trying to link interior design practice with software development parameters and manufacturing considerations, environmental product declaration boundaries, and other contributing factors. At the same time, through the assessment of the findings, possible bridging strategies and potential next steps for tools, product development, and practice began to appear.

Proposing: Finally, the findings were distilled into a set of targeted recommendations intended to make action easier and more accessible. While the topic remains a dense and complex issue with serious and pressing time constraints, a set of next steps and best practices were extracted and form the Strategies and Solutions section of this report.

Along with the research into practice, LCA methodology, Environmental Product Declarations (EPD), LCA software options, and manufacturing uptake, a series of interviews were conducted with interior designers, topic experts, manufacturers, and software developers. The interviewees were extremely generous with their time and their insights helped reveal the many challenges that this topic presents along with some opportunities that can support forward progress.

The interviews were so enlightening that consolidated transcriptions have been included in the appendix of this report for further reference.

One Workplace

OVERVIEW

This section provides a brief background of the environmental issues and milestones that led to the increasing awareness of the global impact that carbon, and embodied carbon in particular, has on the environment. It also describes some of the vehicles currently used to capture and organize the data needed for assessment and analysis of carbon factors. A short summary of the interior design processes is also included to provide better context and a common baseline for those who are not interior designers.

Climate Change and the Built Environment

The study of environmental impacts related to the built environment dates back to at least the 1960's, when concerns about the effect of human impacts on the natural balance and the finite nature of raw materials began to arise. Dr. Rachel Carson wrote her seminal book, *Silent Spring*, in 1962 and a man named Harold Smith presented his "cumulative energy concept" at the World Energy Conference in 1963. His idea was a precursor of the LCA approach to impact assessment. Global Modeling studies *The Limits to Growth* and *A Blueprint for Survival* with their forecasts of the exhaustion of resources and changes to the climate were both published in 1972. The sustainability and environmental justice movements began to gain ground in the 1980s. In the 1990's the idea of life cycle assessment started to gain traction as scientific approaches to the study of the impacts caused by material extraction, transportation, manufacturing, installation, and end of life began to emerge. The U.S. Green Building Council was founded in 1993 and launched their market changing LEED (Leadership in Energy and Environmental Design) Rating System in 1998. In 2006 Architecture 2030 issued the 2030 Challenge putting the architecture and building community on notice that urgent change was needed and providing a strategy and timeline for that change. Since then, awareness of the impact of the built environment on the environment has continued to increase dramatically; as have the efforts to find solutions to counter the negative effects of the industry. With the acceleration of climate change, there is an even more urgent need to step into action.

> *"The embodied carbon emissions of building products and construction represent a significant portion of global emissions… embodied carbon emissions from the building sector produce 11% of annual global GHG emissions."*
>
> Architecture 2030

Buildings and their interiors are large contributors to greenhouse gas emissions (carbon) because of the ongoing impacts of their operation and the embodied carbon of the materials used to build them. Embodied carbon represents the carbon dioxide emitted during the manufacturing, transportation, and construction of building materials as well as the end of life emissions. Life cycle analysis calculations are generally based on a building having a 60 year life cycle. The embodied

carbon of the materials used to build a building are present immediately and irretrievable embedded in the physical components of the building.

Initially the impact of the materials used to build the core and shell, especially in the case of concrete and steel structures, is far greater than the impact of the building envelope and interior fit out combined. However, if we compare the life cycles of the interiors, which are subject to renovation or replacement on a conservatively estimated average 15 year cycle, to the 60 year building model, it becomes evident that the interiors can actually have a greater impact over the life of a building than the original structure does.

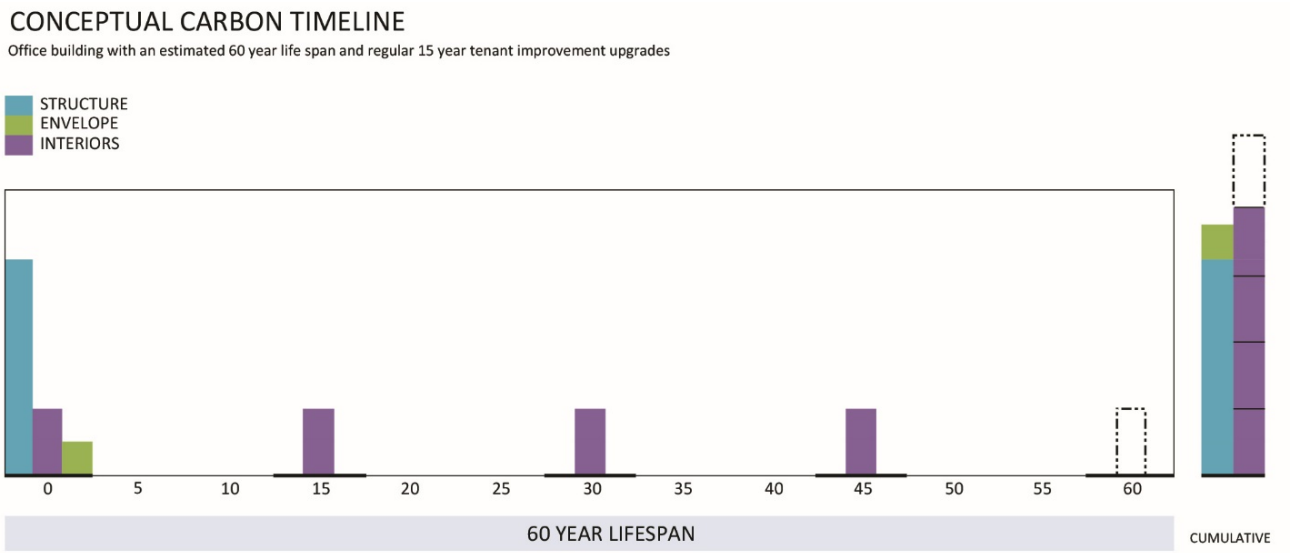


Figure 1. Conceptual embodied carbon impact of a 60 year office building over its lifespan, Nic Kaspereen, HPS

While some may argue that 15 years is not a defensible estimate, in some places that cycle can be alarmingly shorter. In San Francisco, while the structural impact of embodied carbon is an important issue, there are a lot of tenant improvements and class A office spaces that turn over even more rapidly.

> *"[Turnover] is even faster than [five years]. This is what we're learning. We also have a lot of restaurants and retail. So those are key sectors or sub-sectors of building occupancy that I'm targeting to understand tenant improvement [impacts]."*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

Life Cycle Analysis is a powerful construct that can organize and yield information on a variety of sustainability issues. By taking into account the entire life cycle of a product, a better understanding of both the challenges and opportunities becomes evident. This more complete perspective on emission sources based on a global standard for LCA (ISO14040) allows targeted, more effective solutions to be developed and implemented.

Life Cycle Analysis

Understanding the full impact of a given product on the environment requires the examination of the inputs and outputs associated with it starting from inception, including: design, raw material extraction, production, assembly, transportation, installation, use, and end of life (reuse, repurposing, recycling or disposal).

> *"Life cycle is the consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. Life cycle assessment (LCA) is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. Life cycle inventory analysis (LCI) is the phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. Life cycle impact assessment (LCIA) is the phase of life cycle."*
>
> The International Standard ISO14040

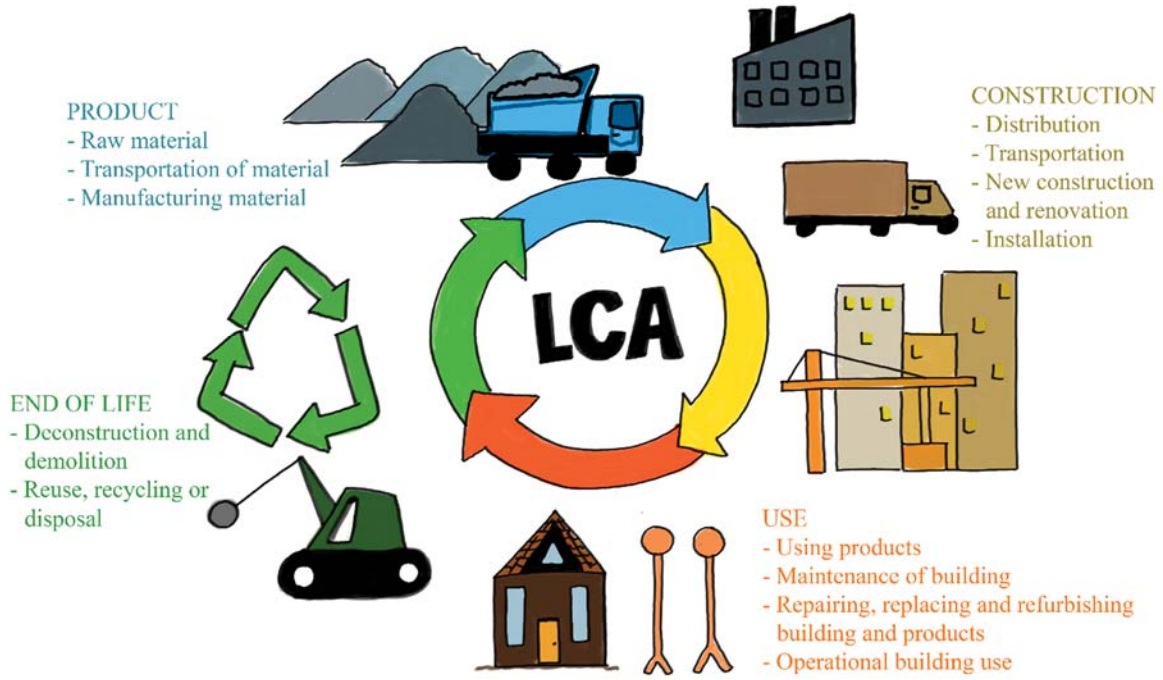


Figure 2. Life Cycle Analysis, Nic Kaspereen, HPS

Life Cycle Analysis (LCA) is a standardized, science-based tool for describing and quantifying the environmental impacts of materials or services. The International Organization for Standardization (ISO) provides guidelines for conducting life cycle assessments according to ISO standards 14040 and 14044. A life cycle assessment begins with the definition of the scope. Then an inventory analysis of associated extractions and emissions is performed followed by an impact assessment relative to pertinent impact categories. Finally the results are formulated to identify particular issues, communicate opportunities for improvement, and allow for comparison with other products.

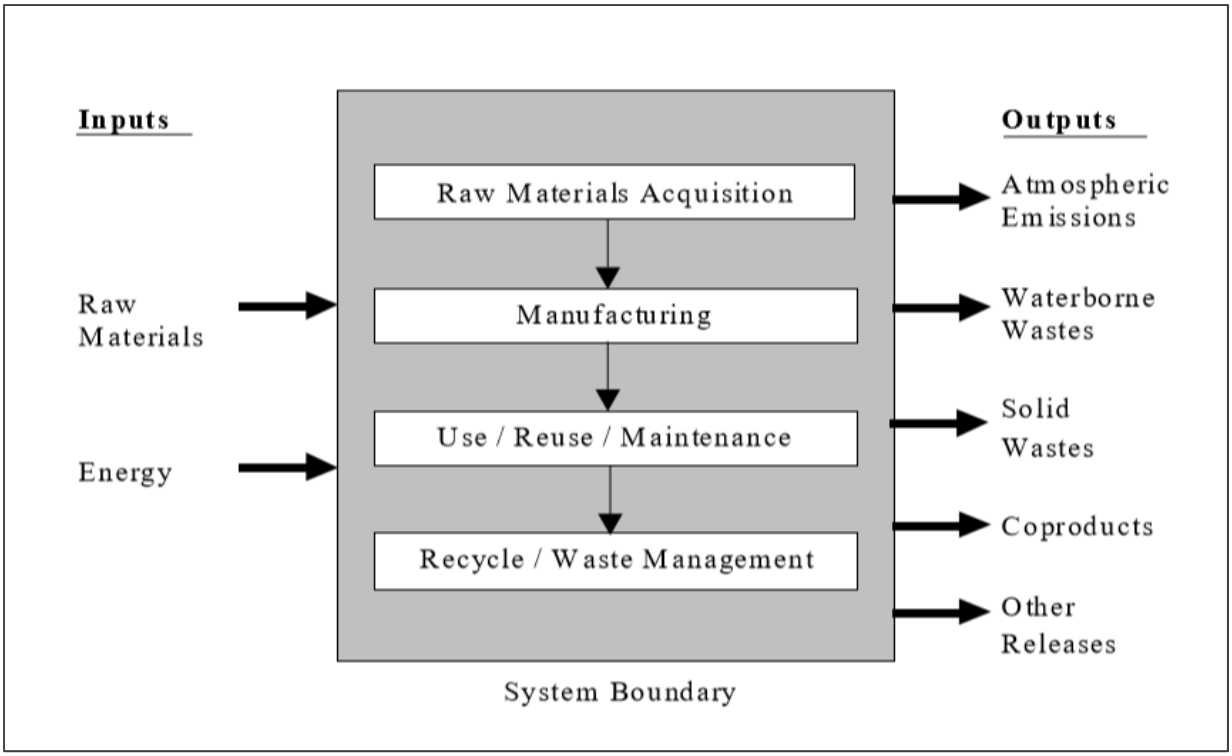


Figure 3. Scoping and Inventory Analysis Diagram, US EPA Life Cycle Assessment: Principles and Practice, 2006

The boundaries of an LCA are set during the scoping stage. The goal and parameters of the LCA will determine the level of detail and other factors needed to establish the basis for comparison to other similar products.

During the inventory analysis phase inputs and outputs associated with every stage of products life are identified and recorded.

LCA assessment is the evaluation of the potential environmental and human health impacts, as well as resource depletion associated with a product or service. The data from the inventory analysis is grouped and quantified during this stage, then evaluated relative to applicable global, regional, and local impact categories.

Impact Categories and Associated Endpoints

The following is a list of several impact categories and endpoints that identify the impacts.

Global Impacts

Global Warming - polar melt, soil moisture loss, longer seasons, forest loss/change, and change in wind and ocean patterns.
Ozone Depletion - increased ultraviolet radiation.
Resource Depletion -decreased resources for future generations.

Regional Impacts

Photochemical Smog - "smog," decreased visibility, eye irritation, respiratory tract and lung irritation, and vegetation damage.
Acidification - building corrosion, water body acidification, vegetation effects, and soil effects.

Local Impacts

Human Health - increased morbidity and mortality.
Terrestrial Toxicity - decreased production and biodiversity and decreased wildlife for hunting or viewing.
Aquatic Toxicity - decreased aquatic plant and insect production and biodiversity and decreased commercial or recreational fishing.
Eutrophication – nutrients (phosphorous and nitrogen) enter water bodies, such as lakes, estuaries and slow-moving streams, causing excessive plant growth and oxygen depletion.
Land Use - loss of terrestrial habitat for wildlife and decreased landfill space.
Water Use - loss of available water from groundwater and surface water sources.

Figure 4. Common Impact Categories, US EPA Life Cycle Assessment: Principles and Practice, 2006

Current LCA tools for building design and construction support new construction analysis, but are focused primarily on core and shell components. With a few notable exceptions, interior design components are not yet well supported in LCA tools. This is partly strategic as the streamlining of this complex process is still in the relatively early stages of development. Energy intensive and otherwise high embodied carbon materials, such as concrete, steel, and aluminum that are also present in high quantities in most building core and shells, are understandably the primary focus of these tools. After all, the carbon associated with the initial buildout of a building has been "spent" in the process of assembling the building.

Carbon reductions in these high carbon materials through design optimization to reduce the overall quantity and/or careful selection based on LCA values make an immediate difference. Even within the same class of materials the difference in global warming potential of one product compared to another can differ by a factor of three or more. This is due primarily to manufacturing practices and energy sources.

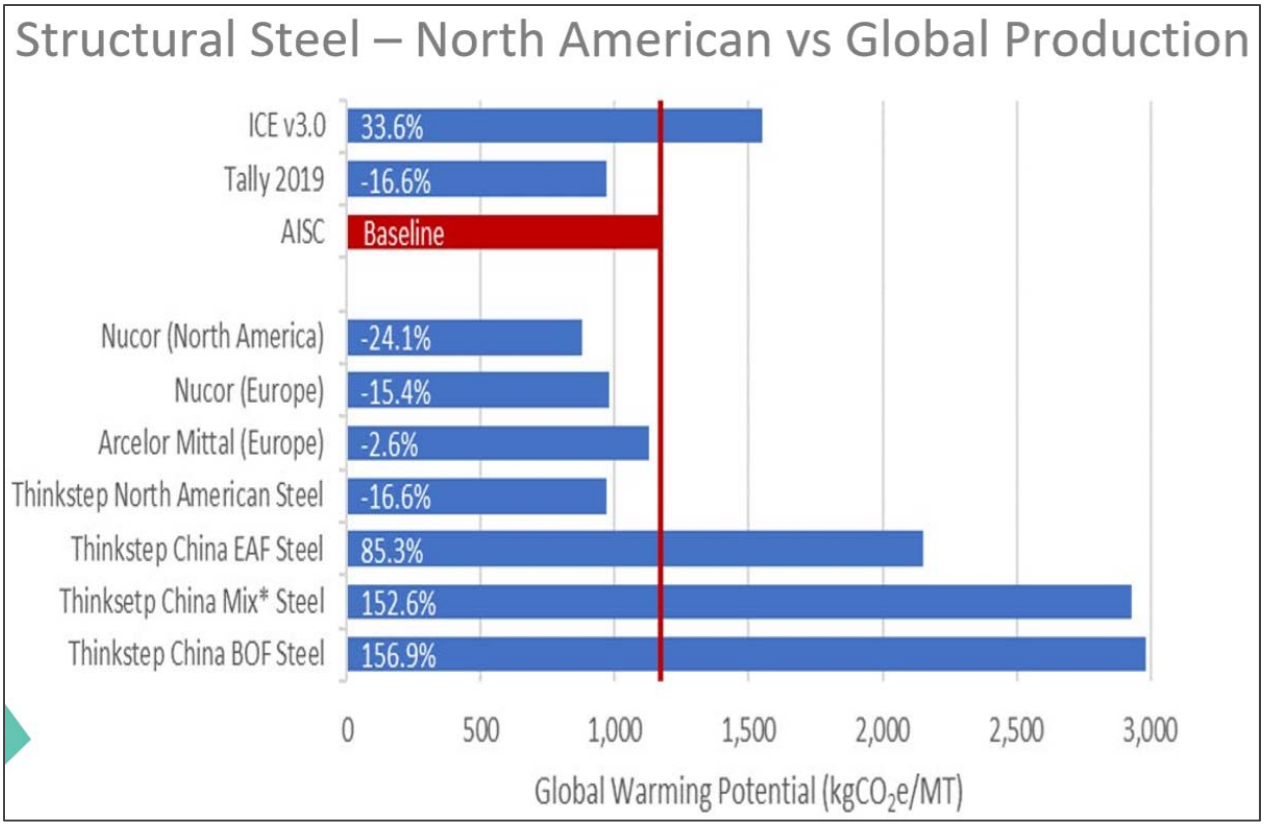


Figure 5. Structural Steel – North America vs Global Production, courtesy Kirsten Ritchie, Gensler

Attempting to do individual analyses for the hundreds and sometimes thousands of products associated with a given project is a huge barrier for any project team.

> *"As we make it easier for people to do the right thing or to select the right materials, the more they will do it. If it is a lot of work and they are under stress it's less likely. If you think about being an interior designer for a hotel, you are specifying in some cases over 10,000 items… And actually, that means they have to understand 20,000 items, because you have to have a comparative baseline in order to pick and say this one is better. They do not have the bandwidth to do [more research]. So they are typically building relationships with certain manufacturers or producers who they are going to be relying on to help them."*
>
> Kirsten Ritchie, Principal, Gensler

Finding an effective strategy to make meaningful decisions within the given constraints requires, not only good data about the projects, but also commitment and leadership.

Environmental Product Declarations

An Environmental Product Declaration (EPD) is a comprehensive, internationally recognized report based on product data provided by the manufacturer and verified by a third party that documents the way a product affects the environment throughout its life cycle. EPDs are based on a common

set of Product Category Rules (PCRs) that facilitate the comparison of products in the same category. EPDs are usually valid for five years.

There are generally five steps in the development of an EPD.

1. Determining the applicable PCR
2. Conducting an assessment of the cradle-to-grave environmental impact
3. Compiling the results in an EPD
4. Verification by a recognized third party
5. Registration of the EPD

Understanding what an Environmental Product Declaration (EPD) is, the importance they play within a Life Cycle Assessment, and how to read them is key to the LCA process.

> *"An EPD transparently communicates the environmental performance of a product or a material over its lifetime. If you are a construction engineer or an architect, you can easily compare the EPD data of the materials you are about to use and choose the most sustainable option. If you are a manufacturer, by certifying your product with this methodology you are making a positive value statement on the issues of climate change, carbon impact, and environmental footprint."*
>
> One Click LCA

Because Environmental Product Declarations are third party validated documents that certify the environment impact of materials and are based on a common, international standard, if certain fundamental details align (impact units, PCR boundary, and life cycle estimate) they can form a relatively reliable basis for comparison.

Figure 6. EPD documents typically include a cover page with a third party certification icon, Nic Kaspereen, HPS

An EPD includes general information about the manufacturer and product, as well as a detailed description of the product; confirmation of certification; standards used; applicable Product Category Rules; assessor's company information, name, and signature; the independent verifier's company, name and signature; units used for the EPD; and the boundary (raw material extraction, transportation, manufacturing, and installation). LCA results and environmental impacts, as well as other data and references, are documented as well.

It takes some practice to read EPDs with confidence. BuildingGreen provides an EPD Quick-Start Guide outlining five easy steps for reading an EPD. They are:

1. Check for verification and validity. Make sure that it was created according to the applicable ISO standards, verified by a third party program operator, and that its period of validity is still current.
2. Identify the declared or functional unit. The impact of a square meter of a product will be considerably less than that of a cubic meter.
3. Identify the system boundary used. Common boundaries are cradle-to-grave (extraction through end of life) and cradle-to-gate (extraction through packaging only). Also note whether exclusions or inclusions exist.
4. Scan the impact assessments.
    - To calculate impact totals for a particular project estimate how many units of each high quantity and/or high impact material are in the project and, based on the declared or functional units in the EPD for each material, calculate the total impact using the impact measure data provided in the EPDs.
    - To estimate projected impacts, focus on the biggest impacts listed in the impact measures and multiply them by the estimated quantity of the material to establish a rough estimate for the whole project. The Global Warming Potential (GWP or embodied carbon) metric is considered the most reliable data and can be used as a proxy for the other impacts.
5. Compare results. Rough comparisons of EPD results can be done if the PCR, functional or declared unit, and system boundaries match. If any of those items do not match, the comparison will be flawed.

Even without calculations, if the PCR, declared or functional units, and boundary criteria match, products being considered for the same use can be compared to each other and the one with less impact selected. Alternatively, materials with high environmental impacts listed in the impact assessment can be scaled back in the design process to reduce the quantity and thus the overall carbon impact of the project.

There are limits to EPDs. They rely on impact estimations that are subject to variation. EPDs based on different life cycle stages, documented using different PCRs, and/or that are missing relevant environmental impact data are not comparable. EPDs created using different systems cannot be reliably compared either. This is one of the biggest challenges for LCA software providers who would like to increase the number of products available in their databases, but need to ensure that they are providing solid, apples-to-apples data for comparison.

Environmental Impact Assessment Tools

A number of Life Cycle Assessment tools exist and/or are being developed to support design and construction industry efforts to reduce the substantial impacts of GHG caused by the built-environment. LCA software uses manufacturer's EPDs to generate assessments that allow designers to compare the environmental impacts of design options.

The Athena Sustainable Materials Institute (ASMI) and its predecessor organizations in Canada have been doing important work on the environmental footprint of building materials for decades. Their research, focused on structural and envelope building materials, was first published in *Building Materials in the Context of Sustainable Development*, in 1994. Their *Athena Impact Estimator for Buildings* software was first launched in 2002.

The National Institute of Standards and Technology (NIST) Engineering Laboratory created a consensus based tool with the goal of making it practical, flexible, and transparent for industry stakeholders to use. The BEES (Building for Environmental and Economic Sustainability) project began in 1994, calculates the sustainability performance of individual building products, and supports cost effective, environmentally preferable building product selection. NISTS Building Industry Reporting and Design for Sustainability (BIRDS) supports whole building evaluation.

> *"NIST is collaborating with the National Renewable Energy Laboratory (NREL) and Athena Sustainable Materials Institute to combine NIST's BIRDS sustainability framework and ASMI's Impact Estimator for Buildings to create an API that allows OpenStudio users to calculate custom, detailed whole building life cycle assessment estimates for residential."*
>
> Dr. Joshua Kneifel, Research Economist, NIST

The *Tally® Life Cycle Assessment App* was developed by KT Innovations, an affiliate of KierenTimberlake, in partnership with Autodesk and thinkstep (now Sephera). Tally is a Revit™ plugin that allows Revit users to incorporate data about selected materials directly into their design models. It supports the analysis of building components, design option comparison, and LCA reporting. To maintain the quality of their LCA reporting, the EPD data that is entered into Tally must be created according to a special data format generated by GaBi software by Sphera. It is designed to work with the quantity take-offs extracted from a Revit and the Tally plugin. While this does limit Tally's ability to incorporate other data sources, it does allow Tally the ability to compare product impacts for products that are intended for the same purpose, but are subject to different product category rules.

> *"Tally is unique in the sense that it takes materials that have different product category rules, say like mass timber used for structure and steel that's used for structure. They're going to have very different product category rules. So we're able to take the EPDs for each and then reprocess them in Gabi so that they have all of the appropriately aligned background data assumptions, cutoff points, and things like that. That way when a user brings in these two very disparate materials and tries to compare them in the same application, they're able to do so accurately."*
>
> Roderick Bates, Principal at KieranTimberlake

The Carbon Leadership Forum (CLF), an alliance of academic and industry partners, convened to place a multidisciplinary focus on reducing the embodied carbon in building materials. In November 2019, they launched the *Embodied Carbon in Construction Calculator* (EC3). It is a free, cloud-based, open access tool to simplify the complex process of comparing materials.

Quantity data from construction estimates and/or BIM models and a robust database of third-party verified EPDs allows EC3 to estimate a project's overall embodied carbon emissions and potential options for better, lower carbon choices.

According to CLF, The EC3 tool also allows owners, green building certification programs and policymakers to assess supply chain data in order to create EPD requirements, and set embodied carbon limits and reductions, at the construction material and project scale.

EC3 allows users to plan buildings and compare product choices early and in real time. Boxplot diagrams, generated from EC3's dataset of EPD information, are used to provide a visual assessment of the range of options. Using the EPD data for a given material category, it shows the option with the highest embodied carbon, a Carbon Leadership Forum baseline for the category, the lowest embodied carbon option, and an understanding of the impact range of available options.

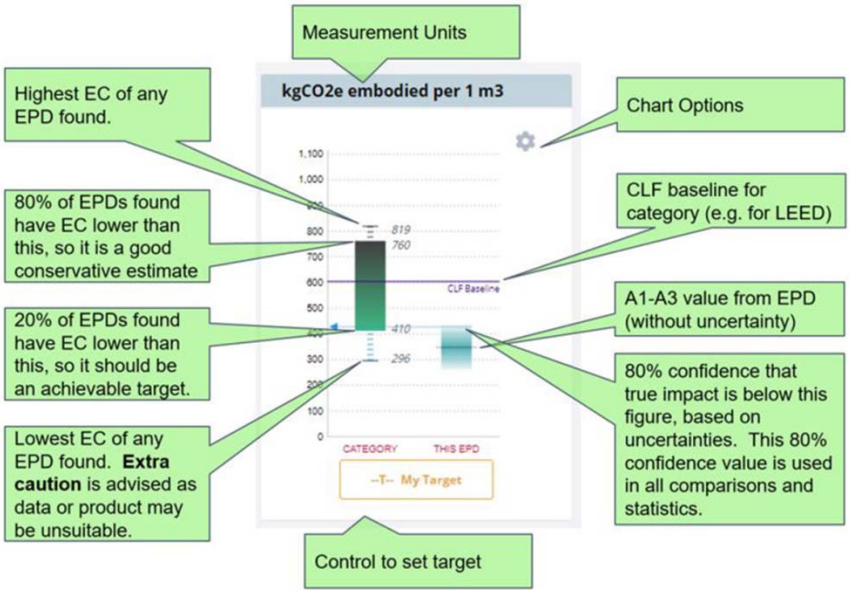


Figure 7. Typical EC3 tool boxplot output, Carbon Leadership Forum

CLF hopes that this data-driven tool will increase the demand for low-carbon solutions and incentivizing construction material manufacturers and suppliers to invest in disclosure, transparency, and material innovations that reduce the carbon emissions of their products.

The Tally and EC3 teams have found a way to use Tally and EC3 together to support a workflow that helps design and construction teams optimize embodied carbon reduction. It utilizes Tally's ability to extract quantity and material data from Revit models and EC3s ability to highlight lower carbon choices. The following diagram illustrates the proposed blended work flow.

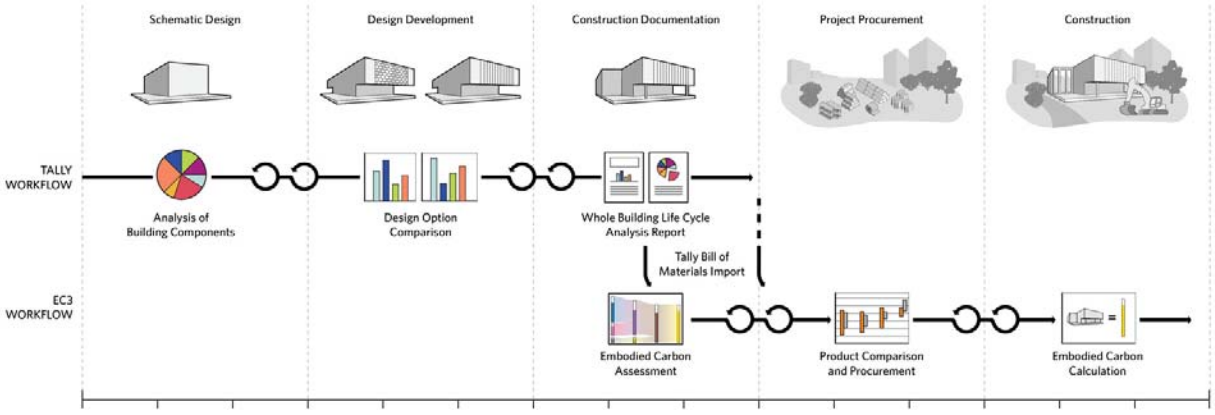


Figure 8. Tally/EC3 Workflow diagram from KT Innovations an affiliate of KieranTimberlake Architecture

Tally's ability to compare products subject to different PCRs make it particularly valuable in early design stages. While Tally is a promising tool for early interior design assessment and the current database includes some flooring, wallboard, and ceilings options, the interior design materials are limited. In addition, in order to assure the integrity of the database, it has strict criteria for the EPDs that can be added to the database. Never-the-less, the database is easy to update with the correct type of EPD and growing.

EC3 provides a streamlined method for comparing options and perhaps just as importantly, understanding the relative impact of materials under consideration. This is especially valuable during specification and procurement. The tool is new, but the number of materials in the database continues to grow.

Interior Design Process

While interior designers each have their own strategies, tools, and techniques that work for them and some building types or clients require a particular approach, similar steps are common to nearly any interior design project. To provide a common context for discussion, an outline of the basic interior design phases and tasks is provided in the following table. There are five fundamental interior design phases. Note that the tasks associated with furniture design, specification, and procurement are related to and interwoven with the interior design phases.

Conceptual Design is the phase of the project during which the parameters of the project are determined and the designer develops an idea into a design. Ideas often relate to the project's physical location, purpose, and/or the demographic of the occupants using the facility. The design is the translation of the program, vision, and other criteria into a design concept or direction.

During the **Schematic Design** phase, the approved design direction is further developed and a space plan is created based on the elements and factors determined in the conceptual design phase. Based on the design concept and use, broad categories of materials are established. From that point multiple options are examined and preliminary selections are made.

Final decisions on the space plan and finishes are made during the **Design Development** phase and presented to the client for approval.

In the **Construction Documents** phase the design is documented and detailed for bidding, permit, and construction purposes.

During **Construction Administration** the designer works with the construction team to make sure that the design intent is carried through the construction phase of the project and that the final results achieve the goals established during conceptual design, developed through schematic design and design development, and documented in the construction documents phases.

The following table outlines key tasks that typically occur during each phase and shows how the furniture selection and documentation is interwoven in the design process.

Interior Design Practice – Common Phases and Tasks

Design Phases	Tasks
CONCEPTUAL DESIGN	• Design Standards: If there are client design standards, review them. Collect information and sample materials. If there are no standards, research options. • Visioning: Engage the client and other stakeholders to establish the vision for the project, including design and cultural inspirations and sustainability goals. Establish image/branding principles and aesthetic direction. • Programming: Identify departments and the required and preferred adjacencies between them; staff types and quantities; preferred ways of working; office/ workspace size per staff type and workstyle; and other functional space needs • Field Verification: If the project is a tenant improvement, visit the existing site and verify existing conditions such as wall, window, and door locations, lighting and electrical locations. • Budget Analysis: Determine the client's budget and design expectations. Assess how to create the idea within those parameters • Initial Presentation: Include photos of design styles, images of local points of interest, color direction, and other early design inspirations inspired by the vision and other parameters of the project.
FURNITURE PROGRAMMING	• Develop standards for workspaces, as well as other areas that may be templated • Develop preliminary space planning and/or furniture layouts • Develop preliminary furniture schedule • Establish preliminary Furniture Budget
SCHEMATIC DESIGN	• Develop the design direction • Develop the functional layout and initial ideas for interior elements such as interior architectural form, lighting, casework, finish materials, material/color distribution, furnishings, signage, artwork and graphics • Coordinate details and materials • Refine conceptual presentation • Present options to client to finalize design direction
FURNITURE DESIGN DEVELOPMENT	• Place and tag furniture on the plan per furniture type • Research and select furniture products • Select fabrics and furniture finishes • Finalize furniture specifications • Provide specifications to furniture dealership(s) for quotes

DESIGN DEVELOPMENT	• Finalize construction materials and interior elements • Finalize layouts • Finalize details and materials • Prepare and present final design
CONSTRUCTION DOCUMENTATION	• Complete CAD drawings • Complete project specifications • Detail how elements should be constructed
FURNITURE QUOTE VERIFICATION AND PROCUREMENT	• Verify quotes from the furniture dealer(s) for correct tag number, locations, specifications and fabrics • Provide correct quotes to the client for processing, purchasing and procurement
CONSTRUCTION ADMINISTRATION	• Coordinate with contractor, subcontractors and owner • Review and process construction submittals • Provide additional clarification and drawings as required • Create a punch list of items that need correction before the client takes possession of the facility

The interior design process has also had to adapt over time due to increasing pressure on design and construction schedules. In some cases, that moves finish and furniture selection earlier in the design process.

> *"[Selection is] set pretty early, now [it is] done in schematic design. It did not used to be that way. It used to be in design development, but my primary medical client requires us to get everything set early so they can start to look at pricing."*
>
> Karen Glaser, Senior Interior Designer, Associate, Hawley Peterson Snyder Architects

Manufacturing

In the context of an LCA, the core product information upon which assessments are made and designers depend comes from manufactures. It is their product information that is reflected in Environmental Product Declarations (EPD) and Health Product Declarations (HPD). By contributing the needed product data, they are key contributors in the effort to move the built environment in a positive direction. Collecting and assessing the needed data can also facilitate an internal effort to improve products overall.

Optimizing a product based on LCA results involves a process similar to the design process used by an interior designer or architect in which multiple, sometimes competing, factors must be considered and iteratively studied to find the optimal solution. A systematic approach can begin by first investigating the elements of a product that make up the greatest quantity or have the most impact, while considering all of the pertinent criteria such as global warming potential, aesthetics, and durability. Manufacturers can then begin the cyclical process of improving the product's overall profile. Integrating LCA data at the beginning and through all stages of development is an important strategy for sound product development and ongoing improvement.

> *"We incorporate LCA data into our decision making beginning with Design. All of our business units (innovation group, technology group, new product development group) review materials as part of the new product development process. The requirement is*

that they review the proposed materials from both an LCA and a material health lens… Its starts, in the beginning, in our innovation groups."

Anita L. Snader, Environmental Sustainability Manager at Armstrong Ceilings and Wall Solutions

Including embodied carbon and LCA factors in the product development process helps ensure that the resulting product can be as optimized as the combined market factors allows, while revealing areas for future improvement in subsequent rounds of product analysis and development.

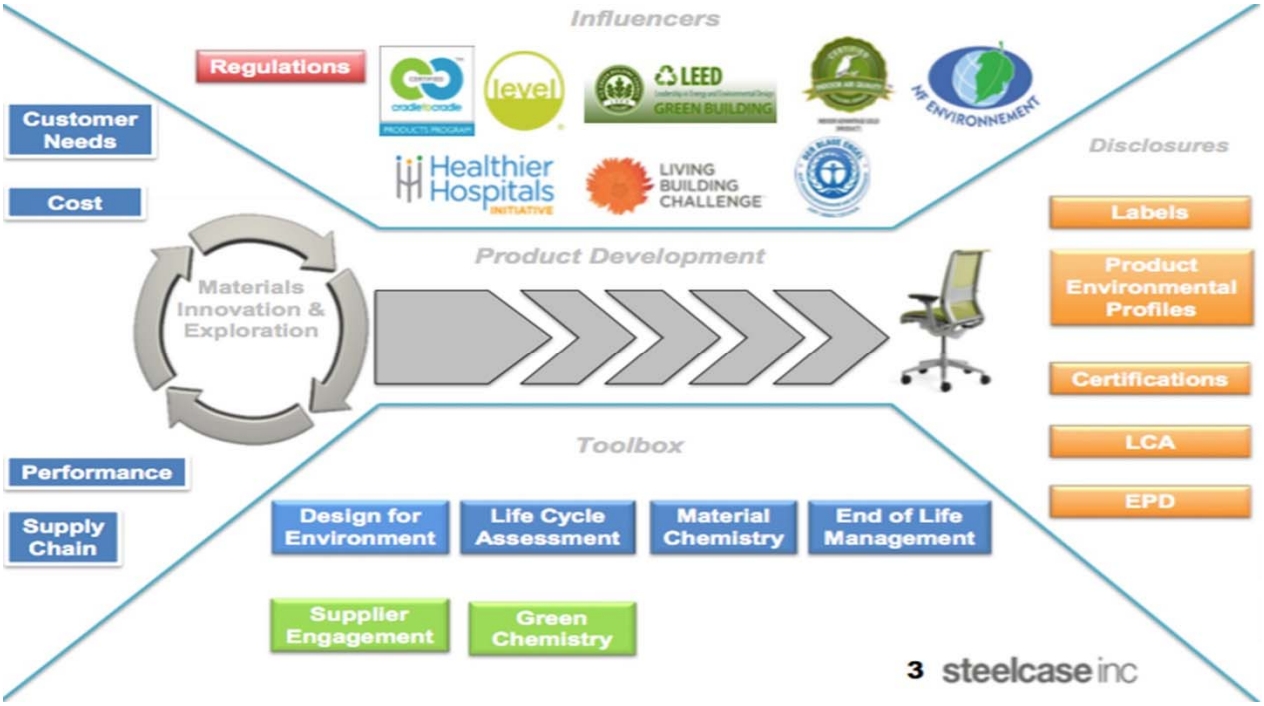


Figure 9. Product design process from inception to market, courtesy Clinton Boyd, Steelcase, Inc.

"Very early on [Steelcase has] a stage where we focus on the design of the product. We help the engineers and the designers to make choices around material selection and sourcing, and actually improve the environmental profile of the product. So we'll use life cycle assessment as part of that."

Clinton Boyd, PhD, Principal Scientist-Green Chemistry & Sustainability for the Global Sustainability Initiatives Team, Steelcase Inc.

A number of manufacturers are taking proactive steps to be part of the solution to improve their products and raise awareness about embodied carbon industrywide. The Carbon Action Network is a collaboration of global building industry stakeholders that are addressing the smart prioritization of embodied carbon in building materials. They have committed to improving embodied carbon awareness through multiple industry channels; supporting the development of methodologies that facilitate analysis and the prioritization of carbon reduction goals in specifications; and highlighting case studies of interiors that have successfully reduced carbon impacts. Their materialsCAN.org website includes a collection of resources and links to tools, such as the Carbon Leadership Forum's

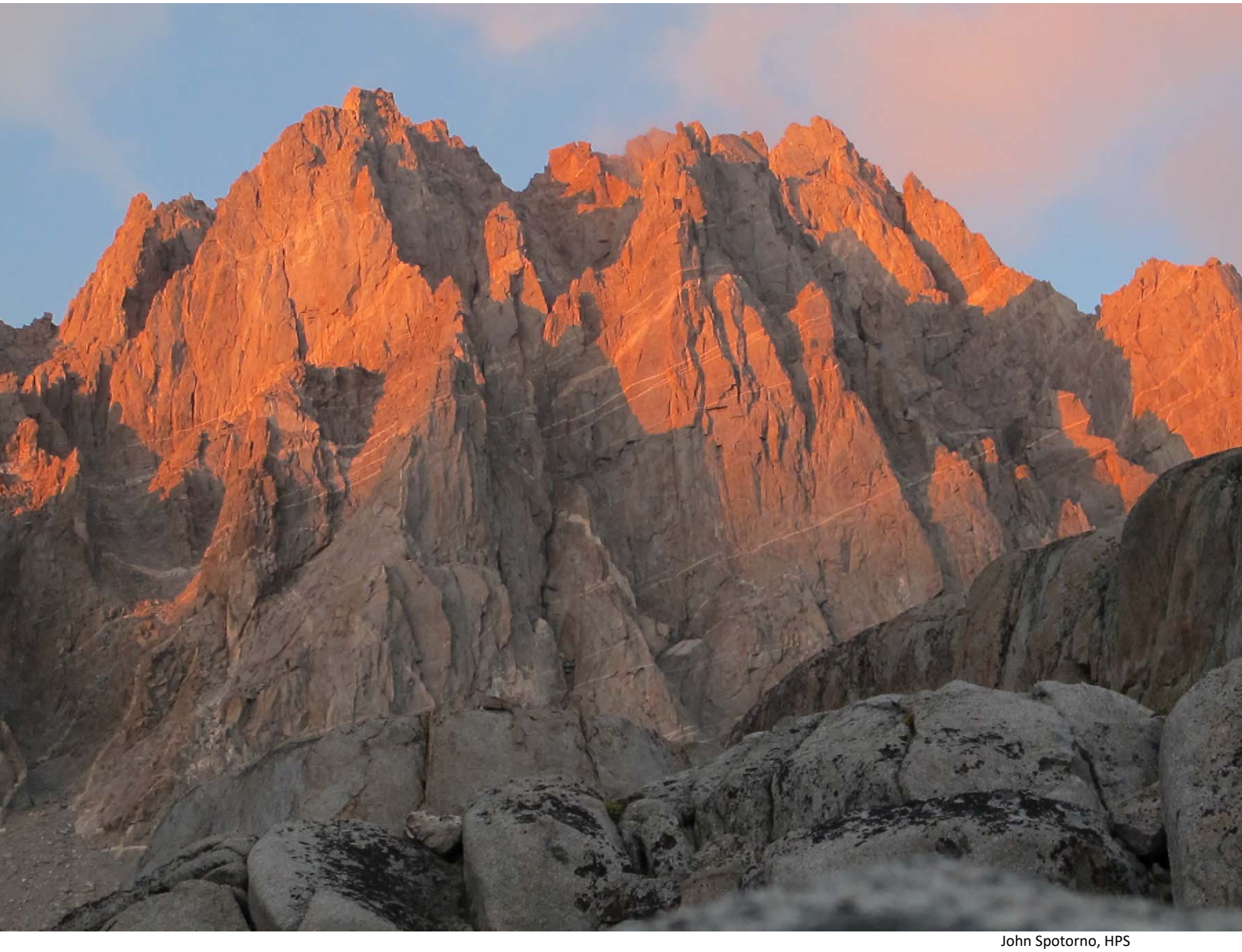
Embodied Carbon in Construction Calculator (EC3), which is the product of another collaborative organization linking industry and academia in the effort to find solutions.

A number of manufacturers are also leading the way by making recycling and other waste diversion strategies more accessible to the construction industry by providing such programs as take back collection systems. Some of the programs accept product from any manufacturer, not just their own.

> *"Armstrong Ceilings has had a recycling program for the past 20 years. It is designed to recycle acoustical ceilings from renovation projects and return (them) to our closest plant."*
>
> Anita L. Snader, Environmental Sustainability Manager at Armstrong Ceilings and Wall Solutions

> *"All of Dunn-Edwards retail store locations in California are Paint Care Collection Centers, where anyone may bring their leftover paint (of any brand) for responsible end-of-life management."*
>
> Robert Wendoll, Director of Environmental Affairs, Dunn-Edwards Corporation

It is efforts like these that move the industry forward and closer to a circular economy and closed loop system versus landfill.



John Spotorno, HPS

CHALLENGES

Incorporating LCA design criterion into the interior design process presents a number of challenges. Through the course of this research and the interviews with multidisciplinary stakeholders in particular, several barriers to the seamless incorporation of LCA as a design criteria were revealed.

Inaction

The cost of inaction on life cycle assessment and carbon in particular is not immediately self-evident. There is no visible sign of the damage done, nor cost or liability implications. It is not a mandatory requirement of design or construction practice. Because of this, there is little incentive to incorporate LCA considerations into the process.

> *"…the last challenge that we're seeing is just adoption. This isn't an impact that has a direct financial implication for projects. It's not like an energy model. If you do things a little bit differently, you can save thousands of dollars a year every year. This is something where the impacts are insidious. They're unseen and there's no government tax on the impact that your building's having on others from an embodied impact perspective."*
>
> Roderick Bates, Principal, KieranTimberlake

Complexity

One of the largest barriers to making an accessible LCA design tool is the complexity of the underlying data that must be reconciled and presented in a timely and user-friendly format.

> *"LCA is a great tool for tracking from a manufacturing process perspective. I think that the biggest challenge is that it is complex. It's math. How do we make it really easy for designers?"*
>
> Kirsten Ritchie, Principal, Gensler

If the results of a life cycle analysis are indecipherable to an average design professional or difficult to access or interpret, the uptake will be very limited.

Limited Database

Expanding the products covered by LCA or carbon assessment tools is underway, but there is not always a simple path forward.

For companies that make numerous products and/or a highly variable product line, going through the process of collecting the data and pursuing an EPD for each of them may be time and cost prohibitive.

In addition, not all product categories have defined Product Category Rules (PCR) and that is a limitation. Without an applicable PCR for their product category, even the most well intentioned manufacturer cannot have an EPD for their product(s) because the common rules on which to base an EPD for their product type do not exist yet.

Data Consistency

When there is an applicable PCR in place, there are still a variety of options that need to be sorted out before an EPD can be created for a product, including the base assumptions used for the EPD.

A clean database is essential for software that supports comparisons between not only products but product types used for the same purpose. Tally has been built using EPDs created by GaBi software to ensure a common set of assumptions and standards. While this improves the consistency of the data and therefore the reliability of the outcomes, it does represent a key limitation to the growth of the database. Because not all EPDs are created equally, not all can be incorporated into a single database without compromising the usefulness of the results.

> *"Interface's LCAs are reported through EPDs. For carpet industry LCAs, 60 years is too long. EPD version 1 product category rules (PCR) provide guidelines. As more data becomes available, those PCRs are updated. We know EPDs expire in 5 years. So when ours was acquired we were already on PCR version 3. This is what makes EPDs not comparable. In that different version of the PCR, there were different assumptions for the life cycle of carpet. Some people had data on 5, 10, 15 years. The life cycle estimation would at least be called out in the EPD."*
>
> Lisa Conway, Vice President, Sustainability – Americas, Interface

The baseline assumptions, including PCR, impact units, and life cycle estimation, must align in order to make a meaningful comparison.

Model Integrity

LCA software such as Tally incorporate life cycle analysis into the design flow by extracting material type and quantity data from the design's BIM model. This works relatively well for shell and core components such as the structural frame and envelop materials, which are usually established relatively early. However, it is more challenging for interior components.

Some interior finishes are not typically modeled, especially not during the early stages of design when the design is more in flux, but when carbon impact information would be most useful in the decision making process. In other cases, the modeling software does not export the environmental property information needed by the third party LCA software. Casework, itself a highly variable component, is an example of this export problem.

> *"One of the challenges for incorporating interior finishes and furniture into an LCA overall probably has some degree to do with when certain components are modeled. Typically interior things are coming in quite late and as a result a lot of the big decisions that really are driving impacts one way or another have already occurred."*
>
> Roderick Bates, Principal, KieranTimberlake

Other factors related to model integrity have to do with the quality of the modeling itself. Early design modeling is often less precise than the final model as the design continues to evolve and shift. In addition, the speed with which models can take shape is both an advantage and risk.

> *"We are not paying close enough attention because it looks deceptively complete."*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

Cost

From a soft cost perspective, the added research and changes to standard practice associated with incorporating embodied carbon analysis into the interior design process can have real cost implications for designers, their clients, manufacturers, and software developers, at least for those who are early adopters.

> *"Designers want to do the right thing, but for reasons of time, fee, or lack of resources or knowledge, are not always able to bridge the gap to sustainable solutions. When fee doesn't support the amount of research needed, people often resort to specifying a product they've used before. Or a decision may be made based on appearance only, pricing, or availability, without balancing all the other factors."*
>
> Denise Tom-Sera, Senior Interior Designer, Associate, Hawley Peterson Snyder Architects

When designers incorporate the research on and consideration of additional criteria into their workflow, their overhead or fees need to reflect that effort. Manufacturers will need to both pursue product EPDs for inclusion in the LCA process and use them to optimize their products going forward. Software designers will need to grow their capacity and robustness to ensure adoption.

As the emerging tools, strategies, knowledge base, and policies continue to evolve and become more mainstream, the financial impacts should be less noticeable or at least be common for all stakeholders.

Quality

There is a persistent perception that other measures of quality and success – aesthetics, cost, and schedule – must suffer for projects focused on optimizing environmental performance, whether it is energy efficiency, indoor environmental health factors, embodied carbon values, or other measures. This is not a given, especially when intangible benefits such as occupant health and productivity are considered.

"I think even more challenging is getting [people] to understand that reducing environmental costs in a lot of cases has zero cost implications, zero aesthetic implications, and zero traditional performance implications. All it does is produce a better building from an environmental impact perspective. For a lot of people, that's hard for them to wrap their minds around – it's that easy to do. I think they all assume that to be true, they would have to wear a hair shirt and suffer to achieve a better building based on LCA. I think convincing them to the contrary has been one of our biggest challenges."

Roderick Bates, Principal, KieranTimberlake

Time

To make informed choices, research is required. This front loads the design process in a way that is contrary to the current push to shorten a project timeline by whatever means possible. However, to optimize material selection outcomes, time must be spent on assessing and evaluating the options.

Furniture

Assessing the impact of furniture selection can be especially challenging. It is often made of numerous components, involves a variety of materials, comes in nearly endless variety, and can have a significant impact on the carbon footprint of a project.

Furthermore, for various reasons, furniture is not always modeled in detail in a BIM model. There is also no average LCA or EPD data for a piece of furniture against which to compare a selection.

"Furniture is challenging because there isn't a generic furniture figure – you cannot ask for a generic desk for example."

Roderick Bates, Principal, KieranTimberlake

The expense of having an EPD done for every piece of furniture in a manufacturer's line becomes a barrier as well.

Reality of Practice

The interior design decision making process is at times drawn out and at others fast paced. It is nearly always multi-variable and highly susceptible to change due to cost, availability, stakeholder input, and other factors.

From a carbon impact perspective, in new construction attention is usually focused on materials that represent larger quantities and/or higher impacts, such as the structural system and envelop materials. These are systems that are calculated to last 60 years or more. For interior design projects, especially those done in an existing building, that equation is a bit different. The high quantity materials are generally wallboard, flooring, and ceilings. The life span of interior finishes and furniture varies depending on the material and traffic and rarely has a life span equal to that of

the base building components. This is a fact that must be accounted for in an LCA. As many interior designers point out, “Interior finishes often ugly out before they wear out.” In other words, they are frequently replaced before the end of their useful life.

Numerous materials are likely to be present in smaller quantities and are currently less likely to be present in the LCA databases even though they may be especially carbon intensive to manufacture.

For interior designers working for clients who are not focused on the issue of carbon, the fluid and often competing considerations that exist for any project leave little room for additional selection criteria.

Incorporating LCA/Carbon Knowledge into Practice

Change can be difficult, especially when it relates to successful skills and techniques that have been developed over the course of a person’s education and career. Design professionals like anyone else, find an approach and build work habits that lead to success. When attention to an existential threat and opportunity to make a difference require change, it can be hard – even for interior designers who are pioneering the consideration of embodied carbon impacts in their work.

> *“That is the hardest part. We have the research and knowledge, but putting that into daily practice is the most difficult thing. Even now I don’t have it totally figured out from the one case study we presented at Greenbuild… I started thinking in that way about whole building LCA and accounting for future renovations. It is definitely something we should start looking at. We need to be able to understand what the highest embodied carbon impact would be in every renovation and understand what that means when making design decisions.”*
>
> Jenn Chen, Associate Interior Designer, LMN

Suddenly there are new criteria and steps to be taken and considered. Familiar processes have to change to accommodate this, all while tools, schedules, policies, codes, and fee structures are still evolving to catch up to this practice.

Leadership

An organizations direction and priorities are set by its leadership. While individual champions have played pioneering roles in the green building movement within organizations and more broadly, the power of leadership to influence the direction and focus of company and inspire real progress cannot be underestimated. It is key to sustained and meaningful advancement. Its absence can be a barrier to progress.

Education

The scientific nature of the core LCA methodology makes it difficult and unwieldly to learn and use in its rawest form. This problem is exacerbated by the limited amount of fundamental education dedicated to the environmental impacts of material choices in most design education programs.

> *"…the hardest part is the software itself. We use GaBi software. We went through training. We had a two day workshop here and were able to train some, but if you don't use it all the time it is hard to remember. It really is ripe for improvement to bring it into today's world of software tools. It has lived in the science world for many years that is how it was designed. Now it needs to evolve to be more user friendly."*
>
> Anita L. Snader, Environmental Sustainability Manager at Armstrong Ceilings and Wall Solutions

Policy

Policies and building codes changes are powerful components of change. They level the playing field and expand the market uptake by requiring the same base standard of care from all stakeholders. They are particularly important when the purpose of the policy is for the greater good, even if the implementation of the policy requires additional effort, a change in practice, or inconvenience.

However implementing new policy or code is a course that requires perseverance and patience. To assure a thoughtful, considered process, many steps may be required and forward progress can take years.

In California, cities willing to set higher environmental or efficiency standards for construction than the minimum standards described in the code, must file findings showing that the economic impact is within certain bounds and that specific products or proprietary tools are not required in order to meet the proposed new standards. Even in the City of San Francisco, one of the most active cities moving to counter climate change in the world, new policy can only be enacted within the given framework which requires a balance between environmental, economic, and social factors.

John Spotorno, HPS

STRATEGIES and SOLUTIONS

In June 2019 at the American Institute of Architects (AIA) national conference, architects from around the world gathered at the annual business meeting to set the direction for the organization's future. In an historic note, over 93% of the 5,200 delegates present voted in favor of *Resolution 19-11: Resolution for Urgent and Sustained Climate Action*, which called on the AIA to prioritize and support urgent climate action to exponentially accelerate the "decarbonization" of buildings, the building sector, and the built environment. The resolution called for three actions:

- Declare an urgent climate imperative for carbon reduction
- Transform the day-to-day practice of architects to achieve a zero-carbon, equitable, resilient and healthy built environment
- Leverage support of our peers, clients, policy makers, and the public at large.

This marked a significant shift in focus for the 162 year-old association and underscored the importance of incorporating life cycle assessment strategies in the design process for both buildings and interiors. The findings outlined below can contribute to carbon reduction and help transition practice in support of these goals.

> *"Human beings don't have a pollution problem; they have a design problem. If humans were to devise products, tools, furniture, homes, factories, and cities more intelligently from the start, they wouldn't even need to think in terms of waste, or contamination, or scarcity. Good design would allow for abundance, endless reuse, and pleasure."*
>
> The Upcycle: Beyond Sustainability – Designing for Abundance, by Michael Braungart and William McDonough

While there are many exciting developments and emerging tools that have the potential to support life cycle analysis for interior design and thus the reduction of embodied carbon in the built environment in a robust way in the future, a clear path to widespread adoption and solutions for all of the challenges outlined in the preceding section do not exist yet. However, a number of actionable, positive steps did emerge during the course of this research that are outlined in this section of the report. They can be thought of as "bridging strategies"; steps that can be taken immediately to bridge the gap between the growing knowledge base related to embodied carbon in the built environment and the evolution of interior design strategies and practice to incorporate reduction goals.

Durability vs. Low-Carbon solutions

Because interior finishes often "ugly-out before wearing out", consider prioritizing low-carbon solutions over durability. While durability is a positive attribute, it may come at an environmental price. The impact of commercial interiors can be amplified by the short cycle between renovation

and replacement that often takes place, a phenomenon which may increase the need to find solutions that support easy reuse or repurposing and may reduce the imperative for durability.

> *"…the focus for interior designers is not to choose more durable materials… The materials are typically replaced because people want something new. So figuring out a modular design that can be pulled up and put somewhere else is a better goal. Design it so that the material can be repurposed or choose manufacturers that have good take back programs where they take the material back and repurpose it."*
>
> Larry Strain, Principal, Siegel & Strain Architects

Market Uptake

Ask for Environmental Product Declarations and other third party verifications for the products being considered for a project. This is a simple yet powerful step to take.

The manufacturing industry is attuned to the marketplace and by extension what customers are asking for. By requiring or at least requesting GWP and other environmental data from manufacturers, the design community is signaling its growing importance in the material selection process. It was this strategy, spurred on by early versions of USGBC's LEED Rating System, that helped establish the Forest Stewardship Council (FSC) and their third party certification of wood based products as an international standard.

Even if manufacturers do not have an EPD or any other form of third party verification, if enough designers ask for them, manufacturers will understand that they need to pursue EPDs to remain viable in the marketplace.

Reward Early Adopters

A number of manufacturers are already leading the effort to assess and optimize their products. Reward those who are by selecting their products whenever possible.

> *"A number of firms signed a letter to manufacturers saying, "We want you to start supplying material transparency labels" [and some did]. Then after a while the manufacturers said, "Hey, we responded to your request, but we are not making it into your projects. It is hard for us to go to our leadership and ask them to budget for us getting transparency labels.""*
>
> Jenn Chen, Associate Interior Designer, LMN

Early adopters take on the challenges and expenses associated with product analysis and complying with the requirements of third party transparency labels such as an EPD, Cradle to Cradle certification, or the Carpet and Rug Institute's Green Label Plus program. Sometimes the genesis for their actions is driven by company culture or an otherwise strong leadership position on environmental issues. In other cases, there is a champion or an in-house green team that helps promote this level of transparency. In any case, designers, primarily through selection and specification, are in a powerful position to reinforce and encourage this goal.

Join or Convene a Group with a Focus

Dive deeper into a particular topic and explore best practices by joining or convening a group of professionals with the same passion.

The Healthy Materials Collaborative in Seattle did just that in 2017 by convening materials librarians from a number of area firms for a Librarian Summit. Together they were able to learn more about the issues, brainstorm and develop relevant strategies, create a unified voice for change, and develop a strong network of like-minded professionals.

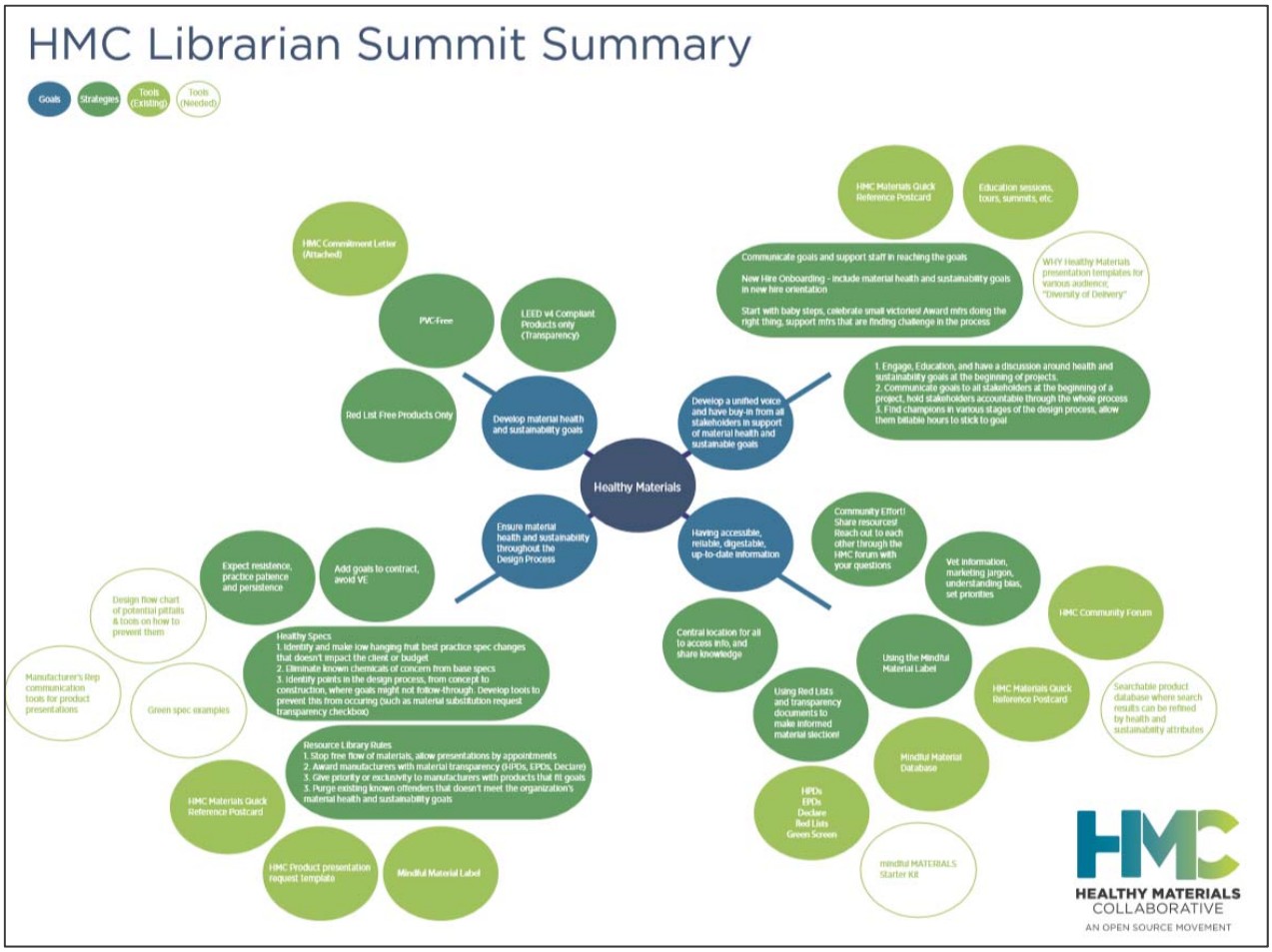


Figure 10. Healthy Materials Collaborative – Librarian Summit Summary, Jenn Chen, LMN

The resulting networks of passionate professionals can be an especially powerful resource and force for good.

Material Libraries

Use the firm's market leverage to encourage best practices, inform the material selection process, and streamline the documentation requirements for third party certifications.

"…our materials library requires all manufacturer representatives that want to come in to have some sort of transparency label and be found in MindfulMATERIALS. We also have a non-PVC policy in our office. So anytime a manufacturer reaches out to come in and do a tabletop, we would send them an information request for HPDs or EPDs or Declare and they have to say, "Yes, you can find our transparency label in Mindful MATERIALS," and "Yes, we will not be bringing any PVC products" before they can come into the office."

Jenn Chen, Associate Interior Designer, LMN

This ensures that materials in the library will contribute to certification goals, streamlines the necessary research, and puts LCA into practice.

Material Selection Process

Analyze the material options being considered from the outset.

"It is sustainability in design to promote health and wellness. So we place that equation right up front and hopefully that will follow all the way through."

Kim Pham, Space Planner, Interior Designer, Maxim Integrated

This may require training, but by incorporating ongoing analysis of the GWP and other environmental factors into the early selection process it can become routine and eventually part of the company's culture.

"For example, for our materials and health group we have a spreadsheet that's basically tracking typical materials that are in our specs, alternate materials that would be better for the environment, and things that have better material ingredients… we might start doing that for the embodied carbon."

Jenn Chen, Associate Interior Designer, LMN

As time goes on, designers will develop a better overall understanding about where the challenges and opportunities lie. This will help them know where to focus their efforts.

"Carpet is a high impact material, way higher than concrete - four to five times the impact of concrete per pound. Interface is taking global warming seriously and working on carbon sequestering carpet. They are great and have been doing great work forever."

Larry Strain, Principal, Siegel & Strain Architects

Materials will emerge that are great performers on most if not all fronts. They may become part of a "go-to" set of materials that is part of a baseline palette of materials used to kick of a project. This can be especially helpful for materials that have little or no effect on aesthetic aspects of a project, such as the wall board selection or particular brand of paint. Most any manufacturer would like to have their products on that list.

Optimizing Product Development

Include environmental goals in the product development process from the outset and work with suppliers to ensure optimal results.

> *"It really starts with product development (early in the process). There are three main pillars: Embodied carbon (footprint), Circular economy (can it be recycled, end of life options for materials), Green Chemistry (using materials safe for people and planet). It's a balancing act, the lens we assess through."*
>
> Lisa Conway, Vice President, Sustainability – Americas, Interface

Like interior design, product development is driven by a diverse array of criteria that can sometimes be conflicting. To elevate a product all of the criteria must be considered from the beginning.

> *"We have been doing LCA for a while. We have an LCA expert on staff internally (working as part of the product development and assessment process)… From a business and production perspective; the critical thing is supply chain reliability. How fast can we get it, how much material is available, and can we deliver our business needs with this material?"*
>
> Lisa Conway, Vice President, Sustainability – Americas, Interface

Including LCA criteria in the supply chain assessment will allow manufacturers the opportunity to improve the overall LCA results of their products. By asking for and prioritizing supply chain contributions to an LCA, manufacturers are signaling the growing importance of these criteria in their decision making and source selection process.

Transparency Labels

Start tracking transparency labels and environmental performance early in a project.

This avoids the risk of locking onto a particular material that is a poor performer, resulting in the need to either backtrack or let it remain in spite of project goals to the contrary.

> *"For all LEED projects we have a certain amount of transparency labels that we must get. Most of our projects are going for some sort of certification, and we have built in the process of looking for EPDs and HPDs early in the design process to make sure we are able to get the points."*
>
> Jenn Chen, Associate Interior Designer, LMN

Requiring documentation that certain standards have been met is one of the ways that the U.S. Green Building Council has so successfully helped raise awareness and create a dramatic market shift. By asking manufacturers for transparency labels, designers are contributing to the positive shift in the market.

Prioritizing High Impact Materials

Assess the relative quantity of high impact design components and start by optimizing those materials.

The Carbon Leadership Forum (CLF), a collaboration of industry and academic leaders, hosted at University of Washington, has been doing research on embodied carbon in building materials for about a decade. A 2019 report on the carbon impact of tenant improvements projects in commercial buildings in the northwest revealed a number of high impact components and the significant difference reuse and recycling can make.

> *"The results identified high-impact TI components as: office furniture (offices, cubicles, chairs, tables), ceiling panel suspension systems, carpet, doors, glazing, and acoustical panels. These findings suggest that the environmental impacts of TI can be mitigated by re-using or recycling these high-impact and sometimes high-quantity components."*
>
> Life Cycle Assessment of Tenant Improvement in Commercial Office Buildings, CLF, April 2019.

Designers can prioritize their efforts and minimize time spent on research if time or fees are an issue by focusing on the high impact components.

Picking the Best Option

Implement best practices based on the best data that can be found (paying careful attention to the source), as well as the tools and time that are available.

If the databases that support the LCA tools have not caught up to the product categories under consideration, review the data that is available and compare the top two to three contenders that best meet other project criteria.

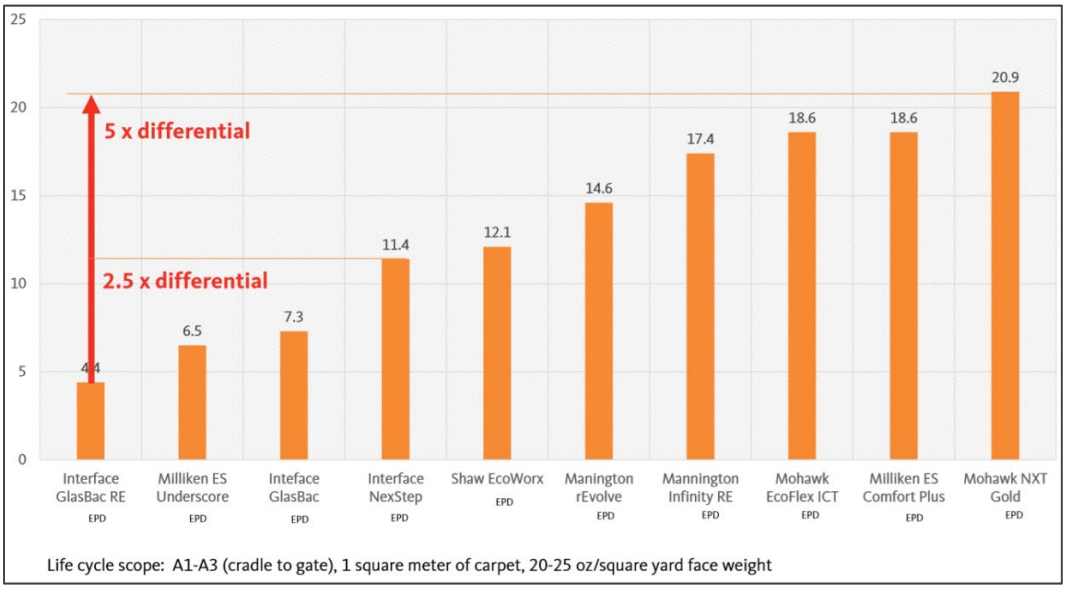


Figure 11. Global Warming Potential of US Carpet Tile, Select Examples (kg CO2e/m2), courtesy Kirsten Ritchie, Gensler

The carpet tile table shows a comparison of the Global Warming Potential (GWP) for some of the top carpet tile options with verified sustainability attributes. Even within this curated selection there is a fivefold difference between the best GWP option and the worst. Although this is only one of many environmental measures that can be measured and compared, it is considered the category with the most reliable data. What should be noted in this example is that it does not include all of the "better" carpet options, nor does it represent the full range of results for carpet tiles. There are options for which the results would be off the chart.

> *"…it's still an evolving science. It is part art and part science to actually get it implemented. We need to provide things like that carpet chart that give designers a way to quantify the carbon footprint or you're not going to get where you need to go. The action that they should be taking is identifying and specifying the lower carbon products. We can back into what they've done by backing into the analysis of how much carbon was produced. That's second to actually getting the products specified and procured that have the lower footprint."*
>
> Kirsten Ritchie, Principal, Gensler

While doing the carbon accounting for projects is an important way of increasing understanding for future projects, doing so *during* design can ensure more informed decision making for a project and thus lead to better outcomes right away.

Speaking to Clients

Integrate product attribute information into client presentations during the material and furniture selection phases to inform the decision making process.

> *"Having quick, easy-to-use LCA tools… would help not only with product selections, but also with educating the client about the best solutions. Having a clear tool with environmental comparisons, pricing, and availability could be a helpful conversation-starter when working with organizations that have established standards with lower sustainability levels."*
>
> Denise Tom-Sera, Senior Interior Designer, Associate, Hawley Peterson Snyder Architects

Decision making for most clients involves balancing a complex mix of programmatic needs with budget, schedule, and other, often competing factors. Introducing additional, environmental factors into the mix for clients who do not already prioritize them is often not welcome. Clear, concise, reliable data that could help make the case for better choices, especially when there are no cost or schedule impacts, would help make the case.

Carbon Sequestration

Manufacturers can explore creating manmade carbon sinks to improve the carbon equation.

> *"There are a few folks, such as Blue Planet LTD and CarbonCure Technologies Inc, that are trying different processes for reducing the embodied carbon of concrete through means other than fly ash and we need to find better opportunities, but then sometimes the best concrete is a different material altogether."*
>
> Eden Brukman, Senior Green Building Coordinator at San Francisco Department of the Environment

This goal requires innovative thinking and a deep knowledge of every aspect of a product. Finding a carbon sequestration solution for a product is a worthy goal and would certainly draw the attention of the design community.

Waste Diversion

Prioritize waste diversion thorough all aspects of product development, construction documents, and policy.

In 2018, San Francisco led the drafting of a commitment with C40 for the Global Climate Action Summit called *Advancing Towards Zero Waste Declaration*. About two dozen other cities signed on. Its goal is to reduce consumption by 15% and disposal to landfill or incineration by 50% by 2030.

The focus cannot only be about optimizing the manufacturing of new products. Part of the approach is to generate less stuff, or just buy less. That is why reuse can play such a big role in embodied carbon reduction. It takes the place of virgin material in the supply chain. How long something can stay in circulation is also part of the equation. Once carbon is spent, it is in the atmosphere.

There are businesses are championing this concept and doing well. Patagonia's Worn Wear program is a good example of that. GCI General Contractors created a spin off named Madrone that inventories no longer needed products in existing building projects and looks for new homes for them. They have created a network of several hundred nonprofits and education organizations, and instead of taking materials to the landfill, they deliver them to places where they can be used again.

> *"We are exploring ways to change upstream practices to make material reuse more viable. How do we create new markets? How do we get rid of some of the roadblocks? How do we get people to even have their first thought be about reuse and assuage any fears of a legal liability tied to reuse? There is a lot to deal with, but to me that is the biggest thing we can do – use what we have."*
>
> Eden Brukman, Senior Green Building Coordinator at San Francisco Department of the Environment

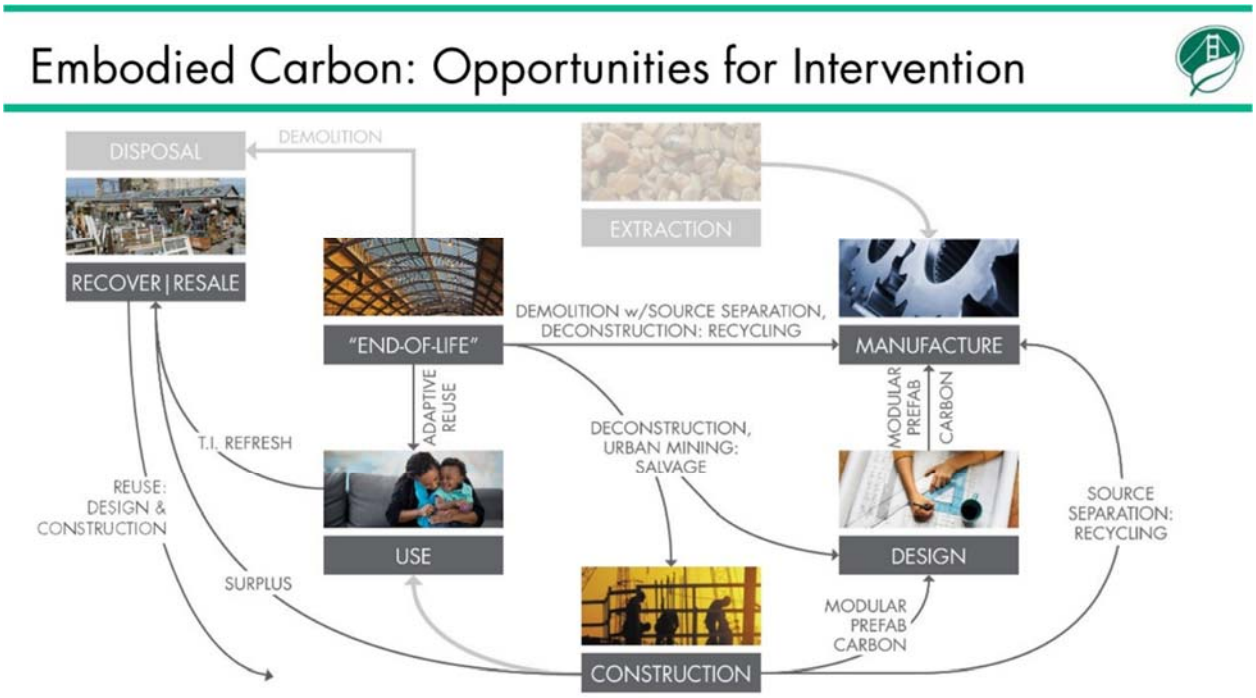


Figure 12. Options for reuse and urban mining relative to traditional lifecycle phases, courtesy Eden Brukman, San Francisco Department of the Environment

The strategies for minimizing landfill include: Designing for reuse by considered material selection and detailing, mandating best practices in construction documents, and identifying and utilizing takeback programs.

Right Sizing the Approach

On bigger projects with longer timelines and larger budgets, where the impact of material selections can be much more significant than it would be on a smaller project, whole building LCA is an important carbon reduction strategy. Projects like San Francisco Airport's (SFO) 770,000sf Terminal 1 project, which opened in 2019, not only reduced the project carbon footprint by double digits (19%), it can also serve as test a case for projects of more modest scope; creating a positive ripple effect for the industry.

> *"I'm advocating for whole project LCA. Start with a narrative. Start with how are we asking the question? How are we going to understand a little bit more about embodied carbon impacts? Where should we be based on the scope of our project? What should we explore? Do we want to do a whole project LCA?"*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

On smaller tenant improvement projects, consisting mainly of paint, wallboard, and carpet, at least ask for and compare product EPDs for the primary components of the project and choose the better option.

Project Kickoff

Convene the entire interdisciplinary team, including the owner and construction team to review environmental priorities and criteria in the project description and scope from the outset. Set targets and define measures of success.

There are often important opportunities for early interdisciplinary solutions. For instance, energy demand and mechanical system size can often be reduced by early attention to external shading and/or internal shades. This also supports access to natural light and glare mitigation for improved occupant comfort and health outcomes. The optimal window for identifying and incorporating these kinds of multi-faceted solutions is at the beginning of the project with input from the whole team.

> *"As a designer, I think the way to approach this is to think of it like how we do energy analysis at the beginning of each project by identifying energy saving opportunities, doing sun studies for the building envelope, etc. We should do the same thing for the interiors of the building. We should do the same life cycles analysis for the materials because that is where all the decisions are going to be driven… All of this needs to happen at the beginning during research because that would help us make the right decisions… It's not just about the function or the finishes of the furniture (aesthetics), there is also a bigger picture than that."*
>
> Kim Pham, Space Planner, Interior Designer, Maxim Integrated

Review the goals and related strategies with the full, interdisciplinary team during the project kickoff meeting and check back in with the team regularly to ensure progress towards achieving those goals.

Specifications

Build a strong set of specifications that include key performance indicators such as limits on global warming potential, volatile organic compounds, and PVC, as well as requiring third party certified products like FSC (Forest Stewardship Council) certification for wood based products, and products with EPD, HPD, Declare labels and or other recognized distinctions. Firmly set baseline requirements, especially relative to potential substitution requests, to communicate product performance criteria.

Specifications are a powerful and important component of contract documents and provide leverage during construction when other factors may threaten to compromise the procurement process and the environmental goals of a project. This also supports market change.

> *"…We can set up our standard specifications to prioritize low carbon products and make it easier for [manufacturers of low carbon products] to just then move to market."*
>
> Kirsten Ritchie, Principal, Gensler

Use lessons learned from project to project to improve base and standard specifications.

Submittal Reviews

Pay careful attention during submittal review to make sure that the environmental compliance targets are being met as required by the construction documents; in particular as called for in the specifications.

Not all submittals are created equally and not all construction partners are knowledgeable about the requirements associated with a project that has a deep green focus on LCA, carbon reduction, LEED, WELL, or other similar goals. It can be helpful to provide training at the beginning of a project for the project engineers or others assigned to processing submittals and/or creating certification documentation in order to help the process flow more smoothly and assure an outcome in line with the project goals.

Leadership

Validation of the importance of environmental goals, including life cycle analysis and carbon accounting, from firm leadership is critical to the wide spread adoption of best practices, especially before regulatory requirements have been created to support broad, mandatory attention to and action on the topic.

Champions

Discover your passion and be the champion for it.

Through personal focus and agility relative to best practices, an individual can lead the way in a firm or volunteer organization. While a group can have a strong impact on a particular outcome through advocacy or other means, the power of a champion should not be underestimated.

Interior Designers

To address bandwidth issues related to time and fees in this early adoption phase of LCA, follow a material selection strategy that begins by investigating the environmental implications of high impact, large volume products; ask for and look to manufacturers to provide the required data.

> *"There are certain material types that there will be a lot of. Some things we know probably have bigger carbon footprints associated with them than others. So we have to focus on the higher impact items first. It is interesting because in some cases those are things that [interior designers] don't really care about, like what brand of wallboard is used… you can use that rule of thumb and say as a designer we should really be focusing on those things we buy a lot of and we should find out the footprint."*
>
> Kirsten Ritchie, Principal, Gensler

Prioritize material research targets, build on expertise from project to project, and most importantly take the first step.

Manufacturers

Be diligent about providing the best data possible and do so in a format that will support LCA tools and designers as transparently as possible. Use the results of third party assessments to further optimize the supply chain and products through development.

Manufacturers play a vital role in the accuracy and usefulness of life cycle analysis. The information they provide about the makeup of their products forms the foundation of the results. Products with high quality, readily available data will make the selection process easier for interior designers.

> *"A big opportunity for LCA is getting real data from the suppliers. The less specific the data is, the higher the carbon footprint will appear. This drives a goal to work with suppliers to know where their carbon emissions come from based on their specific way of creating and selling material vs. having to use industry average data. That is the biggest opportunity to get more exact data."*
>
> Lisa Conway, Vice President, Sustainability – Americas, Interface

Manufacturers that prioritize product transparency and optimization will become trusted resources for the interior design community.

Advocacy

Make your voice heard. Individual advocacy and organizing a larger movement to get the interior design community and others to recognize the significant impacts of interior design decisions over time and what needs to be done can lead to important advancements. It can change standard practice, policies, and codes.

> *"It's powerful to write letters individually, but even more powerful if you can get a group that represents a lot of people."*
>
> Larry Strain, Principal, Siegel & Strain Architects

Policy makers and politicians, like the manufacturing industry, react to input from stakeholders and constituents. At the end of 2019, as "Reach Codes" (requiring stricter energy performance and carbon standards than the new building code) were being considered by a number of jurisdictions in California. A grassroots effort loosely supported by not-for-profit organizations and an ad hoc group of individuals began tracking adoption trends. They also began writing to decision makers – city council members, planning officials, and others – and more importantly, showing up for meetings to advocate for the stronger standards and it made a difference.

Whether by individual effort or with the support of a group, engagement in the process is a key to change and progress.

Existing vs. New Construction

Whenever possible, opt for existing over new construction. The embodied carbon of an existing building has already been "spent". By choosing to upgrade an existing building, a large quantity of embodied carbon associated with a project will be avoided. The focus of the carbon reduction measures can then be on interior material selections and energy related upgrades.

> *"If you can take operational carbon emissions [in existing buildings] and reduce it to half or 100% that will have a huge carbon impact… The focus must be on retrofitting and energy upgrades we are currently doing this with about 1.5% of our existing buildings every year. If we could get that up to 5-10% a year it would have a huge impact on emissions. That feels like a shift in not just the architectural profession, but also for the developers, owners, and city policy. We need policies that would encourage that or would reward that. It is not going to happen if you just let the market do it. You need to up the numbers of retrofits and if possible, build fewer buildings because you are retrofitting older buildings and making use of them longer and avoiding the impact of new construction."*
>
> Larry Strain, Principal, Siegel & Strain Architects

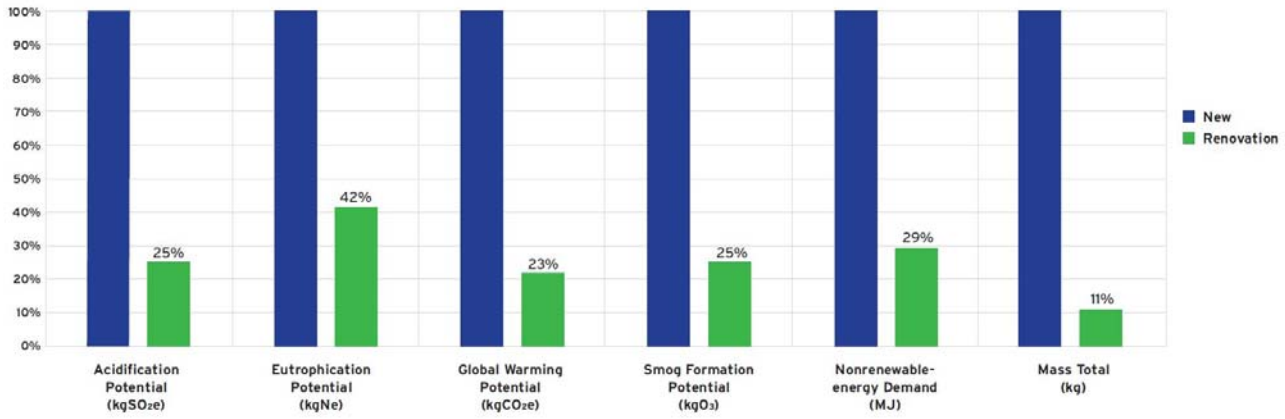


Figure 13. LCA Comparing new construction and renovation, Courtesy KieranTimberlake

While new construction and existing building retrofits should both increase energy efficiency and reduce embodied carbon impacts, the following can be thought of as a good rule of thumb:

> *"For existing buildings implement serious energy upgrades and for new buildings serious embodied carbon reduction on materials."*
>
> Larry Strain, Principal, Siegel & Strain Architects

Reuse | Repurposing | Recycling

Incorporate reused or repurposed products in design wherever feasible. When that is not possible, take care to make sure that any product waste is minimized and diverted from landfill through a robust recycling programs, guidelines, and construction documents.

"…we were really interested in how we can use reused or salvaged materials …where we can source the quantities that we need, [consider] how we work through that stream, not always look for something that's readily available off the market, and maybe look at innovative ways to use materials."

Jenn Chen, Associate Interior Designer, LMN

Where state code or local law do not already mandate it (and even if they do), include robust waste diversion requirements in the construction documents that insure that product takeback programs are utilized and diversion strategies are optimized and verified during the whole demolition and construction process.

Designing for Reuse | Repurposing | Recycling

Consider the downstream impacts of all components in a design and specify or detail them accordingly.

Composite materials can be particularly difficult to recycle or repurpose at the end of a products useful life. Products such as Steelcase's Think Chair, which can be deconstructed are particularly effective solutions, especially because they support repair of damaged components thereby extending the life of the product.

Figure 14. Think Chair Deconstructed, Steelcase

The same strategy can be applied to other components of interior design to optimize the end of life options.

> *"We are also looking into developing some details where we can disassemble assemblies in a way that does not hurt the integrity of the original material to maximize reusability. If everyone can think of one new way to practice, it would be easier for the whole market to change."*
>
> Jenn Chen, Associate Interior Designer, LMN

Beginning in 2015, the EU funded extensive research into Buildings as Material Banks (BAMB, https://www.bamb2020.eu/) to investigate reinventing the building industry by identifying circular building solutions that would result in waste reduction and reduced demand for virgin resources. Extensive research was focused on the concepts of a circular built environment, material passports, circular building assessment, and reversible building design. Sample policy and standards were developed and business models studied.

A Reversible Building Design Guidelines and Protocol was developed as part of the BAMB project to enable different stakeholders in the construction value chain to implement reversible design strategies and approaches in construction and refurbishing activities. Reversible building design outlines the potential for resource efficient repair, re-use, and recovery of building materials, products, and components by promoting a design strategy that prioritized criteria that supports access without impact on other parts. The protocol was published in 2018 outlining three targets of reversible building design that focus on the reversibility of space, structure, and materials.

Another key concept that was developed in the BAMB study is that of Material Passports. This system for electronic tagging aims to increase the future value of materials in a building, create incentives for suppliers, support material choices, make it easier to choose materials that support the circular building materials concept, and enable the logistics of material take back and reuse. The idea is that materials are "deposited" into a building and removed later when they no longer serve their initial purpose. Material Passports, like a chain of custody for FSC, track the material attributes, manufacturing history, and installation, then facilitate simple access to that information when needed.

Furniture

Even though developing comparable EPDs for furniture is made complex by the highly variable nature of the available products and because EPDs can be based on different PCRs (product category rules) and/or different calculation models, there are steps that can be taken now.

> *"We haven't been doing as much as we want on furniture, but I think if we can, we'll actually just look at comparing two different manufacturers. …but that's one of those areas that is emerging. If you don't have a way to get to a baseline, and it's early on in this world of understanding, just take the two you like the best and compare those."*
>
> Kirsten Ritchie, Principal, Gensler

Designers can identify the top contenders (identified based on other selection criteria) and simply compare the climate impacts for prioritized categories and pick the better option. This is a step that can be taken now and supported by a relatively simple spreadsheet.

Education

Expand on the educational offerings related to material selection for professionals, clients, and students to create a common knowledge base relative to material impacts, EPDs, LCA, available tools, and best practices. Foster collaborative efforts between students and design professionals to increase the understanding of the relationship between practice and sustainability as part of design course curriculum and community engagement projects.

Several of the experts interviewed for this project identified lack of education as a barrier to progress.

> *"Yes. I think it is important that designers have enough training and it actually should be addressed in school. It really is unfortunate that for the most part material lifecycle impacts are woefully underrepresented in interior design curriculum, as well as architecture. It's a big hole that needs to be fixed."*
>
> Kirsten Ritchie, Principal, Gensler

> *"Education is important and not just within the industry, but with public education, that is what happened with LEED and sustainability… There was a lot of promotion to the public and there was a level of demand… and people got educated about it… We need to break down complexity and use info graphic; like Annie Leonard's, "The Story of Stuff"… to break it down in a way that most of us can relate to. There needs to be more resources supporting how I can easily explain it to clients, how I can present it to the users so that it is not a bunch of numbers… It is about our health, our environment, and we are not presenting it in that way. That is the main barrier/limitation."*
>
> Morana Medved, Senior Tech Lead, Artik Art + Architecture and Lecturer, San Jose State University

> *"Education and getting people familiar with the language, [and comfortable with the process], is key. We should start with educating the next generation of designers coming out of school. I know when I was going to school, none of this was ever talked about. Sustainability, material health, and embodied carbon were not talked about as part of the integrated design process [when I was] a student. If people are familiar with the language, it feels more approachable."*
>
> Jenn Chen, Associate Interior Designer, LMN

Expanded educational opportunities can be created and provided by a number of entities, including academic degree programs, professional licensure programs, and professional organizations, product manufacturers, and software developers depending on the needs and goals of the target audience.

Case Studies

Case Studies that include explicit how-to information can play an important role in educating stakeholders not only about how to approach the topic, but also the potential results that can be achieved.

> *"Providing nice, clear cut examples of the possibilities, improvements made, and the differences that are possible when you start thinking about LCA in the course of designing interiors would go a long way… The simpler, the better."*
>
> Roderick Bates, Principal, KieranTimberlake

Case studies can be shared via articles, websites, or presentations at conferences, programs for local organizations, or in academic settings. Consider modifying case study presentations based on the audience and their primary motivations to maximize the effectiveness of the message.

Cost Benefit Studies

Calculating and sharing the cost benefits of projects through the lens of health and carbon reduction can be a powerful communication tool and help make the case for those interested in environmental and financial bottom lines.

> *"If you can make the business case for more sustainable decisions, it will make promoting the decisions much easier."*
>
> Dr. Joshua Kneifel, Research Economist, NIST

San Francisco Airport's recent Terminal 1 modernization project is a 770,000sf project designed to handle 17 million passengers per year, while improving the experience for employees and passengers, increasing retail and concessions revenue, and lowering energy and carbon emissions. The carbon reductions were 75% below the existing operation levels.

> *"This was our LCA work saying… we are reducing the carbon emissions about 20% just on the embodied materials. This does not include operating carbon, this is just embodied carbon. We are reducing the impact and generating health savings of almost $13 million."*
>
> Kirsten Ritchie, Principal, Gensler

To confirm the accomplishments of the project, a triple bottom line return on investment study was done. The financial life cycle assessment included: capital expenditure, operations and maintenance (excluding utilities), replacement costs, and residual value of assets, as well as the cost of electricity, gas, and water. The social and environmental considerations included: air pollution, carbon emissions, employee productivity, absenteeism, health costs, and passenger productivity. Each of these aspects of the project was evaluated relative to the following categories: Indoor water use reduction, low emitting materials, life cycle impact reduction, thermal comfort, and renewable energy production. The low emitting materials alone had a benefit cost ratio of 82.01 and the life cycle impact reduction ratio was a remarkable 127.17.

LCA Software

Include the ability to define and investigate the life cycle impacts of interior products, which generally have a shorter life cycle than the base building.

Current LCA software is primarily focused on the high impacts of the shell and core materials such as concrete, steel, aluminum, and glass for which a 60 year life span is assumed. As the number of interior products in LCA databases increases, the life span of those materials needs to be more easily accounted for and adjusted by the user who may wish to understand LCA impacts for interiors that are replaced on a much shorter cycle, sometimes as short as two years, for reasons other than durability.

Database searches that include one-click access to a product's EPD, streamlines the process and makes the data more accessible. Including other product specific data that will inform decision making would also be helpful.

> *"Products are warranted for an amount of time, so it would be nice to have the warranty listed. It also would be good if the software info included the adhesives and everything that is a part of the installation process. When they do fire testing for furniture, the whole assembly has to be put together, and then burned up to determine if the product is safe. It's the same sort of thing for LCA. If the incorrect adhesives are used with flooring, the "assembly" might not perform the way it should, and the life cycle will be shorter."*
>
> Karen Glaser, Senior Interior Designer, Associate, Hawley Peterson Snyder Architects

LCA Databases Output

As LCA databases continue to grow the desire for ever more concise and clear distillations of data becomes increasingly clear.

UL's *EPD Transparency Brief* lists the benefits of a streamlined output format as:

- Condenses the complex information presented within the many pages of an EPD into a concise, easy-to-understand, "nutrition label-like" document that takes up no more than one page front-and-back
- Acts as a "quick reference guide" to a product's EPD, enabling specifiers to readily access the EPD's most relevant information—thus saving time and effort
- Serves as a unique sales, marketing, and specification tool that—in a single page, front to back—discloses a product's most relevant environmental impacts while also showcasing a manufacturer's commitment to transparency

Access to Data

Collections of EPDs are available on line and include: Origin, mindfulMATERIALS, and UL SPOT. Tens of thousands of product EPDs can be found on these sites.

INSIDE/INSIDE, a non-profit, NGO, is proposing a new, European standard for comparing interior products based on health and environmental impacts. This single point scoring system for interior building materials has been developed by the Dutch Green Building Council (DGBC), NIBE and Ex Interiors with the support of multiple industry partners with the intent of providing a simple, impartial sustainability-comparison tool for interior materials.

Figure 15. INSIDE/INSIDE online platform user interface, INSIDE/INSIDE, Dutch Green Building Council

INSIDE/INSIDE uses a collection of product LCAs as the database and provides a simple, intuitive tool to access and present the data for easy comparison and consideration.

Policy Development

Create and support policies that address climate impact reductions. There are many improvements to climate impact that a designer or architect can strongly influence and others they cannot. Prioritizing the use of existing building upgrades over new construction is an example of the latter.

> *"[Reducing carbon] is a big undertaking, but all the technologies are there because we know how to retrofit buildings and implement energy efficiency in buildings, we have known that for years. However, we really don't have the mechanism or leverage to make it happen, we don't have the policies, codes, requirements or regulations that would make an owner upgrade their existing building. …We can't do this by architects just doing a better job. It has to happen at a much bigger scale. The needed codes and policies are happening in a few places. New York has got some aggressive new policies that require owners of buildings 100,000 sq. feet (or more) to report their energy use from now on and upgrade every 10 years (or less). Every time a building is turned over to a new owner, they must do some upgrades. They are trying to put upgrade requirements in wherever they can intervene."*
>
> Larry Strain, Principal, Siegel & Strain Architects

Cities are often able to lead policy innovation in ways that larger entities cannot. In 2018 the City of San Francisco adopted one of the strictest carpet purchasing ordinance in the country for municipal construction projects. It prohibits the use of broadloom carpeting (with a few exceptions) and cushion-backed carpet tiles. Carpet tiles must, among other attributes, be Cradle to Cradle Certified™ Silver or better, meet the Carpet and Rug Institutes' Green Label Plus™ certification or equivalent, have an EPD®, and have a compliant HPD® (Health Product Declaration) or Living Building Challenge compliant Declare™ label. Adhesives and packaging are also regulated by the ordinance.

To successfully influence codes and policies like this, there are many requirements that must be met.

> *"We worked with eight major carpet manufacturers over a two-year process. Being that the regulation applies to city government purchases, there have to be at least two compliant manufacturers. You cannot create a requirement that does not have opportunity in the current market. We had three to start; now there are four. A couple other companies have now said they are taking steps to comply. This policy has transparency requirements and includes chemicals of concern that go beyond what is currently tracked in Cradle to Cradle Certified v3.1, which is also part of the regulation."*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

Stretch policies and ordinances are often applied first to municipal projects, monitored for feasibility, and adjusted if needed prior to making them applicable to a broader set of building types in subsequent policy or code cycles. The measures have to be achievable, affordable, and functional.

These policies cannot be written in a vacuum. For instance, if material reuse is the goal, unintended consequences must be considered as well as other influencing factors. In this case, such a factor would be the IRS considering the shutdown of tax deductions for donated materials due to the amount of fraud for misrepresenting the fair market value of those materials that has occurred. This change in tax law could affect the economic viability of a mandatory reuse policy. This is another reason why new policy and code often have a trial period during which they only apply to government projects. The impact of a successful city policy can reach beyond that particular city's boundaries.

> *"What happens in San Francisco has influence locally, regionally, throughout the state, and on other cities globally. In part, this is because city staff collaborate through our networks like C40 [Cities Climate Leadership Group] and CNCA [Carbon Neutral Cities Alliance]. We learn from each other. …A city is very complex and also an optimal framework for implementation, there is tremendous opportunity for scalable impact."*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

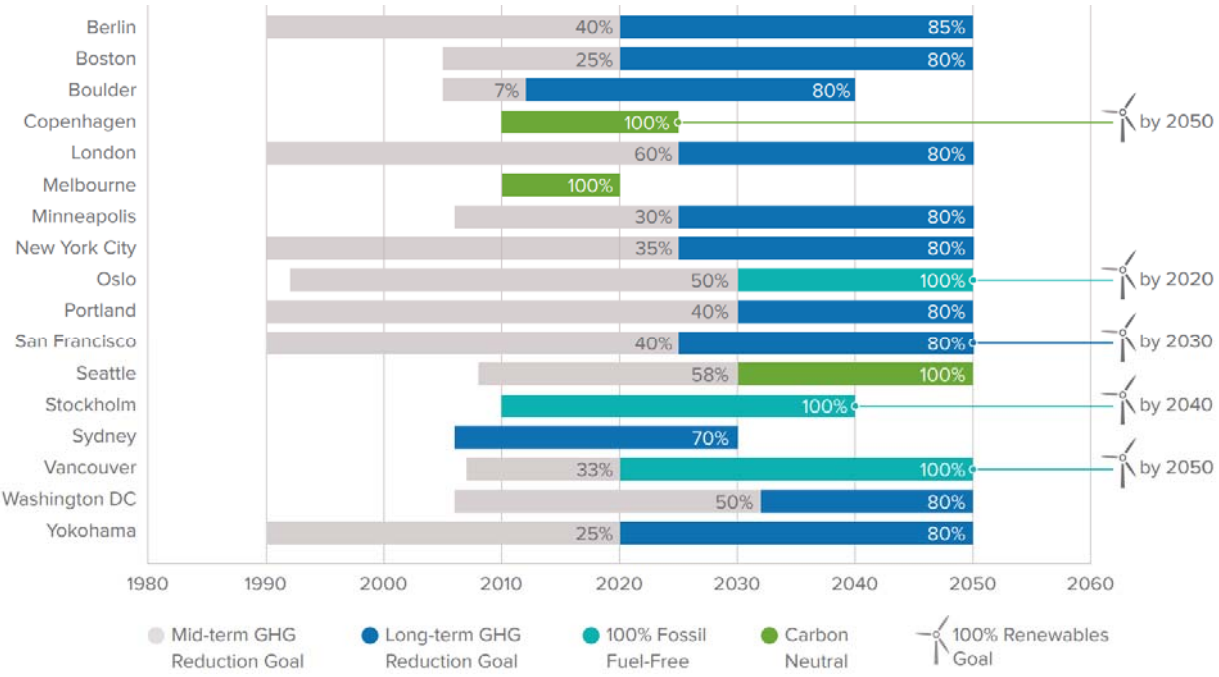


Figure 16. CNCA Cities' Long-Term and Interim GHG Reduction Targets, *Framework for Long-Term Deep Carbon Reduction Planning*, Carbon Neutral Cities Alliance

As complex and lengthy as policy and code development can be, the breadth of its potential impact on issues like carbon reduction is significant and a critical component of increased future success. Cities like those participating in CNCA lead the way by showing that the strategies work, which should eventually lead to wider adoption.

Code

Advocate for and support code improvements that address climate impact reductions.

The building code is often described as the minimum standard for building, because it describes the baseline that projects must meet to be permitted, built, and pass inspection prior to occupancy. While that is true, it is also a powerful driver of market change that levels the playing field for all parties. When all development must follow the same set of rules and standards, market advantages associated with cutting critical corners are taken away along with a certain measure of risk.

In California, reach codes foreshadowing future code requirements are considered by jurisdictions ready to commit to carbon reduction measures sooner than the state is currently able mandate.

In spite of the time that it takes to ratify new code and the fact that it represents a minimum standard, the code is one of the most powerful change agents available because it applies common standards to nearly all buildings. Sea change shifts like this have occurred in past code cycles leading up to which a segment of the industry has claimed that the new measures would be unachievable or cause an unbearable economic burden. This was true of California's seismic upgrades as well as the inclusion of accessibility standards, both of which have improved the built environment since their codification and become baseline standards.

"The only way you can implement anything globally is by making it a rule."

Morana Medved, Senior Tech Lead, Artik Art + Architecture and Lecturer, San Jose State University

As the code becomes increasingly strict on factors associated with operational carbon impacts by requiring greater energy efficiency and increased independence, the relative contribution of embodied carbon in the built environment has come under greater scrutiny.

"Without a doubt, as soon as anything goes into code, it's much easier to get into the project, because there's no hassling with the contractor and no hassling with the owner. It's just this is the way it's got to be. It just makes life easier for that 85% of the folks who really didn't want to have to deal with it."

Kirsten Ritchie, Principal, Gensler

Motivators

When change is needed, consider the possible motivators for the people or entities in a position to make that change, and build your approach around that.

Until carbon reduction strategies are more comprehensively covered by code, and even afterwards, those interested in more immediate progress will need to consider other ways of motivating those in a position to make a difference. Motivators may include recognition, incentives, market share, or simply the understanding that their action can make a positive difference. Consider how doing the right thing can be made easier or even fun.

"…And, in order to make [people] do stuff right and make it something [they] want to do, make it positive… How do we make it easy and simple and fun so that people inherently are doing the right thing? If we can really crack that nut, and it will probably require different solutions for different types of people, that would just be so fabulous. It has to be that thing that people want to do just because it's cool."

Kirsten Ritchie, Principal, Gensler

Awards are an incentive that may also be used to leverage wider adoption of carbon smart practices. The AIA is in the process of incorporating the "AIA Framework for Design Excellence" (formally known as the "COTE Top Ten Measures") into their design awards processes at the national level, with the intention of regional and local components following suit. One of the ten measures covered by the framework is Design for Resources.

"Sustainable design includes the informed selection of materials and products to reduce product-cycle environmental impacts while enhancing building performance. Describe efforts to optimize the amount of material used on the project. Outline materials selection criteria and considerations, such as enhancing durability and maintenance and reducing the environmental impacts of extraction, manufacturing, and transportation. Identify any special steps taken during design to make disassembly or re-use easier at the building's end of life…"

AIA Framework for Design Excellence, Measure 8: Design for Resources, AIA

By including environmental measures as part of their design awards criteria, the AIA is signaling its recognition of the importance and urgency of the issues. This will likely result in broader attention to these factors by the design community.

Messaging

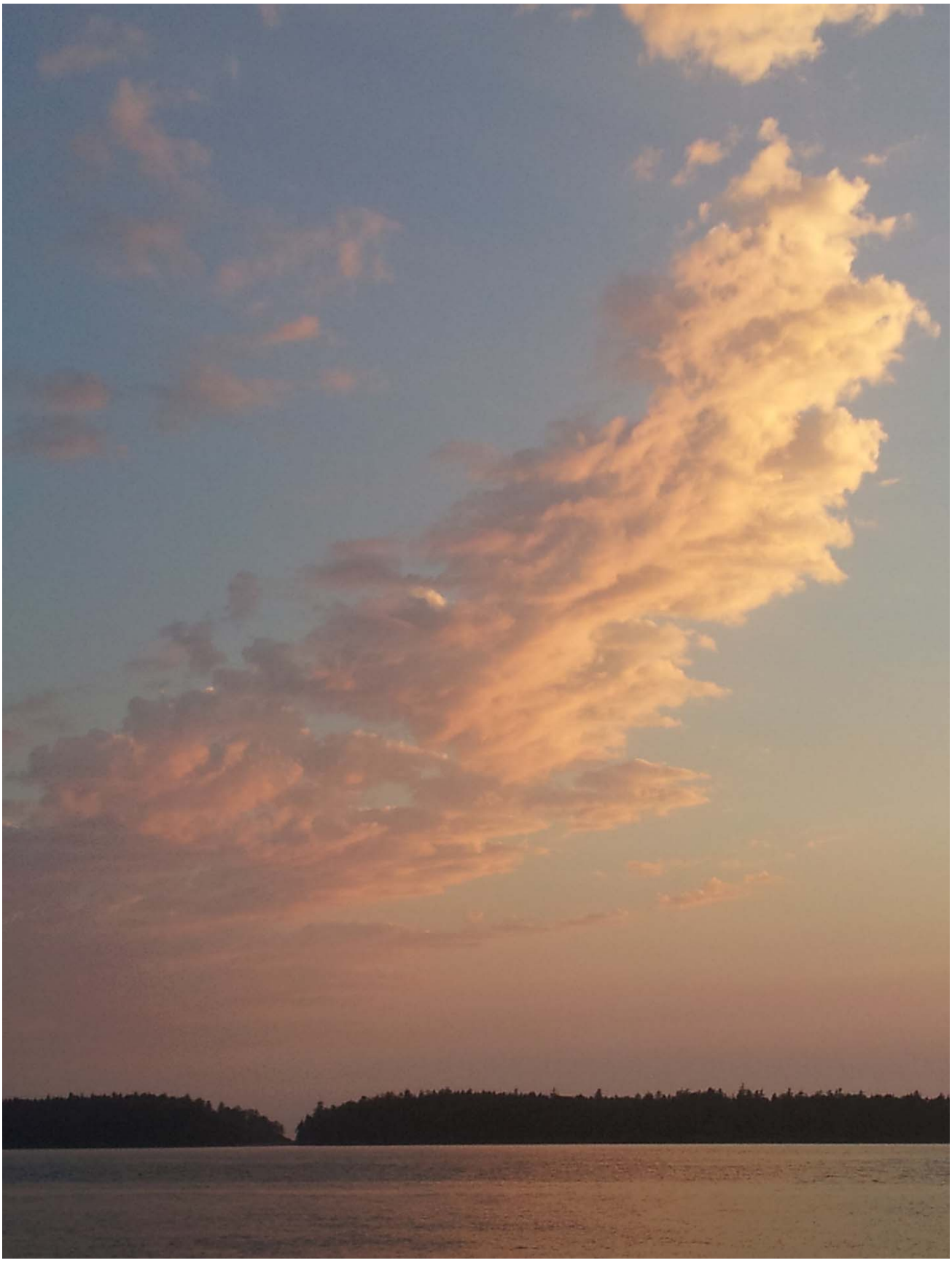
When communicating about climate goals and proposed measures for improving the environment, such as actions to reduce the embodied carbon impacts of the built environment, consider the audience.

While there are those who embrace environmental improvement goals enthusiastically, there are others for whom such changes are perceived as threatening or otherwise undesirable. In such cases, understanding how LCA measures might also support other factors is often the better path to take. To the extent that the data and available tools support improvements relative to any of the three traditional drivers of construction – cost, schedule, and quality – may prove more effective.

> *"I used to resist using carbon as a metric because it isn't native for us. For example, how much carbon is in that cup of coffee? You could tell me how much it costs. You could tell me a dollar value. You could tell me how many beans. But it is unlikely that you could tell me the emissions related to its extraction or manufacture or transportation because it is another language. Until we start quantifying carbon in a way that people understand they won't grasp the issue… To show what the real impacts are and how they translate to something tangible, visualizations are really important."*
>
> Eden Brukman, Senior Green Building Coordinator, San Francisco Department of the Environment

Even for those directly motivated by environmental progress are subject to nuanced preferences and influences. Some may prefer to be described as "cutting edge", "change agents", or "pioneers", while others prefer to simply make forward progress in the context of their own particular circumstances.

To be effective, communication should be based on an understanding of the audience, their drivers, and their measures of success. Graphics and/or "how-to" cheat sheets are sometimes the most effective way of communicating the desired information.



John Spotorno, HPS

CONCLUSION

With the anticipated effects of climate change already manifesting themselves in the world in the form of extreme weather events, extraordinary fires, sea level rise, and other phenomena the time for counter measures is becoming increasingly short.

The built environment is responsible for a large share of global greenhouse gases which have a negative impact on the environment and contribute to climate change. Of the 39% of global GHG emissions that are attributed to buildings, 28% are from operations and 11% are accounted for in the embodied carbon. Efforts to improve energy efficiency and move to clean energy sources have started to reduce GHG emissions from operations. Therefore, the GHG associated with the embodied carbon in materials and infrastructure represent a larger share of the built environment's impact. Embodied carbon is especially critical because its impacts, unlike operational carbon that accrues over time, is immediate.

> *"Clients and designers need to understand that every time they are making a decision, say they want that facade or they want this one what have you, that there is an environmental cost that comes along with that. They are in a position to make decisions that can dramatically reduce that environmental costs."*
>
> Roderick Bates, Principal, KieranTimberlake

By finding ways to measure, consider, and compare the potential impacts of materials being considered for Interior design projects in a timely manner, real reductions can be made on a project by project basis. This effort reveals opportunities for focus and potential greater impact on future projects and can eventually lead to policy and code changes that can bring along the entire industry.

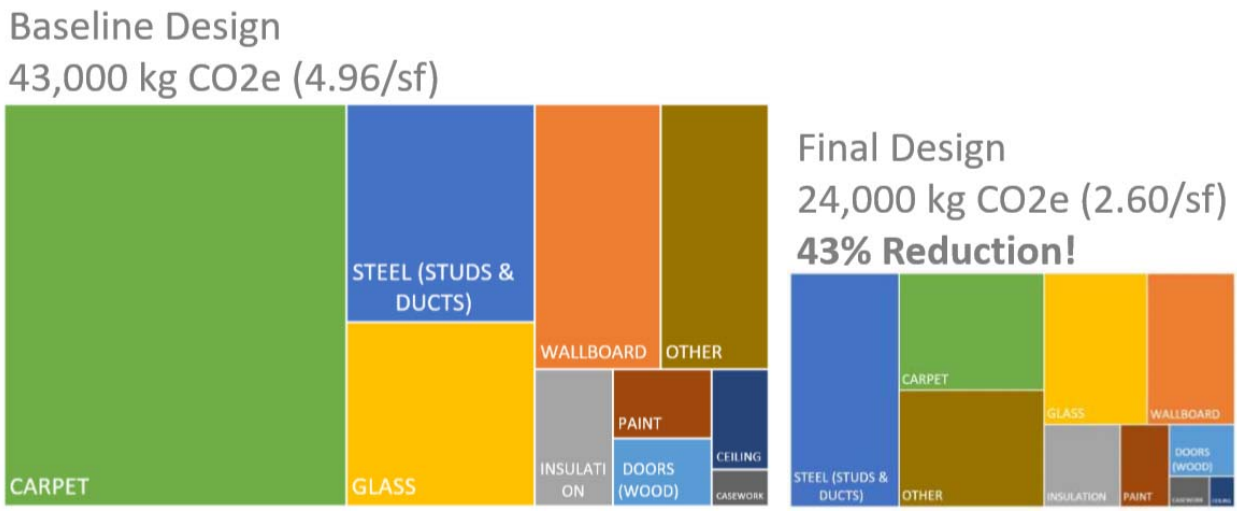


Figure 17. Success at a Smaller Scale (10,000sf TI), courtesy of Kirsten Ritchie, Gensler

In his bestselling 2007 book, *Blessed Unrest*, author and activist Paul Hawken chronicles the worldwide movement for social and environmental change and the efforts of countless organizations and individuals, large and small, well-known and unheralded that make this the largest movement on earth. His findings expose the urgent need for action, inspire hope for the future, and invite action.

In the spirit of Winston Churchill, who famously said, “Perfection is the enemy of progress”, it is the hope that each reader will find at least one individual intervention that they can move forward with today. Together we can all make a difference and it is important that we take what action we can as soon as we can.

> *“Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has.”*
>
> Margaret Mead, PhD, American Anthropologist

INTERVIEWS

A number of interviews with experienced interior designers, topic experts, manufacturers, and LCA software developers were conducted as part of this research.

The purpose of the interviews was to gather a broader understanding of challenges, opportunities, and influencing factors related to the use of life cycle assessment for interior design. The variety of perspectives provided insight into the potential value of LCA as a tool for improved environmental outcomes, specific details about issues that must be overcome to realize its potential, and some strategies for action that individuals can take even at this early stage of its implementation.

The interviews were completed individually, either in person or on the telephone. Each interview was recorded, transcribed, consolidated, and shared with the interviewee, who was then offered the opportunity to further polish their words for clarity and intent. A few written responses were provided in place of an interview and have been identified accordingly.

The interviewees were all generous with their time and their passion for improving the built environment and addressing climate change was palpable and inspiring.

The following people participated in the interviews and the transcripts of those interviews are included in the following pages:

Interior Designers

- **Jennifer Chen, WELL AP**
  Associate Interior Designer at LMN Architects, Seattle, WA
- **Karen Glaser, IIDA, LEED AP**
  Senior Interior Designer, Associate at Hawley Peterson Snyder Architects
- **Kim Pham**
  Space Planner, Interior Designer at Maxim Integrate
- **Morana Medved, NCIDQ, CID, LEED AP ID+C, WELL AP, EDAC**
  Senior Tech Lead, Artik Art + Architecture
  Lecturer, Interior Design Department, San Jose State University
- **Denise Tom-Sera, IIDA, LEED AP BD+C, EDAC, CEAS**
  Senior Interior Designer, Associate at Hawley Peterson Snyder Architects

Topic Experts

- **Eden Brukman, RA, LEED Fellow**
  Senior Green Building Coordinator at San Francisco Department of the Environment
- **Kirsten Ritchie, PE, LEED AP O+M**
  Consulting Project Director, Principal at Gensler
- **Larry Strain, FAIA, LEED AP**
  Principal at Siegel & Strain Architects, Emeryville, CA

Manufacturers

- **Clinton Boyd, PhD**
  Principal Scientist-Green Chemistry & Sustainability for the Global Sustainability Initiatives Team at Steelcase Inc., Grand Rapids, MI
- **Lisa Conway, LEED AP ID+C**
  Vice President, Sustainability – Americas at Interface, New York, NY
- **Anita L. Snader, LEED AP BD+C**
  Environmental Sustainability Manager at Armstrong Ceilings and Wall Solutions, Lancaster, PA
  Liesl Heil Morell, CSI, CCPR, LEED AP, Industry IIDA, MBA, WELL AP
  Architectural Sales Manager at Armstrong Ceilings and Wall Solutions, Burlingame, PA
- **Robert Wendoll**
  Director of Environmental Affairs, Dunn-Edwards Corporation, Los Angeles, CA

LCA Software Developers

- **Roderick Bates, LEED AP BD+C**
  Principal at KieranTimberlake, Philadelphia, PA
- **Dr. Joshua D. Kneifel**
  Research Economist at National Institute of Standards and Technology (NIST)

Jennifer Chen, WELL AP

Associate Interior Designer at LMN Architects, Seattle, WA

Jenn is an interior designer with a focus on sustainability. She has a strong interest in how everyday design decisions can impact human and environmental health. In addition to focusing on healthy materials and lowering embodied impact in her daily work, Jenn helped launch a finish material library vetting process, as well as a new waste stream process within the office. Jenn is also a main contributor to the local Healthy Material Collaborative, leading efforts to promote awareness for healthy building materials through public and industry installations and engagement events. Such efforts include pulling together a 10' cubed pavilion on healthy building materials at the Seattle Design Festival Block Party, and leading a Librarian Summit, which led industry practitioners through a series of exercises to help overcome challenges when selecting healthy, sustainable materials.

SR: We are looking into how the growing knowledge base and tools related to LCA and carbon can be utilized effectively in the interior design process. In other words, what is the most promising bridge between LCA criteria and decision making in interior design practice.

After I saw your presentation [at Greenbuild] and saw that you had found a way to address this, I knew we needed to speak to you.

JC: That is the hardest part. We have the research and knowledge, but putting that into daily practice is the most difficult thing. Even now I don't have it totally figured out from the one case study we presented at Greenbuild.

Q: Could you talk about the environmental impacts of design decisions? …and the impact that using LCA as a decision-making criterion could have?

JC: The environmental impact of design decisions is apparent in EPD's where not only embodied carbon is listed, but also ozone depletion, ocean acidification, etc. Now that operational carbon is decreasing, the embodied carbon of finishes and materials is becoming more important. This means looking at the finishes and materials that goes into a building and making sure we are making design decisions that can lessen a building's carbon footprint overall. LCA has been focused on structure and envelope, but as an interior designer, I begin to wonder what impact my practice can have on embodied carbon, especially considering the idea that materials often times [are replaced before the end of their useful life]. There's the phrase - *"it uglies out before it wears out".* So, we are looking for materials to last a long time and will take any wear and tear, when really, we are tearing them out faster than they are wearing out.

Through our Greenbuild case study, where we calculated the total embodied carbon of all the past renovations for our own office, we now have a good idea that the embodied carbon impact of cyclical interior renovations is just as significant, if not more, than structure and envelope over the lifetime of a building.

The impact of cyclical renovations is significant. Based on the embodied carbon data we have gathered from 1995 to present day, the total interior carbon impact is fairly high compared to structure. If we include another remodel that likely occurred prior to the beginning of our data, it is actually higher. There has been so much focus on lowering the embodied carbon of concrete mixes. If we simulate having successfully achieved a 30% reduction in concrete mixes in this study, the cumulative embodied carbon of renovations is actually higher than structure and envelope combined. I started thinking in that way about whole building LCA and accounting for future renovations. It is definitely something we should start looking at. We need to be able to understand what the highest embodied carbon impact would be in every renovation and understand what that means when making design decisions. We need to push for materials that have higher reuse value to lower embodied carbon impacts, start with materials that have low embodied carbon to begin with, and know what information to look for to know how to lower the impact.

Have you seen the calculator on Carbonleadershipforum.org? That is the calculator we used for the LMN office renovations case study. We also looked into EC3 and Tally Currently, Tally doesn't have a lot of interior finish

materials and it is not possible to assign your own materials with custom GWP input. So, the spreadsheet, at least for us, was the tool we found easiest to customize for our purposes.

Q: How do you and/or other interior designers at your firm incorporate informed material decision making and when? Please elaborate on the process.

JC: Before this study, we were more focused on material health. For all LEED projects we have a certain amount of transparency labels that we must get. Most of our projects are going for some sort of certification, and we have built in the process of looking for EPDs and HPDs early in the design process to making sure we are able to get the points. Before all of that, our materials library requires all manufacturer representatives that want to come in to have some sort of transparency label, and can be found in mindful MATERIALS. We also have a non-PVC policy in our office. So anytime a manufacturer reaches out to come in and do a tabletop, we would send them an information request for HPDs or EPDs or Declare and they have to say, "Yes, you can find our transparency label in mindful MATERIALS," and "Yes, we will not be bringing any PVC products" before they can come into the office. If it's a material that we are interested in, but they don't have transparency labels because they are a small manufacturer that just can't get around to it, then we work with them to find out where they are getting their materials from. Some manufacturers are willing to get transparency labels if they know that will result in specification. The goal is that anytime we go into our library, we know that what we're picking up has been vetted in some way. So, I think the first step is communicating the importance of transparency within our office, and with the manufacturers. After that, it's a matter of keeping track of the flow of materials all the way to specification and documentation. We did a study for King County a while back where we researched various tools for tracking materials in a project. We looked at Green Badger, which is a platform for searching for sustainable materials, and it is more integrated for LEED documentation. We also looked at Red2Geen, a similar service but more geared towards LBC projects. These are subscription based. You pay a fee and then you can use their database to search for materials that have been successfully vetted for building certifications. Everything that is in the Red2Geen database has been used in some part of a Living Building Challenge project before and that's how they make sure the database is applicable and vetted in some way.

SR: What about mindful MATERIALS? Isn't that website free and do the same thing? Have you used that?

JC: Yes. So, mindful MATERIALS is more like a database in terms of manufacturers being able to upload information. But I think the appeal for Red2Geen and Green Badger is that they have a direct link to building certification documentation. From Green Badger you can directly upload information to GBCI and Red2Geen you can do that too for LBC. It is not just a database, but also it is a platform for you to organize the documentation process and all the team members can have access to it at the same time. Mindful MATERIALS, is a place where you can search for information, but it doesn't have integration with any of the certification processes as far as I know

SR: Getting back to the process that your firm uses, interior design must be integrated with building design, right? Is that a fair assumption? Where exactly is the understanding coming from that carbon will be looked at for a project? How is that decision made and who is in charge of actually doing it?

JC: Historically we have been gathering transparency labels, more for health, but going forward for a few of our projects, we're going to adopt the calculator that CLF created and start asking the interior designers in the office [to fill it out as they go]. The idea is that hopefully we all know what we're looking for and can start seeing the embodied carbon impact of the design decisions we make. For every project we have a sustainability coordinator and the coordinators meet once a month to exchange ideas and compare what they are doing on their projects. I think carbon is definitely something that, going forward, we're going to start focusing on. At the end of the year, we report how much operation and embodied carbon (mostly for structure and envelope) there is and how much reduction we have per project. We might start doing that for the TI for the interior portion of those projects as well. We are trying to be more aware overall.

SR: Is it just your firm's way of doing things, an expectation that this, whether it is an EPD or HPD, or carbon, is something that you are tracking? Has the yearly report always happened?

JC: That has always been happening for structure and envelope. I think that's part of the 2030 challenge. Our Sustainability Director can speak more about that.

SR: It sounds like the company leadership is a hundred percent behind this as part of the ethos of your company. Is that right?

JC: Yeah. I think some of it is dependent on our Sustainability Director. We have a lot of task forces in the office in support of his initiatives. We have an embodied carbon working group, a materials and health working group, etc. These task forces get together regularly and set goals. For example, for our materials and health group, we have a spreadsheet that tracks typical materials that are in our specs, alternate materials that would be better for the environment and human health. If the alternate materials have no significant cost difference, then that items can go on to be approved to make it into our base spec. The idea is that each time spec has to be written, it is a bit more sustainable than the previous version. We could start doing that for the embodied carbon.

SR: How is the time spent on this task force budgeted?

JC: If the study happens to be done for a specific project and ties into the project's sustainability goals, it is billed to the project. In addition, there is a proposed amount annually for sustainability efforts. For example, I have a certain number of hours that I can spend on sustainability and that is billed to sustainability overhead.

Q: I know you mentioned Green Badger, Red2Green, EPDs and HPDs, but if applicable, what data sources are most valuable for comparing material choices for you?

JC: For me, there are four pillars that drive decision making when it comes to what materials or products to use. There is aesthetics, which is important for an interior designer. There is cost and then there is performance and then there is sustainability. Usually sustainability falls off and becomes a nice to have. Having transparency labels gives the product an edge over other similar products that might not have labels. It's also always helpful when reps are knowledgeable about the sustainability stories of their products in addition to cost and performance. Other than the databases, it really helps when the manufacturers know where their product components came from and what impacts they have. Ease of access to the information needed is extremely valuable. Many times we are too busy to be able to sit and research each material in depth. The product that provides the easiest and clearest path to knowing I'm making a good decision is best.

SR: Would you say that certification, like The Living Building Challenge or LEED, is in any way a driver that helps you put a border around the scope of work that you're going to do on this?

JC: I have a strong interest in integrating sustainability into the day to day practice, but it is one of the hardest things to do and one of the hardest things to convince people to do. For me it does not have to do with whether the project is going for LEED or The Living Building Challenge, but more of a baseline of what I hope to achieve sustainably. In our firm we are hoping for every project whether or not it's going for any certification to be at least a LEED-Silver certifiable. That is pretty achievable for Seattle I would say. It is not necessary that we have a certification to work towards a baseline.
SR: I've been involved with LEED for a long time and I see it as a market broadening program. There are those who are out there in front addressing environmental impacts of the built-environment because it's the right thing to do. They don't really need LEED, but the framework and incentive that it offers really helps widen the tent.

JC: Yes, I agree. I think because we are in the Pacific Northwest and on the West coast LEED is approachable and achievable. LEED is definitely helpful in certain situations where it maybe is not familiar or the process of thinking about sustainability in the design practice is not typical. I think for someone who's not as familiar with the whole process, LEED is definitely a great jumping off point to get familiar with what should be considered. I think I mentioned during the Greenbuild presentation that before I started looking into embodied carbon, I was asking for EPDs for LEED purposes but I never actually read them all the way through. That is what LEED is good at. It's prompting you to pay attention to aspects you might not have considered.

Q: As a recognized leader in sustainability with a commitment to doing right by the environment, do you have any suggestions on how best to bridge practice (designers) to LCA for interiors?

JC: Yes, I don't think this tool exists, but in my mind, the ideal world, there will be some kind of algorithmic decision making tool, where I can rank all the sustainability concerns so that I can make the better choice.

After I presented this case study, I briefly talked about it to the interiors group here at LMN and the responses were, “This is great, this is awesome. I know I can make an impact, but what the heck am I supposed to do?” and “I have no idea where to start. I don't know what a lot of these things mean to our practice.” Education and getting people familiar with the language, [and comfortable with the process], is key. We should start with educating the next generation of designers coming out of school. I know when I was going to school, none of this was ever talked about. Sustainability, material health, and embodied carbon were not talked about as part of the integrated design process [when I was] a student. If people are familiar with the language, it feels more approachable. I remember going home in an uber and the driver asked what my presentation topic was. I realized I had no [simple] way of explaining it to him in a way that is easy to understand.

SR: You needed an elevator pitch.

JC: Something that is approachable and easy to understand and having tools that are easy to use would be really helpful. We [had the audience do] an exercise comparing EPDs of a few different products to decide which one would be the best choice. We did not have the right answers for the groups, and the groups were also coming up with different answers because not all EPDs are written in the same language, so it was hard to compare apples to apples. Making sure [we are all using the same terminology and baseline is important]. It would be great if we just had one giant database that we could rely on instead of five different small platforms that everyone's trying to start.

SR: Is it fair to say that along with these tools, that the critical path is leadership’s full support?

JC: Yes. At least at our firm, there is a lot of trust in our sustainability director. Leadership might not be directly involved with all the sustainability initiatives, but they know what they are and that there are passionate people who are interested in these topics and want to do this research. That they are given the freedom and support to do so is very important.

Q: Please tell us about the librarian summit that you led, especially the material selection challenges that were identified and exercises that were designed to address those challenges.

JC: The librarian summit focused on material health. We have a local group called the Healthy Material Collaborative. It was started by some other people from other firms and LMN became very involved in it. The summit brought together 75 people from 20 firms. This included anyone who might be specifying or influencing material specification. We got together and tried to walk through the design process, [identify] where typical pitfalls might be, and set goals. There is a summary mind map that we created at the end of it. Which goes through setting goals [and identifying tools], and the tools that we still need.

The mind map captured what everyone discussed, what they have tried to do in asking for transparency, and where there might be pitfalls on transparency goals during the substitution phase. The mind map was this way to take all of the things that were talked about and organizing it so that people know where to start. We have to get these stakeholders in the conversation. It was for anyone who might specify materials and telling them we should all get on the same page and ask the manufacturers the same questions. So they know that the 20 firms represented here are all interested in having transparency labels. Have you ever heard the manufacturer’s response to architects demands for transparency?

SR: I gave a couple presentations when HPDs first came out and it seems like the lawyers are the most concerned. They were afraid that they were going to be revealing something that was going to be the next asbestos and did'nt want to admit that it's in their product.

JC: A number of firms signed a letter to manufacturers saying, “Hey, we want you to start supplying material transparency labels” [and some did]. Then after a while the manufacturers said, “Hey, we responded to your request, but we are not making it into your project. It is hard for us to go to our leadership and ask them to budget for us getting transparency labels.” It was an interesting back and forth. On the designers and architects side we're saying, “Yes, we are trying to specify you but then things get switched out.” So now owners or contractors are the ones we have to convince. Through the whole design process there are so many situations where the sustainability goals can fall off the map. Going back to your question on how to suggest how best to bridge practice, even from the design standpoint, we need to make sure through the contractor and through the client and through all the stakeholders, that everyone gets on the same page from the get-go. Having a goal setting session in the beginning of a project is really important, just so everyone knows what the sustainability goals are and that has been hard. We try to do a sustainability kickoff meeting for our projects but a lot of times it happens too late , due to schedule and the , difficulty in getting everyone in the same room. Every project should have a sustainability visioning session to inspire everyone to want to achieve the same sustainability goals. It would be great if some common pitfalls are introduced so the project team knows how to navigate those situations if they come up.

Q: What do you think we need to see in future codes to support LCA for interiors?

JC: We do not have a consistent benchmark.

SR: That's a good point. If you don't have a benchmark, you can't really write code language around it very easily.

JC: Yes. There are some groups starting to establish the baseline of a typical project so we can compare to the same baseline.

Q: Is there anything that you'd like to share or guidance that you have on this topic that we haven't already talked about?

JC: I’m thinking back to how difficult it is to be able to easily incorporate sustainability into everyday practice. That is the focus for the second part of this presentation. I did not want to just end at our study. I want to really be able to start saying maybe there are specific things that we can do. One thing that I thought was interesting at Greenbuild this year is the idea of thinking about carbon as something that you can invest in and spend and not something that you just want to cut out without seeing the whole picture. After I did the study, we were really interested in how we can use reused or salvaged materials. Trying to understand what using salvaged or reclaimed material means. Forcing us to look at where we can source the quantities that we need, [consider] how we work through that stream, not always look for something that's readily available off the market, and maybe look at innovative ways to use materials. We are also looking into developing some details where we can disassemble, assemblies in a way that does not hurt the integrity of the original material to maximize reusability. If everyone can think of one new way to practice, it would be easier for the whole market to change. It feels like we are shifting because we have this high focus on embodied carbon. Just being able to put that into practice is exciting.

NK: How much time are you given to research topics you are interested in?

JC: 5% of my time in my billable hours, but when I was putting this together, it was on top of my regular day job. For every project, if you are not the sustainability coordinator, you have some time specifically for that project, but a lot of times that goes into documentation for LEED or, coordination etc. For research like this, a lot of it is on my own. I have to get my project responsibilities done before I can do something like this. It was okay during the few weeks that I really tried to hunker down and study for this. I spent half of my time on it.

Karen Glaser, IIDA, LEED AP

Senior Designer, Associate at Hawley Peterson Snyder Architects

Karen Glaser has been with HPS since 2013. She has 35+ years of experience in the design field. Prior to HPS, she worked as a Professional Associate at HDR for over 21 years doing projects in the Healthcare, Corporate Workplace, and Government segments. She also has been a Healthcare Design Conference Nightingale Awards Juror for five years.

It is important to look to the future when designing. Not only should interior spaces be comfortable and attractive, they should be safe for the inhabitants and for the earth once the selected products and materials have outlived their use.

Q: Being an interior designer who is passionate about integrating great design and sustainability to promote health and wellness for occupants, what is LCA's place in that equation?

KG: The biggest opportunity I see it is in flooring and having to do with maintenance, and how long it will take to pay for itself. Carpet usually "uglies out" before it wears out. I have not noticed it in furnishing.

NK: I had a conversation with a carbon expert about this and he said, when looking at the impact of a building and comparing it to finishes and furniture, the impact of the finishes and furniture after three remodels is actually more than that of the building.

KG: Yes, that is true. I honestly don't think about LCA, especially on certain projects for clients who have taken sustainability into account in standards for what to use and what not to use. As far as furniture, they reuse it as much as they can, then it's recycled, or it is donated to schools or organizations that need it before it goes to landfill. Chairs get recovered and reused.

The furniture dealerships don't have programs that I know of. I talked to One Workplace to see if they had suggestions for where the furniture can go, and they knew of an organization that took furniture to third world countries. I know that Steelcase and others are making as many cradle to cradle, sustainable, and recyclable products as possible which is great. But I don't know who is actually doing the recycling or reducing. (Actually, the Move Coordinator that one of our medical clients uses has a vendor that takes everything apart to be recycled before the leftovers go to landfill)

NK: We need the furniture manufacturer's to take it back and repurpose it like flooring manufacturer's do with their products.

KG: It used to be when Steelcase was all steel, that it would be recycled down and reused.

Q: At which point in your design process are finish and furniture decisions made and more or less set?

KG: They are set pretty early, now they are done in schematic design. It did not use to be that way. It used to be in design development, but my primary medical client requires us to get everything set early so they can start to look at pricing.

Q: How do you think LCA should or could be integrated into practice and at what point?

NK: You mentioned schematic design. Do you think a database comparison would be helpful?

KG: Yes, it would be really great. I just don't work that way - although that is a great tool, I just would never use it.

I generally know which finish is the right fit for each project. Although a lot of times, you could use linoleum or a rubber sheet good, and it would be fine. I would never think about comparing the materials. That is where you

could come in with LCA; linoleum must be polished, so you need to account for the wax over the lifetime of the product.

NK: What if you had the option of inputting the product that you typically use, and then it could tell you right away how much of an impact it had.

KG: That would be fantastic. I really go more toward aesthetics and the feeling I am looking for, the color, whether or not it's available. A lot of times the finish palette is driven by the preference of the users. They may say, "We don't have any rubber in this building. We only have sheet vinyl, so we don't want rubber." HPS doesn't specify sheet vinyl if we can avoid it, so I would use Purline or something that is not rubber because the cleaning process if different between rubber and sheet goods.

NK: Do you think the users should be involved in the process by letting them know the impact of the choices made?

KG: Yes, I think that is really helpful. I think it depends on the clients, some of them don't really care. For a remodel situation, the users don't care. For new buildings, if you get the facilities people involved from the very beginning, they can have a say as to which material they think is best. They will say, "We really like this product and we want to use that." So I give them a couple of different options. But I usually start with the carpet, and then choose the resilient flooring to go with it.

NK: And carpets are usually a huge part of the space so it's more of an impact.

KG: All the carpets we use are PVC free and as sustainable as they can be. It's really, important to my primary medical client, so I use the same types of products with my other clients.

NK: Yes, the occupants' health is already taken into consideration.

KG: Yes.

Q: What are the barriers to making LCA a design criterion, a principle, or standard by which something can be decided?

KG: Ease. And that is totally it. Because if something is difficult and takes a lot of research and time, it is not going to get done.

Q: Can you think of any solutions to those barriers?

KG: Well I liked your idea of putting something in and having it spit [LCA data and/or rankings] out. I mean that's fantastic.

NK: How about a score card something where you put in this product and it spits out number(s) and you know the carbon impact through this numbering system.

KG: Yes, that would be fine, to have some kind of number system. For furniture, a lot of times you have to search for the information. It's not always somewhere easy. It would be nice if all manufacturers had a sheet, (I know that Steelcase does and some of the others) for each finish material or piece of furniture that lists all the important information for LEED as well as an LCA of the product. It would be nice to have that information.

NK: What I am noticing is that there is only average data and not everything is measured the same. It would be nice to have a consistent baseline and database to get this information.

KG: Yeah, that would be great.

Q: Would it help you to see the LCA impact of furniture and finish choices you are making while you are in the design phase?

KG: It would and yes, and I think it could make a big difference with some of our clients because of initial cost and long term value. A lot of times they want to put in whatever is cheapest because they don't have the money now. That would be a good tool.

Q: What would the ideal LCA software requires input (data) and provide as output information?

NK: What would you want as information? What would help you?

KG: Products are warranted for an amount of time, so it would be nice to have the warranty listed. It also would be good if the software info included the adhesives and everything that is a part of the installation process. When they do fire testing for furniture, the whole assembly has to be put together, and then burned up to determine if the product is safe. It's the same sort of thing for LCA. If the incorrect adhesives are used with flooring, the "assembly" might not perform the way it should, and the life cycle will be shorter.

Kim Pham

Space Planner, Interior Designer at Maxim Integrated

Kim graduated from San Jose State University in 2014 with a Bachelor of Fine Arts in Architectural Interior Design. Kim has a passion for helping others when it comes to her clients or her volunteering with Habitat for Humanity. She has spent the last six years practicing healthcare design with a focus on creating a sustainable and healthy environment for occupants. Her interest in healthcare design has given her the opportunity to research and explore the concept of sustainability and healthy building. Kim recently transitioned into a facilities role to work more directly with end-users. With a passion to continue to bring new design into the community, she is now focusing on modern workspaces and creating a new brand identity for Maxim Integrated. As a designer, Kim believes that good design will activate spaces and create a positive difference for humanity and the environment.

NK: So, you were saying it is about how knowledgeable the user is?

KP: As a designer, I think the way to approach this is to think of it like we do energy analysis at the beginning of each project by identifying energy saving opportunities, doing sun studies for the building envelope, etc. We SHOULD do the same thing for the interiors of the building. We should do the same with life cycles analysis for the materials because that is where all the decisions are going to be driven. So that would be the way that we should approach it, but we do not do that now. We should have the same approach as we do with the exterior of the building for the interiors of the building. We have tools, software for those energy studies for the envelope, but we don't have tools to study the interior components.

Q: Being an interior designer who is passionate about integrating great design and sustainability to promote health and wellness for occupants, what is LCA's place in that equation?

KP: Well that is what I just said, because when we can set the goals right at the beginning of the project they are easier to achieve. It is sustainability in design to promote health and wellness. So we place that equation right up front and hopefully that will follow all the way through.

Q: At which point in your design process are finish and furniture decisions made and more or less set?

KP: If we apply LCA from the beginning, as part of the research.

Q: How do you think LCA should or could be integrated into practice and at what point?

KP: When we do the proposal. I think part of it is not just to educate the user, but since this is a new thing, the firm should be educated about that too. That is how we would make that work, as part of the proposal or contract and part of our portfolio, when we go after a job.

NK: I was thinking about talking to IIDA and getting a CEU around this topic. Hopefully talking to the software companies gets something up and running so we can train people on it.

KP: Yes, Sketchup has a platform called Safari. It is a plug-in to study solar impacts, energy saving and so on. So that is what HPS used years ago. Because we did not have proper practice on that, we tested it out to see how beneficial it is, and it is. But we did not have it as part of our fees, so we spent a lot of time on doing that and did not get paid for it, or have a person who managed it. But yes, something like that they can do for LCA analysis.

It's a simple platform and is good for the starting process.

NK: Are you suggesting a platform or plug in for designers.

KP: Yes, because everything should be there, in the same model.

Q: What are the barriers to making LCA a design criterion, a principle or standard by which something can be decided now?

KP: I think cost.

NK: How much time do you spend looking for these materials? What if there was a database with background and stats/specs on all these environmentally friendly products with their carbon impact available so that you could choose your materials based on that.

KP: I am always thinking about the cost of materials because that drives decisions. For manufacturer's to provide an analysis of their products starting from extracting the chemicals from the ground, through producing a finish, all the way to installation, and the end of its life – that drives their costs too. Does it cost more to produce a product with a lower carbon impact than an average product? The content of lower carbon products versus average products, does that impact the cost? Or might we already have something like that.

NK: If it costs more, I think if you buy products that are maybe $2.00 more a sq ft but it lasts twice as long, you are getting a benefit for the environment by avoiding some landfill and also saving money.

KP: Yes, that is part of what we do to analyze and to convince our client that this is the best choice so that they can accept and not have a **r**estriction on two or more carpets. So I think that might be one of the barriers if the product is more expensive than normally.

NK: Let's say a company is only planning on being in a facility for five years, so they just want to go with the cheaper option, how might we convince them that it is better for the environment and it will last longer even if they are not going to be in that building? When I was talking to a carbon expert, he said that a building or product may have a Life-Cycle Analysis done and it will say it can last 60 years in this building (depending on how they built it) and then you put in your interiors which only last anywhere between 5, 10, 15 years. The materials do not appear to have as big an impact up front. However, when you are putting them up against that 60 year old building that changes. The building seems to have a higher impact until you take the 5-15 year life span of interior finishes and stretch it across 60 years. The interior finishes actually have a higher, cumulative impact than the building.

KP: Yes, so that's true, but after the project is done and you turn it over to the client, how do you ensure the lifecycle of the product? So that is something I don't know how to do.

NK: When I was talking with a carpet expert, she said we tell the client how to maintain the product so that it will last "X" amount of time, but if they do not listen then it most likely will not. If they do not know the vendors of the carpet, they cannot recycle it either.

KP: Every product has default maintenance guidelines. If a company produces them, they have to have the maintenance guidelines. But can they do that in the facility? The maintenance for my company is clean and they are really into it. But for other facilities, afterhours, it is unclear what they do. Think of it like HCAHPS scores (the Hospital Consumer Assessment of Healthcare Providers and Systems) for a hospital to get funding. It's the same thing. Also, to keep a LEED certification you have to meet all of these requirements. If there was a structure you had to follow, it would be good. Otherwise who will ensure that a product will get to the right place? If it doesn't, it defeats all the work we did at the beginning of the contract (convincing the client, purchase, install, and so on).

Q: Would it help you to see the LCA impact of your furniture and finish choices while you were in the design phase?

KP: Yes, again, all of this needs to happen at the beginning during research because that would help us make the right decisions. We would have more criteria to base decisions on. It's not just about the function or the finishes of the furniture (aesthetics), there is also a bigger picture than that.

NK: One thing that I like about Tally the tool is that it actually saves past decisions and generates a report. You don't have to go back and re-input all your choices when you start a new project, it's already in there. I think that would be helpful for interior designers, especially for repeat clients.

KP: It also helps you back up all the decisions you made, like why you suggested that product. Having data in the steps of your analysis will help the clients make the informed decision on choosing the right interior products.

Q: What would the ideal LCA software requires as input and provide as output?

KP: We touched on that when we discussed the SketchUp platform. I think it doesn't need to be that platform, but it does need to be a commonly used platform. One that is used across most firms and so of course we know it is AutoCAD, SketchUp, and Revit. If there were a plug in for each software and each platform, that would be a great start.

NK: What if LCA software was separate, its own standalone. So then you could use any platform.

KP: As long as you can import things back and forth from platform to platform that would be OK. That tool would require the model of the building for area take-offs. You shouldn't have to build an entire model in the LCA tool. As long as you can cross-reference, separate software would be okay. A plug-in platform is what they do right now (similar to Revit). Where everything can exist in one place.

Morana Medved, NCIDQ, CID, LEED AP ID+C, WELL AP, EDAC

Senior Tech Lead, Artik Art + Architecture
Lecturer, Interior Design Department, San Jose State University

Morana Medved is the Senior Technical Lead at Artik Art + Architecture. She has over 15 years of experience in a large variety of projects including commercial (high-tech and other corporate), hospitality, educational, scientific (laboratory), healthcare, retail, multi-family, and residential architecture and interiors. Her passion is using great design to promote the health and wellness of building occupants, while maintaining environmental sustainability of the structure, systems, and site. She is an accredited professional in both LEED (Leadership in Energy and Environmental Design) and WELL (WELL Building Standard).

Morana is a lecturer at San Jose State University (SJSU) where she has been teaching building codes, construction documentation, architectural systems, and Building Information Modeling (Revit) in the Interior Design Department for the past eight years. In addition to teaching she is a faculty advisor for the International Interior Design Association (IIDA) Student Chapter at SJSU. Her past roles include VP of Professional Development for the IIDA North California Chapter and IIDA Student Affairs Chair with the Silicon Valley City Center.

Q: Being an interior designer who is passionate about integrating great design and sustainability to promote health and wellness for its occupants, what is LCA's place in that equation?

MM: It definitely has a very important place in the equation, from the basic standpoint that what is in our materials effects the interior environmental quality. I know we usually approach LCA thinking about how it affects the planet, the sustainability factor, now with health and wellness the emphasis is on the occupants. What we put in a space long term, how it wears, and how it is eventually disposed of more directly will always affect the occupants. Also, knowledge of what we are putting into our spaces has been limited material makeup. It is not just important for designers, but also for the users to understand the importance of this knowledge creates a sense of achievement, connection to the planet, connection to our environment- a sense of place and it elevates the environment (whether it is the working environment or the education environment). It is important on multiple levels, I mean sustainability is great and is in all of our awareness but sometimes we forget about how things effect things right here, right now. I think really addressing indoor environmental quality component and how it makes all of us a part of the bigger planet is important for making those two connections.

Q: How do you think LCA could or should be integrated into practice and at what point?

MM: It should be like the basics of the code analysis and preliminary LEED checklist, all the things that we do early on in design process when we are considering what we are going to do. There should be an element of accounting for that in the schematic phase or pre-planning phase, and setting the standards for multiple, future projects. The best place for this is for any company to make it part of how they do things from the get-go, before there is even a project (schematic, design development, renders etc). We are looking specifically at the interiors, the finishes. A lot of times interiors virtually gets brought in at design development and is not even part of the process. That is why the integrated project delivery process and having the entire team on board early on is going to be necessary to really implement LCA in any way that's not overbearing or difficult so that it ends up being useful.

NK: You think a database would be helpful in these situations?

MM: Yes, I believe there are several databases, this year at NEOCON; they called out several different ones. Even at Greenbuild there is the healthy materials, the Mindful Materials, the origins database, there are several of databases that are tracking all the different types of certifications and materials. There is a big push in the industry to have one coordinated database and in looking at LCA and how it's being addressed in building codes; we start to look at it as a whole building thing, not just the finishes. I think we still need a lot more education. A lot of resources are there, but if you are not sure what it means and how to use them or even why you are searching them, it cannot succeed.

NK: With my research, I'm noticing that if you do an initial carbon calculation for the furniture and finishes (F/F), there does not seem to be a huge impact at install, but when you consider the amount of time the building lasts, and then calculate the F/F, after five to fifteen years it adds up and is more significant than the impact of the building.

MM: The problem with that is a lot of times the design team is on a tight schedule, which is why it is important to be part of not just the integrated process but having a strategic plan. Educating our clients and working with the facilities team is a strategy we can put into place. The companies that we are working with and the clients themselves are usually thinking about replacement and cleaning. It has been mind boggling on the educational side, doing the public projects where a lot of sustainability things get dismissed because of first cost. If you are looking at a full life cycle, then what is it going to look like at 5 or 10 years? A lot of the interiors don't go beyond 10 years. Somehow that whole process needs to be part of the consideration of the design team. A lot of times you can bring things up and they may not want to have that conversation. Difference being, healthcare environments, they do look at that and evidence-based design, but a lot of other branches of the industry do not, unless it's big part of their company culture. They will dismiss the conversation. I think that's where the biggest problem is.

Q: What are the barriers to making LCA a design criterion, a principle or standard by which something can be decided now?

MM: It is the lack of understanding education and policy. The only way you can implement anything globally is by making it a rule. Education is important and not just within the industry, but with public education, that is what happened with LEED and sustainability. We had it way before the green building codes. There was a lot of promotion to the public and there was a level of demand that appeared from only a relatively few companies that had high goals. Then it was publicized, and people got educated about it. We really need to educate not just the clients but the users to know what the advantages are. The way it just, the fact that we always use the acronym and when you look it up, you know, there's the ISO 14040, I am fairly versed on the topic, but even when I read it I feel it is slightly glazing over how it's approached. We need to break down complexity and use info graphic; like Annie Leonard's "The Story of Stuff" which had a great impact, it is great that things have more of a scientific basis now, and not just looking at what someone's values I am going for in a project. We need to break it down in a way that most of us can relate to. There needs to be more resources supporting how I can easily explain it to clients, how I can present it to the users so that it is not a bunch of numbers. There should be a YouTube video that breaks it down. It is really very scientific. It is about our health, our environment, and we are not presenting it in that way. That is the main barrier/limitation. If there is awareness, then there comes a public push, and eventually it can become part of the regulations. When you do not explain things well now, building codes will not improve understanding. For instance, it is hard to understand how codes contribute to well- being, etc. We do not want LCA to be something that people dread.

Q: What does the new 2019 code that takes effect January 1st, 2020 require relative to LCA?

MM: I had to look this up. It is an elective in a nonresidential section. I did see that there is a section in both required and voluntary measures in both residential and nonresidential. There is a note that this is what we are going to be doing in the future with more things to come. Keep that in mind, the newest California energy code is a big change (beyond LEED), there was a big push to do it and then we had to postpone it for actually six months because it wasn't ready. It does take a long time for the original way it was presented. I am sure the legislature will take a long time. Next three years into the tiers, six years non-residential, who knows if the public starts connecting it to health outcomes and how we effect the environment, there might be demands to do it sooner. I think for LCA there are a lot of different ways you can do this. So, what is the right way? There are 7 different focuses (all regarding sustainability) there are different effects/parts and how do we even (in the LCA documentation) look for different things if they are broken down into separate categories. The interior parts (finishes and furniture) that is an added consideration. The baseline is building materials. That has been the precedent for net zero etc. When LCA began to emerge it was around the same time of the EPD's Environmental Product Declaration and HPD's Health Product Declaration and I think they were easier to understand with a particular focus and LCA data was off to the side. How can they all come together? We should not have to have more standard regulation.

NK: They are often average data, not consistently based.

MM: We still are lacking the basic knowledge of cracking how to look at the data and how to even look at that for it to be useful. A database can only solve those criteria for which it is organized. This is another big problem with the code and international green act/structure codes and building codes. It was a big topic at the 2018 Greenbuild. We have ASHRAE; we had the CALGreen and building codes (multiple documents). They have been trying to integrate the green building code and ASHRAE all in one place, but it should be an extra thing. We don't have time to double check the CALGreen checklist. The architect needs to sign that they checked it. There is very little checking on what's new, some of the building departments will do it some wont. These need to become part of the building codes, so when we're looking at different aspects of the building code, these elements already built in. Obviously, the energy codes go elsewhere, since we have the interior environment that should be in the environmental chapter.

NK: If that happens, that means the whole United States will have to comply, right?

MM: Yes, but then again the California uniform Building Code (2001) was still on the old cycles it was a standard, over 10 years ago. But we are thinking about these things on separate tracks. The Building Code was a small book now we have a shelf full of many books. We need to simplify to find a simpler way of understanding. That is the big problem.

Q: What do you think we need to see in future codes to support LCA for interiors?

MM: We need to start building it into the criteria that the interior designers actually look at. We have the interior finishes, the interior environments and interiors finishes sections are both really tiny, and the finishes section does not talk about sustainability at all. It talks about fire spread and those are things we know how to look up on the check list. There is no reason that we could not require EPD's and HPD's in the same section. I remember telling an interior designer about the checklist of requirements for materials in CALGreen. We needed to fill it out. She did not know it was there because we do not focus on that. It is not really referred to us. Also, at a minimum there needs to be cross referencing.

Q: How would one incorporate LCA into codes? Do you know?

MM: Well, every time a new code comes out, there are public meetings and hearings. They have a call for comment, a discussion. There is a public process. Finding the time to participate and act, takes a group of people and perseverance to be heard.

NK: Are there other interior designers that feel this way? Do we have enough designers to make a difference, if we asked for signatures?

MM: Well, I do know that every interior designer cares about the wellness and health of the occupants and wants to learn more about it. Whenever we look at materials, we want to know the process, we are talking about HPD's and EPD's, easily now, but LCA data is not part of that conversation yet. It needs a promotional campaign that is easy to understand. Here in the bay area, most designers are passionate and in the field to create healthy, user-friendly spaces for their occupants. There are very few people in our industry who do not take into consideration sustainability. The willingness is there. How do we approach it? Classes are one way. Do you have enough information; do you know how to apply it to the project? There is a bid educational component. One of the fist places we should be taking this is to design schools. They usually have extra passion on their hands.

Q: Would it help you to see the LCA impact of your furniture and finish choices while you were in the design development phase?

MM: Yes. Finishes and furniture are such a small budget/percentage and should be looked at early as possible. People think about first costs before anything else, even though potential impact of finishes and furniture on the occupants is much greater than what is inside of the walls. Better to start early. Finishes often get taken out later on due to the large building cost.

NK: Do you think we could hold manufacturers responsible for LCA impacts?

MM: There are many places that do that. Interface has the biggest and best public campaign. They get used as an example. It is a big part of the company's values and culture. It is now in the public domain, which is why we know about it. We need better public relations (PR).

Q: What would the ideal LCA software require as input and provide us output?

MM: That is going on the technical side. We do have preliminary ideas. We could start with the type of material or the manufacturer's, put in parameters, and then get options based on criteria. There are so many criteria. Also you can look at LCA from different standpoints, most important criteria, and it should be in a database. Designers tend to go to the manufacturers that have user-friendly websites and who have knowledgeable and readily available reps. Even if there's a better product out there, it's too difficult to figure it out, there's just not enough time. I think that should be a basic customer service component, whether the software is offered or not.

NK: Would it be helpful to have a plugin in Revit or would it be helpful to have this option on the manufacturer's website?

MM: Website would be better. Right now, it needs an external thing and has a plug in as a next step.

Q: Is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

MM: I think we need to explain things better. The "why" is still not commonly understood. We need to have a connection and understand how it connects to our values, starting with the design community. IIDA or AIA are good at educating professionals. I do not know how effective that would be.

Denise Tom-Sera, IIDA, LEED AP BD+C, EDAC, CEAS

Senior Interior Designer, Associate at Hawley Peterson Snyder

As an Associate and Senior Interior Designer with Hawley Peterson Snyder, Ms. Tom-Sera has extensive involvement in visioning, planning, and designing healthcare, workplace, and community projects. She views each new project as an opportunity to see the world through a new set of eyes.

Her educational background in Design and Kinesiology (science of human movement) is combined with over 25 years of commercial design experience, with projects ranging from boutique scale to 700,000 square feet.

Her creative problem-solving approach is based on a deep dive into the client's core values, culture, and ways of working – not on a prescribed style. Her unique approach to visioning strives to ensure that the people using the space are recognized and celebrated.

Written responses provided by Denise Tom-Sera:

Q: Being an interior designer who is passionate about integrating great design and sustainability to promote health and wellness for occupants, what is LCA's place in that equation?

DTS: Everyone is challenged by deadlines and limited project fee, so an easy-to-use LCA tool can help with research and evaluation and ultimately smart selections.

This has the potential to become the go-to tool for designers, as the starting point on every project, large or small.

Q: At which point in your design process are finish and furniture decisions made and more or less set?

DTS:

Finish Material Decisions:

Conceptual Design: Based on the design concept and use, broad categories of materials (i.e., carpet, resilient flooring, tile) are established.

Schematic Design: Based on research and evaluation, multiple preliminary selections are made. This is when the LCA tool would come in, with selection criteria including sustainability, aesthetics, performance, maintenance, pricing, schedule, and other factors.

Design Development: Final selections are made.

Furniture Decisions:

Furniture decisions are typically made later, and are based on the established design concept, the use, and finalized Finish Material selections.

Conceptual and Schematic Design: Fabrics and furniture finishes are presented alongside finish materials for concept, preliminary look and feel only.

Design Development: Start process of research, selecting options, and finalizing selections.

Q: How do you think LCA should or could be integrated into practice and at what point?

DTS: Early Schematic Design. But LCA should be in our consciousness from the beginning.

Q: What are the barriers to making LCA a design criterion, a principle, or standard by which something can be decided?

DTS: Designers want to do the right thing, but for reasons of time, fee, or lack of resources or knowledge, are not always able to bridge the gap to sustainable solutions.

When fee doesn't support the amount of research needed, people often resort to specifying a product they've used before. Or a decision may be made based on appearance only, pricing, or availability, without balancing all the other factors.

Sometimes an organization's established design standards may include products that fall below our target levels of excellence.

Q5: Can you think of any solutions to those barriers?

DTS: Having quick, easy-to-use LCA tools. If it's not easy and fast to use, people won't use it. This should be backed up with a comprehensive database.

This would help not only with product selections, but also with educating the client about the best solutions. Having a clear tool with environmental comparisons, pricing, and availability could be a helpful conversation-starter when working with organizations that have established standards with lower sustainability levels.

In developing the LCA tool, start by identifying which items have the greatest environmental impact. Focus on these items first, and choose one item to use as a model or test case.

Start with materials that every project uses, and materials that have many options for different types. For example,

Flooring categories: carpet, resilient flooring, hard flooring

Furniture

This is tricky because furnishings are often assemblies of different materials, which often can't be easily separated or measured. Again, start with the things that are included in most projects.

Systems furniture – workspace (But beware. Lots of moving parts and elements.)

Ancillary furniture – task chair

Q: Would it help you to see the LCA impact of the furniture and finish choices you are making while you were in the design phase?

DTS: Yes, it would be most helpful early in the design phase.

Q: What would the ideal LCA software require as input (data) and provide as output information?

Input:

In our office we have developed a Finish Material Evaluation matrix to help in selecting the best products for our clients. People outside the industry may think that the beauty, trendiness, or cool factor is the main reason to select a material.

But in addition to aesthetics and connection to the design story, we have identified over twenty criteria that we consider. This includes the basics of budget and schedule, plus scrutiny of performance and sustainability factors. Many of these selection criteria could be added to the input side of the LCA software.

We can learn a lot from previous studies such as "Life Cycle Assessment of Flooring Materials", Dovetail Partners Inc. 2009. The study also credited Building for Energy and Environmental Sustainability (BEES) as being a one-stop source of life cycle assessment information about flooring options and the most comprehensive resource available at the time of their study.

I was floored by the breathtaking amount of investigation these organizations have done in order to get the measurable inputs for the Life Cycle Inventory. This included items involved in product manufacturing, and all stages in production, transportation, use, maintenance, and end-of-life disposal. Moving forward we could enlist the deep resources of major manufacturers to help in the process, as the outcome could be useful to them as a competitive marketing tool.

Output:

Again, the emphasis should be on simplicity of use and minimal time to implement. This should be as easy as researching and buying something on Amazon.

I like the idea of a summary scorecard for each product that has different levels of information, from very simple, big picture (one overall score) to detailed (scores and information for each category). This would make it easier to compare manufacturers, apples to apples.

Q: I believe when we hear about others passions we get inspired to do things, what is your personal drive for doing this work?

DTS: I think about the paradises that have been turned into receptacles of our junk, and the microscopic levels that have gotten into the food stream. I think about the youth and next generations who inherited this situation.

It's easy to get overwhelmed or feel like the problem is so big, we should just hide in bed and stay there. We don't want people to feel so discouraged that they do nothing. How can we educate and inspire people?

I think there are small, consistent practices that people can incorporate into their daily lives, small changes that collectively can create a tsunami of change.

If you're asking, "What are the top three things I can do? Or what is the top one thing I can do today?" You can use the proposed LCA tool in your daily practice. And it will make a difference.

Let's make it easy for people to do the right thing.

Eden Brukman, RA, LEED Fellow

Senior Green Building Coordinator at San Francisco Department of the Environment

Eden Brukman is the Senior Green Building Coordinator at San Francisco Department of the Environment. Since 1996, Eden has focused on establishing socially and environmentally responsible solutions for human habitat: she coauthored Living Building Challenge and directed its evolution and global deployment from 2007-2012; served as the first Technical Director of the Health Product Declaration Collaborative; and contributed to the early development of other programs such as Declare, the Pharos Project, and EcoDistricts. Eden was a recipient of the Buckminster Fuller Challenge award and was designated one of the Forty Under 40 in Portland, Oregon, as well as a Living Building Hero by the International Living Future Institute. Also licensed architect, Eden's advocacy efforts have led to policy reform, decentralized building and community developments, and the creation of a network of local action groups in cities all over the world.

Q: How does one develop a new policy?

EB: Coming from startup, nonprofit advocacy organizations, you do a lot of engagement. That's one of the reasons [I was hired here]. When you are excited about something, it's really hard for other people not to catch the energy, even if they are [thinking] what does this mean for my bottom line?

One of the first questions that came up as we started working toward a building electrification policy for municipal new construction and major renovations was what does this mean for affordable housing - even though affordable housing is not municipal. We are also doing a parallel requirement around private development, which is 'electric preferred' for now, but we expect will eventually eliminate natural gas for any new construction. We organized with the Mayor's Office of Housing and Community Development, a half day workshop, looking at affordable housing projects in San Francisco because there are a half a dozen of them going all-electric for reasons of efficiency, user experience, and cost savings. We are not just trying to make people aware of those projects specifically, it is a great education opportunity generally.

I also facilitate the Municipal Green Building Task Force, which is an advisory body that provides guidance for any updates to Environment Code Chapter 7: Green Building Requirements for City Buildings. We had 6-7 meetings about the municipal electrification policy and they had great ideas about tweaks to the definition or ways we should be thinking about how we deal with this issue. There were really good questions and we really drew on the fact that we are very lucky in the Bay Area to have so many industry experts here. The Task Force is an education forum, and our monthly meetings are open to the public. I brought in regional experts to teach and share. If someone had a white paper, I forwarded it to all the members. If other organizations did a free workshop, I let people know. Then I created a folder of resources, like a library. I did what I could to make sure that the Task Force members felt comfortable and aware of the information. Once we got to a point where we had to draft [the policy], a member of the Board of Supervisors or the Mayor's office must sponsor the ordinance. Vallie Brown was the initial sponsor of the municipal policy, and Rafeal Mandelman is sponsoring the one for private development, Aaron Peskin is a co-sponsor. The document also has to be reviewed by our City Attorney for legal language and legibility and to make sure that we don't have complications legally.

NK: Has it been easier to get things approved with Mayor London Breed?

EB: We do frame possible actions based on the Mayor's interests and demonstrate how this work can further her priorities and commitments we have made as a city. The Mayor's office has a Senior Advisor on the Environment and we work very closely with him, especially over this last year as we developed the municipal electrification ordinance. He came to some of our senior leadership meetings with different departments. We had political will, the people of San Francisco care about this topic. They care about climate change and what we can do to mitigate it. They are very passionate. The municipal electrification ordinance happened independent of the declaration of the climate emergency, which just raised more awareness about why this was so important to do.
We are about to start a similar policy process with embodied carbon for municipal projects only.

We're not doing anything related in the private sector right now, but the idea is that it will start as a municipal requirement and eventually, it can get integrated into the SFGBC (San Francisco Green Building Code). We like for municipal projects to lead by example.

Q: In your experience, are policies effective in addressing climate change issues? (Does this help get people to take action?)

EB: They can be, yes. It can have an impact. At the very least it raises awareness. I've been asked, "Can you just create policy?" People often comment there is a difference between "nice to have" and "have to have". For example, let us say one developer company or architecture firm knows something is the right thing to do, but right now it adds to the bottom line because it is voluntary. If they choose to do it and their competitors don't, now there's an imbalance. The approach to the calculation changes if it is law.

In some cases the barrier is a learning curve or new software or just an additional conversation, and other times it is money. Access to solutions for any of those things could potentially become a positive differentiator that helps a company find like-minded clients. If it becomes code, they then have a much better potential to get the initial broad market share, so it can be worth being an early adopter.

NK: That is why I am trying to see how I can help others see the importance of why they need this and why the earth needs this. When speaking to other experts and gaining knowledge on my own, everything points to policy.

EB: It's one of the reasons why I eventually made the move to policy. I started as an architect doing design and trying to bring in as much as I could into one project at a time. Then I created an in-house consulting unit for LEED and other sustainability goals. I was working on two to three dozen projects at a time. But I felt like I was not making the impact I wanted. The reason I made [the next] shift was that I felt like I could not make responsible or accountable decisions with the rapidly shrinking, design phases and accelerated construction schedules: it is difficult to make necessary changes when concrete foundations are being poured before you've even finished design development. These are real problems for the building industry. Then Revit was coming in. It is a great tool, but people were using it as a senior designer instead of a coordination tool, which is what it was meant to be. All this created a perfect storm for me to say "I need a better toolkit." That is when I left, to create better tools.

NK: Is there any software that you would recommend other than Revit?

EB: Oh, no, it's not that Revit is a problem. It is a great tool. In a few hours, you can have an entire building drawn with windows and doors and a complete diagram. It doesn't necessarily mean things are in the right place or the right proportion or [that it reflects] thoughtfulness to the project's program needs. It just means that you have no errors in your model. I was seeing instances in firms where they were saying "I designed it in three hours on a Saturday, now we are going to move into DD." I started at a high design firm, I was very lucky to have that experience. My first paid job was on the Getty Center, working for Richard Meier, where a 16th of an inch mattered. To see the impacts of that shift to a curtailed schematic design phase made me very concerned about how we were moving too fast. We are not paying close enough attention because it looks deceptively complete. Liability is also a 'fear factor'. We are not necessarily going to use new products, new processes, new calculations, or be open to new ideas when there may not be the time to do it right and so much is riding on every decision. Until we fix that foundational level of awareness, we are just going to perpetuate this process indefinitely.

That is why I left practice, to make tools to support more informed and intentional decision-making. Ultimately, I was able to scale my impact: influencing hundreds of projects at a time with Living Building Challenge, and thousands of projects at a time with the Health Product Declaration. With policy, there is an opportunity to impact millions of people. What happens in San Francisco has influence locally, regionally, throughout the state, and on other cities globally. In part, this is because city staff collaborate through our networks like C40 [Cities Climate Leadership Group] and CNCA [Carbon Neutral Cities Alliance]. We learn from each other. That is one of the reasons I wanted to work in local government. A city is very complex and also an optimal framework for implementation, there is tremendous opportunity for scalable impact.

The San Francisco Department of the Environment's really special because it is a government agency, but it has a nonprofit ethos, and is mission-driven. The Department does not receive general funds. We operate on grants, on work orders from other departments to help implement policies that we have created. We get a small amount from the impound fees for curbside collection of compost and recyclables. But whereas most nonprofit's output is *outreach, education, and advocacy*, we do *outreach, education, and policy*. I think it's pretty rare to have that set up.

Q: Have you worked on any policies? If so, which ones?

EB: The electrification policy is the first one that I have worked on from the start. I only have been with the Department for two years. We have worked on this policy for about a year and a half. The team was working on it before I came in, of course, with studies etc. Currently I am working on the Chapter Seven update [of San Francisco's Environmental Code] to include embodied carbon and a few other things. That is just getting started and we will be working on it through next year. I am contributing some to policies related to building materials management, considering options for reducing lifecycle impacts, especially end of life. I also worked on the carpet regulation that we passed in March 2018. I offered feedback on it as a private consultant and then, when I came to the city, I helped finalize it. It was a two-year process to create probably the world's most stringent carpet regulation. Keep in mind, our carpet ordinance stemmed from our sustainable purchasing and pollution prevention policies and Chapter Five of the Environment Code, [which calls for] no PVC.

NK: Is there any carpet manufacturer that is happy with what you are doing?

EB: We worked with eight major carpet manufacturers over a two-year process. Being that the regulation applies to city government purchases, there have to be at least two compliant manufacturers. You cannot create a requirement that does not have opportunity in the current market. We had three to start; now there are four. A couple other companies have now said they are taking steps to comply. This policy has transparency requirements and includes chemicals of concern that go beyond what is currently tracked in Cradle to Cradle Certified v3.1, which is also part of the regulation.

NK: What are you targeting?

EB: PFAS is one class of chemicals on the list. There are fluorinated compounds used for stain and water resistance, but are not very effective and really never break down. It is highly toxic to humans and the environment. Antimicrobials are another class that is red listed; these are also toxic and ineffective. We also targeted Styrene-butadiene, fly ash, and PVC, which all can be found in carpet backing.

NK: Fly ash, can we talk about that more?

EB: Yes, let us talk about this. It is a soapbox for me when it comes to embodied carbon. So, here's the thing. Fly ash has lower embodied carbon than cement. But fly ash is a byproduct of a heavily carbon intensive process to generate a transitional fossil fuel. It is not the be all and end all [solution]. It is just a little less-worse than our current option.

One of the things I've been talking with other cities about is trying to band together around supply and demand issues. We need to rally for innovation in this space so that we do not say putting slag (which is a byproduct of steel process also highly carbon intensive) is the ultimate solution. It is a little different than fly ash because we're going to continue to use steel in buildings, but we are not always going to have coal. We already know that it is a transitional fuel source. We need to really push for innovation to eliminate our dependency on it. There are a few folks, such as Blue Planet LTD and CarbonCure Technologies Inc, that are trying different processes for reducing the embodied carbon of concrete through means other than fly ash and we need to find better opportunities, but then sometimes the best concrete is a different material altogether.

NK: Yeah. What about compacted earth?

EB: I'm a big fan, but there are a lot of restrictions with that.

Q: As a nationally recognized leader, in sustainability with the commitment to doing right by the environment, what do you see the key strategies are for bridging practice and designers to LCA for interiors?

EB: Yes, this is something that we are also really focusing on because in the city of San Francisco, while the impact of embodied carbon from structural materials is certainly an issue, there are also a lot of tenant improvements (TI). San Francisco has a lot of startups and class A offices so it is common for there to be short-term leases with turnover and more frequent refreshes in spaces, too.

NK: It is every five years?

EB: It can be even faster than that. This is what we're learning. We also have a lot of restaurants and retail, which have similar challenges. So those are key sectors we're targeting to understand tenant improvement patterns and impacts. We are in the early days of conversations with these folks and hope to follow projects to learn more about the material flows.

NK: If you take interiors and compare it against the building's life cycle, let's say 60 years, interiors are getting changed out faster and more often.

EB: Yeah. I heard recently from one designer that they did an LCA on an interior and the paint had as much of an embodied carbon impact (just the first application of the paint) as the wallboard. Paint is going to get applied like every five to fifteen years or maybe even every time there is a scratch on the wall.

EB: I don't know if you have talked with Kirsten Ritchie yet?

NK: Not yet, I did email her.

EB: Okay. I will show you a slide that she has circulated on this topic, which I think is a really great example of a visual aid to help people understand. I think visual aids for LCA help with understanding such an abstract concept.

I used to resist using carbon as a metric because it isn't native for us. For example, how much carbon is in that cup of coffee? You could tell me how much it costs. You could tell me a dollar value. You could tell me how many beans. But it is unlikely that you could tell me the emissions related to its extraction or manufacture or transportation because it is another language. Until we start quantifying carbon in a way that people understand they won't grasp the issue. I'm not saying it has to come back to a dollar value. I would like for us to not always have it come back to a dollar value. If we could bring it back to a social equity issue or other things that people care about, that becomes a compelling rationale for change as well as a storytelling mechanism. To show what the real impacts are and how they translate to something tangible, visualizations are really important. This also goes back to the first step of admitting we have a problem. How do we do that? We measure it. LCA is not perfect. It may not be comprehensive or accurate, but it can be consistent. As long as we have something consistent to measure against, even though with embodied carbon [a baseline is elusive]. When I taught, I used to call it 'concentric circles of guilt and shame'...

NK: Where did you teach?

EB: I taught in the National Sustainable Building Advisor Program and have been a guest lecturer at about dozen universities along the Pacific coast. The reason I call it 'concentric circles of guilt and shame' is to emphasize carbon scope and boundaries. [For instance,] this pen has its plastic casing, it has this metal piece, that metal piece, and it has the ink. Okay, those are four different materials. Let us just ignore the plastic inside, etc. Let's just talk about four things. That is four circles, four nuclei, each one of those has its own scope one, scope two, and scope three influences, but who is responsible for paying for the embodied carbon cost of the meal that a worker ate in order to assemble this pen? We have to draw boundaries. How much do we decide we are accountable for to say that we have fully addressed an embodied carbon impact? That is why it is not going to be comprehensive. But we could say, let us just focus on the four main pieces of this pen and overlay the direct impacts from extraction, manufacture, and transportation. So that is what we're going to measure and be accountable for, now we can track it and be consistent to track reductions. People need to understand the extent of the equation.

Now that I'm starting to explore policy options related to embodied carbon, I feel we need to make it clear that there is a broad landscape. There are some materials that are getting called out as the poster children of embodied carbon, whether it is through the Clean Air Act or The Carbon Smart Materials Palette or County of Marin's Low Carbon Concrete Project. There is a potential of inadvertently creating a parallel for embodied carbon that we did for energy efficiency: Some people feel that because they've installed LED light bulbs, they are now done with energy efficiency. So it is okay to ignore other impacts, like having the AC on with the window open, and keeping all the lights on because well, they're LEDs and that's what people understood energy efficiency to be. If we do a single material intervention and do not really explain the context for it, my fear is that we will make a dent but we are not going to get to where we need to go because there isn't a foundational understanding or push for behavior change.

Then there is the rebound effect now that there is more energy coming from renewable sources. [The thinking is] if we're going all electric and it's all coming from renewable energy, then we do not have to worry about efficiency anymore. I cannot tell you how many times I heard that last year. You can imagine that for embodied carbon, the repercussions could be that much worse, especially if you're talking about a TI scenario where you have a short-term lease, like a two- or a five-year lease. In one case, I heard that a company who had a seven-year lease did a refresh mid-way and then had to bring it back to a warm lit shell when they left – That is three TIs in seven years. The period that the ECN report talks about per TI is a 15-year cycle. I've also heard about a high-end tenant in a class A office space that moved to another floor in their building and brought all new things in because they thought their office needed a refresh to meet client expectations. This is what we're dealing with.

NK: This brings up a question, what if we leased things.

EB: So that is a model that we have been talking about with C40 (Cities Climate Leadership Group) Clean Construction work group. Some products are moving to service models, like lamps and elevators. You do not buy the elevator; you buy the number of trips it takes. For some equipment on job sites, we are seeing more as rentals instead of purchase. If we can change availability at the rental level, then we can change what is available more broadly potentially. We are seeing that 'rent the runway' idea in the building industry.

NK: I don't want to put these furniture companies out of business but there has to be a better way.

EB: Someone you can talk to is Teknion, they do systems furniture. They have a program called ANEW. They have partnered with a global company, CSR EcoSolutions, that donates liquidates, and recycles unwanted furnishings. Teknion works with prospective clients and they say it doesn't matter if you want Teknion furniture or not. If someone would like to get rid of furniture, Teknion will come in and inventory it so that it can be donated, liquidated, or recycled.

NK: They are doing what carpet manufacturers are currently doing.

EB: Yes, though they are bringing it to nonprofits or schools for reuse instead of going just to recycling. The products can have second and third life potential. There is another company here who you should probably talk to about interiors called GCI. They are a construction company who has a lot of focus on interiors. They are usually the interior contractor. If you have a large developer that is doing core and shell for a condominium project or an office based project, they will then come in and do the interior construction fit out. They were noticing the degree of churn and furnishing disposal so two years ago they created a daughter company called Madrone. They come in and inventory the materials [and look for a new home for them]. They have created a network of several hundred nonprofits and education organizations, and instead of driving those things to the landfill, they take the products and do a series of drop-offs. They are keeping the entire product out of the landfill. Sometimes products are new or barely used and this is giving it a real opportunity to have another life. To me, that is a priority move for embodied carbon mitigation. It may not be as obvious as starting with manufacturing, but even more impactful if we need to curb carbon.

In 2018, San Francisco led the drafting of a commitment with C40 for the Global Climate Action Summit called the Advancing Towards Zero Waste Declaration. About two dozen other cities signed on. Its goal is by 2030 to reduce consumption by 15% and disposal to landfill or incineration by 50%. That first part is about generating less stuff, or

just buying less. To me that is why material reuse is such a big part of embodied carbon. We cannot just focus on optimizing the manufacturing of new products. We have to focus on how long we can keep something in circulation. Once you spend that carbon, it is in the atmosphere. So now it is about not needing to create more, I mean, businesses who are championing this concept are not necessarily suffering. Look at what Patagonia's doing with their Worn Wear program.

This is not new, but there needs to be a simple way to inventory and track available materials. That is where material passports come in. The EU is really leading in this. I don't know if you are familiar with BAMB (Buildings As Material Banks) initiative out of the EU. They just finished their first three-year process. The idea is materials retain their value once installed. They could be “deposited” into a building and removed later when they no longer serve their intended purpose. They [could retain] value or possibly even increase in value over time. Material Passports, like a chain of custody for FSC, can track the history of that material or product, how it was installed, how it was made. What if you knew that the door had a certain rating and had a certain core and a certain finish or certain hardware inside? Then you could actually reuse it much more easily.

We are exploring ways to change upstream practices to make material reuse more viable. How do we create new markets? How do we get rid of some of the roadblocks? How do we get people to even have their first thought be about reuse and assuage any fears of a legal liability tied to reuse? There is a lot to deal with, but to me that is the biggest thing we can do – use what we have. Yesterday in my embodied carbon policy presentation, I showed a slide that overlays several options for reuse and urban mining over the traditional lifecycle phases. We cannot just write a policy saying you have to reuse materials. We have to think about unintended consequences. Like the IRS is threatening to shut down the opportunity to claim a tax deduction on donated materials because of the amount of fraud for misrepresenting the fair market value of those materials. If we eliminate something that could be an incentive to help cover some costs to mine those materials, we're not helping ourselves. Yet, I cannot write a policy without considering ways it may influence the potential for fraud, either. There will always be things we don't know until we go in, but we have to account for the things we do know so we don’t end up with a bad policy. We have to do the best we can so we do not have as many of those unintended consequences and really lift up the industry and ourselves as a society.

NK: What is a good direction to start for designers?

EB: I'm advocating for whole project LCA. Start with a narrative that asks a broad question so it can be applicable to the scope of every project. How are we going to understand a little bit more about embodied carbon impacts? If you're doing a small TI, that has predominantly paint, wallboard, and carpet, look for EPDs and compare the document findings.

Do the whole project LCA and at the end check your work. Were any changes made? What was learned from this process? What can be done on the next project? I don't think we are good at this yet. Ultimately, I'd like to have a maximum CO2e per square foot or something to that effect. But let’s simply start by asking, what are we doing? Do we know what our impacts are?

Though there are some new buildings under construction, the city does predominantly tenant improvement and renovation projects. So if we only required projects to consider the embodied carbon of concrete, these projects wouldn’t be prompted to do anything about embodied carbon.

Q: How does one measure or calculate carbon? Can you tell me a little more about that for someone who's new to this?

EB: That is what EPDs are trying to do. EPDs provide information about a product’s global warming potential and other environmental impacts based on standardized Product Category Rules (PCR). That is what establishes the prompts that go into an Environmental Product Declaration. As you can imagine, not all product categories have rules yet and that's one current limitation of it. There is a lot of advocacy to encourage the development of EPDs for more product categories, it is a LEED credit under the Materials and Resources section. The EC3 tool is [a promising] tool that aggregates information from EPDs for comparison (I don’t know if anyone has talked about it, the Embodied Carbon in Construction Calculator led by Skanska).

NK: Yes, Larry Strain and Lisa Conway told me about it.

EB: Good, it is launching next month (November, 2019). One Click LCA is another tool. They are based out of Europe, but they just released the North American data set this summer. My understanding is that One Click LCA can be effective because you can reference a Revit model. You can do early stage calculations where you just know rough order of magnitude or specific product information when the design is further defined. It is subscription based.

That is another thing I'm trying to balance. I don't want a policy to significantly increase the soft costs of a project or require such specialized knowledge that becomes a barrier to implementation. There must be tools that are available that people know how to use. We are still just trying to figure this out. There are some tools, Tally, Athena, One Click LCA, and people are using all of those. We're in early days of researching how tool availability and ease of use will influence the policy direction.

Q: Existing LCA tools look at building materials, mostly shelling and core, based on a 60-year lifespan. Do you think that is a realistic timeframe for flooring or other interior?

EB: No, I don't think so – not for most interior materials. I've already noted that often interiors aren't installed for even 15 years. But it depends on where you are as well as the owner and user. In San Francisco we have a particular occupancy churn rate. We have to be responsive to that. For municipal buildings, I think we could be fairly safe at 15 years, the basis for the ECN report. Some municipal projects like recreation centers, libraries, police stations, fire stations, they do improvement projects, but they are not likely to change a fire station into a library. You don't have that same degree of disruption or removal of material in maintenance as with adaptive reuse.

Q: How can LCA data for interior products best be incorporated into LCA so that it can be used effectively by designers?

EB: Well that's EC3, in a way. You have got to make it accessible to help people understand what they need to do and then make it easy for them to find the data.

In manufacturing you are going to have varying outcomes over time because of differences in feedstock sourcing or changed processes. It would be ideal to have tools that can react and provide information in real time and help people understand a little bit more of what they are dealing with. They need the tools, the guidance, but they need to be able to know how to use those tools effectively. Just like we talked about earlier with respect to BIM. It is about understanding the context, because if you are trying to balance a carbon budget, materials can have operational carbon impacts as well as embodied carbon impacts and both have to be considered. It's not cut and dry. People need to understand how to apply the information, not just what it is.

Q: What does the new 2019 code that takes effect January 1st, 2020 require relative to LCA and what are San Francisco's related reach goals?

EB: As far as I know, there are not explicit embodied carbon LCA requirements in the 2019 code.

Kirsten Ritchie, PE, LEED AP O+M

Consulting Project Director, Principal at Gensler, San Francisco, CA

Kirsten serves as one of Gensler's leading sustainability ambassadors, championing healthful and forward-thinking design solutions and leading public discussion around innovative and high-performance design and operations. Kirsten's experience encompasses the workplace, retail, hospitality, education, transportation, aviation and infrastructure sectors; and she is a recognized authority in green product standards and sustainability rating systems (including LEED and LBC). She serves on numerous boards and in other advisory positions, including roles with the Material and Technical Advisory Group at USGBC, Board of Directors of the Green Electronics Council, Board of the Ecological Building Network, and as advisor to the Health Product Declaration Collaborative. Kirsten holds a B.S. in Civil Engineering from the University of California, Berkeley, and a M.S. in Civil Engineering from California State University, San Jose.

NK: We are looking into how the growing knowledge base and tools related to LCA and carbon can be utilized more effectively in the interior design process. In other words, what is the most promising bridge between LCA criteria and decision making for interior design practice?

Q: Could you talk about the environmental impacts of design decisions and the impact that using LCA as a decision-making criterion could have?

KR: When you talk about design decisions, design is a big concept. We can focus on the interior side and look at the impacts of design on resource consumption and health, and the other environmental impacts that are associated with that. The idea is to talk to designers saying the number one thing that you really should be doing, a top 10 tip, is to maximize access to daylight and views for occupants. From an energy perspective, if you get a lot of natural light, then you do not have to be running artificial lights, you're saving energy. It is a much healthier environment. We work better and our cognitive abilities are better [with natural light]. We are, in sync from a circadian rhythm perspective. The views give us what we need as natural creatures who want that [connection]. That is the number one thing. What are the things we can do to maximize that? I think that's been a factor in moving to more open plan design, because more people can have much better access to light; versus before when you had private offices and daylight got blocked from the rest of the space.

Then you are looking at how you're designing the space so that you can optimize its ventilation in keeping with its heating and cooling systems. But when it comes to interiors, then you talk about all the stuff that you put in there. We have traditionally been more focused on the health impacts of that stuff, primarily [the potential hazards] associated with what it's emitting, whether it is [absorbed] dermally or volatizing and getting into your lungs. That's been our focus because it is aligned with being concerned about the health impacts. For designers really understanding the importance of the health-related impacts of the materials is very valuable. We are finally recognizing that bigger externalities of the effects of all that stuff that we're putting in [projects]. We are better able to quantify those impacts through lifecycle assessment. We used to use our rubric for determining if something was better overall environmentally – Did it have recycled content? Did it come from an FSC certified forest? Was it a bio-based material? Those are benchmarks or alternatives to being able to do a full life cycle assessment. I think there are certain weaknesses in LCA. For example, LCA basically considers the environmental impact of sticking something in a dump as compost negligible. That was one of the early challenges that we had when we were building the circular and recycled content economy. Was more energy being used to take material, clean it up, and bring it back to the point where it could be used as virgin material again than using actual virgin materials? That is because those [traditional sources of virgin material] had been developed over a hundred plus years. There were real efficiencies in scale of taking that dirty material that came out of the earth and making it nice and clean. There are some things that LCA is finally getting better at, but it still accounts for something that goes into a dump as basically having no impact. Those are the weaknesses. LCA is also very weak on what we call ECOS, the impact of ecosystem services. The value of a plant growing versus an acre of dirt, it is not that great [at accounting for that]. It is very good at being able to quantify what the energy inputs are, what the water inputs

and outputs are, and what the impacts associated with those basic resources are. That part we have gotten really good at, but a lot of this other stuff is still emerging. It really is not a tool that can be used to demonstrate that wood coming from an FSC certified forest is better for you than one that is coming from SFI. It is very good at some of the key metrics: ozone depletion, acidification, smog, and carbon global warming potential. It is very good for that. We really recognize that it is critical and that the impact of taking the carbon out of the ground and sticking it into the atmosphere has significant consequences for life. We have to do a lot more to keep that carbon in the ground and not let it get up in the air. LCA is a great tool to track from a manufacturing process perspective. I think the biggest challenge though, is that it is complex. It's math. How do we make it really easy for designers? They want the green dot. They say, just tell me this is good. I always talk with our librarian and I can find a good green something to say about almost anything. There is a reason to put a green dot on almost anything. You have the scale of that - there are so many different things. From my perspective, I worked many, many years on the recycle contents. Which I think is very important because I do believe that there are impacts of sticking stuff in the dump. I think we should be designing and manufacturing systems to be closed loop. I am concerned about health issues, get formaldehyde out of stuff. Then I am also concerned about the carbon that is going into the atmosphere and so what are we going to do to turn that around? That is all at a bigger level.

Q: How do you and or interior designers at your firm incorporate informed material decision making and when? Please elaborate on the process.

KR: If we really focus on the interior design community, it is highly variable. There are some designers that come at things from a perspective of how they want it to be. First and foremost, they want to design things that are going to work as intended, be good looking, and ideally award winning because it helps build their portfolio. Then there are tiers after that. One of them clearly was from a health and environmental perspective and some of them embrace it wholly and say that is all I'm doing. For others it is on an as demanded basis. There is a big range of clients who really are after it. As we make it easier for people to do the right thing or to select the right materials, the more they will do it. If it is a lot of work and they are under stress, it’s less likely.

If you think about being an interior designer for a hotel, you are specifying in some cases over 10,000 items. It is crazy making because of all the little suites. There is invariably this little difference here and this little difference there. There is all kinds of stuff going on. They are saying, “Kirsten, I’ve got 10,000 items here and I want to do the right thing, but I cannot understand these detailed questions and understand the LCA of those 10,000 items.” And actually, that means they have to understand 20,000 items, because you have to have a comparative baseline. In order to pick and say this one is better, they do not have the bandwidth to do [more research]. So they are typically building relationships with certain manufacturers or producers who they are going to be relying on to help them. It is important for the design esthetic to be good and that it is healthy. I want it to be the best from an environmental perspective. What can you as a manufacturer tell me? They are really relying on the manufacturers as they learn. Eventually they will become better, faster. Things like looking at interior wood products and furniture; we want any wood element to be FSC certified. We also want all carpet to be CRI green label and all the resilient floor needs to be Floor Score certified from the health perspective.

Now the question is what can we do from an LCA perspective? I think that is where we have to really [have a strategy] identified. There are certain material types that there will be a lot of. Some things we know probably have bigger carbon footprints associated with them than others. So we have to focus on the higher impact items first. It is interesting because in some cases those are things that they don't really care about, like what brand of wallboard is used. [Interior Designers] really don't care what gypsum board is used. They are going to care a whole lot about what the finished paint looks like on top of it, but not the wallboard itself. We can set up our standard specifications to prioritize low carbon products and make it easier for them to just then move to market. That helps them a lot. There is that bit of yin and yang for those things that are going into the building that a designer really doesn't care about, but that need to be performing. [Gypsum Board] has to have certain screw strength and its fire rating. I don't really care about the details of the steel stud. I'm going to care a whole lot about what the finish of this carpet looks like and a whole lot about what the finishes on the table look like. We have got to work together on that.

SR: I'm assuming that interior designers have specialties. Is that accurate for a company like Gensler? Somebody does hospitality and that's pretty much all they do, others who do institutional work, and so on. Is that a fair assumption?

KR: Yeah, I mean there are some crossover people who support other things. Traditionally you have designers who specialize in let us say tech space, because it has a different look and feel and in many cases a different supply chain. Then there are others who specialize in professional offices, banks, law offices, etc. They do specialize in those different things and then residential, hospitality, and aviation are other niches that we do a lot of work in.

SR: I can imagine that ultimately people have a comfort zone and go to things that they have used on other projects. Things that they can take forward to new projects based on the palette of materials that goes with their building type. What we are starting to have now is a transition. For example, when computers started appearing in architectural practice, young people were coming in and able to use them, but inexperienced in terms of architecture and design. Meanwhile, experienced professionals didn't know what to do with them. We are at that place with LCA. We need to find a way to integrate these new tools into the process that works well for experienced designers who are making the decisions.

KR: We are, but I do think that we're going to need to provide the short list for them and make it easy. We cannot just give them this. We can do certain things, showing trends and that helps them, but asking them to go in and read an EPD on the different products? That's just not going to happen.

I was part of a panel at Greenbuild with the HBN (Healthy Building Network) collaborative and Interface, but we were talking really from the designer perspective and global health. I don't know if you're aware, but Gensler has launched a cities climate challenge. We want to get greenhouse gases (GHG) out of the built environment. Go on the website and find out all about it. It is all about what are we doing to get it out – both operating the building, as well as the embodied. We are focused right now on building operations, because that's what people are working on. But we are also driving the embodied carbon conversation. 39% of the global GHG emissions are from buildings. 28% are on the operating side, but then there's 11% on the materials and infrastructure. That's the stuff that's going into buildings right now. That's what we're talking about: analysis of embodied carbon or upfront carbon.

We had the opportunity with the renovation of terminal one at SFO to really address this. This is a project where they basically were asking us to increase passenger flow, while improving employee and passenger satisfaction and delight. What are the designers being asked to do? They had to figure out how to make passengers and employees enjoy this and a delight in it more, while increasing revenue and lowering energy and carbon by 50-75% *and* keep the whole thing operating while you're doing all that. This was really the first chance to work on a big project where we were doing whole building LCA. We were actually working with Urban Fabrick on that. They are the ones who are actually doing this and we are using Tally, which is a plug into Revit. We are doing all the design in Revit and then they do some model cleanup. They can take that model and estimate the quantities and add in the default Tally database (which is based on GaBi), to create the baseline calculations.

Then we do the EPD specifying and provide specific recommendations on what the maximum global warming potential can be for the concrete and steel. We start to plug in design data, and we get to the design case (showing slide). You can see, this is a traditional big superstructure-based project, and these are the big impacts, which are concrete and steel. There are still other impacts as you get on to the interior side with glass office fronts, wallboard, which we use a lot of on the interiors. Carpet tile and Trespa are other large quantity items. [Trespa] is a wall-based material that's used a lot, it is very durable. It's used a lot in schools, hospitals, and airports. We have not found an alternative to Trespa yet, so that is why it stays the same.

Overall, we were able to reduce the footprint about 20%. Part of the challenge is also just getting the language right. Talking about a carbon footprint based on EPDs is not straightforward. They do not use the term "carbon footprint". They usually use "global warming potential". If we talk about it expressed as millions of tons of CO2E, people are going to say what is that? We have talk about CO2 reduction. I like the idea of talking about "carbon use intensity" like we do for "energy use intensity". The thing is energy use intensity is always about the operation. Carbon use intensity could be about the carbon of the operating side [and/or the embodied carbon]. What are the

terms and language? I think that's one of the things that we're going to have to deal with. What we also did with this was look at the sustainable return on investment. We used a tool called AutoCASE by Impact Infrastructure and they are developing an online version of it. We have looked at a number of different things to try to show the financial benefits. We were very interested in low-emitting materials. We expected them to cost about $75,000 more for a little bit of extra design research and just giving a little extra cushion on some material costs, but for the most part there were all of these materials that are a result of [now having to comply with] CALGreen. The emissions requirements, which are basically the same as LEED, are primarily associated with getting formaldehyde and the VOC's out. This actually has linkages to improved employee productivity, reduced absenteeism, and improved passenger productivity. We have to think about that. We are putting 17 million people through this space with less exposure to formaldehyde. We are able to quantify and show a benefit cost ratio of 82. Anything over one is great. 82 is huge.

SR: How do you put a dollar value on it?

KR: They have done research on finding out a lot of academic, peer reviewed articles, documents to help quantify all of these different linkages.

SR: That comes out of AutoCASE?

KR: Yeah. That basically reinforces why it is a smart thing to specify low-emitting materials, because you are making the linkage that it is healthy and health links to productivity. It links to attendance. It links to a positive effect on employees and passengers. Then we did the same thing looking at life cycle impact reduction. This was our LCA work saying. We figured we are spending about a hundred thousand dollars more on the analysis, the settings, and the specs to specify these materials. We are expecting that there is no cost differential to get the lower carbon materials. By doing that, we are reducing the carbon emissions about 20% just on the embodied materials. This does not include operating carbon, this is just embodied carbon. We are reducing the impact and generating health savings of almost $13 million. There is such a linkage with carbon and written information on increased asthma caused by longer flowering periods, which creates more pollen in the air and increased waterborne disease, and other health related things linked to carbon. The benefit cost ratio in Life Cycle Impact Reduction of the reduced carbon is 129.17. It's off the charts. Huge.

SR: That 129.17 is not a cost savings?

KR: Yes, it is a global societal benefit.

SR: Then it is not a savings for the owner.

KR: Yes. One of the things it is trying to get beyond is the first cost only conversation. In this case the owner felt that [it was important], but this is where you have it. It's working with the contractor, because the contractor is all about the first cost. It is still pretty eye opening.

SR: It's very impressive.

KR: Right. This is one of the health drivers that we need to address. The other thing is if you don't spec it, you are not going to get it. That is really important. That is the challenge that you have mostly for the interior design. Often things are just spec'd right on the plan. You do not put a lot of the specification language that is in your project manual or the same level of detail on the plans. For example, paint is just going to be called out as Benjamin Moore, etc. You call out some special fabric you are using on something or you have your furniture listed there. You are not going to see it. So, now we have to update our plan specs [with more detail], particularly when you have somebody who is making a substitution and you want them to be sure that the carbon conversation is included in that substitution analysis. That is something that we have to change. Requiring every manufacturer to submit an EPD for their product [isn't practical]. Again, it's just for the large quantity items that it's important. We are not going to have an EPD for a piece of Jane Churchill fabric that is going on a pillow. No. But for the wallboard that's going in 20,000 feet of wall, yes. Those are the things we want to start doing. We are getting better at this by giving the contractor the option to be able to select a product based on its global warming potential information. Typically, this is a public bid, so lowest cost that meets all the criteria is what you normally have to go for. But we

could say that they could actually consider a higher priced product, if you have two products that meet all the other performance requirements, but one has a lower global warming potential. The contractor has the ability to say, well we can use that as a break point. We can say we are going to go with a higher cost item because of it is lower global warming potential. We are getting to the point where we're putting in certain things for concrete and steel that shall not exceed this global warming potential. You are putting in floors and they have to be at least 20% less than national average. The state of California, with its clean program, is starting to get the data because they want to do the same thing. They are doing that for steel and for I think insulation and for a couple other products.

SR: Can you tell us what goes into the spec. You give them the option to have improved numbers on the global warming potential. What are you finding on the contractor's side, do they know what to do with that? How does that look when a contractor does know what to do with it and then it comes back to the design team for submittal review? Is that a different process than just a regular review process?

KR: Hit has to be the same process. It is additional criteria we are looking at. The people who are reviewing the submittal have to understand what they are looking at as they are looking down at the specifications requirements and making sure the product is showing that it meets the standard and is a match. We have had to do a lot of training and educating the project engineers on the contractor side who are the people dealing with those subs. We are providing all the material to educate them on this, and it is a big learning curve.

SR: It is like LEED.

KR: It is, but again, that's why we want to go from big impact to little impact product categories. Really focus on those things that really make a difference or that there is a high quantity of. Some contractors have really good people and turn it [around easily] like BCCI actually has a sustainability team that is totally on top of it. When you get on these big, big, big construction projects, there is a huge number of project engineers and they are always rotating them through. It's a continuum. You have to keep up with these important things, but they are learning as well.

SR: On the design team's side, you do not want your submittals to go through a lot of hands. Ideally it will go through one or two people, who know what they are looking at. What does it look like on the architectural or the interior side? Are they up to speed on what to look for? Does it have to go through another set of hands? How does that work?

KR: No, so that is where we have a little bit of extra oversight. I mean I'm involved on occasion in these questions and Urban Fabric is involved, but we have provided the training for our own interior people so that they know the things that they are looking for. For the most part they know. As long as the contractor is moving through what the sub is bringing in what we've already specified, we're good. It's when the substitution is saying different things. We have had those situations where we specified Armstrong Optima, plant-based, which has the lowest carbon footprint and has the best environmental health profile. They wanted to go with a CertainTeed product. Part of it had to do with their distribution chain and they fought tooth and nail and the airport said, "Okay, you can have your CertainTeed product." So that was a time where we had to raise the flag and say, "Wait a minute. This was a basis of design product." There was just stuff going on the contractor side and we didn't win that one, but the criterion was there, and the airport and the contractor had acknowledged it. That's the tradeoff. We are starting to get more and more.

As you talk about what's going to be helpful to people, to design teams we are starting. I don't know if you have seen the carpet chart? I will show you (slide). This is how we are starting to get more and more information from EPD's out there. We are starting to push stuff. One of the big things we want to make sure is that we are designing projects that do not require the use of jumbo steel members, which can only come from China. Here is an example (slide) of why you want to have a global warming potential marker not to exceed. It is crazy making that (BOF) basic oxygen furnace steel coming out of China has more than three times the global warming potential of equal quality steel coming from Nucor in America.

SR: And the Chinese steel comes in the bigger cross sections?

KR: Yes, and also the smaller ones. Traditionally some of the really big jumbo members would only be manufactured there. Even though we used to manufacture them here in America, we gave that up to China and China's steel is very dirty. No matter how you make it, it's dirty.

SR: And it has to get here.

KR: Actually, transportation is minor. Maybe it might be adding a kilogram, it is not a lot. So that's the other thing. People think so much on the transportation and it does not have that huge of an impact unless you are shipping a Corona marble rush job from Italy on an airplane plane. That might be a little bit different.

SR: So, is the design solution for this based on that knowledge to work with a structural engineer on a lighter weight structure?

KR: We have a couple of structural engineers that are really top-notch on this. MKA is just one of them that we do a lot of work with. Walter B. Moore of Houston is another one. Let's say we want to have a structural perspective, the lowest structure and the lowest carbon. They said, “Okay that means we're going to seek out North American steel.” What that means is that the ginormous jumbo members that you’d need, 120 foot single steel I-beam, [won’t be possible]. We're not going to do that, because we can't really get that here. We can have the same look and feel, but we're just going to truss it and experiment by doing different things. That is how, from early on, it is not necessarily a lighter weight structure, but it's the different fabrication or way you design it that matters. The value of having somebody that's totally on top of that on the structural side is really important. From a concrete and steel perspective on the structure, you want the structural engineer to be that because again, liability. The client can come and say, I would like to have this as low carbon as possible, but I still have to have it meet code or perform beyond code, have higher earthquake resilience, and that sort of thing.

SR: There is also a certain implied level of understanding on the architectural design side.

KR: They would still rely on their structural engineer for the most part. We are telling them what we want and exposing them to these things. What also is really interesting is coming into the whole CLT (cross laminated timber) design. Now, it is not net zero. Everybody thinks it must be because it is wood. No. There is a lot of energy that is used in veneering all that wood and then all the pieces that are glued together. For the most part, it is less than steel. If you look at Nucor, Nucor is running all on electric arc, so it's just using electricity. It's not using coal directly. They are sourcing their power from greenhouse gas free hydro.

NK: both companies, North America and Europe?

KR: European plants and some of their North American plants, but not all. That is why they are still showing a higher footprint. They go to using recycled old automobiles because electric arc furnaces can handle a lot of recycled content. Typically 99% of the steel that goes into those is recycled content. Combined with the clean energy, clean electricity; they are reducing the carbon footprint of their steel (slide). Then we bring it to local projects. This is where you take baseline design and get a bunch of information and five pages of Excel spreadsheet behind this that no designer will ever use.

NK: I would like to look at it.

KR: I can show it to you. We have baseline materials that we specified. We can see that big improvement in the carpet, which is an Interface glass back product, and some big savings in wallboard. We did not get the savings we thought we were going to get in steel and it was interesting because the actual manufacturer that we ended up using has a higher footprint than the North American average. You are going to have some that are higher and some that are lower. Just being aware of that and the fact that paint has a footprint, that to me really said it and then I realized paint itself is a polymer. It's plastic. It's going to have a carbon footprint. Any of these plastics now have carbon. Same thing with insulation and glass looking at the differences between laminated and tempered glass. It can make a difference where it's manufactured more in terms of what the electricity source for the ovens is. Are they using more gas? Are they using clean electricity in the tempering process? That makes a big difference as well. This is where people say give me a short list of things (slide).

This was a study that we did a few years ago. It really is looking at carpet tile, all based on a 20 to 25 ounce square yard face weight for a square meter of carpet and just cradle to gate impact. They all have basically the same warranty period, but it was really amazing that you have in essence this five times differential between, Interface glass back which is a PVC based high recycled content product and Mohawks super Uber LBC pedal product. It's because [the Mohawk product is made of] virgin polymer out of concern about a little tiny bit of contamination [associated with] using recycle content. Well, that's wrong. Then there is the whole big PVC issue, and again that's one of my things, it's not PVC that's the problem. It's the phthalate and the stabilizers that are used in the plastics and you don't have those in carpet anymore. You still have it everywhere and you might not know it or you are just used to seeing it. This is information [carpet impact comparison] that I think designers and the design community can really understand. Eventually, carpets are all going to come together. They're going to collapse the carbon impact for Mohawk and others. My friend at Mohawk is probably wishing that I stop showing this slide. [You] can fix that, you have got to do something about that and the fact that you guys have really dirty electricity feeding into your plant. Yes, it is wonderful that you are providing water filtration to some parts of Africa, but let's talk about the impact that you are making right here right now. So, this is what designers can understand and ask for.

We actually have to recognize that this is not static. Clearly manufacturers are getting better and better at doing more. We just need to stay on top of it. This is where it is going right now and being able to have conversations with companies [spurs progress]. Mohawk, what are you doing to improve? We love the super green Living Pedal Challenge product, but the footprint is appalling.

SR: I'm assuming there're ones that are off the chart to the right [much worse]?

KR: Right, yes. As you start to go into, various Chinese manufacturers, but products like Tarkett fall right in there between the Interface NeXTSTEP and Shaw. Their products are generally on that side. There is more that has to be done, but this is the information. We are also getting [a comparison like] this out on wallboard. We are looking to do ceiling tiles next. One of the huge growing flooring operations is LVT. I mean that is just going gangbusters. So, that's another one that we want to do. We want to try and see from a comparable performance perspective if there are differences on the carbon side or is it close enough. I was surprised that there are some differences in paint like Sherman Williams versus Benjamin Moore. The other thing that is interesting about paint, if you consider that it makes sense to buy higher quality paint because it's easier to clean, is that less repainting is required. It is really that the impact of paint is associated with how many times you have to repaint during the life of the project. If you end up repainting less because now it cleans easier, it is a much smarter design decision to select the paint that has scrub-ability, wear-ability, and clean-ability. That means I don't have to repaint the walls as often.

SR: Do you find that those paints have a higher initial carbon or are they just a mixed bag too? Are you making a first pass trade-off?

KR: Well that brings it back to a conversation that I had while working on a report for a classified client. We petitioned for USGBC to allow us to use a whole building LCA methodology to get the LCA credits in interior design and construction. Currently you see there is not a whole building LCA path for interiors. So, we have gone back and forth and back and forth and they finally agreed. This is going to be the basis for developing an alternative compliance path for that credit to actually allow [whole building] LCA. There are a couple of things that we did differently. One of the key things we talked about was how we are using compliant 140444 datasets etc. but have adjusted the LCA methodology. USGBC stipulates a 60-year assessment period, but given the shorter time period of interior commercial tenants, we have adjusted the assessment to reflect a 15-year performance horizon. We are doing one fourth and saying that for interior design there is a 15-year tool default for a whole building LCA.

Our focus is on the interiors and typically a fit out is going to be done every 15 years. Then you have to pay attention to the products that have a shorter than 15 years lifespan or whose EPDs are based on 60 years. Then you have to adjust to make sure that you have the right quantities. So, you have to analyze that consistently. There are two different things to understand. When you do a whole building LCA, you have to take into account a 60-year life. What happens is that an EPD for a product may say, for example, carpet has as a life expectancy of 15 years. So, in your model you have to say we are going to be replacing that four times in the project. Versus ceiling tile which may have a warranty period of 75 years, so it is once through. It is those things that actually get replaced, which primarily are paint and flooring [that need adjustment]. In this case, I said I'm not going to do an analysis for

a 60-year footprint, I'm doing the analysis for a 15-year footprint. If I'm actually using carpet that is only good for seven years, then I've got to take that and do three cycles of it. If I'm using paint that only has a design life of five years, I have to do three cycles of that paint. That's how you have to figure it, but if I'm using a paint that has a 10-year life, I have to do two cycles. I don't do a one and a half. It's like paint is on or it is not. So those are some of the things that we had to do a little bit differently. You can see here (slide) this is the baseline scenario. We had the product category, product description, estimated quantity of the declared unit, and so on. We had to do a lot of the conversion because the declared units in the EPDs were different than the 15-year performance horizon. Once you have identified what that is, then you have to do the multiplication to get the global warming potential and ozone-depletion, etc.

SR: You are an engineer, right? That is how you were able to do this math?

KR: Yes, that's right. This is not something I would want my typical interior designers to do. This is not something that a typical designer wants to do, nor architects. This gives you an idea of all the products and what we had to do to make that work. The LCA data is out of different databases or EPDs (slide).

NK: And you had to do this because they didn't have the same baselines in units, right?

KR: You have to find out what the units really are and quantify them. Now there are tools like one click LCA and Tally that are trying to do more of this, but right now all those tools are designed for whole building LCA [based on a] 60 year life and they need to be modified in order to say, no, we want to know what the footprint is for a 15-year lifespan or for a two-year project. That's what we have to be focused on. This was the design scenario. We need to understand the impact of different products, different conversions, and then compare. We are showing a difference of 43% on global warming potential. This is the thing that we're trying to figure out how to make simple and available for people. How we can leverage things like the EC3 tool, to really make it easy I think things like that carpet chart are going to be the easiest for people to really understand and acknowledge the impact of their design choices. Designers says, “I am madly in love with Mohawk flooring and I am going to use it.” but don’t understand the ramifications and tradeoffs. You would be able to see that on the carpet chart. You are taking this huge heavy hit on carbon, what are you doing elsewhere in your project to offset that? I'm going to reduce my lighting power density to reduce that or that I'm going to specify ultra-low carbon wallboard or do some different things to make up for that. I think it is first getting people aware of the impacts that are happening right now in the marketplace that we are responsible for and then showing them that they actually have the ability to make a change. A lot of times designers using LEED don't really know what they can do from a carbon perspective. Now you can do something about it.

SR: So, are the rumors true that there is a LEED credit, or a pilot related to carbon and LCA in the works?

KR: Yes. At least the rumors are true. One is that they are looking at an existing building material Option 2 credit in materials. They're really looking at providing a whole building LCA option for interiors.

They were going to be releasing that at Greenbuild, but it didn't happen. It's primarily focused on analyzing the alternative materials that you're choosing. It primarily is associated with industry average. You establish your baseline based on the industry average. For instance, if we're just going to use industry average wallboard and ceiling tile information. There are not really yet industry averages for all materials. In that case, you can do it one of two ways. We used the Quartz database, which Google funded a while ago as the baseline. Or you can say, here's the range of carpet manufactured in the United States. We can take this one as the middle point and use that number. So that's your average. And then you do your analysis, here are the products we have specifically specified to use instead. We're making that decision.

SR: I guess that the confusion for me was coming from the term whole building. So really if you're doing a TI, it’s just the project scope.

KR: It's a Tenant Improvement LCA. It's the stuff that you're adding to it right now, which is part of the 11% of the building materials footprint. That is being manufactured right now and going right into the project.

We're looking to change to Tenant Fit-Out LCA or some other name to recognize that it has a shorter life span. It has a little bit of different focus.

SR: Was that going to be rolled out as a pilot credit or as a 4.2?

KR: They were going to roll it out as an alternative compliance path to the existing life cycle impact credit in interior design.

Q: If applicable, what data sources are most valuable for comparing material choices?

KR: Emerging, you have one that is actually interesting. This is a love child of a former Gensler employee. He started to grapple with a bunch of information on products, the product manufacturer, the category, which of the various sister labels it has, and what the carbon footprint is. He has normalized it and this is a designer friendly tool. There is the EC3 tool that's coming out or that's actually out. Sustainable Minds has a database of stuff. A longstanding carbon footprint databases is ICE, the international carbon and energy database. It's managed by the University of Bath in England. Underwriter's Laboratory (UL) is developing a big database, but they have a lot of information. They haven't really gotten to the point of making it easily accessible for folks.

What Ken Sanders was really trying to do here is ask, "How do we make it easy?" You can do things like [filter by] category. We just want to see flooring and we want to rank it by its CO2 impact. It shows the rank you sorted by and he's got a little bit, from higher to lower. So, it's still in process, but you can see that it will be a great thing. What's nice about it is that you can click that little button and then go to the EPD. So those are the kinds of tools that we really need to make it easy and fun.

UL is supposed to be opening up its database. They've got a ton of stuff. I have significant questions about the usability of the search because they've traditionally made it very engineering friendly and not user friendly.

SR: In a large firm like Gensler, there's room to do this research that informs all your projects.

KR: When we make room. Like in the carpet example, it was the work that I've been doing locally that I was able to pull it together. For a few more projects, we're actually doing more. We can start getting the wallboard and ceiling tile [comparison done]. We're trying to make it happen internally. We have gone back and forth on it. Do we invest in Tally and actually do the whole building LCA for projects? We're finding that in general, that is where the project teams are better served because it's not something that you can just pop into and then pop out of. You need somebody doing it full time, which means you needed a lot of different projects to support it. We are much more inclined to partner or hire Urban Fabric for our projects on the West coast or Walter P. Moore out of Houston. They do a lot for our big stadium projects so we use them for doing the whole building LCA part. It's still something for us to be thinking about (if we want to do it ourselves), but we are not really optimized to have certain people just do one thing across the farm. Where you see this is in energy modeling. You just throw this stuff to them. So you could have an EPD expert, but that's not the way we work on our projects.

We do have a very robust network called GLUG. It's the Gensler LEED user group. We do presentations and we share this kind of information. So that's how a lot of the information gets out and people start acting on it and sharing it within their own different studios and across different offices in the regions.

I think in particular from a design perspective (and my common rule is that if you can lick it, you want to know what's in it, right?) the carbon emissions, the health information, and if you're going to buy more than a ton of it, you want to know its carbon footprint. It is tied to the quantity for the most part. I mean there are a few exceptions where you might have a really high footprint and it's a small [quantity], but if you can use that rule of thumb and say as a designer we should really be focusing on those things we buy a lot of and we should find out the footprint.

We should be working with the supply chain. If I'm a designer of an office and want to find the footprint of your chairs, [who can I ask]? Who's doing what? That's again where somebody like Herman Miller comes in. They have been doing things in LCA on their products for years, really have a grasp of it, and are doing some really, really, really good work. Then you can look into armchairs. Do I need arms, or do I not need arms and what is the carbon

footprint of that [decision]. Are you buying a lot of sit stand stations? Clearly wallboard, clearly ceiling materials, and clearly flooring materials [need to be considered]. Then, if you're doing a lot of wall covering or acoustic materials, that's another area we can start to really hunker down and say we need to know this. But if I am spending a lot of money, let's come up with a plan and figure out what the carbon footprint is, and can we find better alternatives or other things that you can be doing as a manufacturer. I think even just having the designers be comfortable enough to have a conversation with the manufacturers and the reps is huge because the reps are [going back to their company's and] saying we're getting all these people asking these questions about this and what are we doing? For example, asking a furniture manufacturer when there is steel in their product, "Do you have a definitive contract with your steel supplier that lets you actually [establish] the global warming potential limits?" or "Are you only buying from North America or off the spot market?" If they're buying off the spot market, you have to assume the carbon footprint of this steel that is coming from China and take that hit.

If you actually are invested and put in procurement policies you are accounting for the carbon footprint. You're saying we are looking for North American [steel] only or whatever you're doing in order to make sure that you are getting a low carbon footprint, then you can take advantage of that and say that's what we want you and you manufacturers to be telling your supply chain.

SR: It's like 20 plus years ago when we had these conversations about FSC [wood]. We want your blinds, but we want them to be FSC. Then the next year you see them on their product list and they're selling them to other people. It's really satisfying when you see that market reach.

Q: Have you quantified and/or tracked carbon on any of your projects? If so, please describe the process and the lessons learned.

KR: Definitely when you're doing a big building, the real impact is the structure, without a doubt. We have looked at it a couple of ways. Again, it's staying focused on your ceiling materials, focused on your walls, focused on your floor materials, and paint, and then focused on glass. It wasn't only wall materials and furniture that you're buying a lot of.

NK: Did you find a way to establish a baseline? How is it measured?

KR: We haven't been doing as much as we want on furniture, but I think if we can, we'll actually just look at comparing two different manufacturers. I think there are some generic chairs and things that you can actually use as a baseline, but that's one of those areas that is emerging. If you don't have a way to get to a baseline, and it's early on in this world of understanding, just take the two you like the best and compare those.

NK: Any more lessons learned?

KR: Yes, it's still an evolving science. It is part art and part science to actually get it implemented. We need to provide things like that carpet chart that give designers a way to quantify the carbon footprint or you're not going to get where you need to go. The action that they should be taking is identifying and specifying lower the lower carbon products. We can back into what they've done by backing into the analysis of how much carbon was produce. That's second to actually getting the products specified and procured that have a lower footprint.

Q: As a nationally recognized leader in sustainability with a commitment to doing right by the environment, do you have any suggestions on how best to bridge practice (designers) to LCA for interiors?

KR: Yes. I think it is important that designers have enough training and it actually should be addressed in school. It really is unfortunate that for the most part material lifecycle impacts are woefully underrepresented in interior design curriculum, as well as architecture. It's a big hole that needs to be fixed. Part of the problem is that you've got professors [needing to follow] the curriculum that's been approved. It just doesn't change and it needs to.

How can that happen? It would be really cool to get IIDA [International Interior Design Association] to step in. Cheryl Durst [Executive Vice President and CEO of the IIDA] is a pretty savvy lady and says we need to work on this. We need to come up with some program, some recognized program that can be accredited, that becomes part of standard curriculum for interior designers on how to talk healthy materials, how to talk low carbon materials. [So

that designers] understand even the basics of the environmental impact of the decisions that they're making and what the alternatives are. Then they'll have that vocabulary to really continue through and work with the manufacturers.

Number two is having the design community work with the manufacturing communities. That collaboration and that conversation are important. The furniture industry is a logical [place to start]. I mean they have a lot of people that are already out there daily dealing with designers. They could get them connected to their sales chain and to be more comfortable talking about what they're doing from a carbon perspective. They know they're at the forefront of it and their whole model is we want you to always buy the new stuff from us.

We're not so keen on you repurposing things. Which itself as a whole frustrating conversation, but even saying, "Okay fine, you want us to buy the new stuff? What are you doing to reduce this footprint? How are you getting to zero carbon steel? How are you getting to zero carbon polyester fabrics - what are you doing? Where are the impacts of what you are doing to reduce and how are you showing me what your plan is? When I come back in two years, you can show me that you've cut the footprint of that [product]." [When the design community asks these kinds of questions, it will make a difference.]

Q: In your advisory role with the USGBC, where do you see LEED now with LCA and/or carbon reduction pilots or credits? What direction do you see them going with future versions of LEED relative to LCA and/or carbon, especially relative to interior materials?

KR: USGBC has recognized that they need to be really focused a lot more on carbon, both from the energy side and otherwise. It's not just about energy efficiency, but also the carbon efficiency from an operations perspective as well as. Then how do we bring in the embodied carbon in materials? They depend highly on volunteers. This is a relatively new area. I think that USGBC should be investing some money and basically helping to expedite that creation of credits. They have a platform right now. They could easily provide alternative compliance paths for say energy efficiency points. They could allow points for carbon efficiencies instead.

What's really ironic right now is the way the LEED energy credits are set up. They're tied to energy costs and gas is a lot cheaper than electricity. From a LEED perspective, you're better off going with gas than you are with electricity in most cases. We're saying that's not where we want people to go. People really need to be going to electric and the whole grid's going to be going more and more renewable and lowering its footprint. That's what we need to be doing. On the material side, they could find a way to provide more credit for lower carbon materials, both in the individual material credits like the EPD credit and also by providing a pathway to do a tenant improvement LCA.

Q: What do you think we need to see in future codes to support LCA for interiors?

KR: In California we have the Buy Clean California Act. State of California projects are now required to report the carbon footprint of certain key materials, steel, glass, and insulation. Then the Department of General Services has to use that information to determine carbon footprint limits for each of the materials. They are supposed to release them by 2023.

NK: Do you think they're going to take the average?

KR: They probably will take an average and then it would be my guess that they're going to expand [the list]. It's needed for flooring and ceilings. They're going to basically [implement this] through legislation, which will then filter down through code. I think that we're going to get there. There are all kinds of clamoring to say, okay, you need to add wallboard. There're a couple of other materials that are going to be coming too. We can be acting on it sooner rather than later. Without a doubt, as soon as anything goes into code, it's much easier to get into the project, because there's no hassling with the contractor and no hassling with the owner. It's just this is the way it's got to be. It just makes life easier for that 85% of the folks who really didn't want to have to deal with it.

It's occurring. It's certainly rolling out right now through this statewide law for projects that are received state funding, education facilities, anything. Basically, those projects that get state funding are required to report.

A lot of people aren't aware that they have to report structural steel, flat glass, and mineral [wool board insulation]. Public works for several state agencies, which include the Department of General Services, are required to do this.

Q: Is there anything that you'd like to share or guidance that you have on this topic that we haven't already talked about?

KR: I think the real challenge, particularly from a student's perspective, is how we make this easy and fun. How do we provide a pathway? One of the big challenges we've had in the environmental community all this time is [the message], you should be doing the right thing because it's the right thing. It's this moral imperative. Get with the program!

People are saying stop complaining about what we've done wrong and help us do things right. And, in order to make me do stuff right and make it something I want to do, make it positive. Maybe I've reduced the carbon footprint, but I need more, it's not a warm and snugly [motivator]. How do we make it easy and simple and fun so that people inherently are doing the right thing? If we can really crack that nut, and it will probably require different solutions for different types of people, that would just be so fabulous. It has to be that thing that people want to do just because it's cool.

Incentives [work for some things, but] are a bit more challenging for materials. It's one thing for ongoing operation of something causing continued carbon emissions, but I don't want to put an incentive out there to get people to replace their existing carbon with a lower carbon [material]. Because wait a minute - it's already in place. There is a lot to say for reusing and adaptively reusing as much as we possibly can, because that's going to inherently have a lower carbon footprint.

What is the incentive to go all electric? Here's a reverse. What the [SFO] airport's doing is trying to get people to go off gas, but they've got the restaurant tenants wanting gas. What they really wanted to say was we're not even going to pipe a gas line to [the new terminal], but management didn't go for that. So they said, okay, we're putting the pipe in, but while the airport picks of the cost of the meters for water and electricity, we're not picking up the costs for the gas meter. Tenants moving in that wanted gas were going to have to pay for that meter, which is a $75,000 hit. Theirs is a reverse incentive.

For me, it's really interesting. You'll look at ceiling tile and at Tectum, which is wood fiber with really low carbon and good acoustic properties, but it has a little bit of an eco-look and some people don't like the eco look. The default for most commercial interior designers is that they love wallboard ceilings. They like it because they like the smooth, smooth, smooth finish, but the carbon footprint of a square foot of wallboard is two or three times that of acoustic ceiling tile. A lot of people don't realize that you are actually much better off specifying ceiling tile than you are wallboard. Still, it changes the aesthetic, right? But those who understand the tradeoffs when they are looking at different materials [can make a more informed decision]. If all we're doing is looking at wallboard, there's a three-time difference between USG's Sheetrock® Brand EcoSmart panels and CertainTeed's comparable wallboard. Why are we not just identifying the better product as the default? Our basis of design is this lower carbon footprint. CertainTeed with time will be coming down, which is great because that's what you want. Everybody can come down at some point in time, then maybe it won't be an issue anymore because they're all be comparable, but right now there are big, big gaps. That's how we need to drive change, but it comes back to making it fun, making it sexy. With little stories, vignettes, and findings, I think we can share information more quickly. Is there a way, can you co-opt LinkedIn to be a great platform for sharing information, to say, "Hey, guess what I found out", or for me to put up my carbon chart for carpet? The more that we can integrate this into common tools that people are using the better it is. For instance, if you're using SketchUp and doing a layout with wallboard in it and [the program could recognize that and say], "Hey, by the way, did you know that USG wallboard has 50% less carbon footprint than CertainTeed? You should be specifying that." That would be cool along with a link to the EPD, but we're a long way from that.

NK: Well, thank you so much. We can't thank you enough for your time.

KR: Oh, my pleasure, my pleasure.

Larry Strain, FAIA, LEED AP

Principal at Siegel & Strain Architects, Emeryville, CA

Larry Strain is a founding Principal at Siegel & Strain Architects in Emeryville CA, a 20 person firm with a focus on community projects and sustainable design. He is a member of the AIA Materials Knowledge Working group and serves on the boards of the Ecological Building Network and the Carbon Leadership Forum, is chair of the Reuse Task Force of the Embodied Carbon Network and was on the research team for the Embodied Carbon Benchmarking project. He is the author of ReSourceful Specifications - one of the first guideline specifications for green materials; co-authored the Total Carbon Study – an evaluation of a net zero office renovation; authored a white Paper on the Time Value of Carbon, and the chapter on Reuse in the New Carbon Architecture. For the last decade he has focused on reducing the total carbon footprint of buildings and building reuse.

Q: Siegel & Strain has done so many award-winning buildings. How do you incorporate informed material decision making and when and how does this impact your design process?

LS: Well, I would say that the big decisions for embodied carbon concern structural materials. They are the first decisions we try and make. We have the advantage that we tend to do smaller buildings and we work with wood a lot, not much in steel buildings. We work on the models that we are starting with, and see if we can do the project with lower impact materials. So that is the big picture at the structural stage. Then we don't really make hard and fast material decisions on interiors or things like that or even exterior finishes until we have an idea about the design. I would say it's always in the back of our heads that we are trying not to come up with a design that relies on something like aluminum panel walls or something like that, and our tendency is using as many natural materials as we can because they are by and large, lower impact materials. We have worked with the same structural engineers since the mid 1990's. We try and control our concrete with lower carbon concrete fly ash. We sought out structural engineers who know that about us. They work with us and they are the ones that actually write those spec sections. We have to make sure the specs describe what we are trying to accomplish.

Interestingly, in the early days we just specified a replacement (50% fly ash) and what ended up happening was the supplier kept the cement content the same and added 50 % more fly ash. So, it did not change the cement content which is the big impact. We had to start reducing the cement in a cubic yard of concrete. So, you must be very clear about what you are trying to accomplish. It is getting easier now because you can just ask for an EPD and put in the specs that the maximum content for your next design is "X". There are a lot of mix designers who have that information on cement content and even global warming potential of their mixes. That is an example of what you want to do, but you don't get into the specific materials until a lot later in the design process but it is always in the back of our mind. I think sometimes you come up with a design with the client and everyone likes what you are trying to do but you have to look at what it would mean and realize you can't build that in wood. You would have to add structural steel inside to meet the building code to hold up the cantilever or whatever you are trying to do. And then you decide whether to sacrifice the design for absolute minimum carbon content. We keep it in mind as we develop the design. Some people would not go with one of those higher impact designs because they know what it means. Others are more willing to do that. There are decision points in the design where they may require higher energy intensive materials or carbon intensive materials to make it happen. You must know that and make a decision.

NK: Do you discuss that process with one another?

LS: We do. We tend to have semi-autonomous teams working on each project. They make most of the decisions. We are looking have more of an office-wide oversight and input into those decisions. Now that we are larger (22 people), we are trying to incorporate that oversight and input back into each team. When we were smaller we had more hands on with everyone working on every project. We are not big enough to have a sustainability director, but we need sustainable design oversight for that input.

Q: As someone who has had a hand in writing guideline specifications with GreenSpec, how do products in Green Spec get selected?

LS: For GreenSpec, we had funding from Alameda County's StopWaste.org and we just started to find and specify green materials. BuildingGreen had started publishing information about green materials a few years earlier, but we then realized as we were putting them in our projects, that there were no specifications for those new materials. So we decided to write a spec. What we tried to do was take common materials, use the greenest versions of those materials (sheetrock, wood, etc.), and write a guideline that included the impact of each material and the potential to avoid impacts, so people could be aware of impacts and put language into their specs on how to specify the best wood or the best concrete within that criterion. So we started out with a pretty clear objective to cover materials everyone was using, help them get the best materials in that category. We also added a few sections on less traditional materials such as straw bale and rammed earth. California had just passed a code that allowed the use of straw bale in California when we wrote that spec. Rammed earth and straw bale were not in the mainstream. Nobody was using them back then. This was the mid-nineties. There wasn't really a clear directive. (We are now looking to go back to some of these materials because they are some of the lowest impact materials out there.) There was a group of about three other people that I worked with on the first version of the GreenSpec from ADPSR (Architects / Designers/ Planners for Social Responsibility). They had come out with a guide to green materials that was a listing of all the manufacturers who were making green materials. So they worked with me on that first edition. One of them, David Kibbey was really into toxicity in materials before anybody was paying much attention to it. His partner was chemically sensitive and he was really up front about the fact that you cannot put things in your buildings that will make people sick. I was more focused on resources and carbon emissions in the beginning and he was focused on health, so he really contributed to the GreenSpec.

NK: Is it constantly evolving into something else? Are you updating it?

LS: No, it got picked up by BuildingGreen and they published it as part of their GreenSpec Directory for 7 years as part of their directory of all the product manufacturers making green products. The spec sections were incorporated in those divisions. The guidelines [were intended to] help people write a better spec, but people were using them directly, and cutting and pasting our language right into their specs which is how to write good specs and it opened legal issues. So we Building Green stopped publishing it. A lot of other people were coming out with better ideas about how to do specs. MasterSpec created some language that went into their MasterSpec format. So it [GreenSpec] served its purpose and then it went away.

Q: Do you think that model could expand into furniture and finishes?

LS: I know that some of the large architectural firms have developed some in-house specs that are good, open sources, for use all over the country, and there is a lot more information about materials available. One of the differences about interiors is that people are focused on health as a primary issue. They are beginning to think about embodied carbon and pay attention to it. One of the reasons they are, is that the interior finishes in a building, while they don't have a huge carbon footprint, but those materials get replaced every 5-10 years when interiors get refinished. So, the cumulative embodied impact of interior materials over two or three cycles can equal that of structural materials. Over 40 years or so, the impact can be huge. This applies to mechanical systems as well. They are looking at the global warming potential of those systems and their shorter time frame. You can pick a lighter weight sheet rock with a 20% reduction, which cuts global warming. That is great and people should do it, but it doesn't have the same impact as cutting the concrete emission does on a project. Carpet is a high impact material, way higher than concrete - four to five times the impact of concrete per pound. Interface is taking global warming seriously and working on carbon sequestering carpet. They are great and have been doing great work forever.

Q: You spoke at AIA Silicon Valley's AI.19 conference about how our buildings impact the environment. Could you go into more detail about the environmental impacts that are happening because of our design decisions?

LS: That could take hours (ha). What I am coming to realize is that we are not currently building things that are better for the climate. New buildings are making things worse initially, because we have such a short time frame to

reduce global warming. A new building is going make it worse before the energy saving starts realizing benefits. I have been working a lot on this in the last few weeks, trying developed this little simple carbon calculator that looks at the impact of a new building based on typical embodied carbon content and the impact of replacing an existing, poorly performing building and retrofitting the existing building and it is pretty striking what it tells you. New buildings will always have a negative impact on the climate in 10 years unless you are actually making a building out of completely carbon neutral materials. There are few people who are doing this on a small scale and are working to do it on a larger scale. We need to get really serious about making every material carbon neutral and eliminating steel and concrete entirely by going to straw based products. I think you could get to a zero-embodied carbon building and I think we have to go there rather quickly, but it would take a while for the industry to get there. I have been thinking that the easier thing to do, although it is also very difficult, is to focus on existing building because most of the embodied carbon has already been emitted in those buildings. If you can take operational carbon emissions and reduce it to half or 100 percent that will have a huge carbon impact. The bad news is that we all are building new buildings that are making things worse right now while we're all trying to make things better. The focus must be on retrofitting and energy upgrades we are currently doing this with about 1 1/2 percent or our existing buildings every year. If we could get that up to 5-10 percent a year it would have a huge impact on our emissions. That feels like a shift in not just the architectural profession, but also for the developers, owners, and city policy. We need policies that would encourage that or would reward that. It is not going to happen if you just let the market do it. You need to up the numbers of retrofits and if possible, build fewer buildings because you are retrofitting older buildings and making use of them longer and avoiding the impact of new construction. One of the reasons this can be hard is because most people when they tear a building down they don't want to build the same size building. They build a bigger building. It is a hard sell to say just use what you have. I think we could do more of it for sure.

Certainly there is really good stuff happening with concrete now due to the plant in Pittsburg, CA that will produce carbon concrete within a year and that is basically taking CO2 that comes out of power pollutants and turning it into aggregate. This has been done at a small scale. They actually used this at the San Francisco airport remodel and now they are building a medium size batch plant in Pittsburg that will produce this stuff. The plant is under construction now and will be done in 2020. Then we will be able to buy aggregate that goes into concrete in the bay area that is carbon neutral. If it works, then they can start building plants all over the world. It is time that we are up against which is why I focus on retrofitting. This is a big undertaking, but all the technologies are there because we know how to retrofit buildings and implement energy efficiency in buildings, we have known that for years. However, we really don't have the mechanism or leverage to make it happen, we don't have the policies, codes, requirements or regulations that would make an owner upgrade their existing building.

NK: So, we need more codes and policies?

LS: I think we can't do this by architects just doing a better job; it has to happen at a much bigger scale. The needed codes and policies are happening in a few places. New York has got some aggressive new policies that require owners of buildings 100,000 sq. feet (or more) to report their energy use from now on and upgrade every 10 years (or less). Every time a building is turned over to a new owner, they must do some upgrades. They are trying to put upgrade requirements in wherever they can intervene. The real estate industry and developers are pushing back, but if we don't do it, existing buildings will remain a problem. That is where most of the emissions are coming from.

So, it is a two-pronged path. For existing buildings implement serious energy upgrades and for new buildings serious embodied carbon reduction on materials. Reusing a building obviously requires much less embodied carbon than building a new one. It takes roughly a quarter of the amount to upgrade a building and even make it net-zero.

NK: I noticed in CALGreen they are incorporating LCA.

LS: Yes, it is starting to get into places and CA passed a preferable procurement policy that promotes lower carbon materials. The first version excluded concrete from the list which was silly, but there are many materials in there in their codes that address carbon. Other countries are definitely doing this. I think it will start to get into code and policy rather quickly. Right now, most green codes are optional. That probably will change quickly.

Q: How does one measure or calculate carbon? Can you tell me a little more about that for someone who is new to this?

LS: Well, hard question. You can do it with a plug in for Revit which is called Tally (environmental impacts included). That is the most complete way to do it that I know of right now. Not everyone is going to do that because there is an added expense to do that and it also takes technical learning to do it. There is a new tool that was launched announced at Greenbuild this year [2019] that is called EC3 [Embodied Carbon in Construction Calculator], that looks really good. It is a way to measure and calculate embodied carbon and compare materials. We are trying to develop a simple calculator that looks at typical operating and embodied carbon to determine if one should retrofit the building or build a new building. You can see what the difference would be. It is a simple tool for owners to use.

If you retrofit a building and take that existing building that is emitting a lot of carbon and make it net-zero you are saving all that carbon and building with much less embodied carbon (positive). There are databases that are not like tools, but they list typical embodied carbon content of 100's of materials. The most up-to-date is ICE (inventory of carbon and energy) database in Bath, England. You can download from Circular Ecology for free. It gives you a way to get a sense of what the carbon content of sheetrock, concrete, steel carpet, etc. is. Just educating yourself is a great way to get an idea instead of making a deep dive into a full whole building cycle calculation. When it came out eight years ago it was simpler, now it is more complicated with more materials (30 different concrete mixes for example). I recommend educating yourself first about carbon and what the high impact materials (per unit) are. You need to understand what to use a lot of in a building and what we use less of in terms of waste. Some things are surprising like insulation, which uses blowing agents that have really high global warming potential. You might put in a ton of foam in a building and have 30 tons of emissions from that foam. Foam is one of the materials that surprise people because they think they are doing a good job by using insulating materials, but it takes so much carbon to make the foam. So those insights are useful. You must figure this out before you design the building. You can't build it and then start to figure it out. A lot of this you must know before the design. I think the databases are the most successful ones.

Q: The carbon leadership forum is a great resource for manufactures, designers, builders and academics to learn about the carbon embodied in building materials. What would be involved in expanding the focus to include furniture and finishes?

LS: Yeah, I think that it is already happening. I don't think that is an interest area in the carbon network. There is not a specific group on interiors, and quite frankly, you could go ahead and start one. Seriously, but there are people that are doing things like renewable materials or construction practices. The renewable materials (straw-based panels) needs renewable products like straw and you could probably plug into that group and say I am particularly interested in furniture. It's just an open forum list serve. It is great. That would be a place to get involved, network. Look at the ones that interest you.

Q: As a leader in innovative design with a commitment to do right by the environment, do you a have any suggestions about how you would bridge interior design practice with LCA for interiors?

LS: Well, sort of what I just said. I think that the way that I approach all these things, especially around carbon, which is my focus – embodied carbon and all kinds of carbon emissions – is to look at what happened a few years ago with structural engineers. They took the lead and said, look our materials are most of the problems and we're going to take the lead on reducing embodied carbon by being better structural engineers and using better materials. Interior designers could say, well our materials aren't a very big piece of everything in the initial carbon, but over 25 years they may rival the embodied carbon of the structure. So, our choices are just as important. The way that I try and frame it all, every decision you make, and everything that we are thinking about with embodied carbon has to be done within a timeframe. We have to make a real impact in a 10-year timeframe. That is our goal. That is a really hard thing for interiors, because interior designers aren't the ones that say, "Oh, let's replace the carpet every 10 years". The building owner or the new tenants come in and want new carpet – because they all want new carpet, even if it's perfectly good. They want a new design. I would say the focus for interior designers is not to choose more durable materials, because it's not. The materials are typically replaced because people want

something new. So figuring out a modular design that can be pulled up and put somewhere else is a better goal. Design it so that the material can be repurposed or choose manufacturers that have good take back programs where they take the material back and repurpose it. Yeah. Those are the kinds of materials that you want to start specifying. That is acknowledging that we have this huge turnover in commercial interiors and that's the problem, not the materials wearing out with other materials. Making it last longer is good, but with interior there is a whole different problem. Focusing on supply chain issues or from a manufacturer's standpoint would be more effective. So, you start to become an activist with manufacturers by saying, 'look, we want to specify products that can be reused and repurposed. We don't want this stuff to get thrown back. We want you to take it back, refurbish it, and turn it into a new product, whatever it is. Just getting that throw away mentality out of commercial interiors would make a huge difference.

NK: Do you think it would be a good idea to point to manufacturers that are doing this to show that it's possible and profitable. Then ask why aren't you doing it?

LS: Yeah, that's the activist piece. Write to the other manufacturers and let them know that someone else has a product that you would like to use because their products address carbon. So, you say, "I'm sorry, I can't specify your product because you're not doing that."

NK: You're voting with your dollar and your suggestions.

LS: Exactly. Yes. So those kinds of letters individually are good, but the other thing would be to try and organize. We've done some large letters that were signed by hundreds of large architectural firms that went out to the major manufacturers of materials. There was one on material health and I think there's one coming out on climate health, which is low carbon. But if you could start a movement within the interior design community to say we should be writing letters and sponsoring letters saying we want this from our manufacturers it could make a difference. The letters can lay out the criteria that would make commercial interiors way more sustainable. You know it's going to be health and it's going to be carbon. Those are the two big ones I can think of. It's powerful to write letters individually, but even more powerful if you can get a group that represents a lot of people.

There're some great people in large firms that have been doing this for a long time, but have mostly been focused on health. They have begun to really focus on carbon.

Q: Is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

LS: I think we pretty much covered it. I think it's great that you're doing this from an interiors point of view because that perspective is lagging. They led the charge on health because it's all about interiors health. But I think that interior designers have really lagged on the embodied carbon. I think it's completely legitimate, that they start paying attention to embodied carbon because it's a big problem.

Clinton Boyd, PhD

Principal Scientist-Green Chemistry & Sustainability for the Global Sustainability Initiatives Team at Steelcase Inc., Grand Rapids, MI

Clinton S. Boyd, PhD is the Principal Scientist-Green Chemistry & Sustainability for the Global Sustainability Initiatives team at Steelcase Inc. Clinton works specifically on material and chemistry aspects of products across their life cycle, including materials innovation and exploration, product development & launch, and regulatory compliance. Drawing on his expertise in green chemistry, industrial ecology and sustainability, Dr. Boyd works with cross-functional teams to innovate new materials and products that are sustainable and compliant to regulations on a global platform. Dr. Boyd has a PhD in Biochemistry from Rhodes University, South Africa. Before joining Steelcase, Clinton worked in academia as a research biochemist followed by ten years of experience as a consultant on green chemistry and sustainability.

Q: What led Steelcase to include LCA as a product development criterion?

CB: So I think it fits within the kind of larger history of the development of sustainable business and sustainable business practices. If you go back more than 10 years, market reaction to sustainability tended to be [focused on] single attributes. So one of the big, significant things that happened was when the sick building syndrome raised concerns about ground emissions from the parts. It was one of the first big drivers for our sustainable products in our industry. Very quickly that grew, probably next was California introducing its comprehensive purchasing guidelines, called CPGs, which then covered indoor air quality that and also included in recycled content. It was probably the next big thing on the table of content values.

Then around about 2006, 2007 we started seeing the explosion of different attributes or aspects of the product that we were interested in. So it meant that there was now a need for some kind of scientific or more methodological approach to how we could quantify the environmental footprint. We needed a more holistic tools. So that was around about when the UN began shaping the first ISO standards around life-cycle assessment. Steelcase was involved in some of those early developments and those early technical committees. So I would say when the world as a whole started to recognize the need for some more empirical methodological approach to assessing a products' environmental footprint, Steelcase was involved from the beginning. It was an early adopter.

We hired grad students from the University of Michigan's Center for Sustainable Systems and were amongst the first to do work on products about the process of life cycle assessment. Quite a few of test cases are based on Steelcase products. So we definitely see the value of s life-cycle tool and we adopted it very early.

Q: What tools do you use or find most useful for LCA?

CB: I think you had a question about the ways we use LCA, and maybe I should answer that one first because I think which tool we use is kind of tailored to our needs. So I would say that there are, in fact, two main reasons we use LCA, and there may be a third one. So one driver in LCA is the marketplace. At the same time that sustainability is growing in the marketplace, there is also the concern of green-washing. So what we're seeing is there no reason we won't be able to use the tool to avoid the idea that there's been green-washing.

The ISO standards came to address those standards around environmental marketing claims, type one, type two, and type three marketing claims. The type three marketing claim is the most stringent, that's the one that requires environmental verification and EPD. An EPD has to be verified by a third party, it has to be based on an LCA. It has to be based on an LCA done before it passed. So based on that, you kind of have to use tools like third party vendor tools, and very sophisticated tools. So tools like GaBi or SimaPro are the technology options that we would use.

We're doing a full-blown life cycle assessments. EPDs have been a key driver in our marketplace, especially in Europe, and we're starting to see it grow more in the US as well. So that's the way we use LCA so that we could get

these tools. But we've also used life cycle assessment as an independent function. Which is not just as a marketing tool, but as a specific design tool. So within our product development and launch process, sustainability is highly integrated at every stage that we interact with that product development process.

Very early on we have a stage where we focus on the design of the product. We help the engineers and the designers to make choices around material selection and sourcing to improve the environmental profile of the product. So we'll use life cycle assessment as part of that. We have many other tools and many other principles and concepts that we use to design outside of LCA, but LCA is one of those. So again, in that situation we won't be using a full-blown program like GaBi or SimaPro, but what we will do though is always standardize the same coefficients.

Even though we might not be running it through the full-blown LCA, we understand that LCAs are highly susceptible to things like which coefficients are being used, what impact categories are selected, and whether the coefficients are global, regional, or local. We have all those kinds of factors. So how are you going to weight? So we operate our design program using the same framework as we would a full-blown LCA. So you still use the same coefficient, the same definition, the same decision making processes. So that the work we do during the product development is aligned and harmonized with work down the road if we end up doing a full-blown LCA on that same product. We already have the base structure and the basis for that analysis.

So again, we're not necessarily using SimaPro or GaBi, we'll use others (I guess I'd call them hot-spot analysis type tools) to create truncated, hot-spot analysis LCAs. But it'll make the same decision possible.

Thirdly, we are very committed to a carbon strategy at Steelcase as well. We participate in the C2C disclosure project and other carbon accounting projects. Again, we rely on embodied energy and embodied carbon coefficients. So again, not done through a full LCA process, but by making sure that the system still uses that coefficient that we would if we were working on a full LCA. So that's probably the three ways we use it.

So, as I said, we might come up with an abridged or hot-spot analysis tool, but we make sure that it's based on the same, life cycle framework.

Q: How does one measure or calculate carbon for furniture? How is the baseline for a furniture item established?

CB: The way we calculate the carbon footprint would be through an LCA methodology. Within the LCA, you select the impact categories you're going to go after. When we do a carbon footprint of our products, for us it's the same methodology as if we were saying we're going to select carbon or global warming as an impact category. It's the same methodology that we would use if we were doing a full-blown LCA. We do have PCRs [Product Category Rules], I guess the other thing I should mention is that life cycle assessments have to be done according to a PCR kind of category rules.

For our industry, our trade association, BIFMA (Business and Institutional Furniture Manufacturers Association), is our PCR operator. So BIFMA itself is working through NSF, which is our third party accredited standards base. They're the ones that develop those PCRs for our industry. So we develop assessments for seating, tables, and desks, et cetera. Again, those PCRs define the specific requirements that we have to follow for any LCA, or whether it's a sub-step of LCA, like carbon. It dictates where we can use primary data or secondary data, or things like that.

NK: So if I'm making decisions for a tenant improvement project – I'm doing the interiors for this commercial property and I'm selecting furniture, I want to compare it to other furniture. How would I do that? Do the things that you're studying support comparisons? What would the baseline for comparison be?

CB: Yeah, so I think that I understand that question now. I think it goes back to the question about what I think about the environmental impact related to furniture solutions.

I mean it's an interesting concept. I think it is very challenging and I think it could be a long conversation trying to figure out what the right approach would be. I think what immediately struck me with that question, and I think it helps answer your question on the carbon baseline, is that you're right, you have to establish a baseline. As you are

aware, to begin a life-cycle assessment one of the very first things we have to do is to find the functional unit. An LCA has to be based on a functional unit because that determines how to establish the boundaries of what the LCA is. It doesn't help establish a baseline. Over time, the way you show improvements is you have to be able to do the LCA again using the same functional unit.

That's where our struggle straightaway lies, in what would a functional unit look like for a building? I think that's doable. You can say a building of a certain size, that's going to operate in a certain way, located in a certain city... Not only are you bringing in a building LCA, you're also bringing factors that would not apply to a Steelcase furniture, right? You've got to consider location because the climate's got an impact on the aging requirements, the insulation requirements, and all these things. So if you do the LCA you're going to have to define function very carefully to say a building of this size, office building, it's going to be located in downtown Chicago, operating for a certain amount of time. So a functional unit's got to have a geographic component to it, it's going to have a time horizon to it. It's got to have a performance mission.

If you think about that now and say okay now I'm going to include furniture in the building. So if we think about that, okay one of the first things I have to build in is [the timeline]. If I'm saying that the building timeline... Geography probably doesn't matter, as such. The building type will probably influence the type of furniture more; whether it's a hospital, a school, or an office block, would maybe dictate the type, that's okay. But just take the time horizon for example. If you are saying the time horizon for the building is 50 years, but then the functional unit for a Steelcase product would probably be 10 years. So you also then have to build in that fact. You're going to have to calculate that difference... One of the complications with add-in furniture is you're going to have to anticipate what that service life is going to be and how many times you're going to add a thousand fixtures to your model.

If each one of those chairs only lasts 10 years then, as a function of the overall LCA, you have to model for five times that many chairs, right? Then where that creates a problem is that even if you standardized on one supplier, or one manufacturer – let's just say Steelcase, then how do you account for the fact that over that same 50-year period, there are improvements that Steelcase is making to the picture? How is the baseline of the individual chair changing over time? So it's not like you can just calculate a baseline of the chair and then multiply by five. I mean there are ways around this, but these are all the things that you'd have to consider. I mean the nice thing about LCAs is that you can set the boundaries the way you want, you can strategize and can document all your assumptions, and figure out how you want to proceed. But that's the kind of stuff that you would have to start thinking a little differently about, relative to this type of LCA, if you want to include the furnishing and the finishes.

This expands your question on the baseline, because the baseline starts with a building. You're probably never going to be doing a building LCA, because the building analyst would. But how are you going to account for the continuous improvement that's happening to the individual finishes? There's probably going to be at least a turnover for carpets. It might only be 20 years, I don't know, but for some things might turn over in a year. Some things might turn over in 10 years. Some things might turnover in 20 years. How are you going to model and factor all that in?

Q: What is Steelcase's process for product development using LCA data and what other criteria are investigated or considered?

CB: This question I was thinking about a lot because we definitely need a lot more than LCA and I think this question helps address another of your questions as well, just generally about how you see promoting environmentally responsible design. What we see in the marketplace is LCA, but there are a lot of drivers out there, there are a lot of vague definitions of sustainability. Our customers are our main drivers. Our customers have different criteria about what's important to them for sustainability. So we'll have customers that care significantly about carbon, right? Or they care about the recycled content of the products. Again, that's being addressed through LCA, but the ultimate decision, the procurement decision to use recycled content that's really climbing.

Defining the PNR [Problem Need Resolution] process before development is important. I might be choosing to push the particular tensions is what I'm saying, right? I might want to be driving down my carbon footprint, but the

customer may be wanting to drive up the recycled content values. I might only be able to get that recycled content value from a much further away source, which drives up the gas in our emissions. So we face those trade-offs all the time, and that's why we don't always make our choices based solely on [one criteria]. That's why it's a little bit of a nebulous term, “environmentally responsible design”. It is kind of subjective. Every individual attribute or characteristic of sustainability is important, but some matter more than others to some customers. So you're always faced with a trade-off.

It’s not the case that LCA can help inform decision, [such that we can] say, "Okay, well here's the decision." It shouldn’t be used in this way. All right, so we want to drive up our recycled content, what could be the impacts to our carbon footprint, water footprint, or whatever it might be? The LCA results can be a part of that decision-making process, though we may opt to go the opposite direction in the name of environmental responsibility, even if the LCA [appears to indicate otherwise].

A great example (if you go back to the whole point of doing an LCA or why people think there's not a value in LCA) is the idea that it's empirical, empirical methodology. The reason is that people like numbers and facts. It doesn’t go along with sustainability dogma because it can be very nebulous and ambiguous. The market would like something that you could quantify. So that you can quantify what it needs to be doing.

LCA can do that. The whole concept behind an LCA is based on just a mass balance, right? You know how much mass you have and it's a correlation to the formula that you're given, then you get your end count. But it's very dependent on the accuracy of those coefficients. So when it comes to things like greenhouse gases, those coefficients are very accurate. But when it comes to toxicology they're not very accurate. There are large uncertainties in those toxicity potentials. That's the first issue. Secondly, what we see, which I assume you are familiar with in the marketplace, regulatory [requirements] – chemicals that are regulated, or things like Cradle to Cradle's Red List or Living Building Challenge Red List. There is an explosion of these lists. A lot of those lists have chemicals of concern to our customers and certain market sectors. But those chemicals might not have a toxicity potential. That has been not developed for them.

Ironically, and I've seen this happen, they may have a very low toxicity potential. So there's a negative perception about the chemical, but if you actually look at the potential that's been published for that chemical, it's not [merited]. So we at Steelcase at least do not use toxicity. We might asses the chemical impacts or the toxicity impacts of our material choices using LCA. We use completely different sets of tools to do that.

NK: What do you use?

CB: Well, it's a mixture, right? So again, it could be somebody screening against lists, just doing these screens. Or it could be using great certification programs, like having a product certified Cradle to Cradle or having them certified to BIFMA levels. What you do is you're deferring to third party screening assessment tools. It could be using programs like the GreenScreen from Clean Production Action, which segues into one of your other questions.

There are a lot of these from mostly governmental or NGO entities (non-governmental organizations) that have put together what they call hazard assessment tools or chemical assessment tools. Most of them are very thoughtful, though some of them actually contradict each other unfortunately. They're very interesting in terms of this issue. We ultimately use [tools] to make our decisions around the chemical toxicity issue.

Q: Would you mind telling me more about the Clean Production Action?

CB: I smiled when I saw that question because that's from my past. I've been at Steelcase for six years and before that I was an independent consultant. Steelcase was one of my clients, which is how I found employment here. But when I was a consultant, I worked with Clean Production Action. Clean Production Action was one of the pioneers. I'd say about 10 years ago, there was space out there, where there was a need for all these kinds of new chemical assessment tools and frameworks, principles. There was a vacuum out there. There was this gap between [industry] regulations and regulations defining chemicals of concern and there was pretty much nothing else beyond regulations.

There was definitely a lack of good methodological tools or even frameworks and concepts. There was an explosion of entities that came into that space: Cradle to Cradle, McDonough Braungart Designs Chemistry, and Design Center. Some papers were coming out of California, groups up there were developing tools. One of the organizations that came into being at that time was Clean Production Action. They're a non-profit organization. They're a network of very experienced people in sustainability. They've got a network of toxicologists. Some companies are members of their organization, and governmental officials. They're a non-profit, but their model is to create these networks of experts that come together to vet tools.

So today they're known for the GreenScreen. They are the organization that runs the GreenScreen program.

So this reference to Clean Production Action, which is still on their website, is from back when I worked with them. I was part of one of their committees working on various projects. One of the projects that I helped work on was the GreenScreen program.

NK: Okay, wow great. Well, thank you so much for taking the time to answer my questions.

Lisa Conway, LEED AP ID+C

Vice President, Sustainability – Americas at Interface, New York, NY

Lisa Conway is the VP of Sustainability, Americas for Interface – the flooring manufacturer that is leading industry to love the world. As a member of a global team, she and her team are responsible for regional activation of the company's mission: Climate Take Back. They're also responsible for driving higher levels of transparency and embodied carbon prioritization for the building industry as well as training internal associates and external stakeholders on the interconnectedness of environmental sustainability and human health.

Q: Interface has been focused on sustainability and design. How do you incorporate this into informed material making decisions and when?

LC: It really starts with product development (early in the process). There are three main pillars

Embodied carbon (footprint)

Circular economy (can it be recycled, end of life options for materials)

Green Chemistry (using materials safe for people and planet)

It's a balancing act, the lens we assess through. It is not about an order.

From a business and production perspective; the critical thing is supply chain reliability. How fast can we get it, how much material is available, and can we deliver our business needs with this material?

Q: Existing LCA software looks at existing building materials (mostly shell and core), based on a 60 yr lifespan. Do you think that is a realistic timeframe that could be applied to carpet? If not, what would suggest and why?

LC: Interface's LCAs are reported through EPDs. For carpet industry LCAs, 60 years is too long. EPD version 1 product category rules (PCR) provide guidelines. As more data becomes available, those PCRs are updated. We know EPDs expire in 5 years. So when ours was acquired we were already on PCR version 3. This is what makes EPDs not comparable.

In that different version of the PCR, there were different assumptions for the Life cycle of carpet. Some people had data on 5, 10, 15 years. The life cycle estimation would at least be called out in the EPD.

Q: Can you tell me more about carbon neutral floors and how this could improve LCA results and what is the life expectancy of the carbon neutral floor and is it closed loop?

LC: There is a program that we use to purchase offsets for any remaining footprint (as an internal carbon tax) and we do that for the lifecycle (cradle-to-cradle). That allows us to offer all of our products as carbon neutral through our Carbon Neutral Floors program. It is cradle-to-cradle for the whole cycle, closed loop. In that we can't ensure the products will be returned to us, it does have a third party loop built into it if we get the material back. We are working in CA (MN and IL) on carpet recycling. We want it to be at the state level to provide a tax on carpet sold into those states, then have that money go into a fund, which goes to carpet recyclers. (With oil prices being low it's cheaper to make new carpet than reuse old carpet.)

NK: Do you keep documentation of where your carpets are going to check on recycling?

LC: We have imperfect data in that regard. We know who we sold it to, not the address of where it is installed. The user of the carpet is not the person who buys it (the installer buys it). It is hard to know where all of the carpets go. We are looking into (industry wide) artificial intelligence options, opportunities to put kits in the product to read what the product is (so the user can know who to send the product back to). This process is fraught with peril…

because a demo contractor usually pulls old carpet out; they would have to be the ones to identify what the process is and where to send it. This is why this is challenging. This is why we are going the policy route.

Q: Is Interface looking into LCA for their products (with the EPDs) and, if so, what are the processes and obstacles that have been discovered in this process?

LC: We have been doing LCA for a while. We have an LCA expert on staff internally (working as part of product development and assessment process). A big opportunity for LCA is getting real data from the suppliers. The less specific the data is, the higher the carbon footprint will appear. This drives a goal to work with suppliers to know where their carbon emissions come from based on their specific way of creating and selling material vs. having to use industry average data. That is the *biggest* opportunity to get more exact data.

Q: How does maintenance place a role in LCA?

LC: That is a place where you are using average data. We sell to millions of customers and have no idea how customers maintain our products. We have to base it on how we feel they take care of it. Collecting that information seems impossible. But it is also a small part of the life cycle [for carpet]. If you were talking about washing machines, most of the impact is in the use space of the washing machine (operational). For us, it is less than 5% of the lifecycle of carpet. Because nylon is so energy intensive, you are not going to spend your time with [operational] data vs. washing machines or printers for which that would be more important.

Q: Does Interface use any LCA software and, if so, which one and why?

LC: We use GaBi software and I don't know why other than that it is preferred by our in-house LCA expert.

It's the Industry standard. GaBi is used for creating LCA for products. Tally is for designers, architects, and building professionals to use to study LCA data to design buildings.

Q: What would the LCA software require as an input and provide as an output?

LC: For input, you want the most exact data possible. If suppliers could get their exact information into a GaBi tool, then the manufacturers who are purchasing the products could input the data into their formula on the exact supply impacts.

The output would be more exact, better data.

Q: What is Interface's recycling program for flooring? Is it closed loop?

LC: Three carpet tiles, LVT (luxury vinyl tile), and rubber flooring can be recycled. It is closed loop (floor to floor) for carpet tiles and LVT, but not for rubber flooring. We have been doing vinyl (standard) backing forever, and we are one of the few that recycle it back into itself. Its 100% post-consumer.

Q: Is there anything else you would like to share with me?

LC: Your main focus is around LCA – around products and buildings. The one thing that I would point you to is the new EC3 tool. It's an embodied carbon calculator. Tally can be a good tool for comparing different product categories (for example, concrete and steel compared to cross lamented timber). It's based on averages. Then, once the general materials have been selected, you can use EC3 and real product EPDs instead of averages to choose the lowest carbon footprint of that type. This lets you gets a lot more specific. We are an early supporter of LCAs based on third party verification. The tool will not require a license. It's available to anyone with wifi.

Anita L. Snader, LEED AP BD+C

Environmental Sustainability Manager at Armstrong Ceilings and Wall Solutions, Lancaster, PA

Anita Snader is the Environmental Sustainability Manager of Armstrong World Industries in Lancaster, PA. She is part of the Team managing the sustainability strategy for Armstrong Ceiling and Wall Solutions, and serves as an internal environmental advocate, and environmental spokesperson. She is a LEED accredited professional, and well versed in the LEED, WELL, Living Building Challenge and FitWel rating systems. As co-chair of Armstrong's LEED EB team, she led the corporation to a LEED EB Platinum for their Headquarters building in Lancaster, PA in June 2007, and served on the team obtaining LEED EB recertification in 2014.

Recently, Anita has led Armstrong in a new initiative focusing on the Health and Wellbeing of occupants called Better Spaces. She drives the material health and transparency efforts, and created and manages Armstrong's commitment through our SUSTAIN™ portfolio of high performance ceiling systems. Her passion centers in developing strategies for reducing our impact on the environment through product and process innovation, and is always looking at opportunities to share knowledge and innovation with others.

Liesl Heil Morell, CSI, CCPR, LEED AP, Industry IIDA, MBA, WELL AP

Architectural Sales Manager at Armstrong Ceilings and Wall Solutions, Burlingame, PA

Liesl Morell has represented Armstrong World Industries for over 20 years. Her Industry knowledge, Bachelor of Arts in Interior Design, practice experience, and MBA with an international emphasis have helped make her the well-respected, go-to, problem solving resource that she is for the design and construction community based in the San Francisco Bay Area and Silicon Valley.

She has supported a wide variety of project types includes domestic and international airports, embassies, corporate office headquarters buildings, technology, and biotechnology campuses, as well as iconic architectural buildings in San Francisco, the North Bay, the Peninsula and Silicon Valley. She has collaborated with leading architecture and design firms throughout the region on an ongoing basis and evolved professionally and technically as the industry continues to change. As an advocate for environmentally friendly products and specification practices, her ready and innovative contributions have resulted in unique solutions tailored to specific client needs.

Q: Is Armstrong looking into LCA for their products, if so, what does this process look like and what are the main obstacles that have been discovered in this process?

AS: Armstrong has been doing LCA since 2006. We've been in the LCA world for a long time. This is not a new process for us. We initially used it and continue to use it to understand impacts of products. We produce Environmental Product Declaration, which are now a hot ticket. We were ahead of the curve. When [LEED] version 4 was being developed, we were part of that development. We knew there would be much more emphasis on EPDs, so we started updating our environmental product declarations. We were one of the first manufacturers to have a broad array of EPDs in the marketplace. I think we probably continue to lead in that regard.

The process has been part our design for the environment / healthy materials program for many years. We use it in a couple ways: as a way to understand everything about our products from an impacts standpoint and as a design "what if" scenario tool. If we are looking at a new ingredient, or if we are looking at changing something in our manufacturing [process], we can review our potential impacts from an LCA perspective.

We also use LCA to produce our EPDs which are part of our corporate commitment to product transparency.

NK: Did you find any obstacles while doing this?

AS: I think the hardest part is the software itself. We use GaBi software. We went through training. We had a two day workshop here and were able to train some, but if you don't use it all the time it is hard to remember. It really is ripe for improvement to bring it into today's world of software tools. It has lived in the science world for many years that is how it was designed. Now it needs to evolve to be more user friendly.

Q: Can you think of any solutions to those obstacles:

AS: It would be great to put this in the hands of more people here, but the likelihood of that – due to the complexity – makes that just not feasible internally. If there is a more user friendly software that ties in with other reporting systems within our company, that would allow us to keep it updated more efficiently and expand its usage.

Q: Would the ideal LCA software require as input and provide as output?

AS: The inputs are a very manual process right now. It would be great if there were some process that could take our energy, water, productivity and other data, and transfer it into the system rather than requiring manual input. Then the great part would be if it could just spit out an EPD, instead of having to go through the process.

That whole process automated would be very beneficial. With all the data sharing and advancements that have been made, it feels like the software is still stuck in the dark ages.

NK: Have you looked at Tally?

AS: I did in the past. I looked into it with the EPD tool. I just did a presentation with an engineer for a group of manufactures at an event in Boston with the USGBC Chapter at USGBC's conference. They were talking about Tally. I need to dive back into that. I don't know if they have made improvements on that. Regarding software, there would need to be some collaboration with the software.

Q: How is Armstrong shifting how decisions are made based on potential impacts on the environment?

AS: Of course, not only through our LCA efforts, but also how we measure our operational impacts (energy, water, greenhouse gas, waste). That isn't really shifting any decisions. It has always been part of how we operate with the goal to use all of those resources most efficiently. Armstrong was one company with flooring. In 2016, we separated into two separate companies: Flooring and Ceilings. Armstrong Commercial Ceiling and Walls is in the process of setting our sustainability ambitions with a future fit roadmap.

NK: You're just in charge of ceiling systems? Are you close to becoming a net-zero company?

AS: Yes, ceiling. We are working toward reduction in all areas. At this time we are assessing our baseline. Ceilings are very low impact from a product standpoint. We have opportunities in the manufacturing process. So moving forward, we are taking a new look at opportunities across our business.

Q: How is Armstrong approaching LCA?

AS: We have been involved in LCA efforts in the ceiling industry for more than a decade. We have been part of an effort with Interface, which was started with SKANSKA 2 years ago, to raise awareness about embodied carbon in buildings and tradeoffs associated with operational and embodied carbon. It is called materialsCAN (https://www.interface.com/US/en-US/campaign/transparency/materialsCAN-en_US).

We are a material sponsor with the *EC3* effort and have worked with the EC3 development team to create a ceilings category in this tool. The tool was launched in beta at GreenBuild 2019. It contains all of our ceiling EPD information. Also, *mindful MATERIALS* (mM) is a free platform with aggregated information on human health and environmental impacts for products from leading manufacturers, vetted by experts passionate about making it easier to make informed product choices. Their concept is that everyone can put their data into one depository (pulled from HPDs, Declare labels, and EPDs). It's a great platform and screening tool for the industry.

Q: How does Armstrong incorporate LCA data into informed material decision making and when?

AS: We incorporate LCA data into our decision making beginning with Design. All of our business units (innovation group, technology group, new product development group) review materials as part of the new product development process. The requirement is that they review the proposed materials from both an LCA and a material health lens. It starts with our innovation group looking at new materials and processes. Part of that is a requirement that they look at it from a LCA and materials health standpoint. Its starts, in the beginning, in our innovation groups.

Q: How does this impact the process of business and production at Armstrong?

AS: I would say from a business standpoint we are looking at efficiency and using less energy and less water. This helps us to go toward being more efficient and helping to reduce our footprint as well. Each year our capitol and innovation group go through a productivity event designed to achieve process improvement. It's a collaborative effort among various departments to share knowledge and innovation.

Q: Existing LCA materials look at existing building materials (mostly shell and core), based on a 60 year lifespan. Do you think that is a realistic timeframe that could be applied to ceiling tiles? If not, what would you suggest and why?

LM: No, that is not a realistic timeframe for ceilings, but it probably happens. This is concerning, because there have been improvements, some of which are dictated by the PCR (product category rules). Our warranties are 30 years or 10 years depending on the product. Something more realistic is definitely in order.

NK: Since this is happening, are you thinking about a recycling process?

AS: Armstrong Ceilings has had a recycling program for the past 20 years. It is designed to recycle acoustical ceilings from renovation projects and return to our closest plant. We have seen a decline in use of this program, and we are hoping with the focus on circular economy and waste reduction that this will change. It requires a change in thinking about materials during a renovation, and taking advantage of a closed loop system that we provide versus sending all to landfills.

Q: I believe when we hear about other's passions, we get inspired to do things, what is your personal drive for doing this work?

LM: The health of people, in working conditions every day. We learn more about the impact of materials on our houses. We have the answers. We know what we can do. We want to strive (for manufactures) to do better and for us to provide the solutions for customers for them to do better. The health of the occupants using and in the building are the most important. I've talked with green designers about the consumers who are working on research for health topics, what if the building was helping with our diseases! That is something to think about.

Q: Last question: anything you want to share that we have not talked about.

AS: The one area we did not touch on is Existing Buildings. There is a tremendous existing building stock. I n addition to the unprecedented growth in the global building sector, nearly two-thirds of the building area that exist today will still exist in 2050. Therefore, any transition to low-carbon/carbon neutral built environment must address both new construction and existing buildings.

LM: The Interpretation of the EPDS comparing our own product against the other (how to tell which one is better). What's been the challenge with all this documentation is identifying what the baseline for "good" is? I think the EC3 tool is helping with that, but there is so much information in the LCA and EPD documents. How do you know when you are comparing these two similar products – how do you try and simplify it down to a decision point. That it is the big question, with all this data. How do you know which one is better from a sustainability perspective?

Robert Wendoll

Director of Environmental Affairs, Dunn-Edwards Corporation, Los Angeles, CA

Robert Wendoll is the Director of Environmental Affairs for Dunn-Edwards Corporation in Los Angeles, California. He has been with Dunn-Edwards for more than thirty years. His current duties include monitoring environmental, health & safety laws and regulations, determining specific applicability to Dunn-Edwards, and designing and implementing compliance measures and programs. Beyond compliance, Mr. Wendoll also seeks out and develops opportunities for Dunn-Edwards to improve its environmental performance through voluntary initiatives.

Wendoll has been an active member of American Coatings Association (ACA) committees, including its Environmental Management Committee and its Architectural and Industrial Maintenance (AIM) VOC (volatile organic compound) Committee for many years. He received the Industry Achievement Award from the ACA in 2012.

Written responses provided by Robert Wendoll:

Q: How is Dunn-Edwards shifting how paint impacts the environment by designing for life, closing the loop, and driving collaboration?

Dunn-Edwards is aware that paint impacts the environment in a variety of ways, some beneficial and some detrimental. We seek to maximize the environmental benefits of paint, while minimizing its ecological burdens. For example: Paint uses a relatively small amount of material resources to protect and preserve a much greater amount of material resources -- the substrates to which paint is applied, and which make up a large part of the built environment. Coating performance is the key to protecting and preserving substrates, reducing maintenance and repair or outright replacement of building components, thereby conserving energy and material resources. Consequently, our primary goal is to achieve high performance -- with minimal or no adverse impacts, such as emissions of volatile organic compounds.

Q: Dunn Edwards has been focused on sustainability and design. How does Dunn Edwards incorporate this into informed material decision making and when? How does this impact the process of business and production at Dunn-Edwards?

The process begins at the earliest stages of ingredient evaluation and selection. We assess performance characteristics and screen out, to the extent feasible, ingredients that contain known hazardous substances that may result in exposures during production or use of finished products. This does lead to abandoning some opportunities to make certain kinds of coatings -- until better alternatives are available. We remain confident, however, that our commitment to safeguarding the environment, health and safety is in everyone's best interest.

Q: Are there Dunn Edwards products that are Cradle to Cradle (C2C)? If so which ones? If not, what have been the obstacles?

We have investigated Cradle to Cradle certification for our products, although we have not as yet submitted any products for certification. The drawbacks, for us, are that the certification criteria do not include sufficient performance characteristics specifically applicable to paint, and relatively high cost. Many of our products are certified by the Master Painters Institute (MPI) and the Coatings Resource Group, Incorporated (CRGI) Green Wise program. Both of these include performance criteria.

Q: Is Dunn Edwards looking into LCA for their products? If so, what is the process for selecting potential products and what are the main attributes that make a particular product a good candidate or a challenge?

Dunn-Edwards is currently engaged in development of an Environmental Product Declaration (EPD) for select products; specifically, our Low Odor/Zero VOC Interior EVEREST line of finishes, and appropriate primers. EVEREST is one of our best interior product lines, and one that is most frequently specified for LEED projects. As you probably know, an EPD requires an LCA for the covered products.

Q: Does Dunn Edwards use LCA tools to determine impacts on the environment? If so, which tools and how are they used?

An outside consultant, ThinkStep, is developing the LCA for our EPD using the GaBi program:

http://www.gabi-software.com/america/overview/what-is-gabi-software/

The LCA will conform to the Product Category Rule (PCR) for Architectural Coatings, developed by NSF International: https://www.nsf.org/newsroom_pdf/su_architectural_coatings_pcr.pdf.

Q: How does maintenance play a part in LCA outcomes for paint products?

Maintenance of a paint film is quantified as repaint frequency, which is directly related to product quality. See page 12 of the PCR for more information. Longer repaint cycles, of course, serve to reduce various predicted paint impacts.

Q: Existing LCA tools look at building materials (mostly shell and core) based on a 60-year lifespan. Is that a realistic timeframe that can be applied to paint? If not, what lifespan is more realistic and why?

Again refer to the PCR, pages 10 - 11. The functional unit for the LCA is defined as "1 m2 of covered and protected substrate for a period of 60 years (the assumed average lifetime of a building)." The "reference flow," however, is defined as "the amount of product needed to satisfy the above functional unit. In order to satisfy the functional unit, multiple coats or repaints may be needed." The PCR further explains: "When determining product lifespan, both design life and an averaged market-based lifetime shall be used and reported by the EPD. In order to determine a design life, the product must be classified into a low, mid, or high quality level. The specified quality level is variable and is based on the product's performance in various accepted industry durability tests."

Q: What would the ideal LCA software for Dunn Edwards require as input and provide as output?

I don't think I can answer this just yet -- we are expecting the results of the LCA from ThinkStep in mid-December. We will analyze and evaluate the results then. It may be that the GaBi software is already ideal.

Q: What is Dunn Edwards's recycling process for paint?

Dunn-Edwards participated in the National Paint Dialogue involving U.S. EPA, state and local waste management agencies, paint manufacturers, retailers and contractors. The product of the dialogue was the creation of Paint Care -- an industry-managed and -funded nationally-coordinated program for the collection and recycling or disposal of unwanted leftover paint. All of Dunn-Edwards retail store locations in California are Paint Care Collection Centers, where anyone may bring their leftover paint (of any brand) for responsible end-of-life management.

https://www.paintcare.org/

Q: Is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

I will enjoy answering any questions may you may have!

Roderick Bates, LEED AP BD+C

Principal at KieranTimberlake, Philadelphia, PA

Roderick interprets ecological, economic, climate, social, and site data to inform sustainable building design. He assists architectural teams at KieranTimberlake with simulation-driven design evaluations, using the results to envision design modifications and bespoke tools that improve a building's energy performance and thermal comfort. For example, following an initiative to quantify the embodied energy of buildings—an effort that was recognized in 2008 by the EPA Lifecycle Building Challenge award—Roderick worked with the Research Group to develop Tally™, a Revit application that lets designers access accurate Life Cycle Assessment data and reporting tools directly in their digital models

---

Q: Why does Tally focus primarily on shell and core materials?

RB: This question I wouldn't say I take issue with, but I certainly would say we have a fair amount of interior materials: sheet goods, plywood, paint and various other things like carpet, ceiling tiles and what not in Tally. So we do have a fair bit of interior materials and anytime an architect requests something, we will do our best to accommodate it and integrate that in. Really, to-date we don't get requests for interior materials, we have gotten requests for other things. I'd say we either are hitting the requisite number and materials or alternatively the industry as a whole, practically from the interiors perspective, isn't paying that much attention from an LCA perspective. We do have some [interior] materials, but with that being said a lot more attention is being paid to reduction strategies on the envelope and structure. The primary reason being that they make up the bulk of the mass of materials and masses are a very crude proxy of [carbon] impact.

Q: Is there a barrier related to incorporating interior finishes and furniture into an LCA tool? If so, please elaborate on what the barriers are? If not, why is there not more interior and furniture LCA data incorporated at this time?

RB: So there are different barriers for different things, so one of the barriers is from the Tally perspective, but others are from the LCA perspective.

One of the challenges for incorporating interior finishes and furniture into an LCA overall probably has some degree to do with when certain components are modeled. Typically those interior things are coming in quite late and as a result a lot of the big decisions that really are driving impacts one way or another have already occurred. Furthermore, once you move past things like say gypsum, flooring, and ceiling materials, the number of materials that people might be putting in and potentially counting might go down quite a bit and their quantity goes down a bit as well. That has the effect of reducing the motivation for putting in the effort of quantifying the embodied impacts of those particular materials. I'm certainly not saying that those impacts aren't there, and a lot of those materials can be quite impactful, some of the interior finishes could be particularly manufacturing intensive.

From the tool perspective you are going to see less of this because some of the data is quiet hard to come by from the model. So going from the model to calculating the material that can then be associated with an impact is actually quite challenging for certain types of materials. For instance, Revit doesn't provide information that is read by 3rd party EPI's material quantity take off for casework. There are other examples of little things that are quite challenging to read. So, that is the other part of it. Suddenly we are in a position where we can create the perception of expectation by what is possible in the context of tools. There are some other examples of nitty gritty details that are difficult to pull. You also mention some other interesting ones here, particularly furniture. Furniture is challenging because there isn't a generic furniture figure – you cannot ask for a generic desk for example.

NK: Like a baseline for a desk?

RB: There is no average LCA or EPD for a desk. Now you will have manufacture's EPDs for specific products. The fortunate thing is they run on an instance basis – how many you have. You don't really need to go through the complexity of the material take off of a BIM model to be able to say well I have 50 desks. So fortunately that's the position where not only do you have a baseline to compare it with, but alternatively you can very rapidly create a figure by looking at the EPD's and how many there are. There is also an enormous amount of variation of course within interior furniture. I think that is another part of the challenge. Different parties are held responsible. Someone might specify some kind of furniture, particularly the kind that is bolted down like seating in a theater, but not necessarily specify the desks that go into an office space. It's like a world of architecture at that point. It would be a little bit more than we would do normally. I think there is a challenge in how to reconcile scope areas of responsibility and what's appropriate for a BIM tool. Maybe it is better used in excel. As you noted the lack of an industry baseline figure – if you are not comparing it to anything, then what's the point? That's a bit of a challenge as well.

Q: How do the Tally developers envision the tool being used by designers during the design process to lead to better environmental choices and what kind of research was done to support the approach?

RB: We had a really simple requirement from day one and that was that it needed to be integrated into the design process. By that we meant that it was integrated into the design tools. So our approach or our idealized use is that the same individual that is responsible for making the material selection decisions (of course the design process through the BIM model) is the one who is using Tally. When they make those decisions, they are able to try different materials on for size. They can look at their impact and then essentially specify the one that has the best performance, balanced with cost, esthetics and environmental performance.

NK: So this person would go through the process from the start to finish.

RB: Ideally, we are seeing more of that, everyone has this installed on their computer and is using it on every project. Our users are those who have fully embraced the iterative nature, have Tally baked into their template files, and are using it on every project. Every employee has it installed on their computer and when they model they model with Tally. It is just part of their process. I'll be frank, there are people using the tool better than we are. That is great, but it is a little embarrassing.

NK: But that just shows that you have created something that is user-friendly.

RB: Yes, exactly and that's the idea. For a long time, and it is hard to think back to 2013 but at the time, LCA was a practice that was closely guarded. Honestly the data and tools that were employed were very closely held by the professionals. It was almost like the priest speaking Latin. There was no intent to obfuscate their methods. We really wanted to crack that open and provide absolute access because we felt that was user-friendly. It must be very robust in its methods, so it performs accurate lifecycle assessment and does so iteratively. It must also perform them so quickly and easily that it's not as if you do it as some sort of a capstone at the end of the project, rather you are doing it continually throughout a project. The LCA is that quickly and easily accessible.

NK: I am seeing how important that is because I am trying it out on a project. It is somewhat frustrating because I don't know what went into the building and not everything gets picked up in the model and you don't know all the materials. So I have to go back.

RB: Exactly

NK: I have to go back and talk to the person who maybe touched it two years ago. They don't know, because they are working on other projects now. So I see the importance of doing it from start to finish.

RB: You are hitting on the second model, someone coming along whether it be from the firm itself or later and that individual has to essentially apply data as a consultant that inherits a model from another architectural firm. People sometimes reach out to us asking us to run Tally assessments for LEED and stuff like that. The challenge there is of course the quality of the model or the use of generic families. There are a number of challenges that come along with that. They're all surmountable. It just takes time. It certainly is not in keeping with our idealized intent. It isn't [an approach] that allows for that optimization that we are looking for. The idea might be, well let's

just do this by creating some fake baseline and say we did better. The purpose is really to drive down those impacts. However, if you apply this very conscientiously, you can see some massive differences. I mean you're talking 30% decreases in embodied carbon. That's big.

NK: How does Tally collect data on manufacturers and how are manufacturers chosen to be included in the software?

RB: We're really pretty open minded. So there's two parts to Tally when it comes to the data side. One is us. We create a lot of the data that relates to understanding the quantity takeoffs and the additional questions that go into what you're being prompted for as you specify a material. We call this look up tables. That's our responsibility as well as, application rates and replacing rates. Then the actual life cycle impact data, the kilograms of carbon equivalent per a kilogram of material, is provided to us by a company called Sphera, which was formerly thinkstep. They are the makers of the GaBi software. We work with them and they provide a custom database for our application. Because if you ever look at Gabi, you'll find that it essentially breaks everything down to about the smallest constituent process and material. So if you want concrete and then you have to specify the manufacturing method, the energy input, all those kinds of things, its far more than anyone would ever want to do. What we do is we work with them to create a custom database, sort of a hybrid prepackaged for Tally. As far as manufacturer input goes, we will accept any manufacturer data that is contributed for inclusion in Tally. We're more than happy to do so, as long as it conforms to the Revit categories that Tally is able to read, given the Revit API. Now if it's outside of that, then there's not much we can do.

NK: Are manufacturers coming to you and asking you to include their products in Tally?

RB: Yes. For instance, we just had SageGlass ask us to include their product in Tally and that was just finalized a week or two ago. Now if you go into Tally [it's there] and that's a nice thing because our database which is cloud hosted. When they requested, I could go ahead and add it pretty quickly. The challenge, however, is that we're basically willing to take anything in and don't charge for it. Thinkstep on the flip side, when you get an EPD generated by them, the inclusion in Tally is a no cost, additional option. Most manufacturers will opt for that. However, there are a number of other ways or other software tools and databases that one can draw from to create and EPD. You can't just take an EPD that was created in SimaPro, or maybe using GaBi, but using a different database like say ecoinvent instead of just the pure GaBi database, and throw it into Tally for several reasons. Once that background data is different, there are challenges associated with that. There are a lot of assumptions that go into modeling. A lot of those are reflected in a PCR (product category rule), but Tally is unique in the sense that it takes materials that have different product category rules, say like mass timber used for structure and steel that's used for structure. They're going to have very different product category rules. So we're able to take the EPDs for each and then reprocess them in Gabi so that they have all of the appropriately aligned background data assumptions, cutoff points, and things like that. That way when a user brings in these two very disparate materials and tries to compare them in the same application, they're able to do so accurately.

NK: That was one of my questions. For instance, what if I want to compare floor tile to bamboo flooring?

RB: Exactly. I don't know actually what their product categories are or whether the rule sets are different for those or not. I think maybe a better example might be a brick facade versus a curtain wall.

It's totally different, right? If you just took the straight EPDs for those two things and then said, okay, I got 10 square meters of this and 10 square meters of that and you just tried to compare them, it would be an absolutely bunk comparison. There's no way to know that the model practices, the background data and all that kind of stuff is right. That's one of the big things that Tally and particularly Sphera are bringing to the table – the alignment of that. It takes a lot of time. To be perfectly honest, that's not a small task. That's one of the hurdles when a manufacturer says they want their data in Tally. We're say great, who made your EPD? If it was made by Gabi, no problem. It's probably already in there. If not, we can get it in, in a matter of hours. If it was made using a SimaPro or some other software or different databases, not by Gabi, then it's not that simple. Then they would have to have a whole EPD – the whole LCA – rerun in Gabi. That's a pretty big lift. I think for some manufacturers there's a real cost there. We see some doing that when there's a big project coming through and if they know they're going to be specifying, I don't know, a hundred thousand or a million square feet of whatever the product is. We can step

up for that [and find a way] but by and large, that's a pretty tall order. That's one of the challenges. It does not ensure that the quality of the data in Tally is really high when we don't necessarily have confidence that everyone playing in this field abides by [the same rules].

NK: We might've talked about some of these points, but I'll ask the question anyways. In terms of material, data input rather than inventing yet another material reporting form MSD or declare HPD or EPD, is there an existing form that requires the kind of input data needed for Tally or that could be easily expanded to do so? If so, which one(s) and what makes them promising?

RB: Honestly, I think the EPD from the Tally perspective is really where it's at. It's got everything we need, and it allows for us to link back to the source that is publicly available and signed off on. It's not ideal because it doesn't combine the health side of things. The fact that you have HPDs and EPDs as separate things seems a little silly to me. That's just the way it is but I think that the EPDs work exceptionally well. I'd be surprised in the future if you don't see a combination of HPD and EPD, type information. I think one of the challenges with an HPD is that [unlike] an EPD, which is very good at providing a sense of the magnitude of impact for the various categories of the LCA, HPDs identify the presence or absence [of a potential risk]. The exposure and risk calculation is quite challenging. But my ideal is, if there were to a clashing of the results based on HPDs and EPDs, the impacts would be report similarly.

Q: As Tally was being developed, what were some of the obstacles and how did the team get through them?

RB: I don't think there was anything but obstacles. It was very hard. I think one of the things is that, we were coming from a purely technical perspective. We were engaging Revit at a level that was fairly significant and we were continually bumping up against the level of documentation available for their API. Fortunately, the support we have from Autodesk was significant and one of our developers actually went to their headquarters and spent several days working with one of their engineers that developed Revit. It made a huge difference. You're able to learn all these tricks. I think part of it is that, and I appreciate this more and more, there is an amount of legacy code in software over time. The longer it's around the more there is, that is just that's the nature of the beast. You need to have backwards compatibility. Certain design decisions, as far as code structure and things like that, were made years ago that had implications. Now if you were to do it all over again knowing how things ended up, you certainly wouldn't do it [the same way] again. It really made a huge difference to be able to work directly with them and get that type of high level support. That was one challenge. We still face certain challenges along those lines. For instance, Excel recently changed the way that auto generation of Excel reports are created. That was an unannounced change. It was just absolutely a tiny little piece of code, but it affected the generation of an Excel file for Tally and certain Tally users and there's no way we would notice it was going to happen. We're just not, a big enough deal that Microsoft's going to tell us. There's no way that they'll document it anywhere. We just find out that it happened. There're always these technical challenges about how much information you're able to find out on that code and development level.

I think the other significant challenge we found at the time was getting industry buy in. This is was something else that Autodesk was really helpful with. It provide a lot of resources and connections and brought people on board, whether it be firms and that were starting to think about LCA or were sort of ahead of the game. It came down to practice and making sure that Tally informed how they were going about things. Also some of the other players in the world of LCA, particularly the Athena Institute, helped make sure that everyone understood what we were trying to do and how we were complimenting the whole, as opposed to say a cannibalizing somebody else's position. From our perspective, there shouldn't be competition amongst the, software providers in the field. All of our goals ideally are the same.

NK: The environment and people.

RB: Yes, exactly. That was a big challenge, getting everyone's buy in and to realize that they were a part of the community. I think the last challenge that we're seeing is just adoption. This isn't an impact that has a direct financial implication for projects. It's not like an energy model. If you do things a little bit differently, you can save thousands of dollars a year every year. This is something where the impacts are insidious. They're unseen and there's no government tax on the impact that your building's having on others from an embodied impact

perspective. This is really something that requires a degree of education. Clients and designers need to understand that every time they are making a decision say they want that facade or they want this one, what have you, that there is an environmental cost that comes along with that. They are in a position to make decisions that can dramatically reduce that environmental costs. I think even more challenging is getting them to understand that reducing those environmental costs in a lot of cases has zero cost implications, zero aesthetic implications, and zero traditional performance implications. All it does is produce a better building from an environmental impact perspective. For a lot of people, that's hard for them to wrap their minds around – it's that easy to do. I think they all assume that to be true, they would have to wear a hair shirt and suffer to achieve a better building based on LCA. I think convincing them to the contrary has been one of our biggest challenges.

Q: Other LCA software is not as user friendly as Tally. How did Tally develop the strategy used and what are the key components of that strategy and the user interface? Can you tell me about point list? Is it related to Tally in any way?

RB: From the user friendliness perspective, we are in a fairly unique position as a software developer by being first and foremost an architecture firm. So we have probably about a hundred or so of the most critical possible Revit using testers you could ever imagine. You know, they just love to critique here. It's part of the model of the firm, which takes pride in critiquing other people's work. So, it has provided an excellent basis for us to develop the software and to test it. This type of testing could happen in extremely short cycles, which was fantastic. The other thing that was really key to developing the interaction and easy of use was that we also have a very good peer network as a firm. We have a lot of relationships with firms all over the country that we work hard to maintain. So we did a fairly serious testing of Tally and the UI [user interface] with outside firms, about 25 or so testing firms. Then of course within those firms they had a number of additional testers and we did comprehensive feedback calls to make sure that we were really nailing that usability side. So that was pretty key. The other point is that we have a few people on our staff, particularly Ryan Welch and Christopher Connock, with special skills. Ryan Welch is our building performance specialists and lead coder and Christopher Connock is our Design Computation Director, who has an incredible eye for UX [user experience] design. Both of them are fantastically skilled. Their contributions made a very big difference as far as the usability of our software.

PointList is a reflection of the maturity of our thinking about usability. We wanted to take something that was, similar to the content of Tally, very complex – in this case, building monitoring – and make it something that would be highly accessible. This solves a lot of the problems that we found with traditional monitoring, which was being able to basically access and share data. PointList makes access incredibly easy and then one is able to repurpose and allocate equipment incredibly easily. Those are some challenges that are pretty significant when you start dealing with actual hardware. So we found an interface solution to be able to do that. I would say that PointList did teach us that hardware is incredibly challenging. Hardware that is combined with software is essentially a nightmare. That's not something that we provide to the public. We do provide it to research partners and development partners, but it's not something that we're selling at this point. We sold a few kits to individuals here and there that really wanted it and had unusual applications, but by and large, we keep that as an internal tool. We have about a hundred or so kits downstairs and for the team that needs them to do some monitoring. They can just grab a kit off the shelf and they're good to go.

NK: When you were doing the research and having people use the software and tell you their thoughts, was it people that didn't even know anything about LCA?

RB: Well, it was a portion of them. The market Research endeavors we did were an industry wide survey. I'm on the 1500, maybe 2000 different contexts that we, the firm has generated over the years. These are people we had worked with and some who we had never worked with. We actually surveyed the same group multiple times, which has been rather fascinating. There were similar questions. If you look at our first survey, I could probably dig it up somewhere, but it's asking questions like, "Do you know what life cycle assessment is?" and "Do you think that building materials have an environmental impact?" Really basic questions. If I recall correctly, in the first survey, about a third of the people basically had no clue about whole building LCA. The concept of it did not click.

NK: That's 500 people.

RB: Yeah, exactly. That was people who had no clue. Then there were some people that had some clue and then there was a minority, and it was probably like 20% or less, who got the concept. This told us a couple of things. One of the things that it told us is that education is going to have to be part of our marketing strategy and it still is part of our marketing strategy. I'm sure you've experienced this from a customer support perspective, we work pretty hard to provide a high level of support because we said Tally is a tool that is a reflection of a rational process. As such, you can't just throw it out there and expect people to understand. You do have to work with them and help them learn because there aren't a lot of other resources out there. So we looked at the tool as an educational opportunity. Additionally, it also told us that, releasing the tool may not be some sort of a fantastic commercial sales opportunity. Rather in a lot of ways, we aren't sure we could make money on it. But at the same time, it was also something that is a reflection of an ethical imperative.

This was a long time ago, right? This was 2013 that we were making that decision. In a lot of ways, it's not the most profitable product we could have developed, but it's one that we feel is probably one of the more important ones.

Q: Can you tell me more about Roast [KieranTimberlake app for conducting post-occupancy evaluations]?

RB: Well, Roast is something that's really exciting to me because it, it reflects a lot of our thinking in the context of Tally. It puts it into a very different realm. Tally is really about decisions made, before you flip on that first light switch and all the impacts that are incurred. Roast, it's really about all those impacts that happen after the building is done. It's related directly to operations and, similar to Tally, it reveals impacts that people just don't think about. They fail to realize that the way that they use their building has enormous implications as far as energy use – for example, the decisions they make as far as set points or shading, whether the window shades are used or not, ventilation rates, things like that. If the windows are open or closed, all have huge implications. What we have done with Roast is create a mechanism that allows you to really take the pulse of what's happening in the building and how the occupants are experiencing it. At the end of the day, we're creating the building for the occupants; the design task is not just to create volumes of space. It's really there for people to interact and hopefully to function better than if the building didn't exist. With Roast we found that there is a real opportunity to optimize the performance of buildings, given the real time feedback on how people are experiencing that space. This came out because of our own office, where we had a fairly sophisticated mixed mode system. Initially we actually didn't even include air conditioning and of course in Philadelphia that turned out to be a bad idea. We had created a very crude survey methodology for capturing how people felt and we were able to associate responses with where people sat – how people felt in a location at a given time. We had a sensor network set up in our building that was capturing temperature and humidity in time and space as well. By putting these two pieces of information together, we were able to really fine tune set points, and also people's perception of comfort. We used that information when we ultimately installed air conditioning in our building to size the system. We knew exactly how big the system needed to be to hit the set points that people felt they wanted to feel productive. That system ended up being about 30% smaller than otherwise would have been the case. That was pretty significant. Once we started using the air conditioning system, we continued to use the survey method to not only find problems like where say vents weren't properly functioning or perimeter systems had failed and things like that, but also to optimize the set points and setbacks during the weekend and things like that. The remarkable thing is that while our energy use when we didn't have air conditioning was less than after we installed air conditioning, but we applied what we learned from Roast so it only increased 0.5kWh per square foot. We were at I think 37.9 and went up to 38.4. So basically a tiny increase from going from no air conditioning to having air conditioning in our building by using a survey methods to find out how to pinpoint and apply air-conditioning, by fine tuning the location, quantity, and time that it was needed. And this really blew our minds. The idea that you could add a whole air conditioning system and essentially see almost no difference in energy performance.

We thought, wow, this is something we've got to share. So we created some proof of concepts, shared it with other entities, and that was really the motivation behind Roast. It provides this mechanism by which people can optimize their buildings after they're built to achieve the highest level of performance. We are hopeful that people will take up that challenge. And at the end result, of course, is that people are happier. They're comfortable. If there are issues in the building, they report it quickly and it's all done in a way that's very visual and easy to understand. The sophisticated software is all under the hood, but from the user's perspective, it's incredibly explicit. You can really easily tell exactly where, when something's going wrong or how people are feeling.

NK: Is Roast software free?

RB: We provide it free for academic use and certain nonprofits. Actually, I got an interesting ping today from a school in Canada for instance, that was built in 1921. They can't afford to put in air conditioning, but they really want to try to optimize their performance. So they asked for Roast access for free which we provided. But for commercial customers, whether they are property owners, HR managers, or architects we do charge for it. We provide a free trial, but we charge for the software itself. There's a pretty hefty R and D burden to it to develop that one. We also see the gains as being massive. For instance, in our building, we run the set point, at around 79 in the summer versus 70 as recommended by our engineer. For the cost of the difference in degrees, we basically paid for that software in the span of probably about two weeks.

So it's one of those things where it is really pretty eye-opening. We're looking forward to it. We just started a big campaign and digital ad campaign, so fingers crossed.

Q: Is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

RB: There aren't a whole lot of examples of people demonstrating the benefits associated with applying LCA, thinking to interiors in particular. I think a lot of times there isn't as much imagination as you might hope out there amongst the design community. Providing nice, clear cut examples of the possibilities, improvements made, and the differences that are possible when you start thinking about LCA in the course of designing interiors would go a long way. That's the type of thing that starts spurring thinking and action. That's one of the challenges that are out there, particularly when you think about life cycle assessment and interior design.

The simpler, the better. I think that was one thing that we actually talked about as one of the internal challenges. We have people that are true LCA experts. Then we had people like me that are more in tune perhaps with the perspective of the consumer. There was a lot of back and forth initially about how complex to make the output of Tally. How should the user interfaces of Tally or the interaction with Tally be? I would still firmly say simpler is better. Trying to achieve some hypothetical levels of perfection at the cost of uptake is in my opinion not the strategy.

Dr. Joshua D. Kneifel

Research Economist at National Institute of Standards and Technology (NIST)

Dr. Joshua D. Kneifel is an economist in the Applied Economics Office of the Engineering Laboratory (EL) at the national Institute of Standards and Technology (NIST). Dr. Kneifel joined the staff at the Applied Economics Office after receiving his PhD from the University of Florida in 2008. His research at NIST is focused on quantifying sustainability performance of buildings. Dr. Kneifel implements whole building simulations, life-cycle costing, and life-cycle assessment to determine the economic, environmental, and occupant consequences of increasing the energy efficiency of building construction.

Dr. Kneifel is the project lead for the "Metrics and Tools for Sustainable Buildings" project, which uses measurement science to develop and implement metrics, data, and tools for quantifying sustainability performance in buildings.

Dr. Kneifel oversees the development of software tools that calculate the sustainability performance of individual building products (Building for Environmental and Economic Sustainability – BEES) and whole buildings (Building Industry Reporting and Design for Sustainability – BIRDS).

Dr. Kneifel is collaborating with the National Renewable Energy Laboratory (NREL) and Athena Sustainable Materials Institute ASMI) to combine NIST's *BIRDS* sustainability framework and ASMI's Impact Estimator for Buildings to create an API that allows OpenStudio users to calculate custom, detailed whole building life cycle assessment estimates for residential buildings. He is overseeing the development of the *Economic Evaluation Engine* (E3), a publicly available API that will provide standards-based economic calculations that can be leveraged for custom internal and external research and tool development. Dr. Kneifel is also the project lead for the *Building Life Cycle Cost* project funded by the Department of Energy (DOE) Federal Energy Management Program (FEMP).

Q: BEES determines the life cycle cost and environmental performance of individual products used in the construction of buildings. What is the process you use to add a product to the database?

JK: The general process of adding products has two steps. One is we do regular updates in terms of updating the entire product categories. When we go to do that, basically we update all the products that we currently have in BEES. We also reach out to the manufacturers and see if there are other products. Either they can remove products they have or they can add in new products. Once we have that list, we have an LCA practitioner that we contract with that actually goes through the process of developing all the life cycle assessment results for each of those products. Then once the LCA practitioner completes that, then we upload the results into the software. That happens on a recurring basis. At this point, with the newest version, we're basically trying to align it for when product category rules get updated. For example, flooring is one of the biggest products in BEES. The next time its product category rule gets updated, we will immediately take that and update our LCA results to be consistent with what the new version of the product category rules state. Another option is a manufacturer can really submit a product at any point in time, if they provide the information that's required to complete the LCA. They can either use the same LCA practitioner or they are going to have to have their own LCA practitioner do the work. Regardless, our LCA practitioner has to do a critical review of that to make sure that all the assumptions, the methodology, the underlying data and the software used are all consistent with, what we do to develop our LCAs. The main reason for doing that is so that every single LCA for a product category is developed in the same way. That way they're actually comparable because a lot of times, if you've seen a lot of EPDs that are out there, you're not necessarily certain that you can make the comparisons. Different LCA software can lead to different results. If you use different underlying databases for your secondary data, you get different results and so forth. So that's one of the kinds of key things that we feel is needed, that comparability and transparency into what goes into the LCAs. So that's the general process associated with how a product gets included. Along that line, in terms of the data collection, our LCA practitioner works closely with specific manufacturers' product lines or for industry level, industry average, or generic products. She works with industry organizations to get the best available data. A lot

of times data is using the same information that was used for a previously developed LCA or previously developed EPD or even the PCR. Like for concrete, we use that as the basis for the products that we're assessing. We use products that are primarily concrete to try and make sure they work in the system and have them review what was done to make sure that there's nothing that we're missing there. So, one thing to note is that I haven't mentioned the funding yet. When we update an entire product category, the main reason we do that is because you can do a whole bunch of products at once and attractively reduces the cost per product that you've developed the LCA for. So when we do that, we're able to drastically reduce the cost per unit. So the more products you get in, the cheaper the LCAs get on average. So we offer to pay for all of the LCAs that occur at that time. If the manufacturer wants to add a product outside of that kind of schedule update, then they'd have to pay for the LCA themselves.

NK: How many months out of the year does it take to do this update?

JK: Well we've just gotten all the products moved from the original BEES online to v2.0 and now to BEES 2.1 and so we update those not on a monthly basis. It's updated based on when those product category rules come out. So now that we've got the products moved over, all the products that are in there will get updated when the product category rule gets updated. Then we'll redo the LCAs and that's a five year cycle. But manufacturers can submit a product at any time. So that could get included once the LCA is completed. Adding a product to the database actually is pretty straight forward and relatively automated from this perspective, because we basically just take the impact category results and drop them into the tables that we already have. We just append the data and then the tool itself automatically recognizes. If there's any new product, it shows up when you want to make a selection.

NK: So you have a system down already.

JK: Yes, it's pretty straight forward. A couple of years ago, going from BEES online to BEES 2.0 we did some revamping (if you go to the main page, you can actually see a link to both tools). They are very different in terms of the user interface. So that was one big thing I wanted to make change to in terms of the data. I also want to make it so it's much easier to add products and allow for that to happen. So that was something we streamlined along the way.

Q: What matrixes are generated by BEES's? Carbon impact, capital costs, lifecycle costs.

JK: BEES has two primary kinds of metrics or, like I probably referred to, criteria. Based on the economic criteria which you're looking at, the life cycle costs is the metric. Then from the environmental perspective it's the life cycle assessment. Within life cycle assessments, we have numerous impact categories that can be selected. The way it's structured, you can either select the TRACI 2.1 categories or you can select what's been defined as the BEES impact categories, which is really just TRACI plus land, water and indoor air quality. The metric is really just for interior products. There's actually not really a measurement for exterior, products or insulation or things that are within the walls themselves. For floors you even have an indoor air quality measure, which is a proxy really for the VOC that are released early on in its installation. Then one other thing that's relatively new to the tool is instead of just allowing for those options for TRACI or BEES, we also are allowing users to select the product category or role impact categories. Sometimes those are TRACI impact categories. But in some cases like flooring, it's actually based on the CML impact category. For those product categories that do require a unique set of categories, we will include those. At this point, everything except flooring actually uses the TRACI impact categories and flooring has the CML as the basis. One thing to note too is there was something that was unique to BEES originally. So, we kept it as an option that a user can actually create a way to normalize the average of those impact categories and create a single environmental impact score. Some people don't like it, some people do. So we've included it as an option, but you don't have to include it. It's based on an ACESM standard, on how you can develop that based on each individual's environmental preferences. That's a feature that is there, if people want to use it. Something else that we've added just in this new version is the option to add in a social cost of carbon into the life cycle cost component. We do it by looking at the global warming potential impact results and then associating a dollar amount, as a settlement cost for carbon. If you want to add it in, you can. If you want to have it zero or exclude all together, you can.

Q: How has product impact comparison support interior designers, i.e. how could an interior designer use BEES to compare one product option to another? For instance, terrazzo vs. polished concrete vs. porcelain tile?

JK: The tool itself is essentially designed to make this comparison. The user will have to input some basic information, in terms of, what product category they're trying to select from. You can filter down to two specific product heights if you wanted to and you can also then put in information in terms of what LCA methodology you'd want to use, whether it's TRACI or so forth. They have better information than what we're providing as default, but then the end result that the tool is really a comparison of those products and so that's kind of a perfect example of what BEES can be used for. One thing to highlight here is that our results are directly comparable, as I mentioned where EPDs aren't always comparable at this point. You know, you're using the same base, in terms of the LCA – the same methodology, the same boundary conditions, and the same software and data sources. Well as the functional units are obviously going to be the same, then you can make that comparison. One thing that the tool does allow that I didn't mention is that instead of just assessing it on a per functional unit basis, you can actually input your value, your quantity, you can get a total intent out of the result and the results are shown. You can see some tables and there are some figures that you can change to look at different impact categories. And you can also download the data so you can manipulate the data however you might want if you want to look at different graphs that we don't provide. BEES can support the most basic comparisons that you'd want to make.

NK: There's not a report that comes in out at the end?

JK: We currently haven't done that. It's something that we've been talking about trying to decide whether or not that's useful and what exactly to include in that. That'd be something that would actually be pretty easy to add into the tool itself. Part of the challenge is trying to get user feedback on it now that we have the tool with all the products moved over. We're definitely looking for feedback on things that we can do to make it better.

NK: I know that, LEED points ask for it, I think that would be helpful to have a report at the end.

JK: Yeah. I've been interacting with the USGBC, trying to get these into the language as an option to meet some of those material and resource credits. I haven't been able to ask specifically if a report would be beneficial for that and what information to include. I'm going to keep working to try to provide what would be most useful from that perspective.

NK: Good.

Q: Does NIST plan to include more interior finishes and furniture in BEES? In what timeframe and what are the barriers?

JK: I think interior finishes and furniture are kind of the perfect categories to expand in BEES. The main reason is that I view BEES software as a simple way to allow for late stage design selections and particularly for decisions that don't really impact the operational performance of the building. Operational energy is impacted when you're making structural or energy efficiency based decisions. There's a lot of interaction between the building and the operational efficiency, usually less when you're selecting flooring. It doesn't mean that interior finishes don't have a teeny bit of impact, but it's so minuscule that it wouldn't really impact the overall energy performance. From this perspective, you're just looking at relative value of those finish options. I think it's kind of a perfect fit for BEES. We are just about to release v2.1, for which the main effort was just to move all the products over from BEES to BEES 2.0. Now that that's done and being released, the next question is what we should include in the next version and which capabilities should we expand on and improve. So any sort of feedback on that would be excellent. That's from our perspective, but I'd definitely say to build it into your finishes and furniture selection process. It fits well into what BEES can do.

We're doing some other things with whole building LCA, but that's very much early stage design trying to evaluate energy performance and the implications on environmental performance. Whereas furniture is more of a late stage design issue where you're selecting specific products and wanting to investigate what the implications are going to be. That's exactly where I want to go forward with the tool.

NK: What kind of goals are you setting for yourself? Like three years, five years?

JK: We haven't decided yet. This year is very much going to be about seeing what the feedback is from users. If there's strong enough interest, next year we could start to expand into additional categories. We haven't yet tried to evaluate the cost or kind of industry to target yet. I would think that moving forward we'd probably develop data in 2021 and probably release in 2022.

NK: When does v2.1 come out?

JK: I'm literally waiting for them to move it from one server to another and then it should be released. Right now you can see the v2.0 tool, but it just doesn't have all the data. Version 2.1 has been moved and there's a benchmarking option that allows you to actually compare the percentage change from one product to another. In v2.0 you can see the total and how they compare, but you can't see that it's benchmarked to a baseline product. That's feature that is built into v2.1 and will be available once the v2.1 is released. I mean we've had this cool tool ready and waiting for at least a month, just waiting for it to move to that server. Until then, you'll see about 98% of the features and data in five or six product categories. After the launch, there'll be a lot more data. It should come out sometime this calendar year [2019]. So hopefully it'll be up soon.

NK: How would one give you guy's feedback?

JK: You can contact me. Within the tool there's actually a contact section. There're three people listed, two people who helped me develop the software and myself. So if anyone has any questions, they can go to BEES v2.0, find the contact list, and I'll be there.

Any written feedback would be great – what you were able to do with BEES or an idea that would be a good fit for doing X, Y or Z with BEES – because that's the type of feedback that helps us pick a direction. I've been interacting with USGBC with ASHRAE, trying to work with green folks too and trying to figure out exactly what would be the best value add for us without duplicating anything that's going on out there.

We feel that the ability to directly compare LCA is quite useful. I think people are already doing that with EPD even if they shouldn't. From a scientific standpoint, I think it can be helpful.

Q: I found that BEES user interface a bit difficult to learn, but I haven't tried v2.1, which I'm excited to try. This might be a barrier to early LCA investigations for designers. Are there any plans to make the process and output easier for the design community to access?

JK: Hopefully the new version addresses that. That was one of the key goals. I didn't really like the way that the software was set up. We tried to add some features to make it a lot more user-friendly. There is a filtering process early on to narrow down the product options and some very pointed questions to help make selections. We've also included a lot of information icons along the way. So if there's something that someone's not clear on, they can click on the information icon and get a quick summary. If they need more information, they can go to the user guide that provides a lot of background content, as well as the details of the LCA and everything. Hopefully when you take a look at the new version you'll find it more intuitive. Let me know if there're still things that are not easy to use and we can take that in and make adjustments accordingly. The only thing I'd say is that it's pretty difficult to design an LCA tool for users with zero LCA background, because there're certain things you have to make assumptions about like the LCA methodology. It defaults to the TRACI impact categories, which for most people are just learning that LCA is probably a reasonable selection to make. It defaults to life cycle cost analysis so that you can select whether to select an item or not. If they don't understand it or are not interested, then they can just exclude it from the analysis.

Let me know if we've addressed all the issues that you found in the original BEES online.

Q: a fundamental goal of our study is to identify better ways to link LCA tools, resources and data to interior design decision making in a meaningful way. What are your thoughts on how best to facilitate a more effective use of LCA as a design criteria?

JK: A couple of things came to mind, but I haven't fully formed my ideas on this. I think one thing that would be really useful is to make the suite of information that's out there more easily accessible. A webpage with links to all these things for each summary and finding the right way to disseminate that information. Just by providing the information, people can make better decisions and at least take it into their thought process. Something else that would help is incorporating it into, curriculum. Then they would be exposed to it, which might require beefing up the topic a little bit. That would be an optimal place to point students. Then if you have a website that provides summary information with access to these tools that are out there, they might be able to get used to considering LCA within the curriculum. It could be a learning activity or even homework – something where the students actually had to make a comparison and make an interpretation. In terms of educational material, I think a good resource they may want to reach out to is the ACLCA organization (American Center for Life-Cycle Assessment). They actually have an education committee that's all about trying to help the community communicate and educate people about LCA.

ACLCA is an organization I'm involved in even though I'm not an LCA expert myself. My background is actually in economics. I can do more engineering type things, but LCA is definitely a big piece of our activities. I'm on their board. The education committee there does a lot of really good work and there's actually been some discussion about some newer approaches to teaching and communicating information. It's still all in the early stages at this point, but that would be something to take a look at to see what material they may have. Maybe reaching out to the executive director as a starting point, then connecting directly to people that are involved with that committee.

Q: is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

JK: I'll send you the email I have written up and you can use that as a basis. If anything further comes to my mind, I'll send another note. If there's anything that's unclear or you want to follow up on, just let me know. I'm available at least by email.

Written responses provided by Dr. Kneifel:

Q: BEES determines the life-cycle costs and environmental performance of individual products used in the construction of buildings. What is the process used to add a product to the database? How does NIST collect data on products from manufacturers and how are new entries chosen?

I want to state up front that we have released a new version of BEES Online (2.0), and that is the version that I am referencing below. The Original BEES Online is available, but no longer supported moving forward. All the major product categories have been transitioned and updated from BEES Online to the about to be released BEES Online 2.1. BEES 2.0 is accessible at https://ws680.nist.gov/Bees/.

Products are added in one of two ways.

First, we regularly update each product category (currently planned to align with the release of updated PCRs). At which time, we develop LCAs for all products in BEES (both the generic/industry average products as well as manufacturer product line specific) and ask manufacturers for any additional submissions they may have. NIST funds the development of the LCAs through a government contract with a highly skilled, well respected LCA practitioner. There is no cost to manufacturers for those products included in this product category update.

Second, manufacturers can submit a product for inclusion at any time. The manufacturer must pay for the LCA development in this scenario. The LCA can be completed by our LCA practitioner or will need to be critically reviewed by NIST for consistency with the BEES LCA methodology, assumptions, and approaches.

Adding the product LCA into BEES is relatively straight forward, largely automated process from a software perspective once the data is provided to NIST.

Q: What metrics are generated by BEES (carbon impact, capital cost, life-cycle cost, other?)?

BEES includes two sustainability criteria: life cycle cost and life cycle assessment. The life cycle cost is optional and is calculated using the installed cost and replacement rate as well as an option to include the social cost of carbon (assumes 100% pass through of the GWP impact category CO2 equivalent emissions). The life cycle assessment provides numerous impact categories that are based on well accepted methodologies. All products include the TRACI 2.1 impact categories (Ozone depletion, global warming, smog formation, acidification, eutrophication, human health cancer, human health noncancerous, human health criteria pollutants, eco-toxicity, and primary energy demand) as well as the BEES impact categories (TRACI 2.1 + land, water, and IAQ). We provide an option to select the impact categories based on a product category's PCR requirements, which is either based on TRACI 2.1 or CML. The user does have the option to develop a weighted average environmental impact score (EIS) based on their preferences to come up with a single value for comparison. Alternatively, the user can look at each LCA impact category separately.

Q: How is product impact comparison supported interior designers, i.e. how could an interior designer use BEES to compare one product option over another, for instance terrazzo vs. polished concrete vs. porcelain tile?

Since the underlying details of the LCA development are consistent across all products in a category (e.g., functional unit, methodologies, boundary conditions, underlying data sources, LCA software), the results are directly comparable. This is not always the case using results from EPDs because any variation in how the LCA is developed can lead to significant changes in the results. To make such a comparison using BEES, the user would need to select the products they want to compare as well as some underlying assumptions and desired metrics. The results include totals and product life cycle phase breakdowns and are displayed in tables and figures and are downloadable. Products can be directly compared on each metric of interest to see the relative performance.

Q: Does NIST plan to include more interior finishes and furniture in BEES? If so, in what timeframe? If not, what are the barriers?

We are just releasing BEES Online 2.1, which now includes a transition of all major product categories from the original BEES Online. We will keep those product categories updated on the PCR update cycle (5 years) and continue to add products submitted by industry. NIST views BEES as a tool for comparing products that do not have significant interactions with the operational (specifically energy) performance of a building. Therefore, interior finishes and furniture seem to be excellent product category areas for expansion. We also want to receive feedback from users on what additional products and capabilities would be most beneficial to make more sustainable building product selections. Please provide us with any insights you may have on the BEES tool.

Q: I found the BEES user interface a bit difficult to learn and use. This might be a barrier to early LCA investigation for designers. Are there any plans to make the process and/or output easier for the design community to access?

The newest release BEES Online 2.1 has revamped the user interface to improve its usability. The user is asked numerous questions throughout the tool to narrow down options and information icons are provided along the way to provide immediate information pertinent to the selection. We also provide default values where possible. There is also a user guide that provides an overview that could help explain LCA.

A fundamental goal of our study is to identify better ways to link LCA tools, resources, and data to interior design decision making in a meaningful way. What are your thoughts on how best to facilitate a more effective use of LCA as a design criterion?

Provide a suite of information in an easy to access location for decision makers (e.g., webpage that is well disseminated within the field). Teach it as part of curriculum.

Q: Is there anything that you'd like to share with me or guidance that you have on this topic that we haven't already talked about?

Nothing that I can think of at this moment in time.

Q: For someone who is new to all of this do you have words of wisdom or advice on how to proceed in promoting environmentally responsible design?

If you can make the business case for more sustainable decisions, it will make promoting the decisions much easier.

GLOSSARY

Biogenic Carbon – Growing biomass absorbs Co2 from the air. The carbon from the absorbed CO2 is transformed into the plant tissue and is called "biogenic carbon".

Blue Planet LTD – Economically Sustainable Carbon Capture
http://www.blueplanet-ltd.com/

Blue Vinyl – An award winning documentary that talks about the life cycle assessment of material.
https://tubitv.com/movies/312591/blue_vinyl

Carbon Accounting – Carbon accounting is the process by which CO2 emissions from fossil fuel combustion are calculated.

Carbon Leadership Forum (CLF) – Is out of University of Washington and conducting "research, creating resources, and incubating member-led initiatives" around shared goals. It is made up of architects, engineers, contractors, material suppliers, building owners, and policymakers working together to make the largest impact possible.
http://www.carbonleadershipforum.org/

Carbon uptake or sequestration – Carbon being absorbed and incorporated especially into a living organism, tissue, or cell. "Carbon dioxide is the most commonly produced greenhouse gas. Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. The USGS is conducting assessments on two major types of carbon sequestration: geologic and biologic."
https://www.usgs.gov/faqs/what-carbon-sequestration?qt-news_science_products=0#qt-news_science_products

The Carbon Neutral Cities Alliance (CNCA) – A collaboration of leading global cities working to cut greenhouse gas emissions by 80-100% by 2050 or sooner-the most aggressive GHG reduction targets undertaken anywhere by any city. https://carbonneutralcities.org/

CarbonCure Technologies Inc – "Enabling the concrete industry to improve operations while reducing its carbon footprint" https://www.carboncure.com/

Declaration of Climate Emergency- "is a piece of legislation passed by a governing body such as a city council, a county board of supervisors, a state legislature, or even a national government. It puts the government on record in support of taking emergency action to reverse global warming." Retrieved from
https://www.theclimatemobilization.org/climate-emergency-resolution

Design – "The Hannover Principles aim to provide a platform upon which designers can consider how to adapt their work toward sustainable ends. Designers include all those who change the environment with the inspiration of human creativity. In this sense, design is the first signal of human intention. Physical design implies both the conception and realization of human needs and desires." (P.4, McDonough, *The Hanover Principles*)

Design for Sustainability – "Designing for sustainability requires awareness of the full short- and long-term consequences of any transformation of the environment. Sustainable design is the conception and realization of ecologically, economically and ethically responsible expression as a part of the evolving matrix of nature." (P.5, McDonough, *The Hanover Principles*)

Embodied Carbon Network – A group of likeminded people figuring out ways to design without embodied and operational carbon in our buildings.
http://www.carbonleadershipforum.org/embodied-carbon-network/

Embodied Energy – comes from the materials manufacturing and construction phases of the building project.

Functional Unit – "The functional unit can be defined as the unit of comparison that assures that the products being compared provide an equivalent level of function or service." http://amanac.eu/wiki/lca-terminology/

GCI Construction Company, Madrone Program – GCI has come up with a program for diverting waste that is from demolition. http://madronecr.com/

The Hannover Principles – "Should be seen as a living document committed to the transformation and growth in the understanding of our interdependence with nature, so that they may adapt as our knowledge of the world evolves."
https://www.readingdesign.org/hannover-principles

Life cycle analysis – Sourcing and obtaining raw materials requires different inputs, outputs and processes that impact the environment and need life cycle analysis. This is taken through a process from "birth, including design, raw material extraction, material production, part production, and assembly, through its use, and final disposal". https://enviroliteracy.org/environment-society/life-cycle-analysis/

One Click LCA: Is software to calculate your material use in construction impact on the Environment. https://www.oneclicklca.com/

Operational Carbon – is the emissions of carbon dioxide during the use of a building.

Operation Energy – projected energy use within a building as it operates over a typical meteorological year.

Natural Gas – naturally happens when gas mix, mainly methane, but also including fluctuating amounts of other high alkanes, and occasionally a tiny percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium. https://www.eia.gov/energyexplained/natural-gas/

Sustainability – "The concept of sustainability has been introduced to combine concern for the well-being of the planet with continued growth and human development. Though there is much debate as to what the word actually suggests, we can put forth the definition offered by the World Commission on Environment and Development: "Meeting the needs of the present without compromising the ability of future generations to meet their own needs." But it must also expand to embrace the prospects of restorative acts, the hope for an abundant future based on new systems and definitions of design and productivity. In its original context, this definition was stated solely from the human point of view. In order to embrace the idea of a global ecology with intrinsic value, the meaning must be expanded to allow all parts of nature to meet their own needs now and in the future." (P.4, McDonough, *The Hanover Principles*)

System Boundary – "System boundary is defined as an interface between a product system and the environment or other product systems. It defines the activities and processes that will be included in each life-cycle stage for the LCA analysis and those that will be excluded."
http://amanac.eu/wiki/lca-terminology/

Teknion's ANEW program – ANEW is a program started by Teknion to avoid discarding furniture, fixtures and equipment and repurposing it by giving it a new home at organizations in need.
https://www.teknion.com/ca/tools/inspiration/sustainability/anew

Teknion's EXTEND program – EXTEND is a furniture management program started by Teknion to extend the life of the furniture and give back to the community.
https://www.teknion.com/ca/tools/inspiration/sustainability/a-fresh-look-at-managing-resources

TRACI 2.1 – "Tool for the reduction and Assessment of Chemical and other Environmental Impacts"
https://www.pre-sustainability.com/download/TRACI_2_1_User_Manual.pdf

ABBREVIATIONS

AAP – Aquatic Acidification Potential
https://www.noaa.gov/education/resource-collections/ocean-coasts-education-resources/ocean-acidification

ADPSR- Architects Designers Planners for Social Responsibility
https://www.adpsr.org/

AIA- The American Institute of Architects
https://www.aia.org/

AP – Acidification Potential
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
https://www.ashrae.org/

BAMB – Buildings As Material Banks
https://www.bamb2020.eu/

BEES – Building for Environmental and Economic Sustainability
https://www.nist.gov/services-resources/software/bees

BIM- Building Information Modeling
https://www.autodesk.com/solutions/bim

BREEAM - Building Research Establishment Environmental Assessment Method
https://www.breeam.com/

CNCA – Carbon Neutral Cities Alliance
https://carbonneutralcities.org/

C40 – Cities Climate Leadership Group
https://www.c40.org/

DOE – Department of Energy
https://www.energy.gov/

EC3- Embodied Carbon in Construction Calculator
http://www.carbonleadershipforum.org/projects/ec3/

EIO-LCA – Economic Input Output – Life Cycle Assessment
http://www.eiolca.net/

EP – Eutrophication Potential
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

EPA – Environmental Protection Agency
https://www.epa.gov/

EPD – Environmental Product Declarations
https://www.environdec.com/What-is-an-EPD/

EPI- Environmental Product Information

FFE- Furniture, Fixtures, and Equipment

GBI – Green Building Initiative
https://thegbi.org/

GWP – Global Warming Potential
https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

HPD- Health Product Declaration
https://www.hpd-collaborative.org/

ICE- Bath Inventory of Carbon and Energy
https://ghgprotocol.org/Third-Party-Databases/Bath-ICE

IGCC – International Green Construction Code
https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/

ISO – International Organization of Standardization
https://www.iso.org/home.html

LBC – Living Building Challenge
https://living-future.org/lbc/

LCA – Life Cycle Assessment
https://www.thinkstep.com/life-cycle-assessment

LCC – Life Cycle Costing
https://www.gsa.gov/node/81412

LCI – Life Cycle Inventory
https://www.nrel.gov/lci/

LCIA – Life Cycle Impact Assessment
http://www.athenasmi.org/resources/about-lca/whats-the-difference/

LCIA- Life Cycle Inventory Analysis
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

LCM – Life Cycle Management
https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/life-cycle-management/

LEED – Leadership in Energy and Environmental Design
https://new.usgbc.org/leed

NEI – National Emissions Inventory
https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

NIST – National Institute of Standards and Technology
https://www.nist.gov/

ODP – Ozone Depletion Potential
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

ORD – Office of Research and Development
https://www.research.va.gov/

PCR- Product Category Rule
https://www.environdec.com/PCR/

POCP – Photochemical Ozone Creation Potential
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

PE – Primary Energy
http://www.gabi-software.com/uploads/media/What_is_Life_Cycle_Assessment_03.pdf

PVC – Polyvinyl chloride
https://toxtown.nlm.nih.gov/chemicals-and-contaminants/polyvinyl-chloride-pvc

SETAC – Society of Environmental Toxicology and Chemistry
https://www.setac.org/

SFGBC- San Francisco Green Building Code
https://sfenvironment.org/green-building-ordinance-sf-building-code

STD – Sustainable Technology Division
https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryID=19285

TI- Tenant Improvement

TRACI – Tool for the Reduction and Assessment of Chemical and other environmental Impacts
https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci

TRI- Toxics Release Inventory
https://www.epa.gov/toxics-release-inventory-tri-program

UNEP – United Nations Environment Program
https://www.unenvironment.org/

USGBC – United States Green Building Council
https://new.usgbc.org/

WELL- https://www.wellcertified.com/

LIST OF FIGURES

REFERENCES

Anderson, R. C. (2008). Mid-course correction: Toward a sustainable enterprise: the interface model. White River Junction, VT: Chelsea Green.

Anderson, R. C., & White, R. A. (2009). Confessions of a radical industrialist: Profits, people, purpose: doing business by respecting the earth. New York: St. Martins Press.

Architecture 2030. (2018). *Actions*. Retrieved January 31, 2020, from https://architecture2030.org/2030_challenges/2030-challenge/

Architecture 2030. (2018). *2030 challenge*. Retrieved January 31, 2020, from https://architecture2030.org/2030_challenges/2030-challenge/

Braungart, M., & McDonough, W. (2009). *Cradle to cradle*. London: Vintage.

Buildings As Material Banks. (2018). *Reversible building design guidelines.* Retrieved January 31, 2020, from http://www.bamb2020.eu/wp-content/uploads/2018/12/Reversible-Building-Design-guidelines-and-protocol.pdf

Carbon Neutral Cities Alliance (n.d.). About. Retrieved January 31, 2020, from https://carbonneutralcities.org/

Circular Ecology Ltd (2019). *About.* Retrieved January 31, 2020, from www.circularecology.com

C40 Cities (n.d.). *Programmes.* Retrieved January 31, 2020, from https://www.c40.org/

Dietz, B. (2005). Life cycle assessment of office furniture products. Center for sustainable systems, University of Michigan. Retrieved January 31, 2020, from http://css.umich.edu/publication/life-cycle-assessment-office-furniture-products

GIGA (2008-2019). *Origin*. Retrieved January 31, 2020, from https://origin.build/#/

Hawken, P. (2008). Blessed unrest: How the largest social movement in history is restoring grace, justice, and beauty to the world. New York: Penguin Books.

Hawken, P. (2010). The ecology of commerce: A declaration of sustainability. New York: Harper Business.

Haworth (n.d.). *Sustainability*. Retrieved January 31, 2020, from https://www.haworth.com/company-info/sustainability

Inside/Inside (2020). *English.* Retrieved January 31, 2020, from https://www.insideinside.nl/english-13

Interface. (2020). *MaterialsCAN.* Retrieved January 31, 2020, from https://www.interface.com/US/en-US/campaign/transparency/materialsCAN-en_US

International living future institute. (2019, September 11). *Google's Charleston East Bay view: Talk and nature walk.* Retrieved January 31, 2020, from https://living-future.org/events/googles-charleston-east-bay-view-talk-and-nature-walk/

Madrone (2019). *About us.* Retrieved January 31, 2020, from http://madronecr.com/

McDonough, W., & Braungart, M. (2013). *The upcycle*. New York: North Point Press, a division of Farrar, Straus and Giroux

McDonough, W. (1999). The Hannover principles: Design for sustainability: For the city of Hannover, Germany, Expo 2000, the World's Fair. Charlottesville, VA: W. McDonough Architects

Medeiros, D.L., do Carmo Tavares, A.O., Quixabeira Rosa, A.L., Raposo, S., Kiperstok, A. (2017, August 16). *Life cycle assessment in the furniture industry: The case study of an office cabinet.* Retrieved January 31, 2020, from https://link.springer.com/article/10.1007/s11367-017-1370-3

Scientific Applications International Corporation. (2006, May). *Life cycle assessment: Principles and practice.* Retrieved January 31, 2020, from https://www.e-education.psu.edu/egee401/sites/www.e-education.psu.edu.egee401/files/A%20Brief%20History%20of%20Life-Cycle%20Assessment.pdf

Scranton, C. (2002). *The David and Lucile Packard Foundation Sustainability Matrix*. Retrieved January 31, 2020, from http://www.dodworkshops.org/files/ClimateChange/Craig_Scranton_Presentation.pdf

Spot. (2020). *Resources.* Retrieved January 31, 2020 from https://spot.ul.com/architects-designers/

Teknion (n.d.). *Managing resources.* Retrieved January 31, 2020, from https://www.teknion.com/ca/tools/inspiration/sustainability/a-fresh-look-at-managing-resources

Teknion (n.d.). *Anew*. Retrieved January 31, 2020, from https://www.teknion.com/ca/tools/inspiration/sustainability/anew

The American Institute of Architects. (2020). *Building life cycle assessment in practice: An AIA guide to LCA*. Retrieved January 31, 2020, from https://www.aia.org/resources/7961-building-life-cycle-assessment-in-practice

The Carbon leadership forum. (2019, April). *Life cycle assessment of tenant improvement in commercial office buildings; Final report*. Retrieved January 31, 2020, from http://carbonleadershipforum.org/download/3117/

The Carbon leadership forum. (2019). Embodied carbon construction calculator (EC3) tool. Retrieved January 31, 2020, from http://www.carbonleadershipforum.org/projects/ec3/

Wood, P. (2009, December). *Seventh Generation sustainability; A new myth*. National Association of Scholars. Retrieved January 31, 2020, from https://www.nas.org/blogs/dicta/seventh_generation_sustainability_-_a_new_myth

Wood Research Laboratory (n.d.). Life cycle assessment (LCA). Retrieved January 31, 2020, from https://www.purdue.edu/woodresearch/lca-on-furniture/