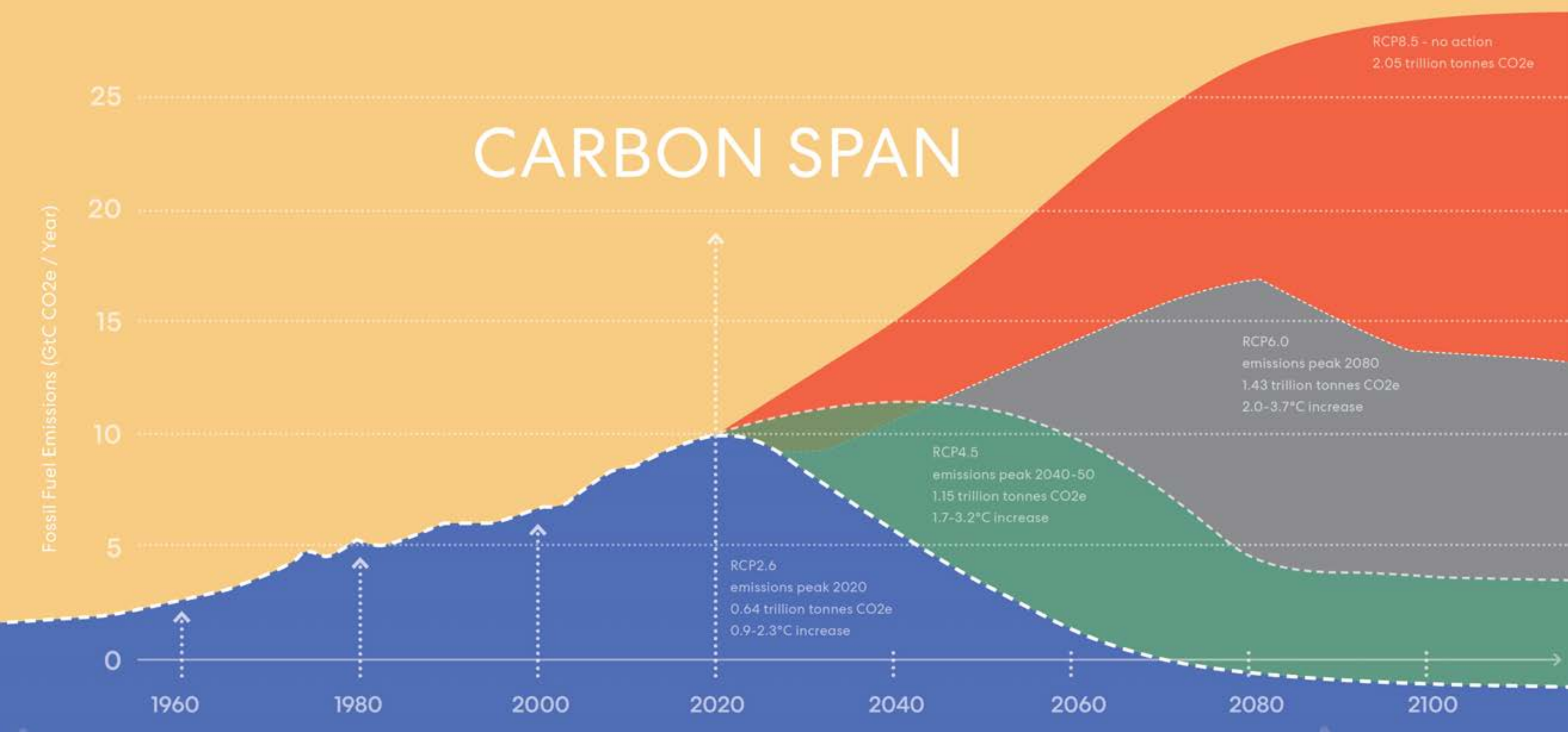
CARBON SPAN



Manuela Londono & Jesce Walz
Innovation Incubator
Perkins&Will

Table of Contents

Introduction

We set out to understand a project's global warming impacts by looking at inflows and outflows of carbon. We found that the following contributors can be quantified for most projects with information typically available to the design team:

- Embodied Carbon
- Operational Energy
- Renewable Energy
- Site materials and site planting
- Carbon offsets for long-term sequestration

By looking at these variables alongside one another we begin to develop a holistic understanding of the carbon impact of a project, and of the levers available to achieve carbon neutrality or better yet, negative carbon emissions.

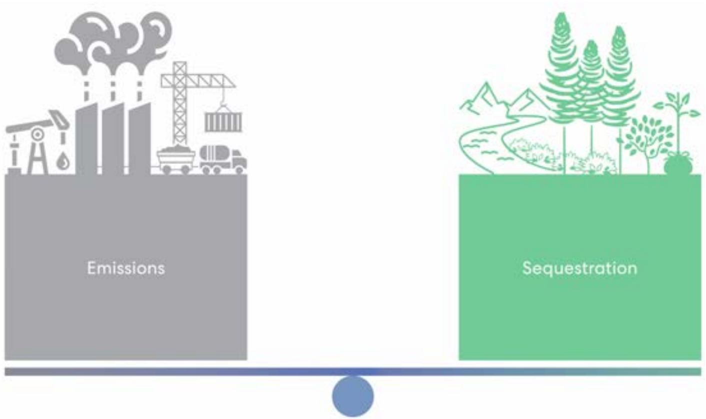
Through this exploration, we see that at this time the only real opportunity we have to remove carbon from the atmosphere is to introduce plants, trees, and healthy soils in our designs. Everything else is carbon avoided. For instance, renewable energy produced through solar, wind, or hydroelectric substitutes energy that may have come from fossil fuels, yet this doesn't directly offset carbon.

Balancing carbon requires reduction, substitution, sequestration, and an understanding of impacts across scales. Each of these measures offers low-hanging fruit that can be applied to many projects. For example, we found that the impact of refrigerants on global warming cannot be overlooked. Refrigerants are potent greenhouse gasses, and the veins of buildings can have large quantities of refrigerants running through them. These gases are bound to leak throughout the life of the mechanical system and at the end of life of the equipment.

Before we could look at these factors together, we had to break them down individually and think of how they could be measured. This led to the development of the Carbon-Span Calculator.

The CarbonSpan Calculator will help teams analyze the carbon inflows and outflows of projects, and understand the necessary interventions to achieve carbon neutrality.

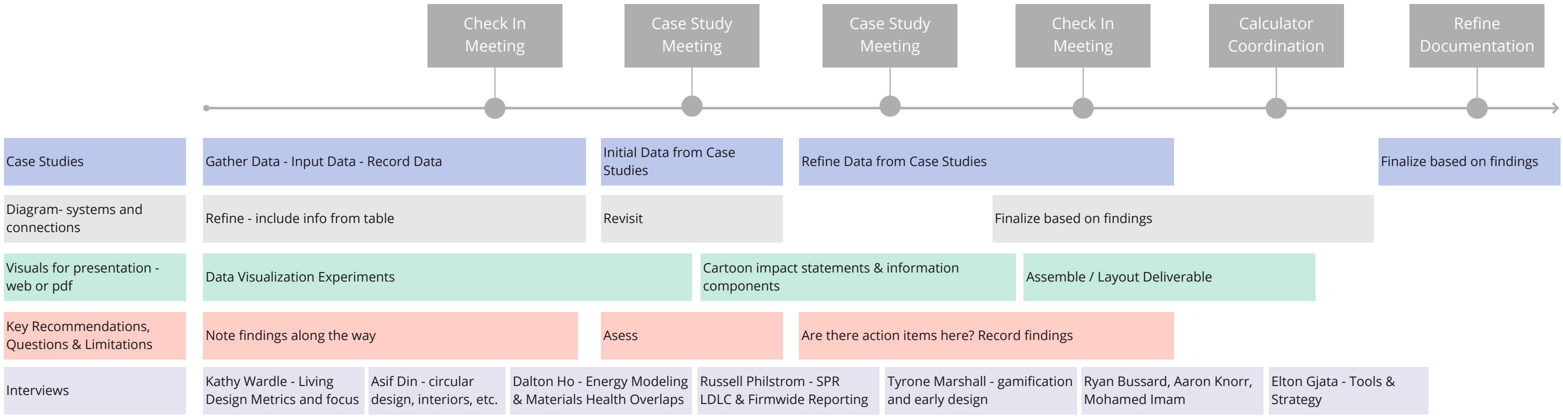
Using the CarbonSpan Calculator, we analyzed three case studies with the intent of painting a whole carbon story for each project.



Process

Our exploration process included data gathering and analysis for specific Perkins&Will projects. We then examined the systems and connections that exist between the variables studied, and finally, we experimented with compelling ways to visualize the data and concepts that emerged in our analysis.

Throughout the research project we held interviews with a number of experts across the firm, these conversations led us to reflect on concepts of circularity, material health, living design metrics, firmwide reporting, tool development, gamification of results, and designing with purpose. These vivid conversations helped shape the outcome of this research, and also helped us identify recommendations and next steps to realize meaningful carbon reductions and removals in our practice.



Definitions

Carbon sequestration is the capture and removal of carbon from the atmosphere through natural or artificial processes. Carbon sequestration is effective in mitigating global warming when the carbon dioxide (CO2) is held long-term, this means that 1 tonne of carbon must be taken out of the atmosphere and sequestered for at least 100 years to be considered a complete negative emission.

Carbon Neutral means investing in offsets that avoid emissions for a quantity that is equal to the carbon that is emitted. These offsets may not mean that carbon is removed from the atmosphere.

Carbon Negative means removing more carbon than is emitted each year.

Drawdown is the point where greenhouse gas concentrations in the atmosphere stop increasing, stabilize, and begin to decline.

Emissions avoidance is an effective carbon management strategy that contributes to achieving a long term carbon balance for the earth. Strategies to avoid emissions include energy generation from renewables, reduced energy consumption, and fuel emission reductions through cleaner energy production.

Global Warming Potential (GWP) allows us to compare the global warming impacts of different gases. GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb typically over 100 years, relative to the emissions of 1 ton of carbon dioxide (CO2). Energy absorbed by these gases and trapped in the atmosphere led to warming of the Earth, also known as the 'green house gas effect'. **GWP is measured in Carbon Dioxide Equivalent (CO2e).**

Net Zero Carbon means removing as much carbon as is emitted.

Embodied Carbon refers to the carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.

Operational Carbon Emissions are emissions associated with the operational energy use of a building; it will depend on the carbon intensity of the energy sources.

Environmental Product Declarations (EPDs) are defined by ISO 14025 as “providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.” An EPD is meant to be a publicly available summary of LCA and PCR activities that enable simple comparisons of environmental impacts.

Life Cycle Assessment (LCA) is a scientific method for calculating the environmental footprint of materials, products, and services over their lifetime.

Product Category Rules (PCRs) are documents that provide rules, requirements, and guidelines for developing an EPD for a specific product category.

LCAs, Product Category Rules (PCRs), and EPDs are needed to help understand the environmental sustainability of a given product throughout its life cycle.

- A PCR defines the way that an LCA must be carried out for a specific material type.
- The LCA then assesses available data based on the requirements outlined in the PCR to model and quantify environmental impacts that occur throughout a product’s life cycle.
- An EPD discloses the results of the LCA.

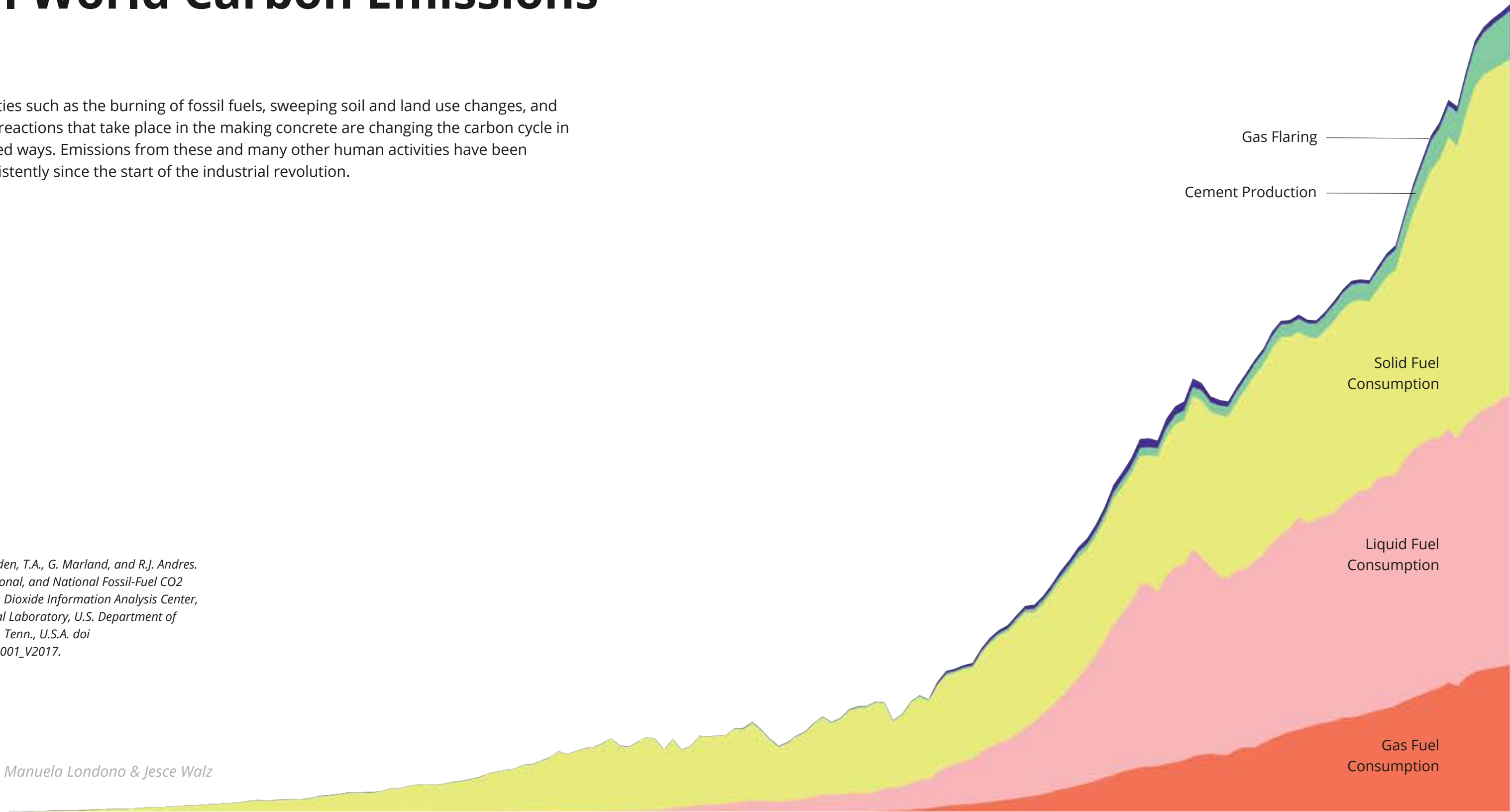
Together, these provide a system for assessing a product’s environmental impact.

Sources:

"Reductions or removals? Why science — not just market forces — must shape our pathway to net zero". Quantis
Digital Practice - Carbon Practice Guide
The Official Microsoft Blog - Microsoft will be carbon negative by 2030
"Embodied Carbon In the Built Environment - A Primer". Perkins&Will
Project Drawdown

Total World Carbon Emissions

Human activities such as the burning of fossil fuels, sweeping soil and land use changes, and the chemical reactions that take place in the making concrete are changing the carbon cycle in unprecedented ways. Emissions from these and many other human activities have been growing consistently since the start of the industrial revolution.

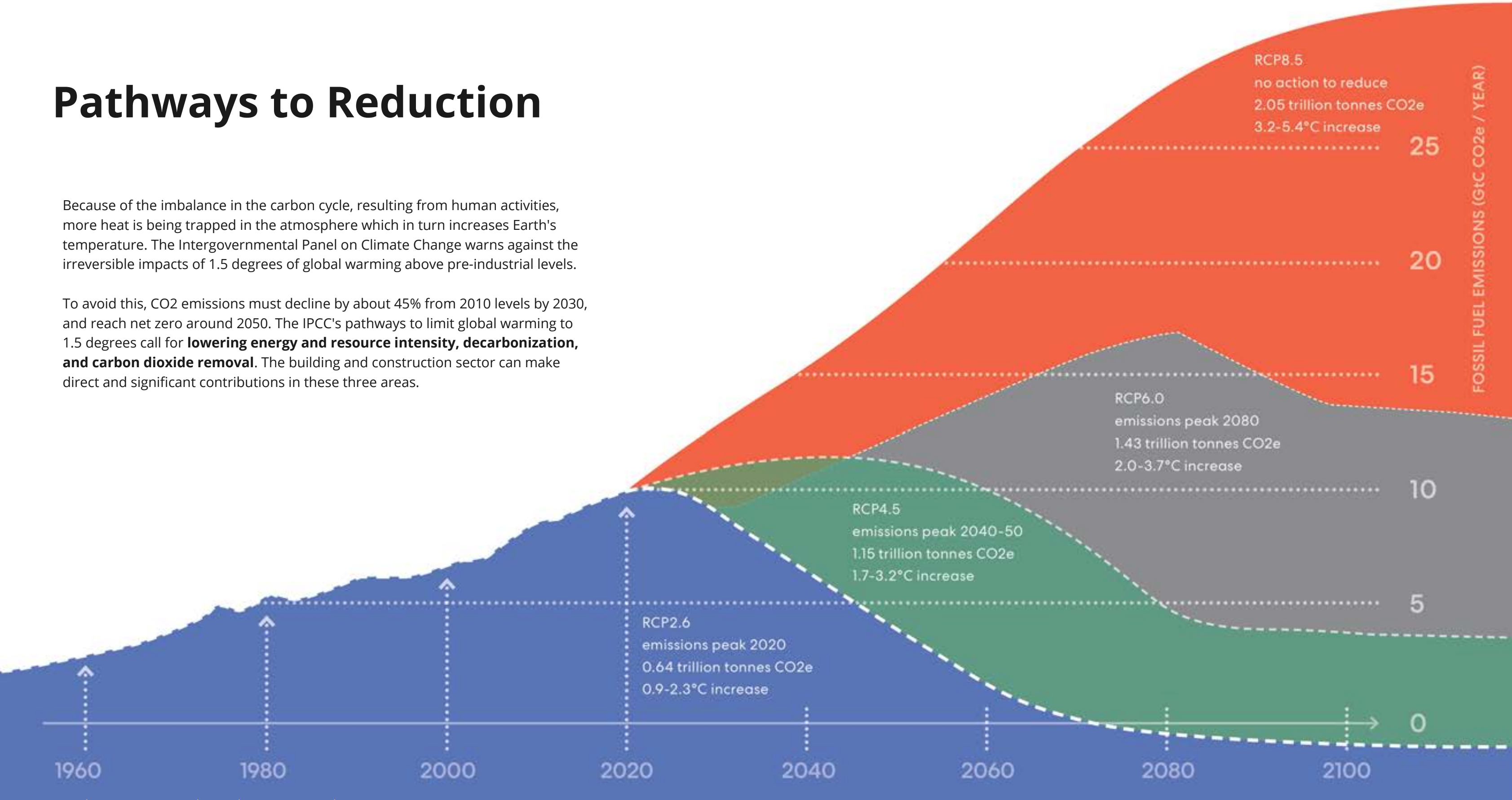


Adapted from: Boden, T.A., G. Marland, and R.J. Andres. 2017. Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

Pathways to Reduction

Because of the imbalance in the carbon cycle, resulting from human activities, more heat is being trapped in the atmosphere which in turn increases Earth's temperature. The Intergovernmental Panel on Climate Change warns against the irreversible impacts of 1.5 degrees of global warming above pre-industrial levels.

To avoid this, CO_2 emissions must decline by about 45% from 2010 levels by 2030, and reach net zero around 2050. The IPCC's pathways to limit global warming to 1.5 degrees call for **lowering energy and resource intensity, decarbonization, and carbon dioxide removal**. The building and construction sector can make direct and significant contributions in these three areas.



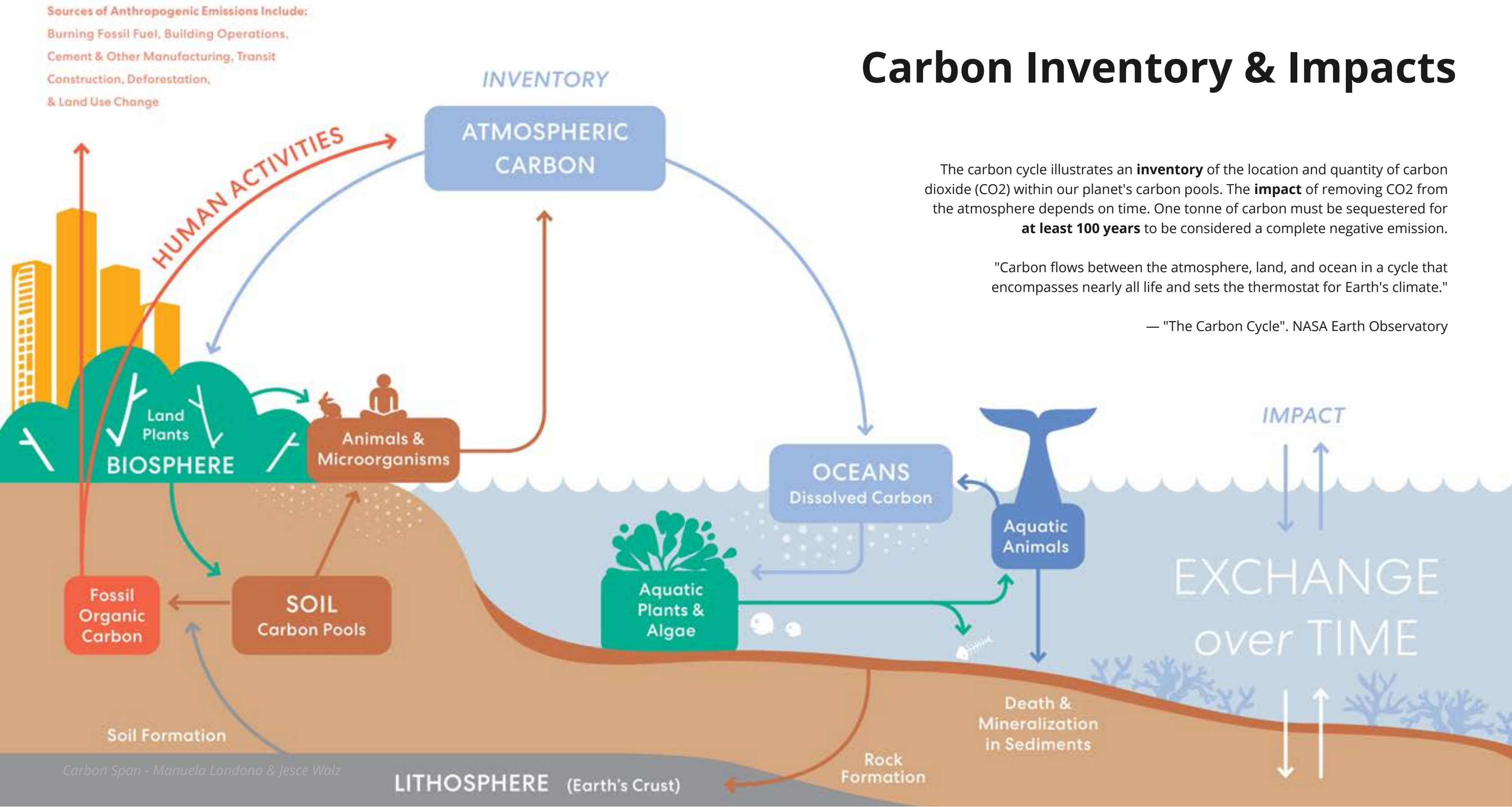
Carbon Span - Manuela Londono & Jesce Walz

Carbon Inventory & Impacts

The carbon cycle illustrates an **inventory** of the location and quantity of carbon dioxide (CO2) within our planet's carbon pools. The **impact** of removing CO2 from the atmosphere depends on time. One tonne of carbon must be sequestered for **at least 100 years** to be considered a complete negative emission.

"Carbon flows between the atmosphere, land, and ocean in a cycle that encompasses nearly all life and sets the thermostat for Earth's climate."

— "The Carbon Cycle". NASA Earth Observatory

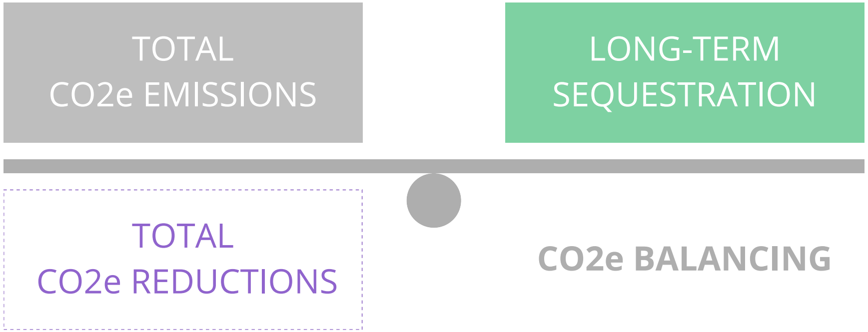


Balancing Carbon

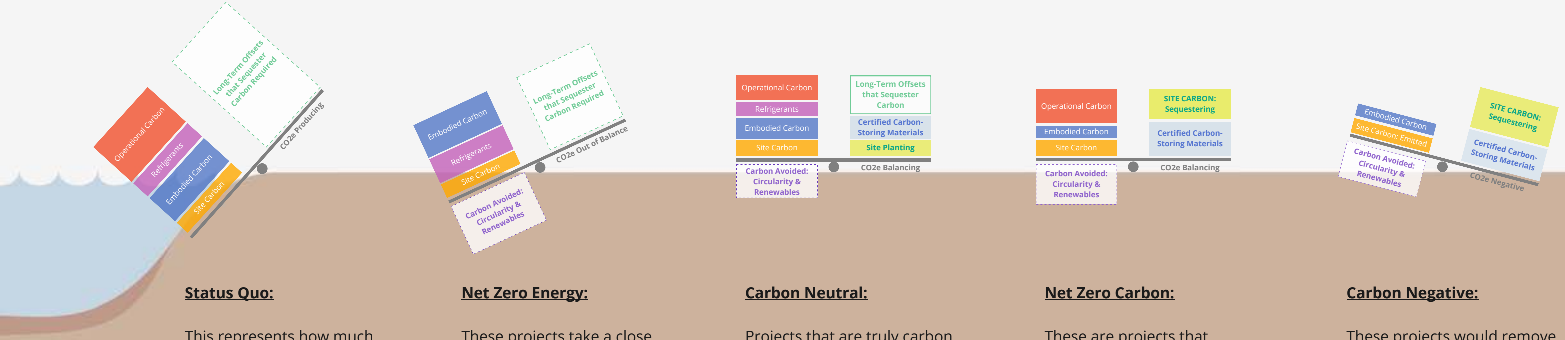
Call for a Carbon-Balanced Architecture

In response to the current climate crisis, we must establish widespread familiarity with carbon and its cumulative impacts, elevate our critique of sustainable design, and embrace our part in balancing our projects' carbon budgets. We can effectively drive down our emissions impacts by examining multiple contributors to CO_2e side-by-side, measuring their impacts, and assessing their intersections, asking questions like:

- What indicators are most impactful, and how can CO_2e be reduced across these variables?
- How would this project look if it began with a true carbon-neutral design?
- What is the site boundary of my project's CO_2e impacts?



Design Scenarios



Status Quo:

This represents how much of the built environment is designed and constructed, depleting more resources than it can replenish.

Net Zero Energy:

These projects take a close look at operational energy and make significant improvements in energy efficiency, then make up the balance with renewable energy production.

Carbon Neutral:

Projects that are truly carbon neutral would study all inflows and outflows of carbon associated with the project, aim to reduce emissions as much as possible, find opportunities to use carbon-storing materials, consider the sequestration potential of planting on site, and lastly procure long term carbon offsets.

Net Zero Carbon:

These are projects that remove as much carbon from the atmosphere as they emit.

Carbon Negative:

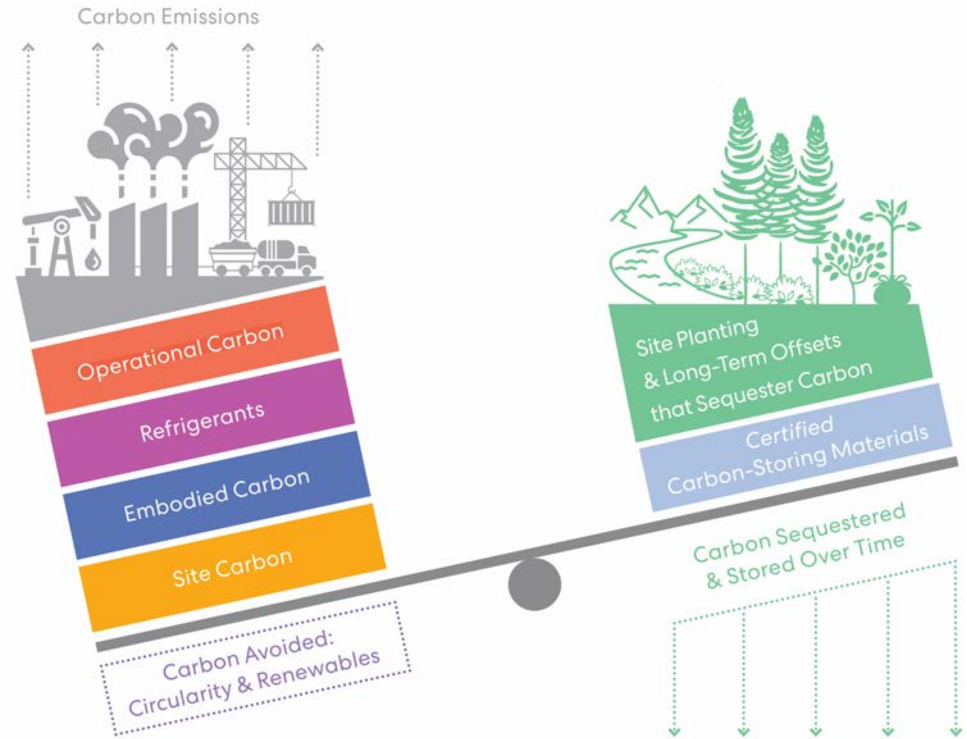
These projects would remove more carbon from the atmosphere than what they will emit over the whole project life.

Current State — 2030 — 2050

CO2e Indicators

A whole carbon balance is required to meet global climate goals. At present, best practices in sustainable design do not focus on whole carbon reduction; this leaves even aspirational projects in carbon debt.

Efforts to reduce operational carbon must be paired with reduction of embodied carbon, refrigerant impacts, site carbon, and more. Once impacts are reduced, fossil fuels may be avoided through use of renewable energy. However, in most cases, even an optimized net-zero and low carbon building will still require long-term carbon sequestering offsets in order to balance its own impacts. With careful planning and analysis, some projects may be able to balance their own carbon impact through on-site planting and certified carbon-storing materials.



Carbon Span - Manuela Londono & Jesce Walz

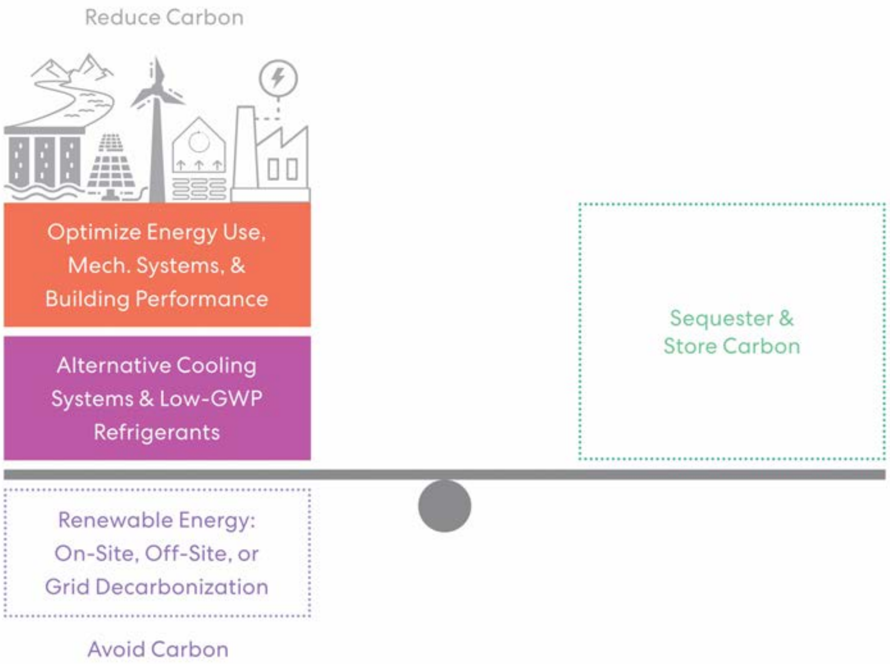
Operational CO2e & Renewables

Operational energy can be driven down through optimization of equipment, massing, orientation, envelope, internal loads, and more.

A project that pursues net-zero or net-positive energy seeks to reduce operational energy loads and meet the demand for those loads with renewable energy sources.

Even a net-zero project will have carbon impacts. When balancing carbon, renewable energy appears as "carbon avoided" rather than "carbon offset." Avoiding carbon through renewable energy is essential, as it substitutes fuel that would have otherwise been burned. In carbon balancing, a project's operational carbon is related to both its energy use intensity (EUI) and its power supply's carbon impacts. A project operating on a clean grid will generally have lower operational carbon than a project on a fossil-fuel based grid unless renewables are employed to offset grid impacts.

One carbon impact that is often overlooked in the effort to reduce operational carbon is that of refrigerants. The impacts of small leaks over time in systems such as VRF may aggregate and outweigh operational and embodied impacts in certain projects, as hydrofluorocarbon-refrigerants have a GWP that is magnitudes greater than that of carbon dioxide.



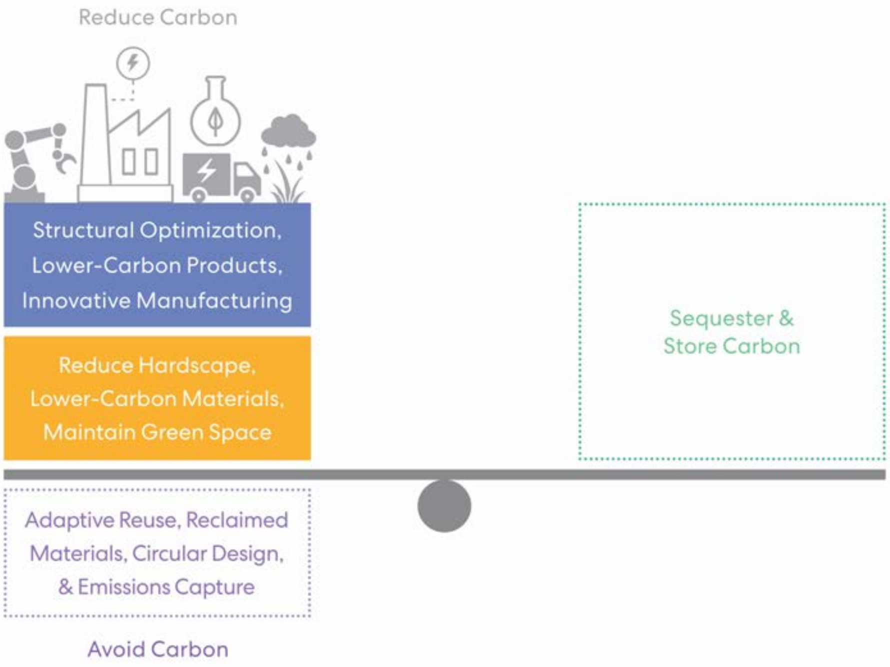
Embodied CO2e: Building & Site

Whole building LCA is key to reducing global warming potential and other impacts in early design. This process allows teams to compare options, and may influence a project's structural materials, form, or spans.

Reuse and circular design are essential strategies for long-term carbon reduction. Cement reduction in concrete also represents low-hanging-fruit for many projects. Once a project's material choices are determined, teams can use takeoffs to select concrete mixes and other low-carbon products based on available data from EPDs.

"With a limited number of regulations in North America, business as usual is not going to reduce embodied carbon emissions to zero by 2040. We can manage only what we can measure, and that is why it is critical to influence design decisions utilizing any of the Whole Building LCA tools available in the market, even though it might not be required or part of a project's goal."

- "Whole-Building Life Cycle Assessment: Comparison of Available Tools," Victoria Herrero-Garcia

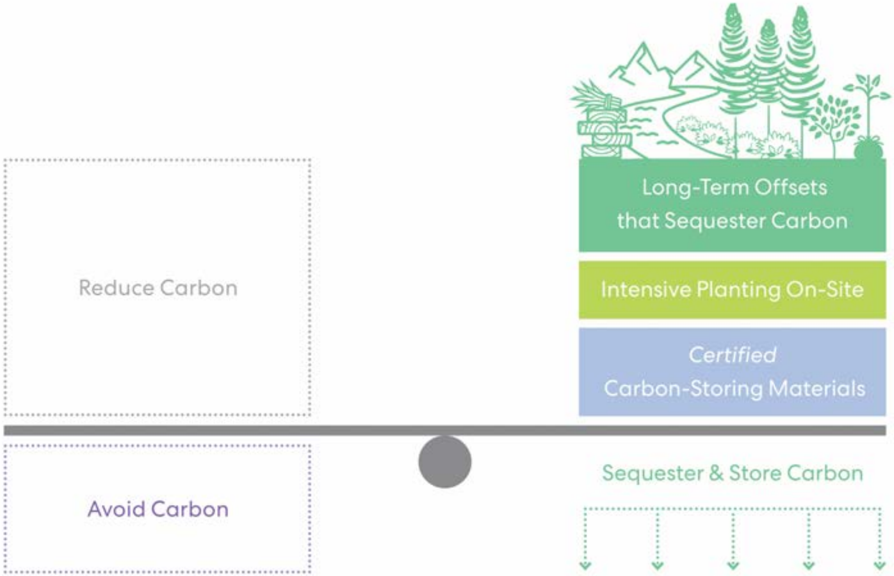


Carbon Sequestration & Offset

Biogenic carbon specialists view the future building stock as opportunity for carbon reduction and carbon storage. Cultivated materials such as timber, bamboo, hemp, and straw have potential to store more carbon than is required to transform them into building materials. In addition to storing carbon, cultivated structural materials substitute more carbon intensive ones, such as concrete and steel.

The caveat is that cultivated materials **must be certified** or otherwise guaranteed to be derived from sustainable land-use practices. When a living material is extracted from its context, an organism that was once sequestering carbon is removed. Land-use conversion of forest is a significant contributor to global CO2e emissions. It is essential to keep forests as forests, and to maintain them in a way that allows their ecosystems to thrive.

In addition, carbon storing materials must remain in the building, or be reused in another building for a minimum of 100 years in order to count as a true carbon sink. For this reason, it is essential to plan for cultivated materials' end-of-life. This time factor also applies to planting on-site and carbon offsets, which require sustainable management and long-term planning to effectively sequester and balance carbon.

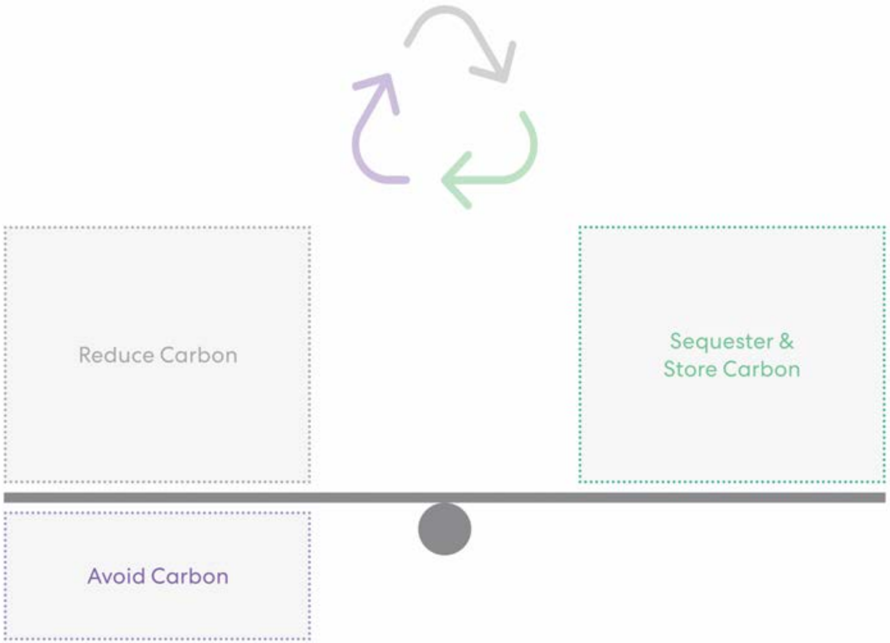


The Carbon that We Don't See

The adage "Reuse, then Reduce, then Recycle" rings true for carbon reduction.

A project's most impactful opportunities to minimize its carbon footprint begin with adaptive reuse and circular design. Reductions can occur through optimized structure and systems, minimization of materials, and design for durability, disassembly, and take-back. Products with recycled content may have lower global warming potential and divert materials from waste streams.

In carbon balancing, a reduced footprint shows up a smaller quantity to offset, making whole carbon neutrality more viable to achieve.

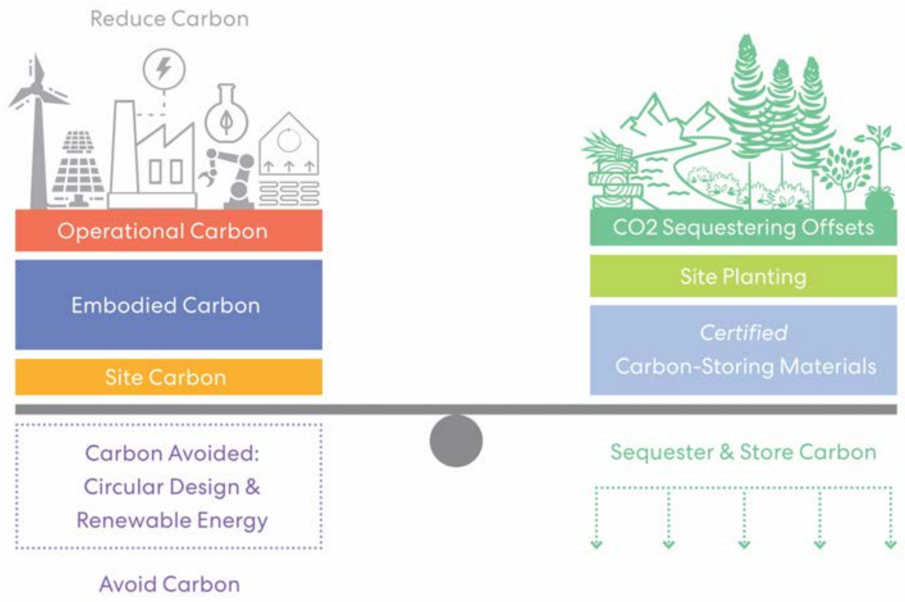


Achieving Balance

Through communication and a framework for accountability, design teams and developers can collectively reach a point where carbon balance is considered on every project.

When carbon budgeting is established as a clear goal, teams can approach that goal as a baseline and work to achieve it with available resources, just as they would with a monetary budget. Reframing carbon as a currency to balance may require some adjustment; however, this shift in thinking is essential for our planet.

Viable paths to carbon balance are available, and climate incentives are clear. Now is the time to assess zero-carbon pathways for the built environment. Conversation, training, data, and tools for measuring carbon can help us to shift into balance together.



Carbon Span - Manuela Londono & Jesce Walz

Case Studies

How do we get there?

How do we measure?

What is balance?

How do we achieve it?

Case Study: Higher Education Building

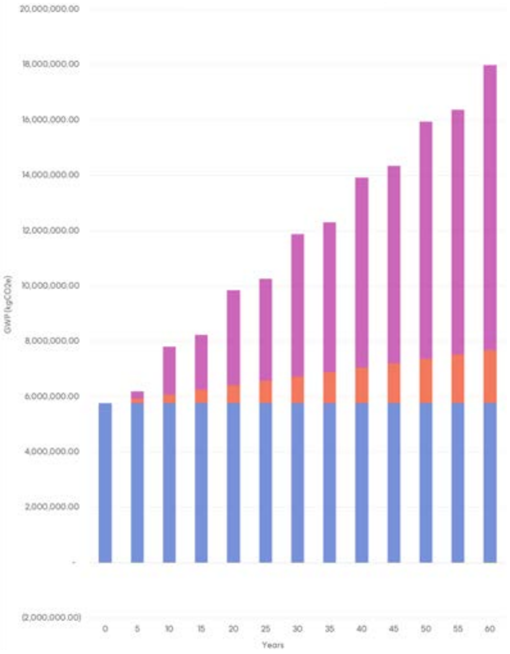
The building is conceived as two five storey mass timber program bars sitting on a concrete base. The program bars are separated by a top lit six storey atrium that is an extension of the public realm.

In support of the University's sustainability goals and commitments, the building is targeting a minimum of LEED Gold certification. The project is also seeking to meet the CaGBC Net Zero Building Standard, which includes passive design strategies such as high-performance envelope, high efficiency mechanical systems, and reduced embodied carbon.

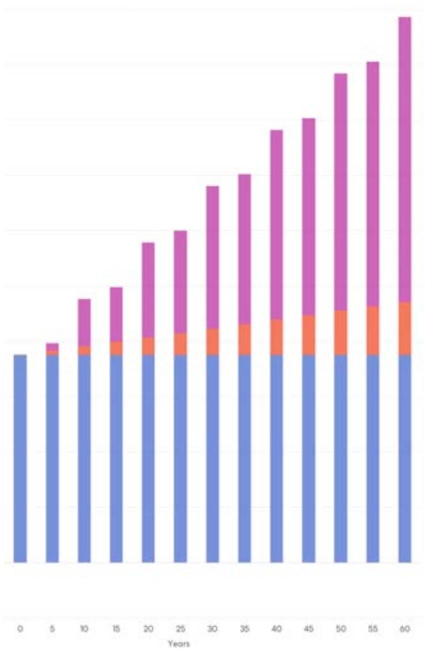
Even with the highly energy efficient design, and timber hybrid structure the project's emissions over its life are far from carbon neutral. At the end of life the largest contributor to GWP will be the emissions from refrigerant leakage.

There are minimal opportunities for sequestration on site as the project has a zero lot line. Lastly, the roof includes an athletic field minimizing the possibility of renewable energy production on site.

Total Carbon Over Life:
Timber Hybrid Structure

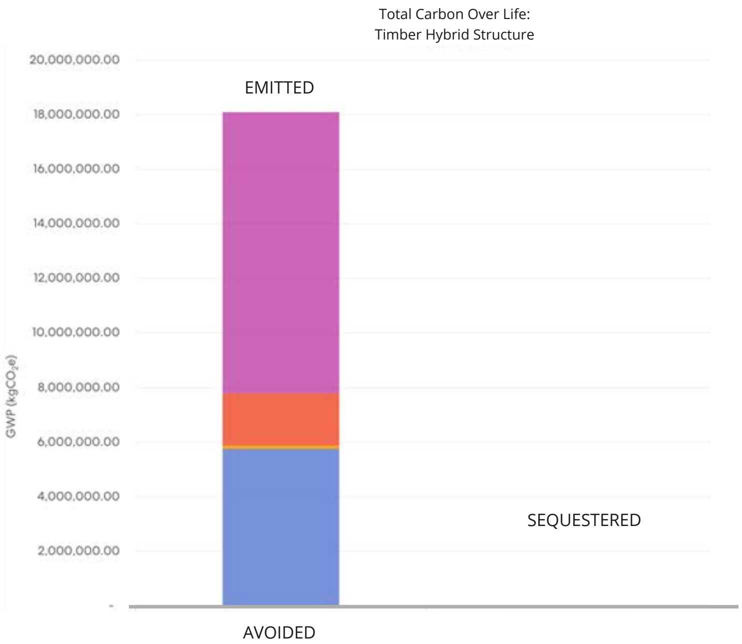


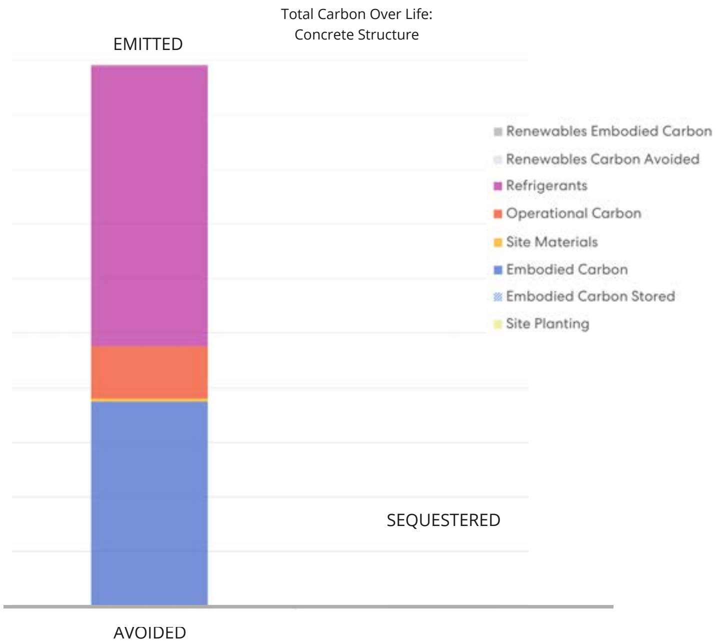
Total Carbon Over Life:
Concrete Structure



Carbon Span - Manuela Londono & Jesce Walz

Case Study: Higher Education Building





Case Study: Higher Education Lab & Vivarium

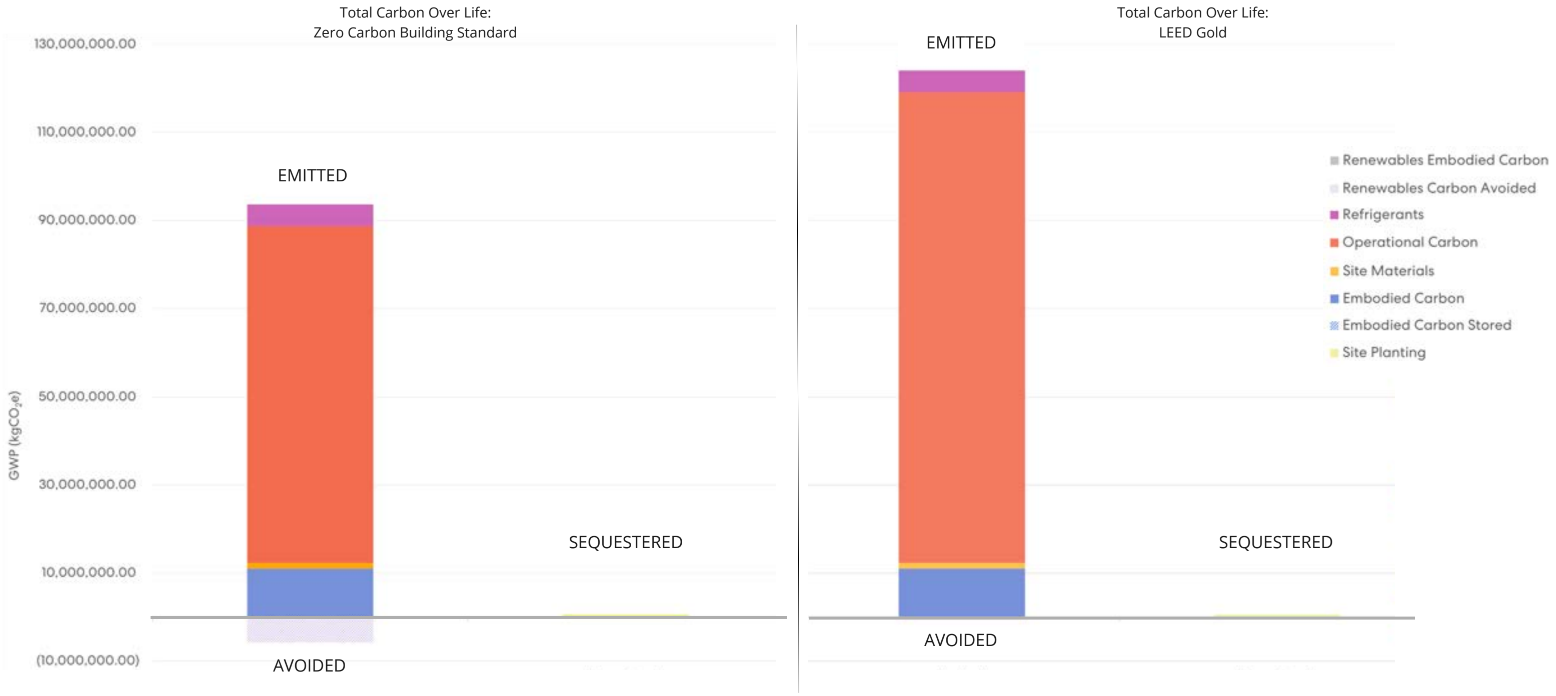
In support of the University’s sustainability strategy, the project is targeting LEED Gold certification. Reduction of energy loads through passive design, high efficiency mechanical systems, and on-site energy generation in pursuit of the CaGBC NZC Building Standard and LEED Platinum are being explored.

The energy intensive nature of the program means that the operational carbon is the major contributor to the building's GWP.

There are significant opportunities for sequestration on site as the project includes a green roof and extensive planted areas, the possibility of covering the remainder of the roof in solar PV was also explored and it results in the avoidance of some operational emissions. The impact of refrigerants is not as significant, this is because cooling comes from a central chilled water plant instead of smaller units throughout the project.

Carbon Span - Manuela Londono & Jesce Walz

Case Study: Higher Education Lab & Vivarium



Carbon Span - Manuela Londono & Jesce Walz

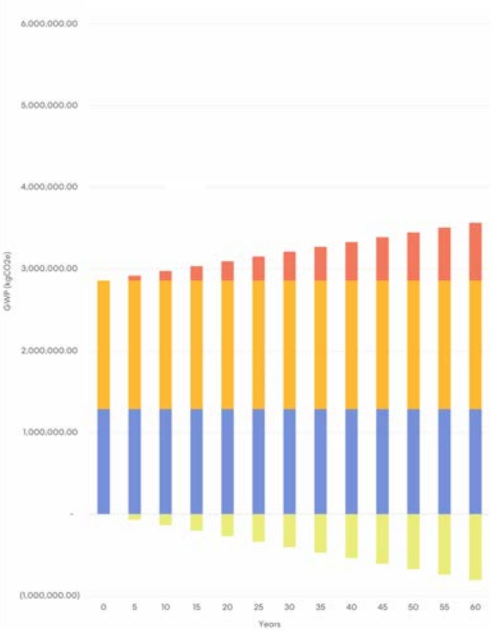
Case Study: Corporate Campus Center

This project is a single-storey 5,000 M2 mass timber campus center with DLT and Glulam structure. The building's electric grid relies on hydropower & renewable energy, and its suburban site is planted with lawn and trees. The project's certified wood structure and clean grid reduce its contribution to global warming.

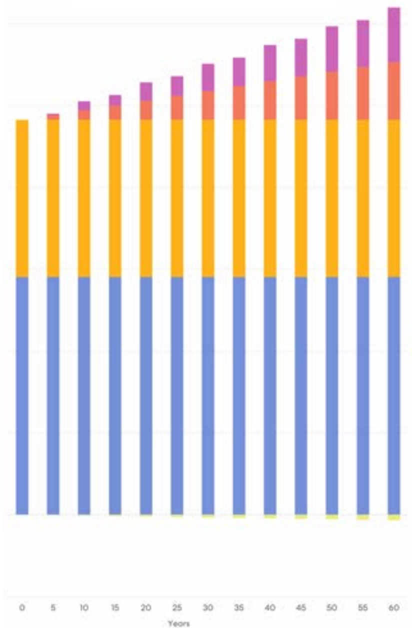
Refrigerants and site paving are primary contributors to this project's CO2e. The project's roof insulation and parking areas have a high impact relative to its single storey form.

Refrigerant impacts are associated with projected leakage from the VRF cooling system and with the embodied CO2e of the XPS insulation's HFC blowing agents. Site impacts are associated with large parking lots surrounding the building. This project could reduce its whole carbon impacts by nearly 40% through elimination of refrigerants and HFCs. If this refrigerant reduction were paired with a reduced parking area and increased planting of trees and wetlands instead of lawn, this project may be able to account for its own carbon costs over time.

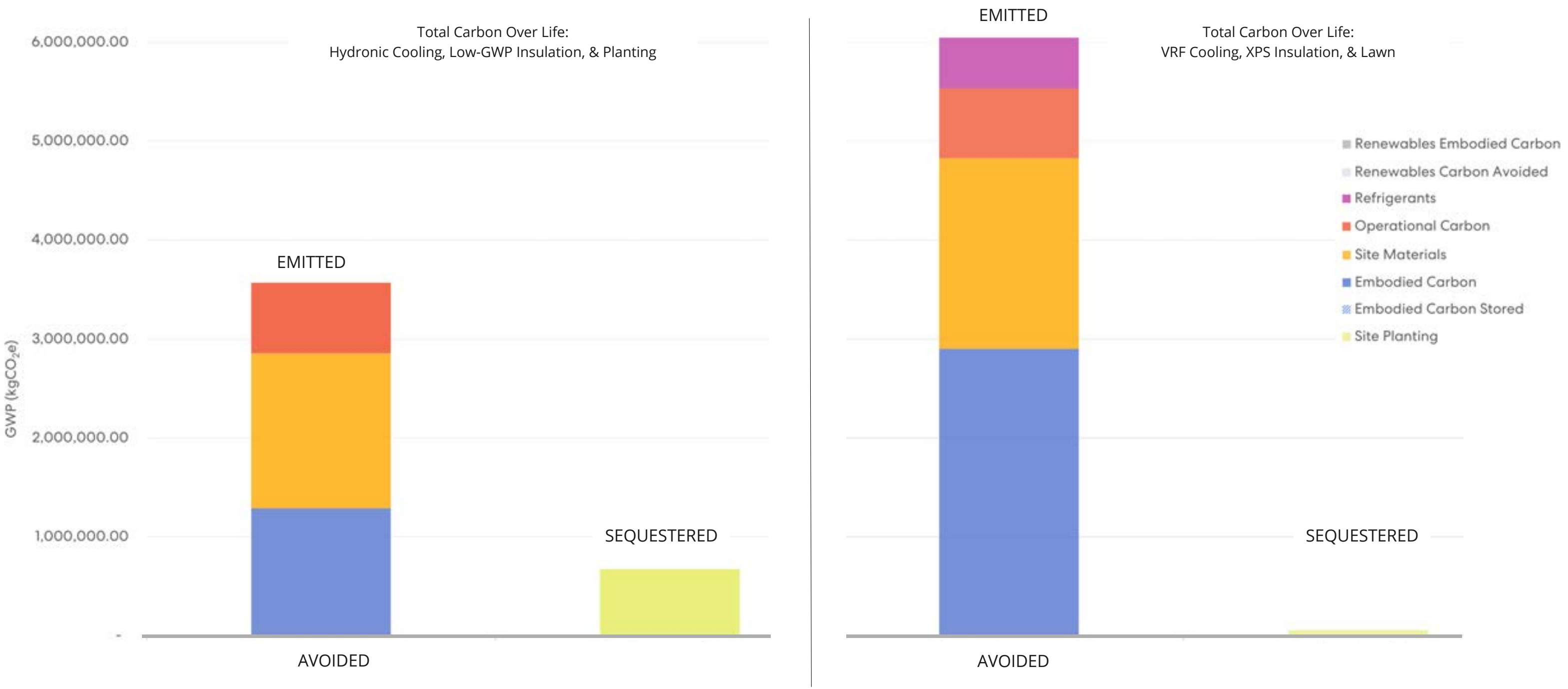
Total Carbon Over Life:
Hydronic Cooling, Low-GWP Insulation, & Planting



Total Carbon Over Life:
VRF Cooling, XPS Insulation, & Lawn



Case Study: Corporate Campus Center



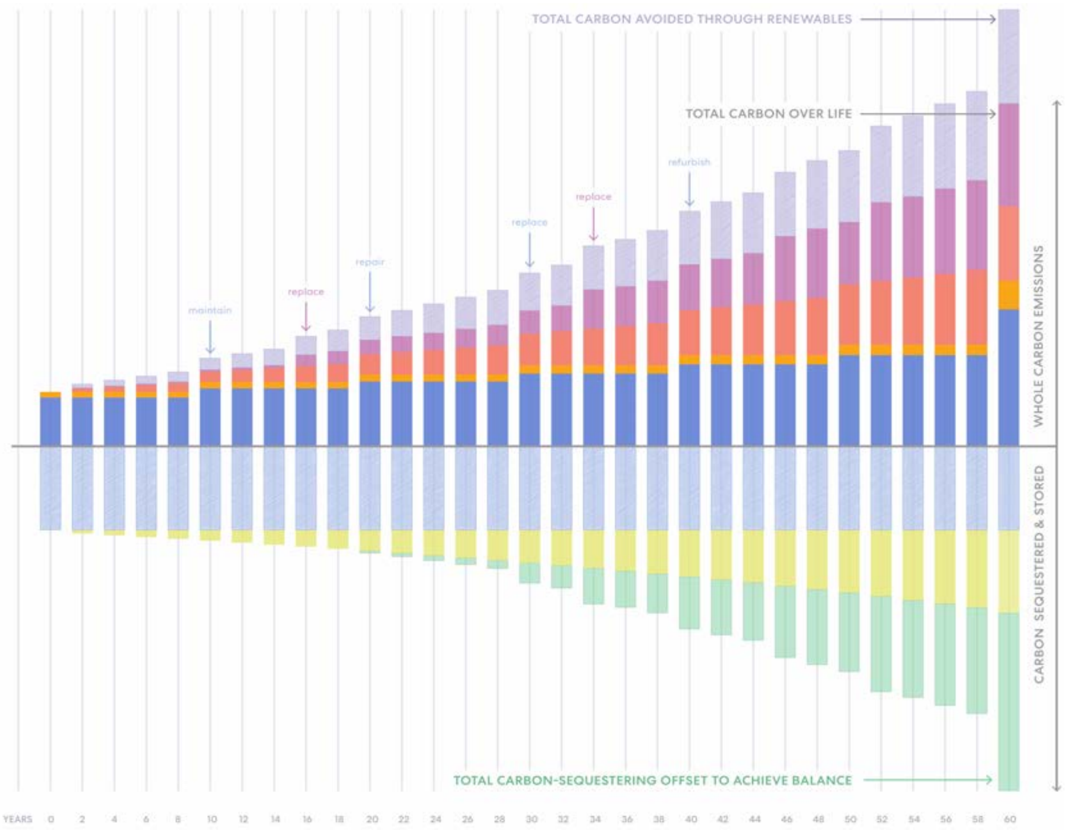
Carbon Balance Over Time

This diagram represents a more granular level of data that could be included in a future iteration of the CarbonSpan Calculator. Additional inputs may include:

- Ability to assess projects by carbon intensity (per M2 or SF) as well as by total carbon over life, so that projects can be compared to one another with a shared metric
- Calculation and visualization of the CO2e spikes that occur at throughout the lifecycle during maintenance, repair, and replacement
- A "payoff" calculator, showing the carbon sequestration required to achieve carbon balance

KEY

- RENEWABLES CARBON AVOIDED
- REFRIGERANTS
- OPERATIONAL CARBON
- SITE MATERIALS
- EMBODIED CARBON
- EMBODIED CARBON STORED
- SITE PLANTING SEQUESTERED
- REMAINING CARBON TO OFFSET

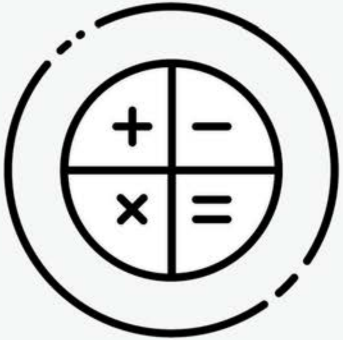


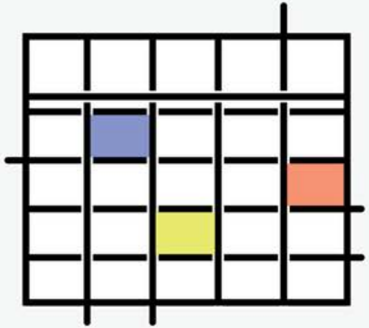
Carbon Span - Manuela Londono & Jesce Walz

The CarbonSpan Calculator

The CarbonSpan calculator was developed to assess the case studies in this report, and is a key outcome of this project . The calculator can be used to translate embodied, operational, site, refrigerant, and renewable CO2e impacts into annualized and total kgCO2e impacts, so that these variables could be understood as a part of one picture. The CarbonSpan Calculator will help teams to quantify and visualize the carbon balance of their projects so that they can work to achieve whole carbon neutrality.

The CarbonSpan Calculator will be made available to teams on Perkins&Will's Digital Practice > Carbon Practice Guide website:
https://digitalpractice.perkinswill.com/quickstarts/carbon-practice-guide/





Findings & Next Steps

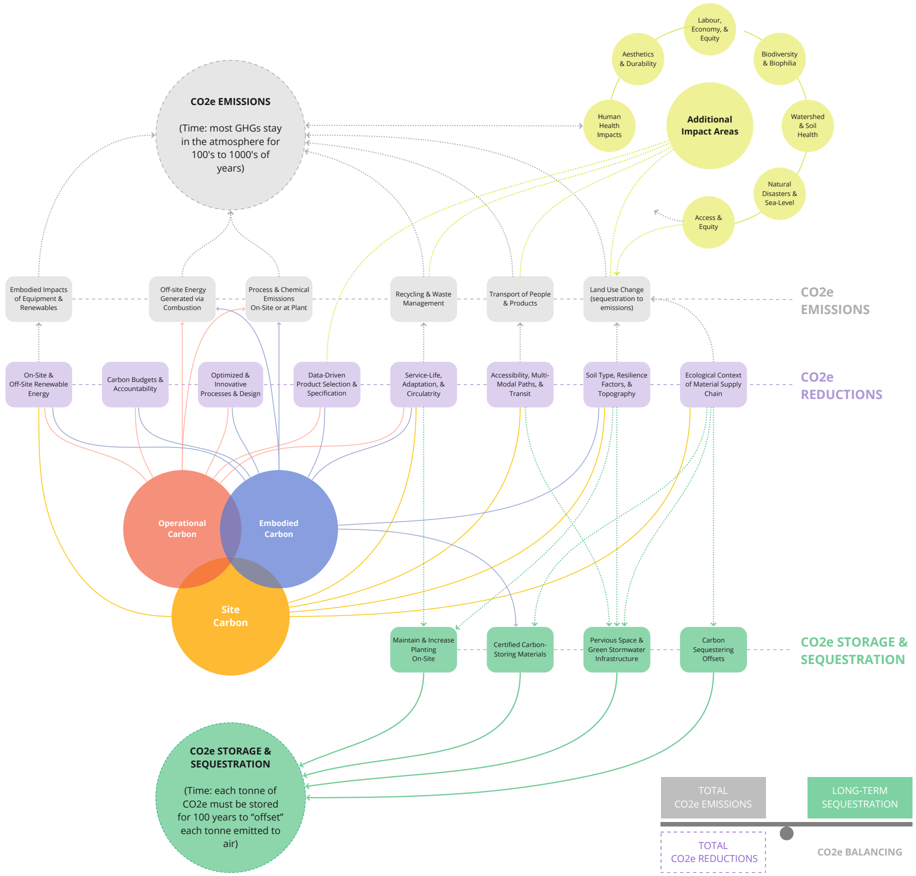
Whole Carbon Systems

"Carbon is the backbone of life on Earth. We are made of carbon, we eat carbon, and our civilizations—our economies, our homes, our means of transport—are built on carbon. We need carbon, but that need is also entwined with one of the most serious problems facing us today: global climate change."

— "The Carbon Cycle". NASA Earth Observatory

The diagram to the right examines relationships between emissions, reductions, and sequestration as relates to the three primary indicators of operational, embodied, and site carbon.

When resources are extracted to make energy and raw materials are extracted to make products, there are implications for human health, land use, biodiversity, and watershed ecology. Responsible management of natural resources requires a deep understanding of connection, scale, and cycle.



Key

- Carbon Emissions
- Additional Impact Areas
- Ways to reduce/avoid emissions
- Building Operations
- Building Materials
- Site & Source
- Carbon Sequestration

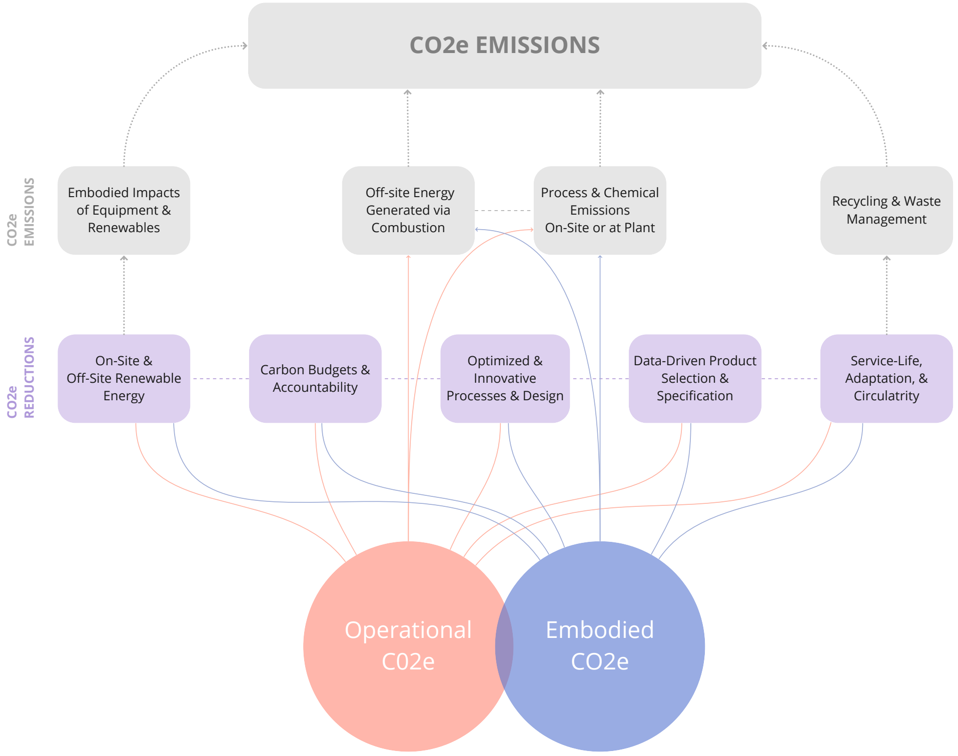
Carbon Span - Manuela Londono & Jesce Walz

Intersecting Impacts

This diagrammatic exploration demonstrates that efforts to reduce operational and embodied carbon overlap with one another. For example, grid cleanup impacts both a building site and a manufacturing plant. Renewable energy has both operational and embodied impacts. Goals like optimization and driving down a carbon budget apply to both design teams and to manufacturers.

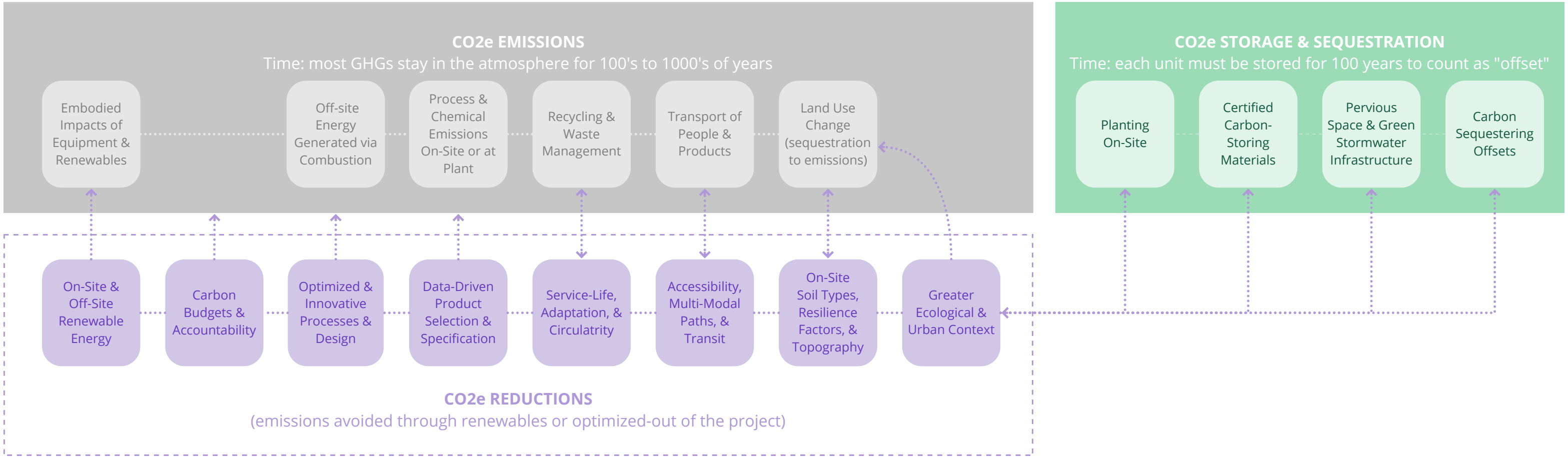
These examples of opportunities to reduce a project's carbon (in purple) cover a broad scope, as there are many ways to drive down a projects' CO2e budget. For example, "Optimized & Innovative Processes & Design" could be mean prefabrication, adaptive reuse, EUI reduction, use of supplementary cementitious materials, and more.

Our projects will be most effective if we approach carbon reduction with both an understanding of data and a systems-based approach to design.

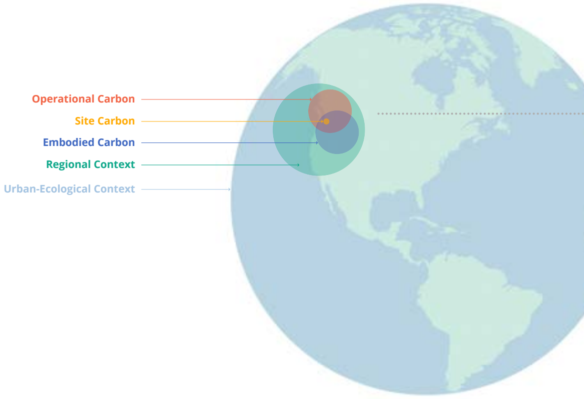


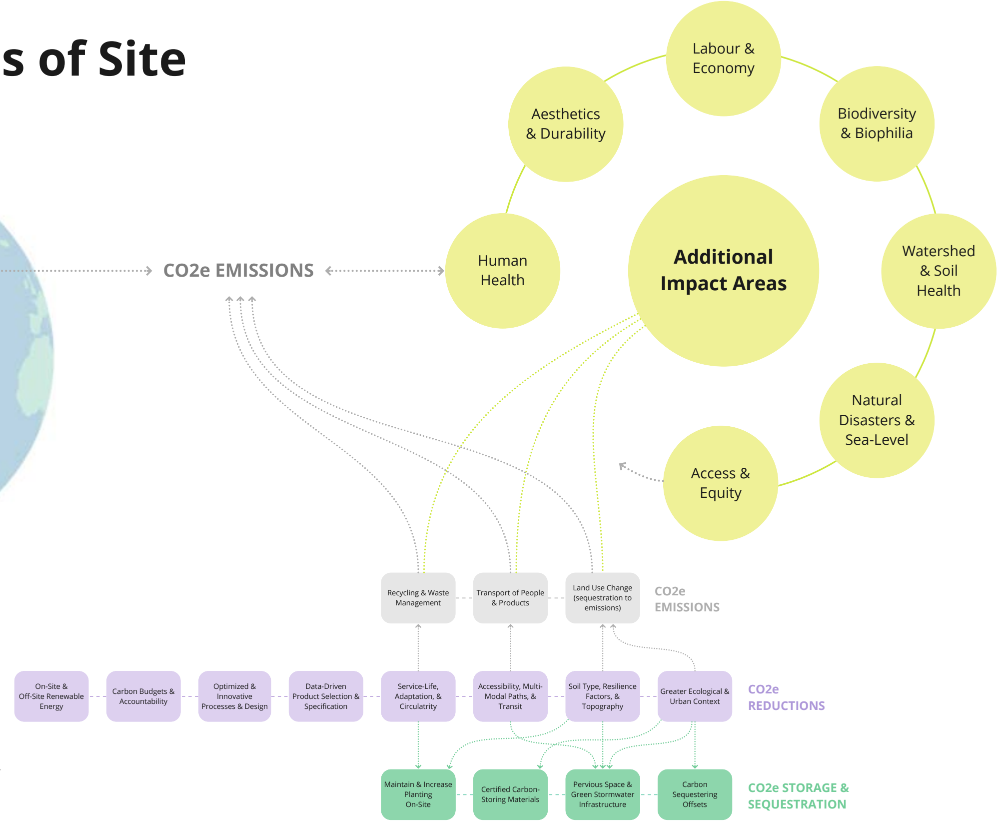
Land Use & Carbon

Everything in the carbon cycle is connected. Any strategy to offset, reduce, or avoid carbon requires consideration of multi-scalar impacts, because a benefit in one location may cause damage in another. For example, a wind farm built on a peat bog may cause the peat to leak carbon into the air. Peat soil contains ten times more carbon than a typical forest, so damaged peatland can emit as much carbon as a coal plant. Conversely, even a small site-based carbon reduction can have cascading benefits across scales. Replacing a piece of pavement with planting can sequester carbon over time, promote watershed health, increase biodiversity, and provide public green space or room for urban agriculture.



Social & Ecological Scales of Site





"Site" extends from the sub-soil, to public space, to the ecological source of materials for a building. While seeking to reduce carbon, designers can help clients and municipalities to address other site and material impacts:

- Proximity to multi-modal transit
- Soils on-site & low-carbon site selection; building on stable soils
- Preserving greenfields, sensitive ecologies, and wild places
- Accessible and bio-diverse public space and urban agriculture
- Healthy materials that do not contribute to human and ecological toxicity
- Stormwater infrastructure and design for watershed health

Carbon Span - Manuela Londono & Jesce Walz

Further Areas of Study

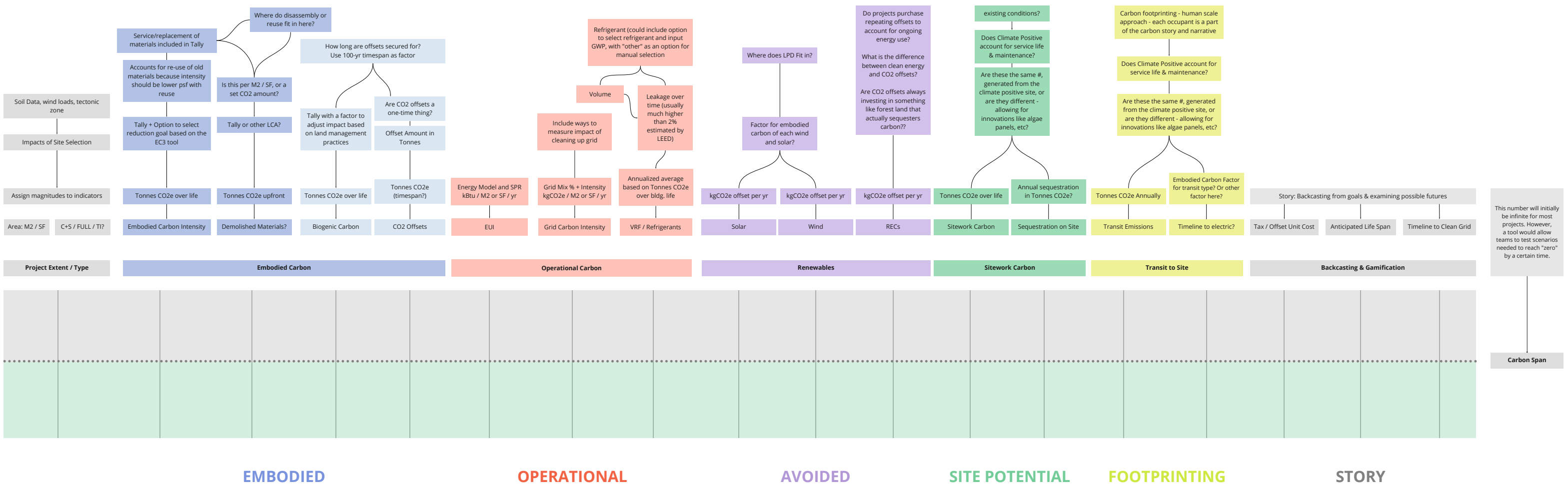
Through this research and the interviews conducted it became evident that the whole industry would benefit from more knowledge in the following areas:

- The relationship between the impacts studied and the tradeoffs made by prioritizing some reduction paths over others.
- The interconnections between GWP and health of building occupants.
- The connection between GWP, project financing, and economic performance.
- Drawing parallels between economic, environmental, and social concepts, for example what is our debt to the environment when we build a status quo building versus a carbon negative building?
- Uniformity and better understanding of carbon terminology, such as the difference between offsets, substitutions, emissions, and avoided emissions.
- Biogenic carbon studies and data to better quantify the carbon storing potential of sequestering materials.
- The direct and indirect impacts of the industry on social equity.
- More awareness and knowledge on the impact of refrigerant leakage and end of life recovery.
- Uptake of a holistic view of building impacts on the environment, human health, and social equity.
- Development of whole life carbon benchmarks based on statistically robust sample sizes.
- Improved transparency and reporting of the embodied carbon in renewable energy technologies.

Gamification

Gamification was a key theme throughout the CarbonSpan exploration and interview process. The diagram below illustrates some of the variables and questions that were considered during development of the CarbonSpan Calculator. A next step may be to develop a tool for teams to explore carbon impacts with varying magnitudes alongside one another.

A parametric whole carbon analysis tool would help teams to "backcast" their designs from an end goal of carbon neutrality, and to understand the costs of carbon-intensive design decisions in a future that may include carbon pricing as an incentive.



Recommendations and Next Steps

The matter of climate change and the building industry is vast and it can be difficult to draw boundaries around a scope of study. Here are some thoughts, ideas, and recommendations for expanding this work in our practice:

Develop and Improve Tools:

1. Develop a pathfinder tool that is capable of considering the whole carbon story of projects. This tool can be an evolution of the CarbonSpan Calculator, and it should be reviewed by engineers and other subject matter experts.
2. Pilot test the CarbonSpan Calculator with a larger group of projects, this could lead to firmwide reporting on metrics beyond operational and embodied carbon.
3. Develop and grow a database of projects' carbon performance, including total carbon as well as carbon intensity metrics. This information can be displayed in a dashboard easily accessible to all staff.
4. Develop templates to share and present the results of a CarbonSpan analysis to clients, colleagues, design teams, and more.

Ramp Up Education Efforts:

- Improve our climate literacy and align the terms we use with those used by leading and reputable sources, this will help avoid the perpetuation of misinformation and green washing.
- Train, encourage, and support staff to undertake CarbonSpan studies as part of the iterative design process.

Deliver Different:

- Establish a design process for low-carbon materials and systems, and for carbon sequestering sites. This might mean studying our current design process, breaking it down, and building it back up to include these design perspectives.
- Test new processes for selecting and tracking materials across a set of projects.

Seek Meaningful Partnerships:

- Continue to support partnerships with Building Transparency and engage in development of tools and resources that facilitate real and significant carbon reductions.

Follow Through with Commitments:

- Create a Perkins&Will carbon budget that can tell us how much carbon we are allowed to spend as a firm to meet or even exceed our climate action commitments.
- Commit to delivering our work within our carbon budget and the drawdown timeline.