

Photo credits: top left by Pat Corkery, NREL, top right by Dennis Schroeder, NREL, bottom left and bottom right by Dennis Schroeder, NREL.

EMBODIED CARBON RESOURCE NAVIGATOR

Guidance to making informed embodied carbon decisions for buildings

Why embodied carbon?

Embodied carbon is the carbon released from the manufacturing, transportation, installation and disposal of building materials. Half of the total emissions released from now until 2050 from new buildings will be from the construction of those buildings¹, thus it is important to consider these emissions when aiming to meet climate targets.

What is this resource?

This resource is a compilation of embodied carbon resources that are organized by experience and educational level to allow the architecture, engineering, construction, and facility management community to make more informed design decisions on lowering embodied carbon. Resources include reports, videos, fact sheets, and case studies that provide examples for inspiration and replication.

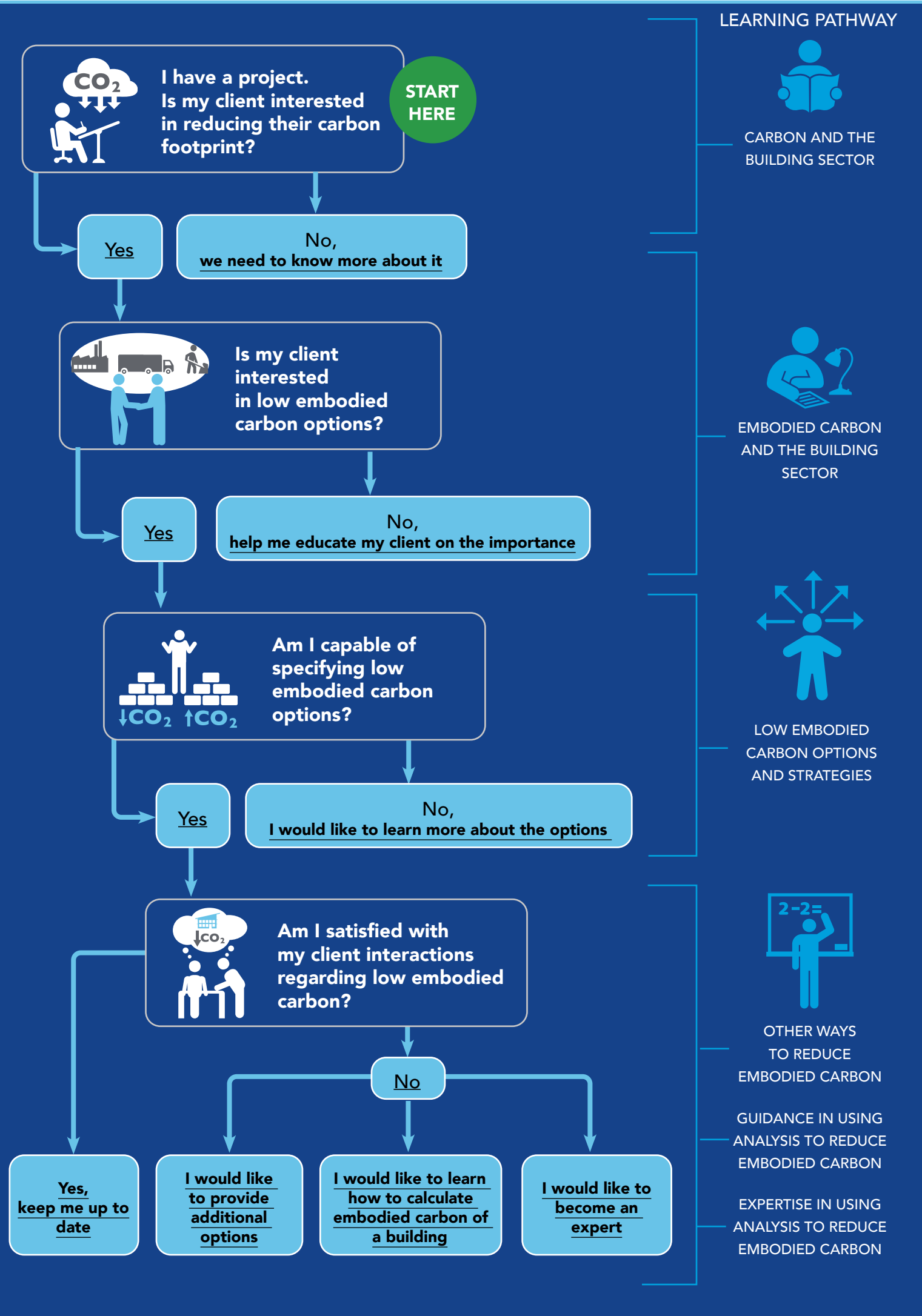
Who should use this?

Architects, engineers, designers, contractors and those who want to reduce their embodied carbon impact through design decisions.

How do you learn more?

Click Here to
GET STARTED

¹ AIA-CLF Embodied Carbon Toolkit for Architects <https://carbonleadershipforum.org/toolkit-1-introduction/>



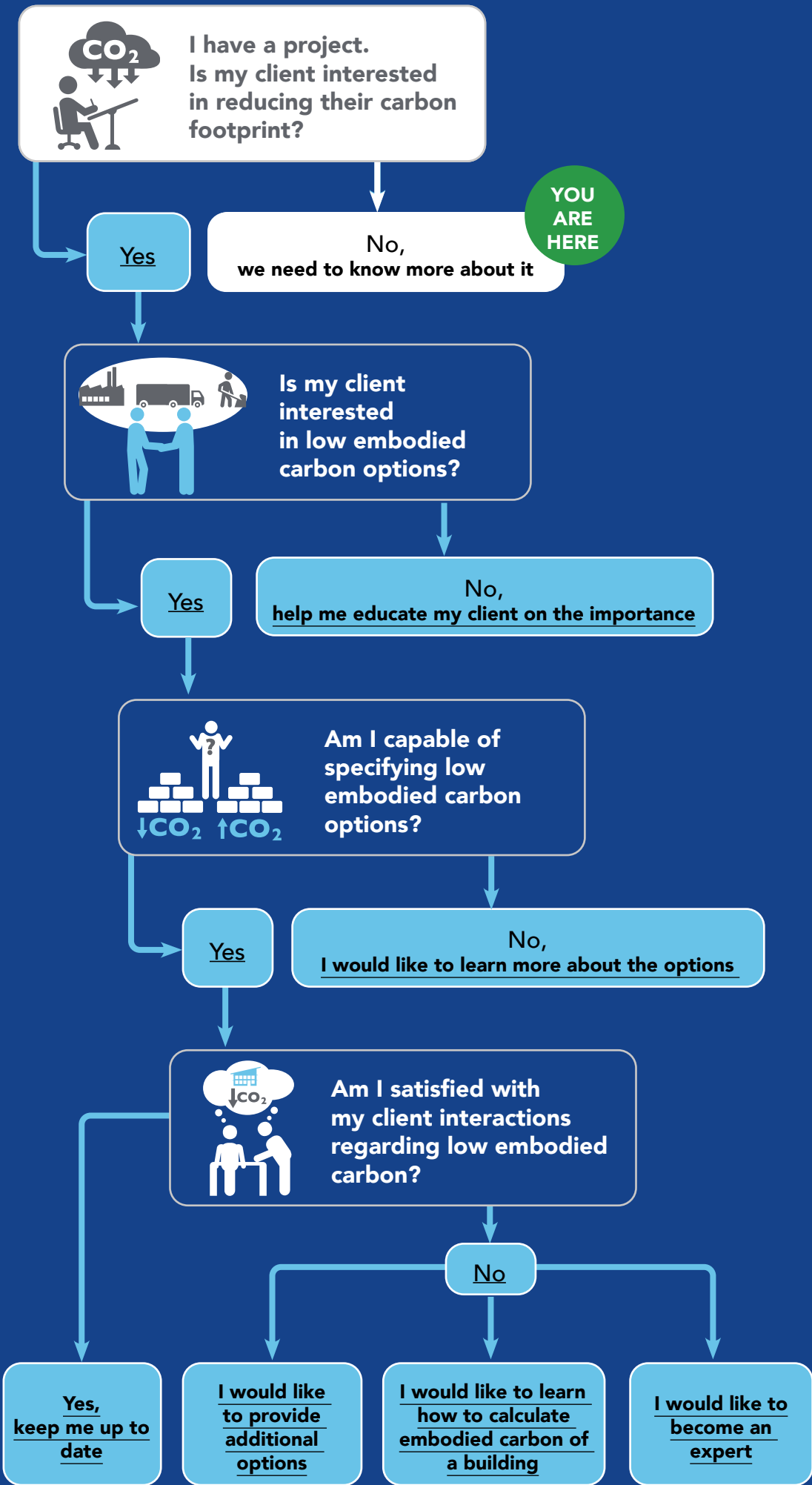
GETTING STARTED

By answering a series of guiding questions, the user will navigate to a set of resources that will provide information at particular experience and educational levels.

Move through the questions and click on the answer that best fits your situation to get targeted resources or go to the next question if your answer is yes.

Resource types are indicated by the following icons:

- Tool
- Website
- Report
- Video



CARBON AND THE BUILDING SECTOR

Buildings are responsible for **~37% of annual global emissions.**

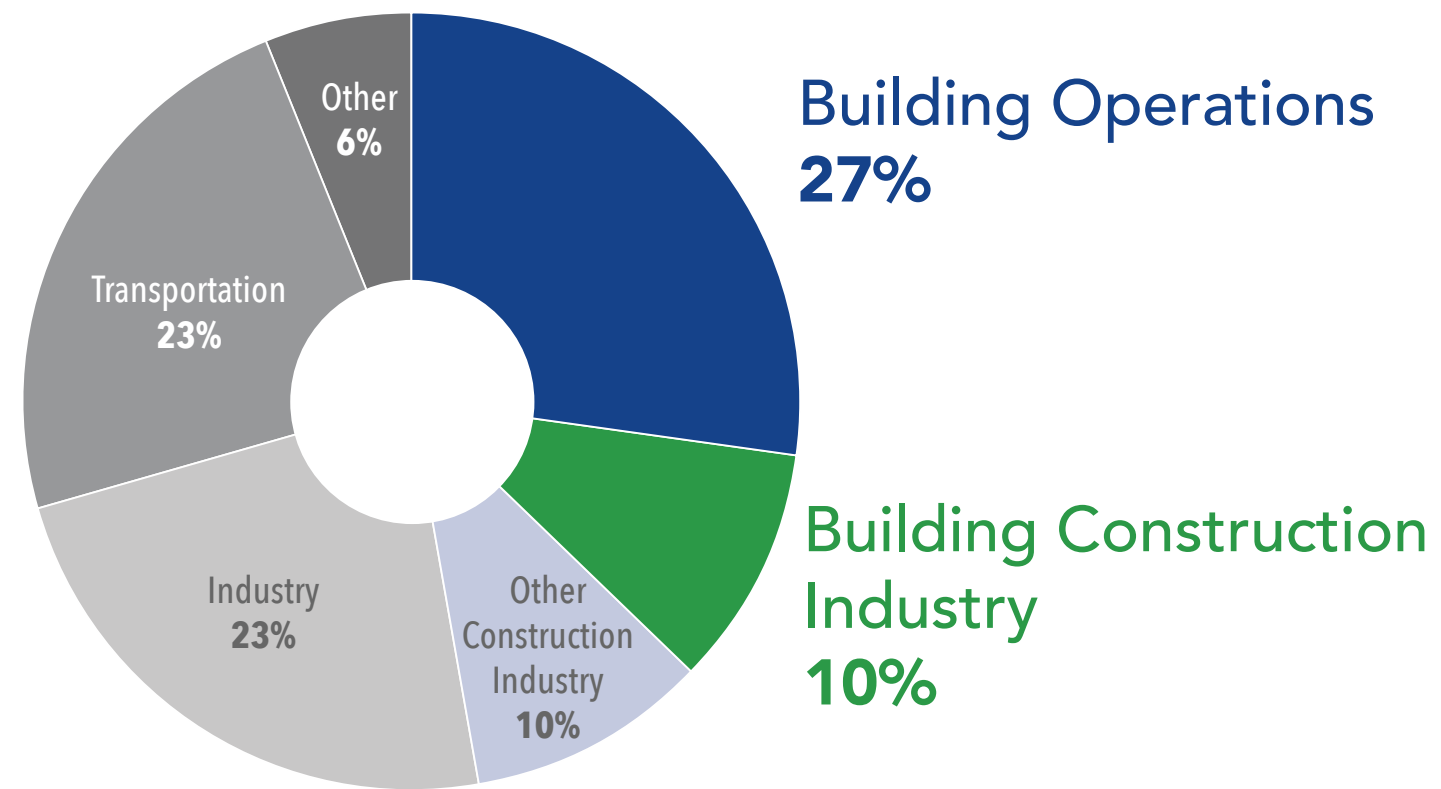
- 10% of annual global emissions are from building materials and construction
- 27% of annual global emissions are from building operations.

By 2040, 66% of the global building stock will consist of buildings that are here today, indicating the **importance of energy upgrades for existing buildings.**

By 2060, global building floor area is expected to double, indicating the **importance of future building construction to include high energy efficiency and low carbon materials and construction methods.**

- Carbon emissions released from building material production and building construction will be responsible for half of the total footprint for buildings built between now and 2060.

ANNUAL GLOBAL EMISSIONS



Three Materials are Responsible for **23%** of Total Global Emissions



Data from 2021 Global Status Report for Buildings and Construction, UNEP (United Nations Environment Programme), <https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction> and Architecture 2030, <https://architecture2030.org/why-the-building-sector/>

FOR MORE INFORMATION SEE:

[Why the Buildings Sector](#)

10 minute read

Architecture 2030 provides statistics to demonstrate why the building sector can help meet climate targets. Statistics cover current emissions generated, the rapid rate of new construction of new buildings, how embodied carbon of buildings play an important role, and the materials in buildings that are responsible for the majority of emissions.

<https://architecture2030.org/why-the-building-sector/>

[What is Green Building?](#)

3 minute read, 1 minute video

Short video and text explains what "green building" is and how green building can help fight climate change. High-performing buildings can help reduce climate impacts of the buildings sector.

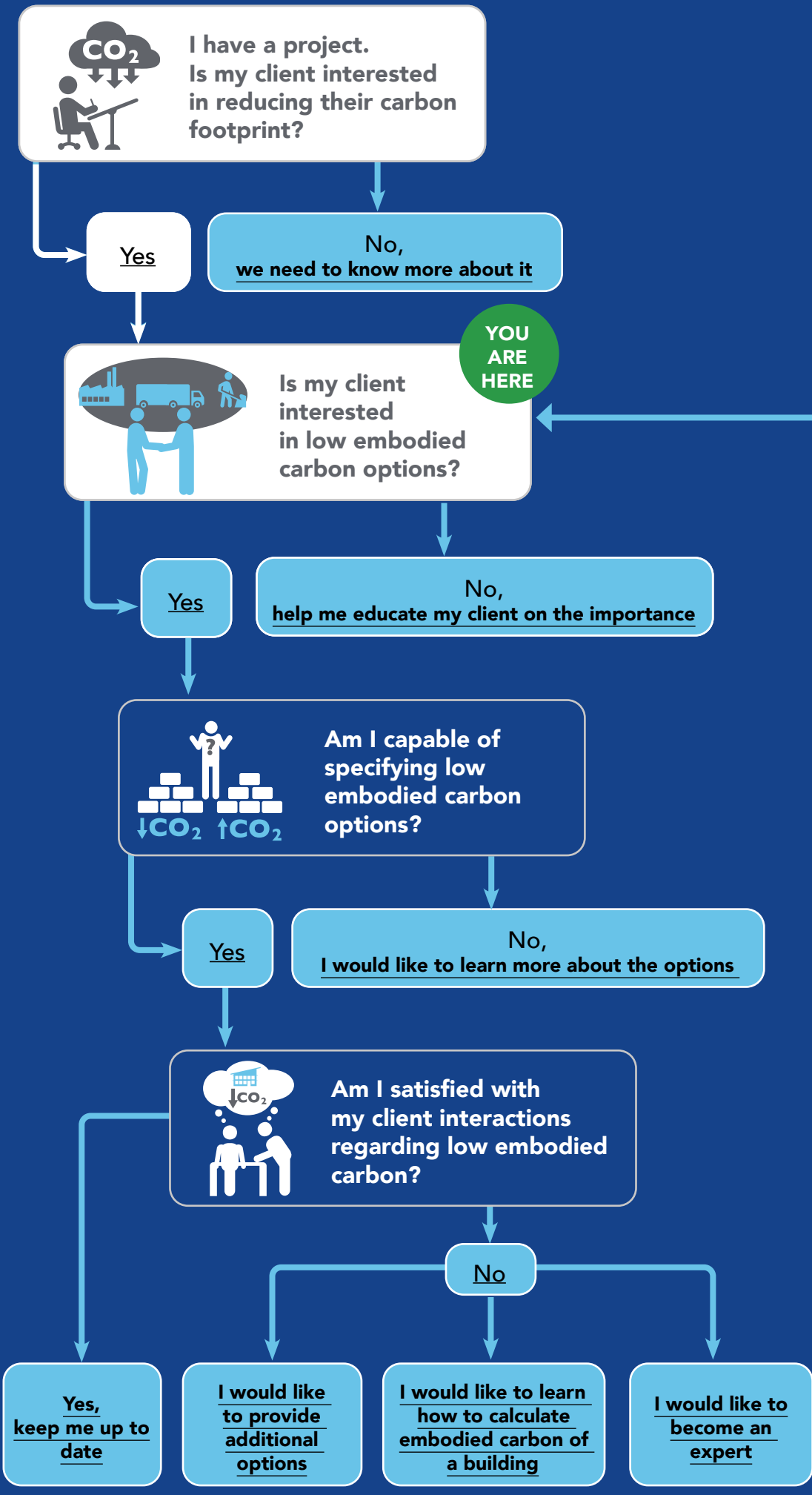
<https://www.usgbc.org/articles/how-green-buildings-can-help-fight-climate-change>

[Bringing Embodied Carbon Upfront](#)

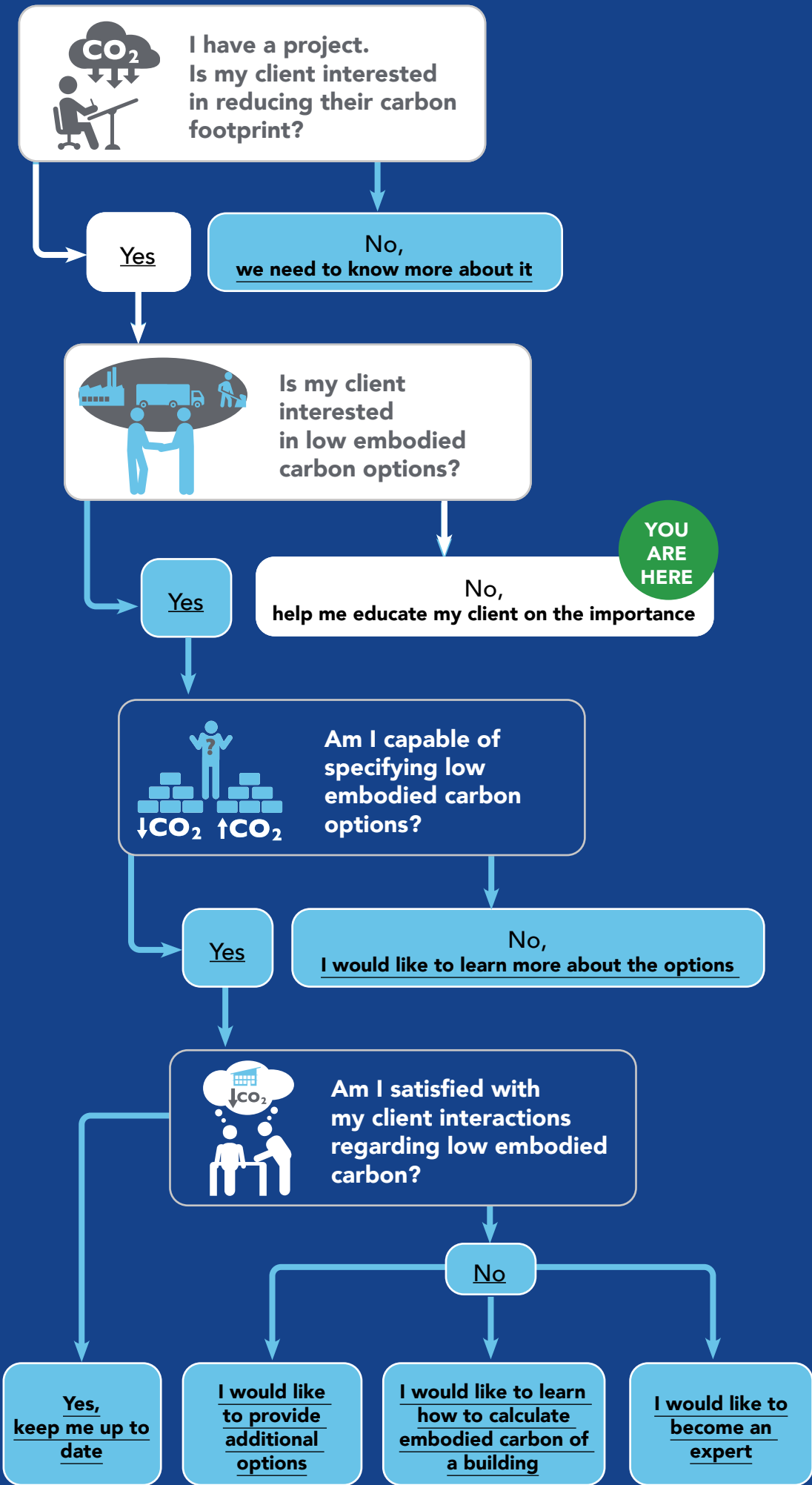
3 min read, 2 min video

World Green Building Council outlines the urgency for action in reducing building embodied carbon and describes pathways that are needed to accomplish embodied carbon reduction goals.

<https://www.worldgbc.org/embodied-carbon>



Answer the question to continue



EMBODIED CARBON AND THE BUILDING SECTOR

EMBODIED CARBON VS OPERATIONAL CARBON

Operational carbon: emissions associated with operating buildings. Emissions are a result of fuel consumption, electricity purchased, and refrigerant leakage.

Embodied carbon: emissions associated with the processes to produce materials and construct, maintain, and deconstruct buildings over its whole life cycle.

ECONOMICS MATTER

- Low and no-cost strategies for reducing embodied carbon exist that can be employed by designers.
- Making design decisions early on can be the most cost-effective approach in reducing embodied carbon.

THE TIME IS NOW

- Once embodied carbon emissions from processing materials and construction are released, they cannot be taken back. However, emissions from daily operations of buildings can be decreased over time through energy efficiency and grid decarbonization efforts.
- Most of the impactful decisions related to embodied carbon happen in the early stages of a design project.

ENVIRONMENTAL, SOCIAL, AND GOVERNANCE (ESG) GOALS

- Addressing embodied carbon can contribute to a company's ESG goals.

Clients and designers are well situated to push for solutions by designing for and selecting low carbon materials and processes.



Clients

- Adopt best practice maintenance in line with manufacturer's recommendations
- Plan for end of life decommissioning
- Adopt low life cycle carbon emissions goals or low embodied carbon goals
- Adopt policies to select low global warming potential (GWP) refrigerants
- Develop a comprehensive refrigerant management plan



Designers

- Design building envelopes and systems to minimize heating and cooling needs
- Be aware of the potential environmental damage associated with refrigerants
- Minimize field installed refrigeration piping
- Specify equipment with low GWP refrigerants
- Design buildings to minimize the life cycle carbon intensity
- Select materials to minimize embodied carbon

FOR MORE INFORMATION SEE:

[Intro to Embodied Carbon](#)

AIA CLF, 8 pages, <1 hour read

This report introduces embodied carbon impacts, how these impacts compare to operational carbon, and how the design community is well positioned to make a large impact in reducing embodied carbon.

<https://carbonleadershipforum.org/toolkit-1-introduction/>

[Building Decarbonization Guides](#)

75 pages, ~8-10 hours

These guides focus on best practices for decarbonizing the built environment and are organized into volumes.

<https://www.collaborativedesign.org/get-the-guide-bdpg>

[Roadmap to Reducing Building Life Cycle Impacts](#)

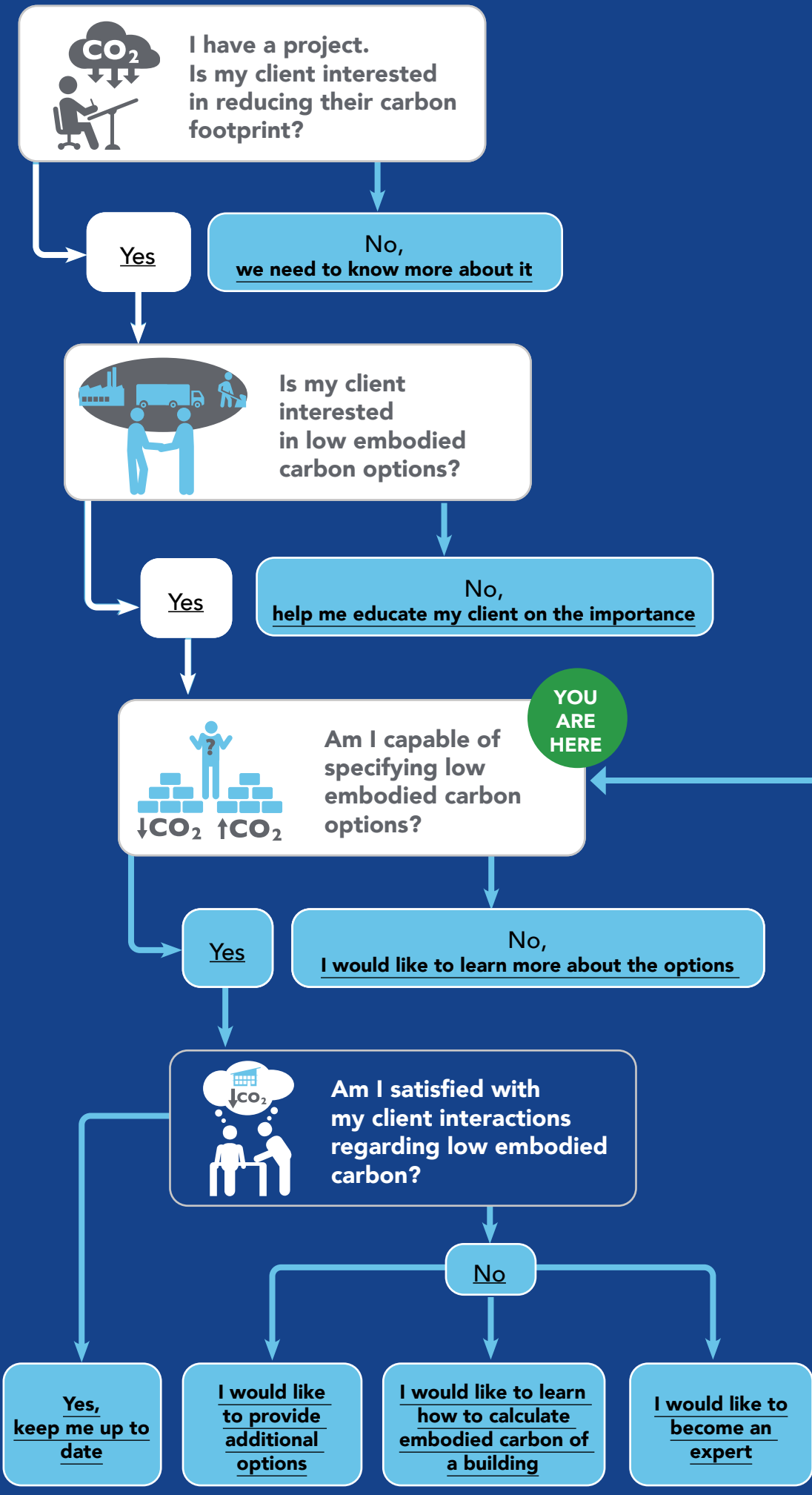
Carbon Leadership Forum

This timeline provides suggestions of when actions can take place to reduce embodied carbon and other life cycle impacts during the design process. <https://carbonleadershipforum.org/wp-content/uploads/2019/05/2019.05.23-LCA-Timeline-Diagram-spread.pdf>

[Reducing Embodied Carbon for Developers and Designers](#)

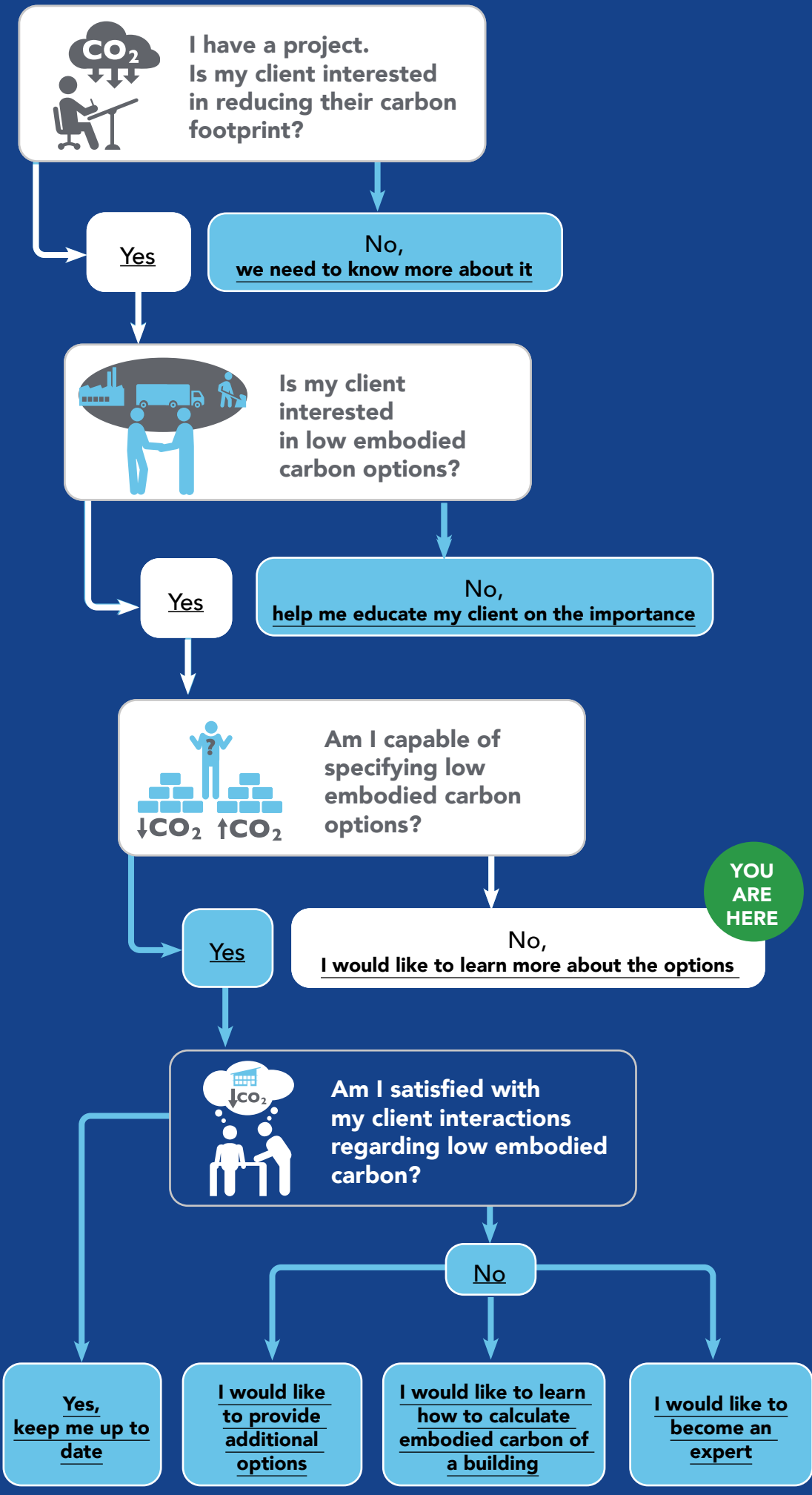
RMI, 2 page, <1 hour

This summary is focused on the developer's perspective: (<https://rmi.org/download/29344/>) and this one is focused on the designer's and specifier's perspectives: (<https://rmi.org/download/29346/>)



YOU ARE HERE

Answer the question to continue



LOW EMBODIED CARBON OPTIONS AND STRATEGIES

STRATEGIES FOR REDUCING EMBODIED CARBON

- Build less, reuse more by extending life of existing buildings and materials
- Build lighter with less given material for the same function
- Substitute low-carbon materials for high-carbon materials
- Procure lower carbon products
- Choose materials with high recycled content and high reuse potential
- Minimize waste and provide pathways to reuse and recovery

CARBON SMART MATERIALS PALETTE

Carbon Smart Materials Palette provides key attributes of materials that contribute to embodied carbon and guidelines for reducing emissions.

REFRIGERANT LEAKAGE IS A LARGE CONTRIBUTOR TO CLIMATE CHANGE:

Carbon equivalent emissions from refrigerants can be a significant proportion of total emissions because of their very high GWP.

Case studies indicate 24%-46% embodied carbon savings at cost premiums of 1% or less

LOW EMBODIED CARBON SOLUTIONS



Graphic inspired by <https://rmi.org/insight/reducing-embodied-carbon-in-buildings?submitted=ecrpfgerbh>

FOR MORE INFORMATION SEE:

[Reducing Embodied Carbon in Buildings: Low-Cost, High Value Opportunities](#)

RMI, 47 pages, ~4-5 hours
 This report identifies low-cost solutions to reduce the embodied carbon of buildings. The report includes case studies of embodied carbon savings potential for different building types.
<https://rmi.org/insight/reducing-embodied-carbon-in-buildings?submitted=ecrpfgerbh>

[Strategies for Reducing Embodied Carbon](#)

AIA CLF, 8 pages, <1 hour
 This guide provides high-level strategies for reducing embodied carbon in the design stage. Guidance includes design strategies, material and system selection strategies, specification and procurement strategies, and process strategies.
<https://carbonleadershipforum.org/clf-architects-toolkit-part-3-strategies-to-reduce/>

[Carbon Smart Materials Palette™](#)

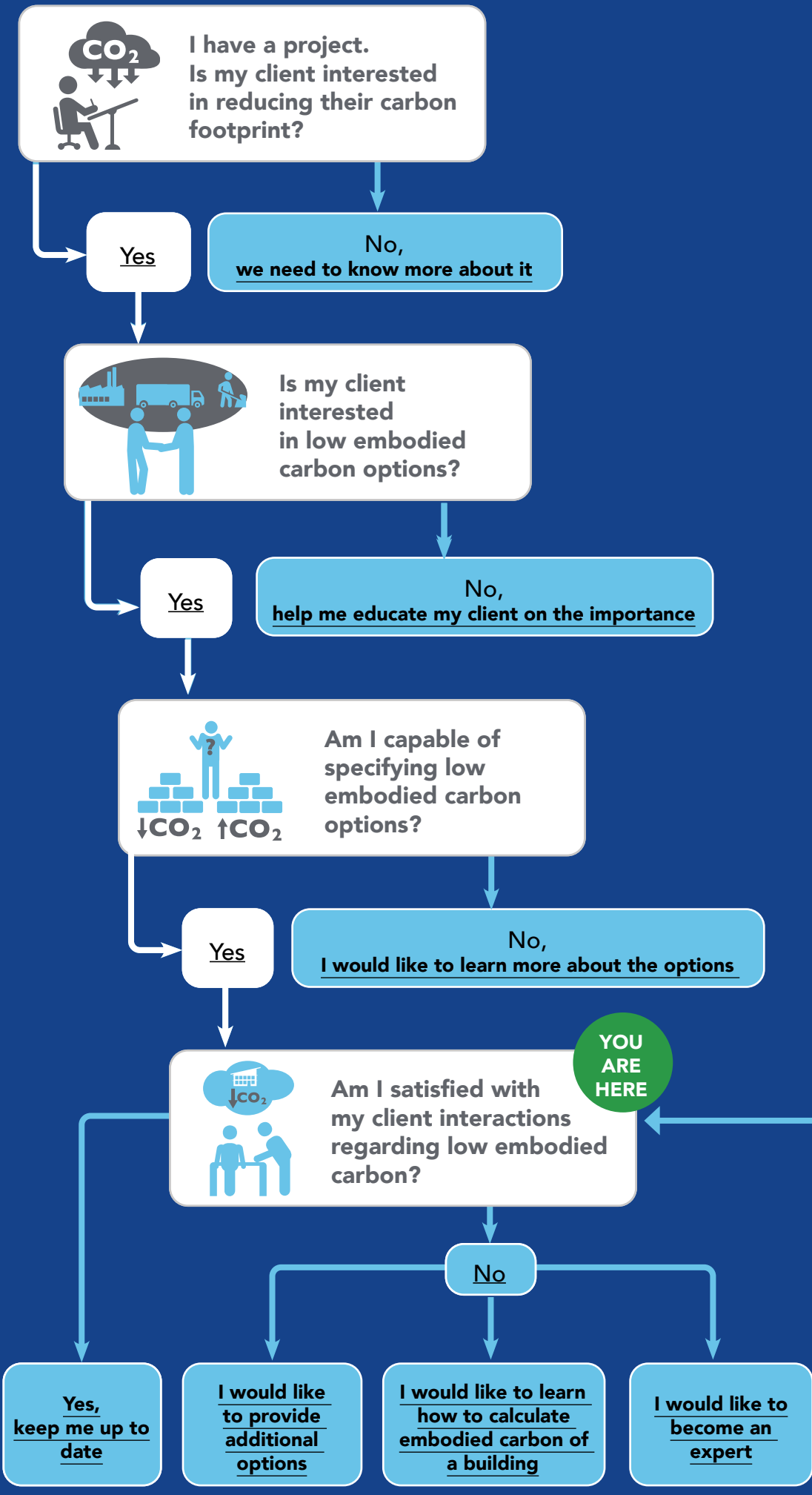
Architecture 2030
 This guide provides information on high impact materials (e.g., concrete, steel, wood, insulation, carpet, gypsum board) including carbon-smart alternative materials and whole building approaches to emissions reductions.
<https://materialspalette.org/>

[ECOM – Embodied Carbon Estimator](#)

SE2050
 The Embodied Carbon Order of Magnitude (ECOM) is a basic embodied carbon calculator to help users estimate the embodied carbon for a material product, an assembly of framing or entire structural frame.
<https://se2050.org/ecom-tool/>

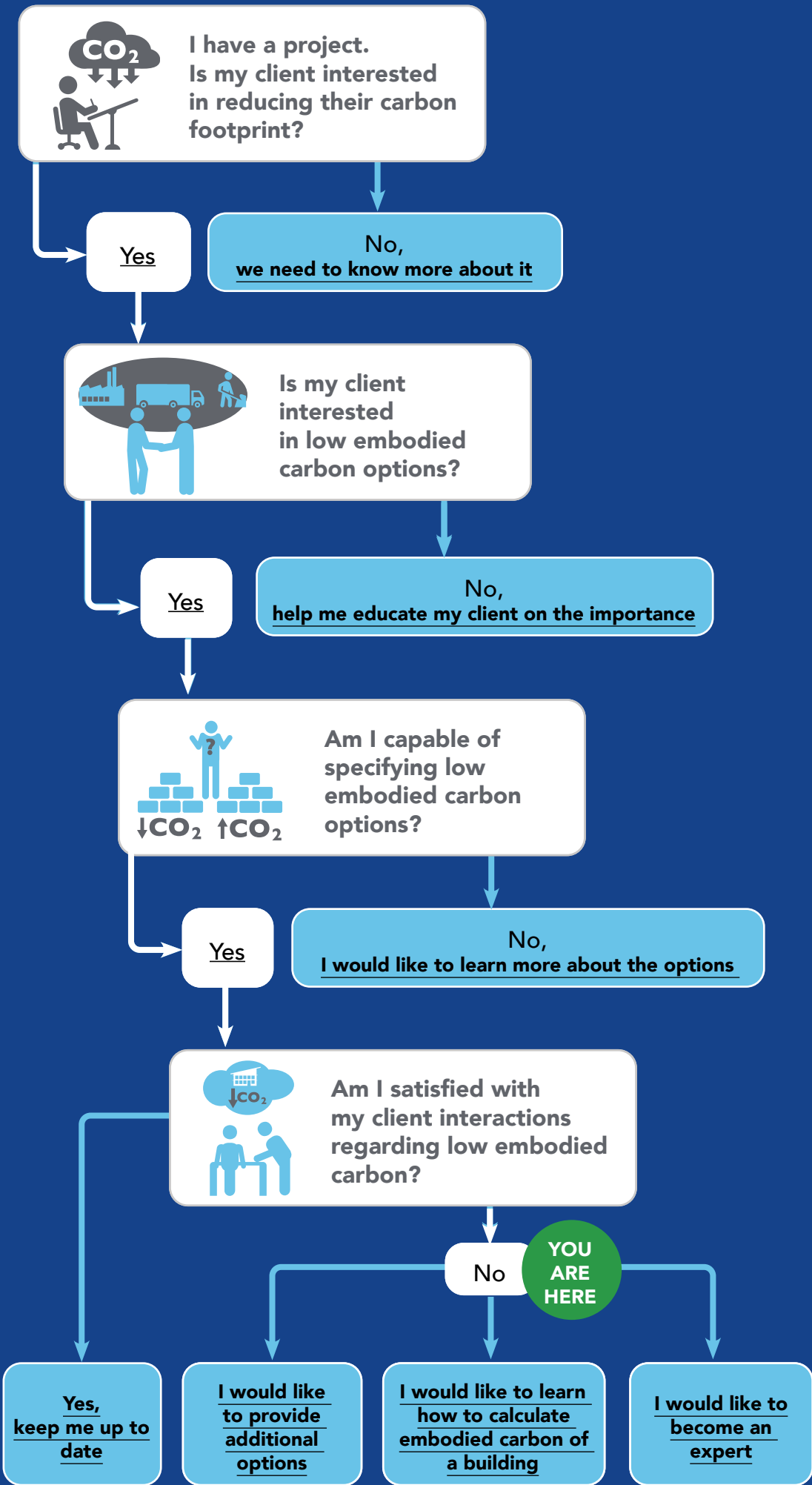
[Refrigerants & Environmental Impacts: A Best Practices Guide](#)

56 pages, ~3-4 hours
 This best practice guide reviews the environmental impacts of currently available refrigerants for commonly used systems and provides guidance on reducing refrigerant charge and leakage and enhanced recovery at end of life.
<https://www.integralgroup.com/news/refrigerants-environmental-impacts/>

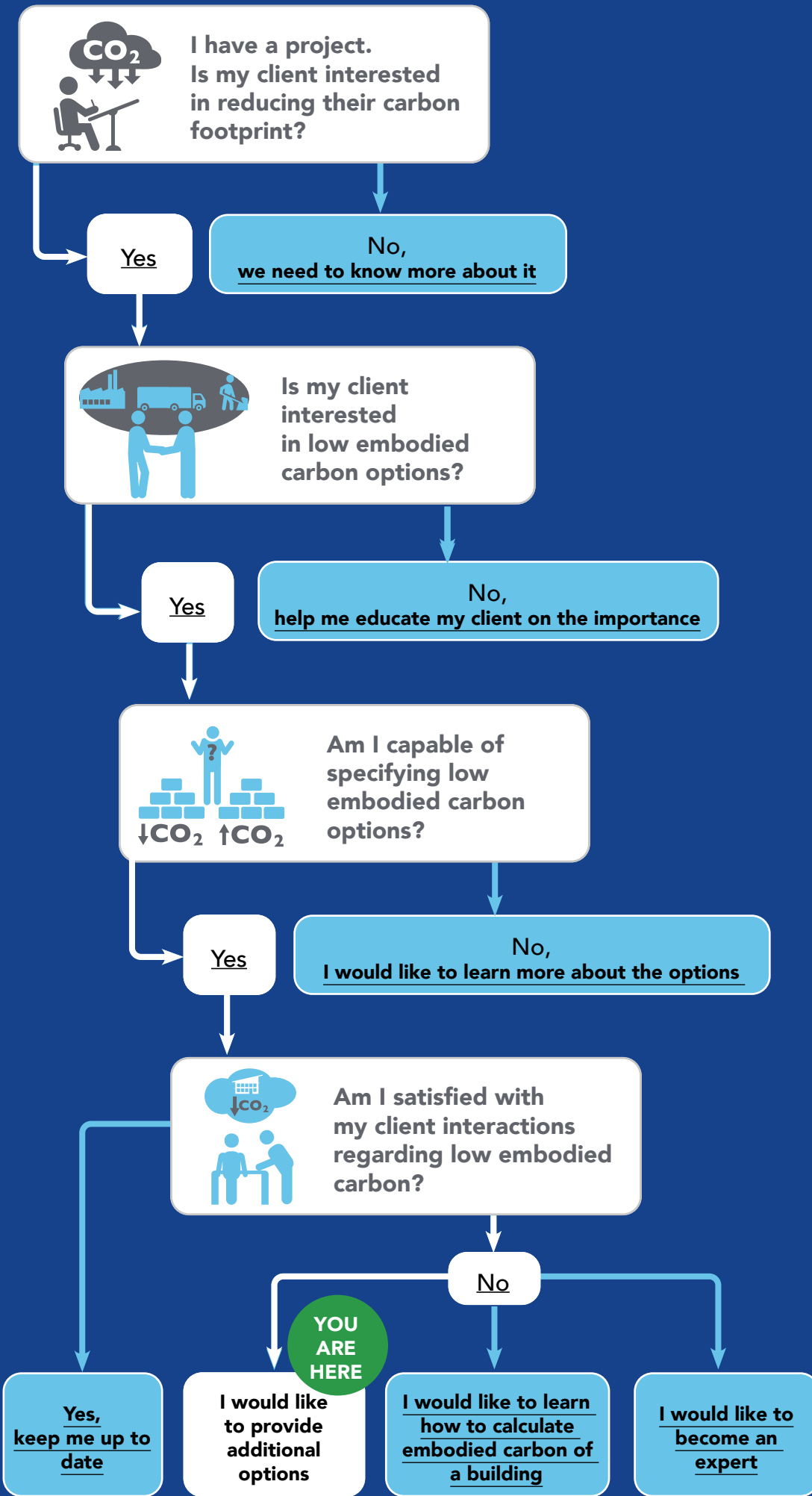


YOU ARE HERE

Answer the question to continue



Select a "No" option to learn more



OTHER WAYS TO REDUCE EMBODIED CARBON

WORKING WITH PROFESSIONALS

- Request information from manufacturers of high embodied carbon materials
- Collaborate with structural engineers to reduce foundation materials
- Conduct order of magnitude carbon estimates on high embodied carbon materials

BUILDING LIFE CYCLE ASSESSMENT (LCA)

- Is a systematic methodology to calculate environmental impacts
 - GWP (i.e. lb CO₂eq or kg CO₂eq) is one of the impact categories and measures the impacts of greenhouse gas emissions, including carbon dioxide
- Can help building professionals design and construct sustainable buildings

- Can be compared with Life Cycle Cost Analysis (both discounted and nominal) to save costs and carbon
- Requires bill of materials (BOM)/bill of quantities (BOQ), calculated energy performance and LCA database information to be completed
 - LCA databases can include product manufacturer-specific information (Environmental Product Declarations [EPDs]) and/or generic material information

WHOLE BUILDING LCA CAN BE USED FOR:

- Providing insight on material choices and design options
- Showing benefits of refurbishment and adaptive reuse compared to demolition and reconstruction
- Comparing systems for optimized reduced impact
- Achieving LCA-based certification

LCA tools can be found at sftool.gov/

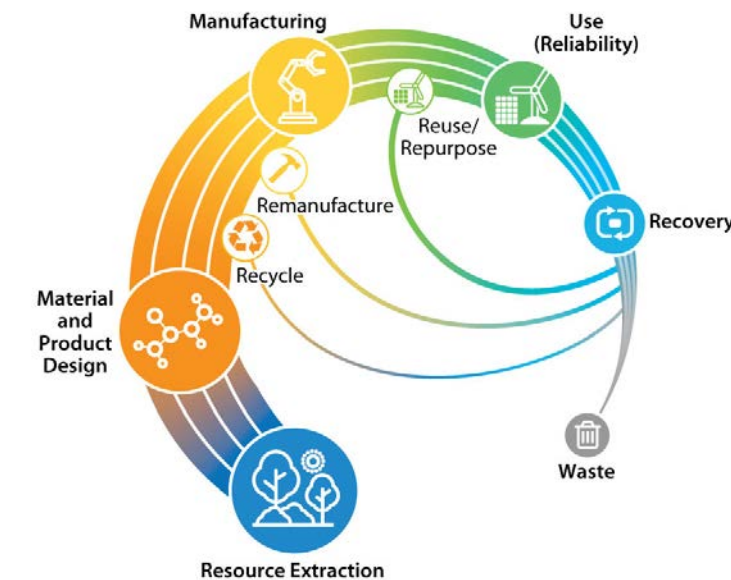
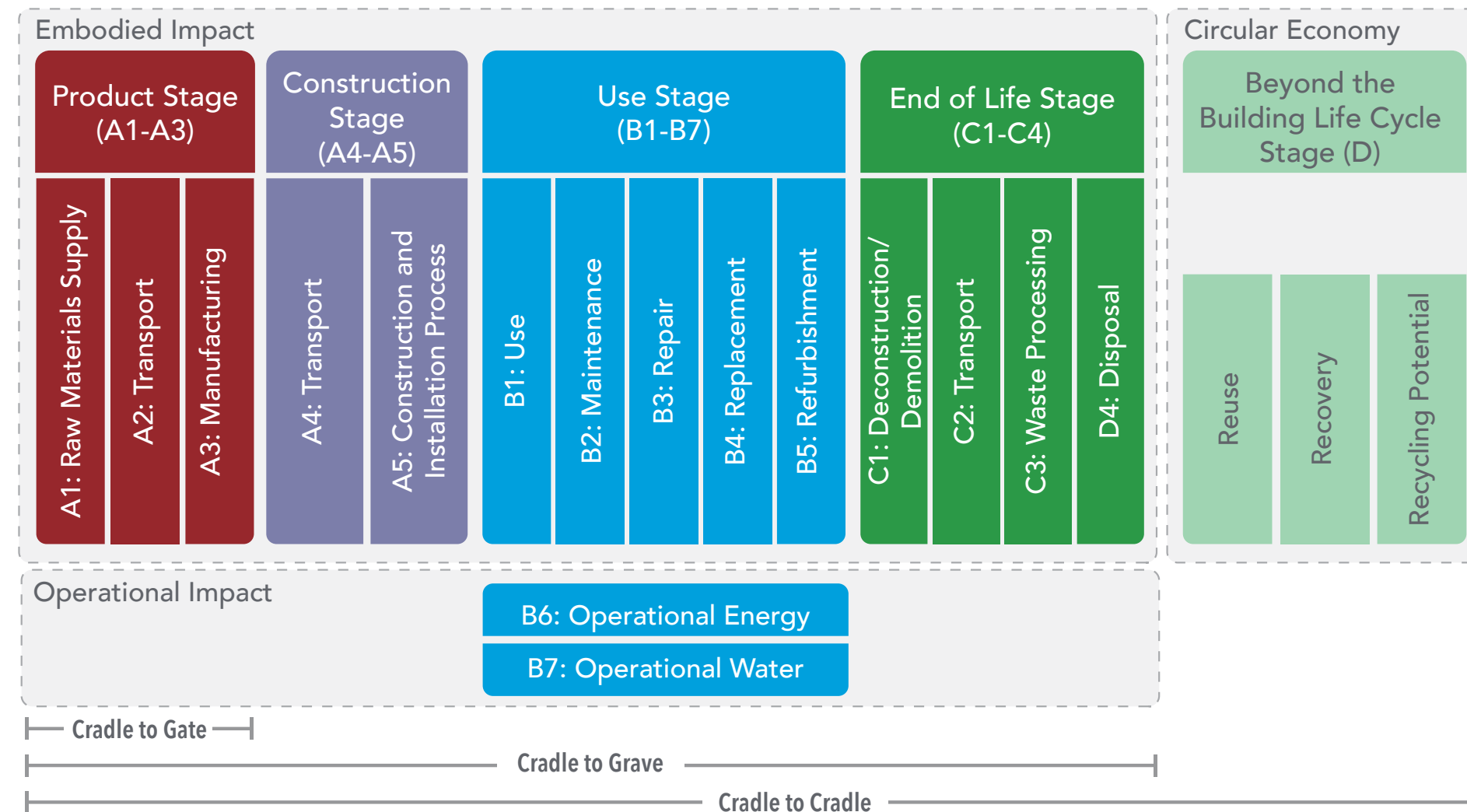


Figure by NREL

LIFE CYCLE IMPACTS AT EACH STAGE



Whole Building LCA is informed by ISO 21931. Life cycle stages from BS EN 15978:2011

FOR MORE INFORMATION SEE:

[10 Essential Facts about Building Life Cycle Assessment](#)

OneClick LCA
 This short article provides basic information on building LCA and why it is important. <https://www.oneclicklca.com/10-essential-facts-about-building-life-cycle-assessment/>

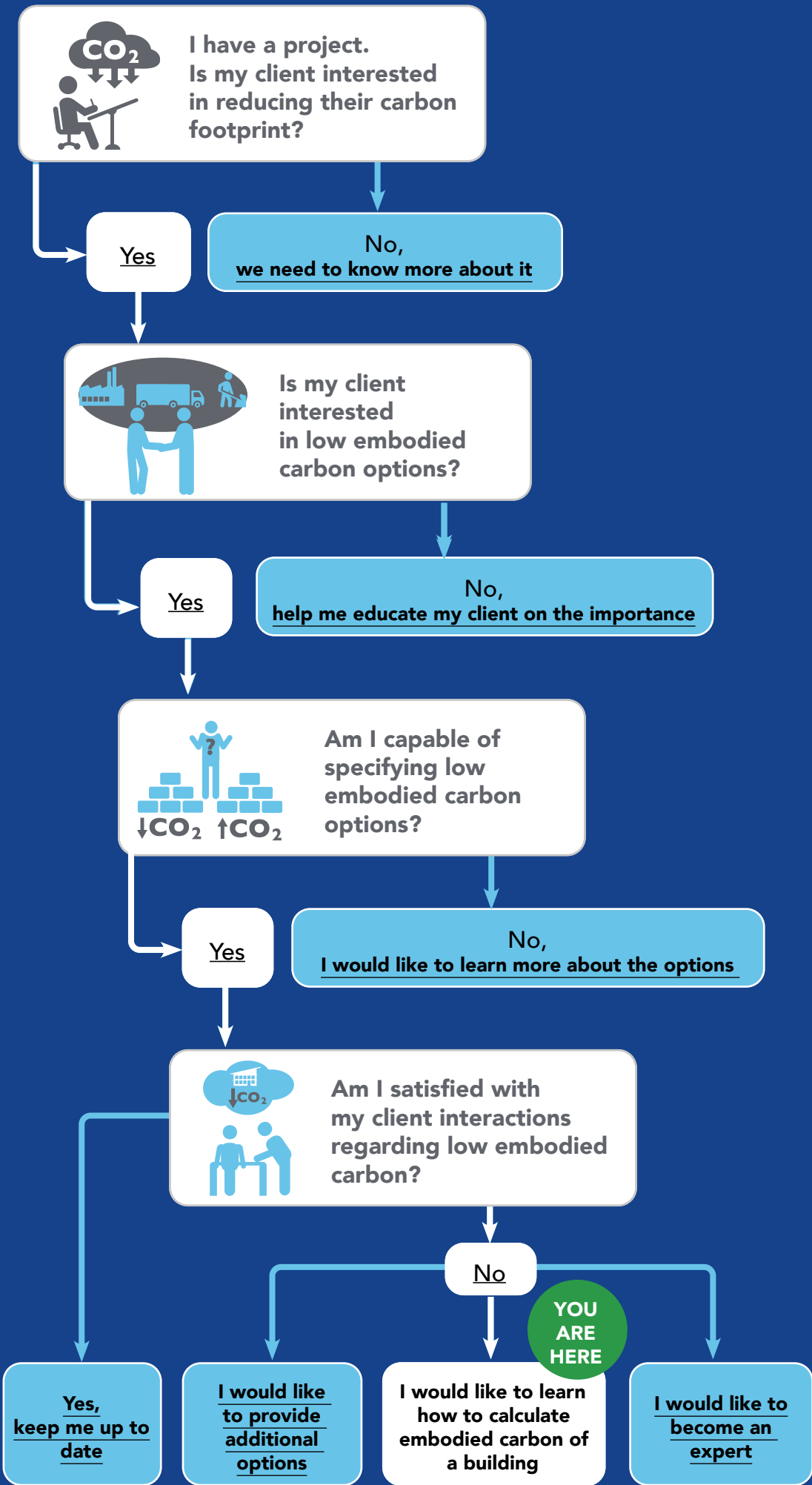
[Kaleidoscope: Embodied Carbon Design Tool](#)

Payette, <1 hour read

This website provides order of magnitude, early design comparisons and information on envelopes, flooring, ceilings, and other assemblies. <https://www.payette.com/kaleidoscope/>

[Sustainable Facilities Tool — Life Cycle Assessment and Buildings](#)

GSA
 This website provides an overview of LCA for buildings and why whole building LCA is useful. Short descriptions of commonly used LCA tools is provided. <https://sftool.gov/plan/403/life-cycle-assessment-buildings>



GUIDANCE IN USING ANALYSIS TO REDUCE EMBODIED CARBON

GUIDELINES FOR INTEGRATING LCA IN BUILDING DESIGN

- Defining sustainability targets of project
- Define the goals and scope of LCA study
- Choosing an LCA tool
- Life Cycle Inventory Analysis
- Life Cycle Impact Assessment (LCIA)
- Interpreting results
- Simultaneous Life Cycle Cost Analysis for ROI-based LCA

LCA tools can be classified based on different levels of LCA application, user skills, region, application to design stage, and the life-cycle phases included in the analysis.

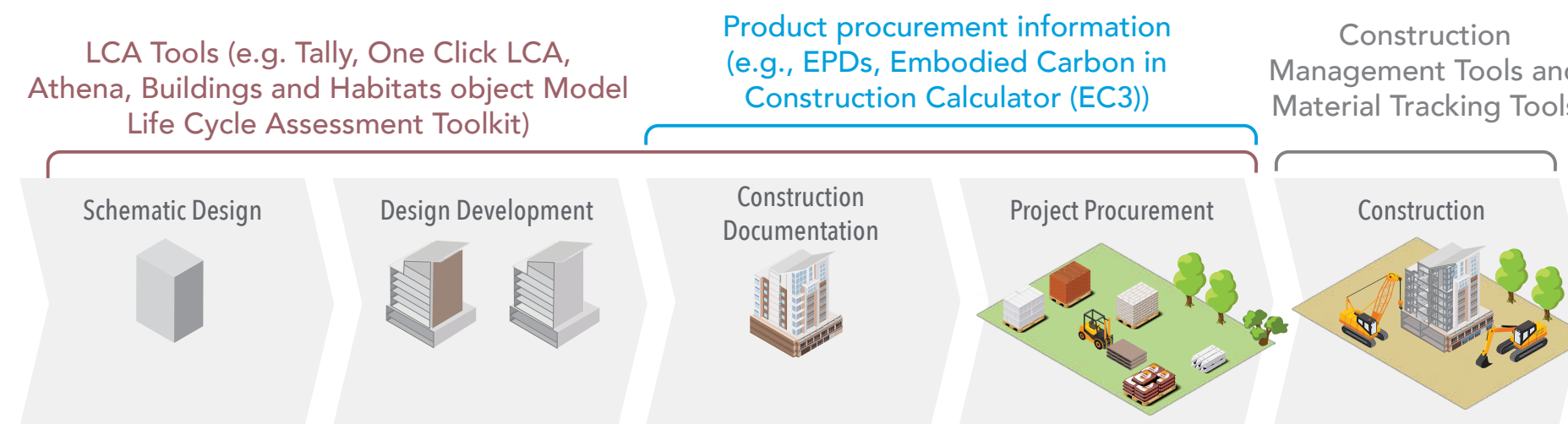
LCA PROCESS

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation

CHALLENGES IN THE USE OF LCA

- Data collection
- Data quality
- Issues with impact assessment methods
- Issues with weighting

ANALYSIS COVERAGE OVER DESIGN AND CONSTRUCTION PHASES



Graphic inspired by Carbon Leadership Forum, <https://carbonleadershipforum.org/guide-to-the-ec3-tool/>

FOR MORE INFORMATION SEE:

[Building Life Cycle Assessment in Practice](#)

AIA, 200 pages, 20 hour read

This paper provides guiding principles for understanding and using LCA methodology in design, directed towards the architectural profession. It includes descriptions of LCA terminology, commonly used LCA tools, and case studies. <https://www.aia.org/resources/7961-building-life-cycle-assessment-in-practice>

[Life Cycle Assessment For Buildings](#)

OneClick LCA, 32 pages, 3-4 hour read

This eBook provides an overview of building LCA, an understanding of why it is important to take a whole life cycle approach to calculating environmental impact, how building LCA is calculated, how to incorporate LCA into a workflow, and the increasing importance of building LCA in construction. <https://www.oneclicklca.com/building-life-cycle-assessment-ebook/>

[Guide to the EC3 Tool](#)

CLF, <1 hour read

This website provides guidance on using the Embodied Carbon in Construction Calculator (EC3) tool. Meant to complement LCA tools already in use, EC3 aims to fill the gap between LCA used in early design and material procurement. This website provides a guide on using EC3. <https://carbonleadershipforum.org/guide-to-the-ec3-tool/>

[Impact Estimator for Buildings Tutorials](#)

Athena Sustainable Materials Institute, 5-20 minute video tutorials

These video tutorials provide basic understanding of the Impact Estimator for Buildings. The total run time of the videos is 2 hours. <https://calculatelca.com/resources/watch-tutorials/impact-estimator-for-buildings-tutorials/>

[GREET Building LCA Module User Guide](#)

Argonne National Laboratory, 80 pages, 8-10 hour read

This user guide provides guidance on conducting and comparing LCAs of building materials and components and whole building analyses using the Building LCA module. Additional information can be found at https://greet.es.anl.gov/greet_building.

https://greet.es.anl.gov/files/greet_building_guide_2021

[NIST Metric and Tools for Sustainable Buildings](#)

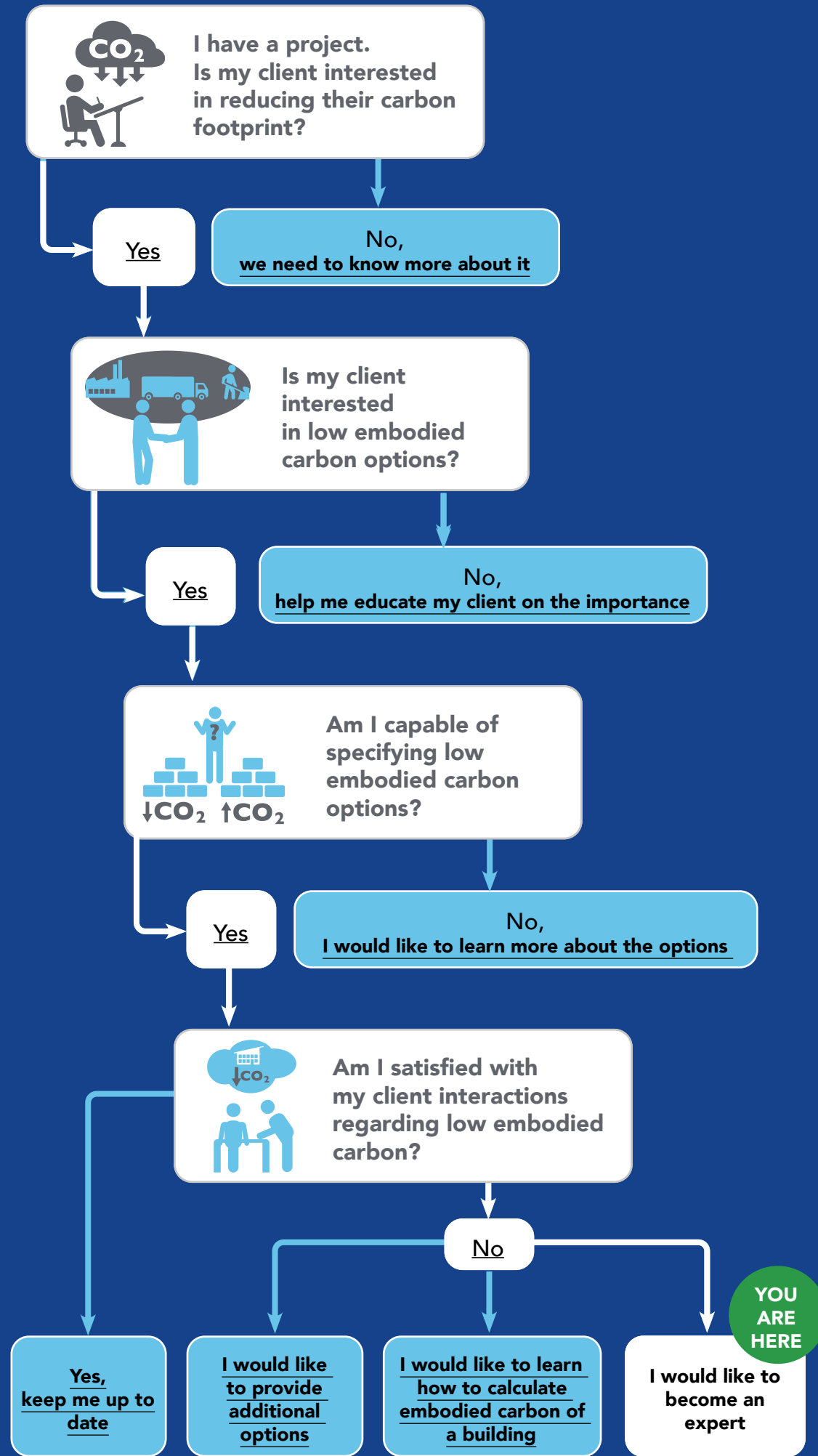
<1 hour read

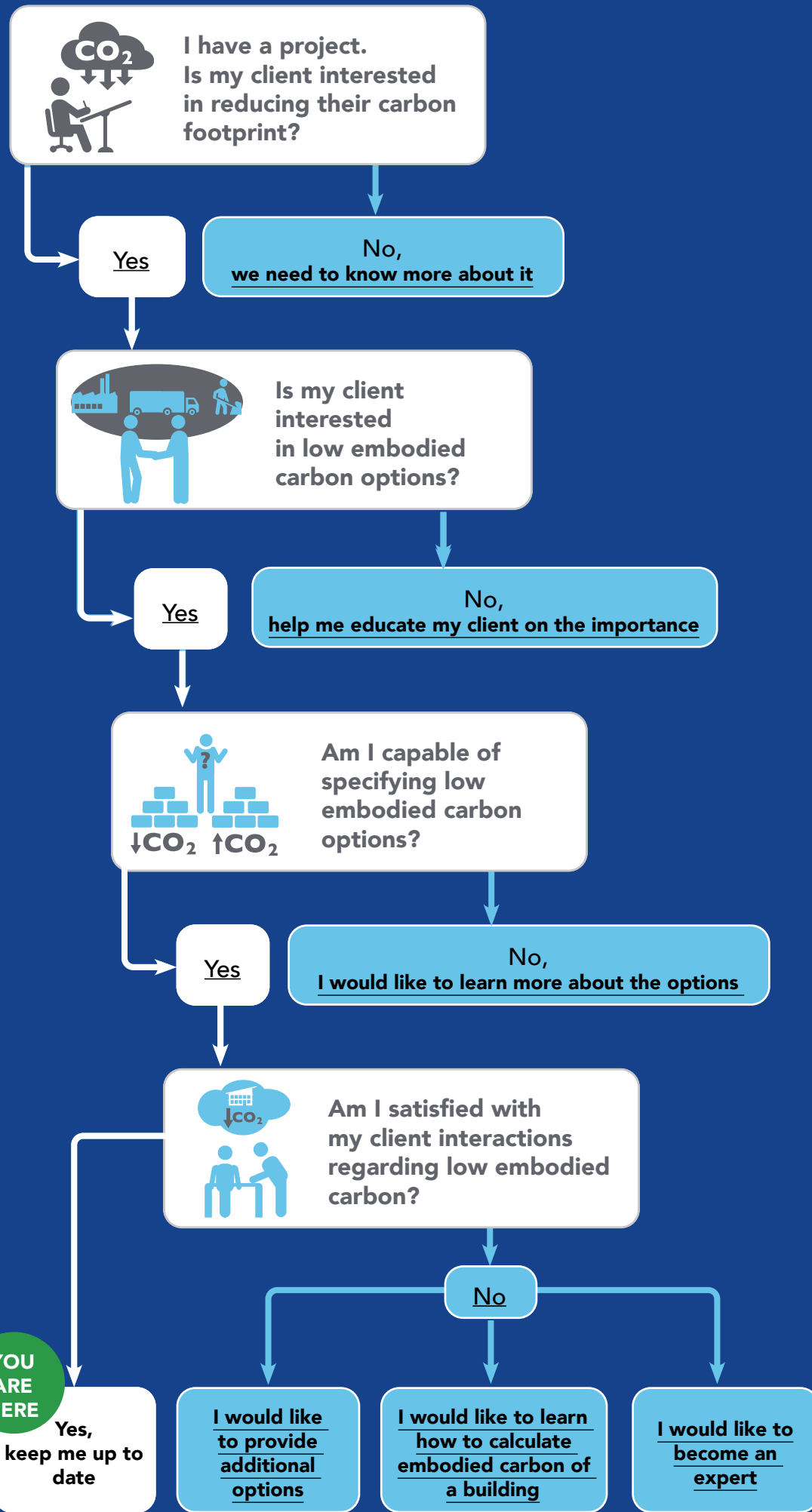
This website describes the suite of NIST tools that are available for sustainability-related design decisions for building products and whole buildings. The Building for Environmental and Economic Sustainability tool (BEES) (<https://ws680.nist.gov/Bees2>) enables performance comparisons of building products. The Building Industry Reporting and Design for Sustainability (BIRDS) tool (<https://ws680.nist.gov/birds>) provides whole-building analysis. <https://www.nist.gov/programs-projects/metrics-and-tools-sustainable-buildings>

EXPERTISE IN USING ANALYSIS TO REDUCE EMBODIED CARBON

American Center for Life Cycle Assessment (ACLCA)
<https://aclca.org>

Life Cycle Assessment Certified Professional (LCACP)
 Certification (<https://aclca.org/lcACP-certification/>)

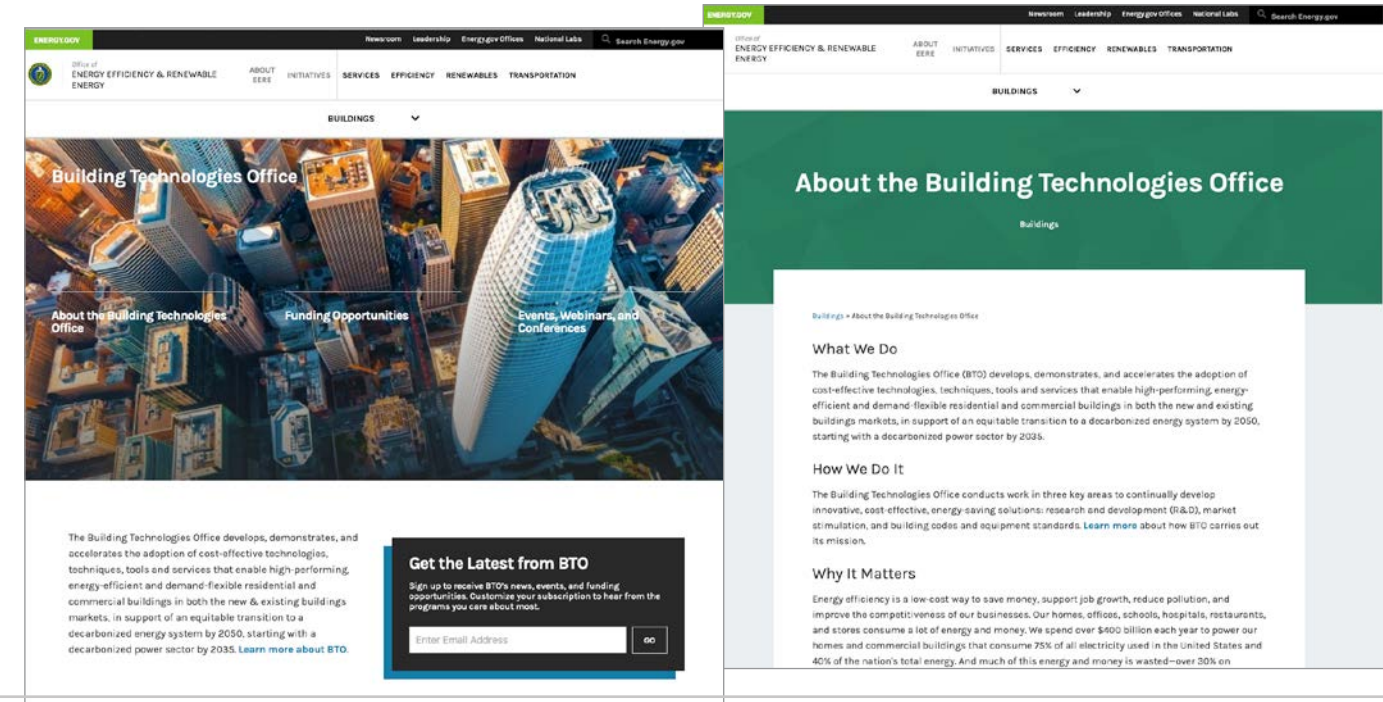




KEEP ME UP TO DATE

FOR MORE INFORMATION ON THE U.S. DEPARTMENT OF ENERGY BUILDING TECHNOLOGIES OFFICE

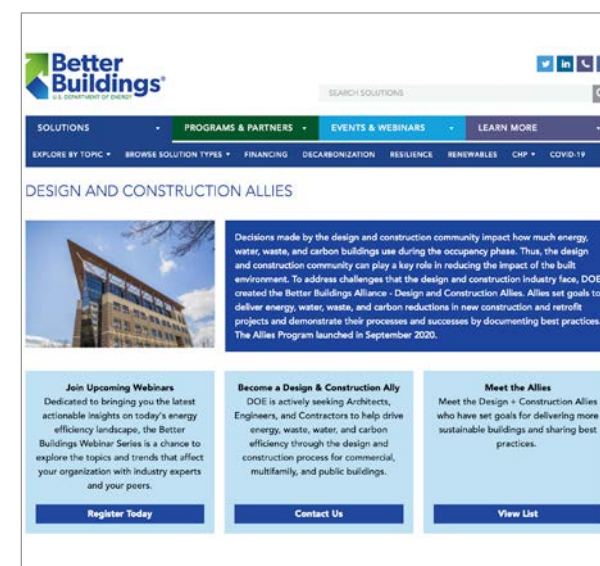
<https://www.energy.gov/eere/buildings/building-technologies-office>



FOR MORE INFORMATION ON BETTER BUILDINGS PROGRAMS

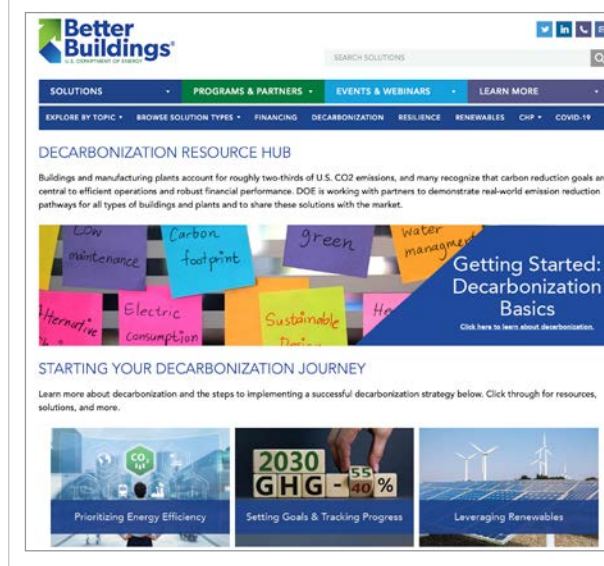
Design and Construction Allies

<https://betterbuildingsolutioncenter.energy.gov/alliance/special-initiatives/design-and-construction-allies>



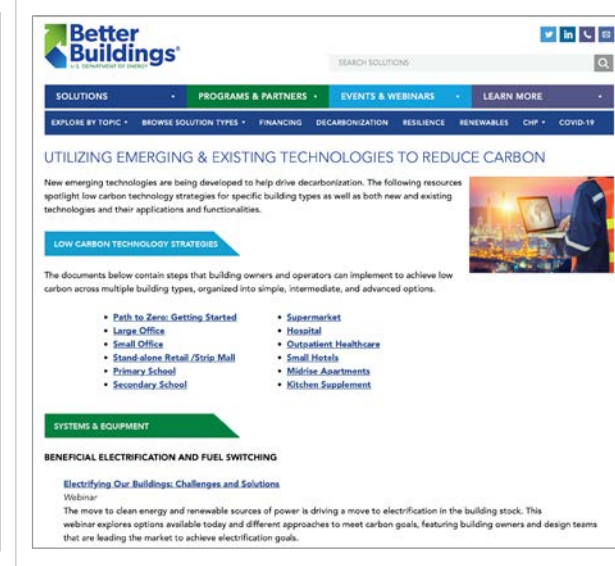
Decarbonization Resource Hub

<https://betterbuildingsolutioncenter.energy.gov/carbon-hub>



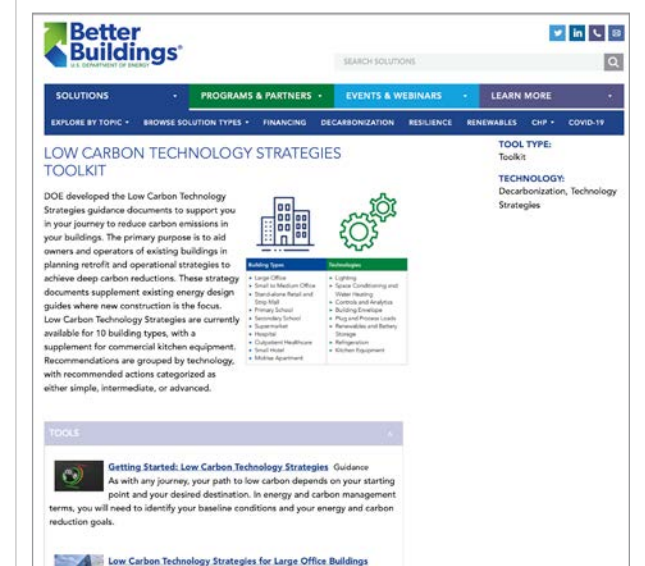
Low Carbon Technology Strategies

<https://betterbuildingsolutioncenter.energy.gov/carbon-hub/emerging-technologies>



Low Carbon Technology Strategies Toolkit

<https://betterbuildingsolutioncenter.energy.gov/toolkits/low-carbon-technology-strategies-toolkit>



For other industry information, search for "embodied carbon community"

REFERENCES

CARBON AND THE BUILDING SECTOR

Why the Building Sector?

<https://architecture2030.org/why-the-building-sector/>

How Green Buildings Can Help Fight Climate Change

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Bringing Embodied Carbon Upfront

<https://www.worldgbc.org/embodied-carbon>

EMBODIED CARBON AND THE BUILDING SECTOR

Architects Toolkit: Part 1 – Intro to Embodied Carbon

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Reducing embodied carbon for designers

<https://rmi.org/download/29346/>

Reducing embodied carbon for developers

<https://rmi.org/download/29344/>

Roadmap to Reducing Building Life Cycle Impacts, A Timeline of Key Milestones

<https://carbonleadershipforum.org/wp-content/uploads/2019/05/2019.05.23-LCA-Timeline-Diagram-spread.pdf>

LOW EMBODIED CARBON OPTIONS AND STRATEGIES

Reducing Embodied Carbon in Buildings, Low-Cost, High-Value Opportunities

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Architects Toolkit: Part 3 – Strategies to Reduce Embodied Carbon

<https://carbonleadershipforum.org/clf-architects-toolkit-part-3-strategies-to-reduce/>

Carbon Smart Materials Palette, Actions for Reducing Embodied Carbon at Your Fingertips

<https://materialpalette.org>

ECOM – Embodied Carbon Estimator

<https://se2050.org/ecom-tool/>

Refrigerants & Environmental Impacts : A Best Practices Guide

<https://www.integralgroup.com/news/refrigerants-environmental-impacts/>

OTHER WAYS TO REDUCE EMBODIED CARBON

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<https://www.oneclicklca.com/building-life-cycle-assessment-ebook/>

Guide to the EC3 Tool

<https://carbonleadershipforum.org/guide-to-the-ec3-tool/>

Impact Estimator for Buildings Tutorials

<https://calculatelca.com/resources/watch-tutorials/impact-estimator-for-buildings-tutorials/>

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https://greet.es.anl.gov/files/greet_building_guide_2021

Additional information can be found at <https://greet.es.anl.gov/greet-building>.

NIST Metrics and Tools for Sustainable Buildings

<https://www.nist.gov/programs-projects/metrics-and-tools-sustainable-buildings>

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<https://aclca.org>

Life Cycle Assessment Certified Professional (LCACP) Certification

<https://aclca.org/lcacp-certification/>

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Building Technologies Office

<https://www.energy.gov/eere/buildings/building-technologies-office>

Design and Construction Allies

<https://betterbuildingssolutioncenter.energy.gov/alliance/special-initiatives/design-and-construction-allies>

Decarbonization Resource Hub

<https://betterbuildingssolutioncenter.energy.gov/carbon-hub>

Low Carbon Technology Strategies

<https://betterbuildingssolutioncenter.energy.gov/carbon-hub/emerging-technologies>

Low Carbon Technology Strategies Toolkit

<https://betterbuildingssolutioncenter.energy.gov/toolkits/low-carbon-technology-strategies-toolkit>

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