CALIFORNIA
AIR RESOURCES BOARD

Embodied Carbon in Buildings

Workshop #2
March 13, 2025

CARB

Workshop Agenda

Time	Topic
10:00 am	Welcome
10:05 am	Introductory Remarks
10:15 am	Staff Presentation: Baseline Emissions Modeling
11:15 am	Public Comments
12:00 pm	- Lunch Break -
1:00 pm	Staff Presentation: Manufacturer and Project Reporting Frameworks
2:00 pm	Public Comments
2:45 pm	Next Steps

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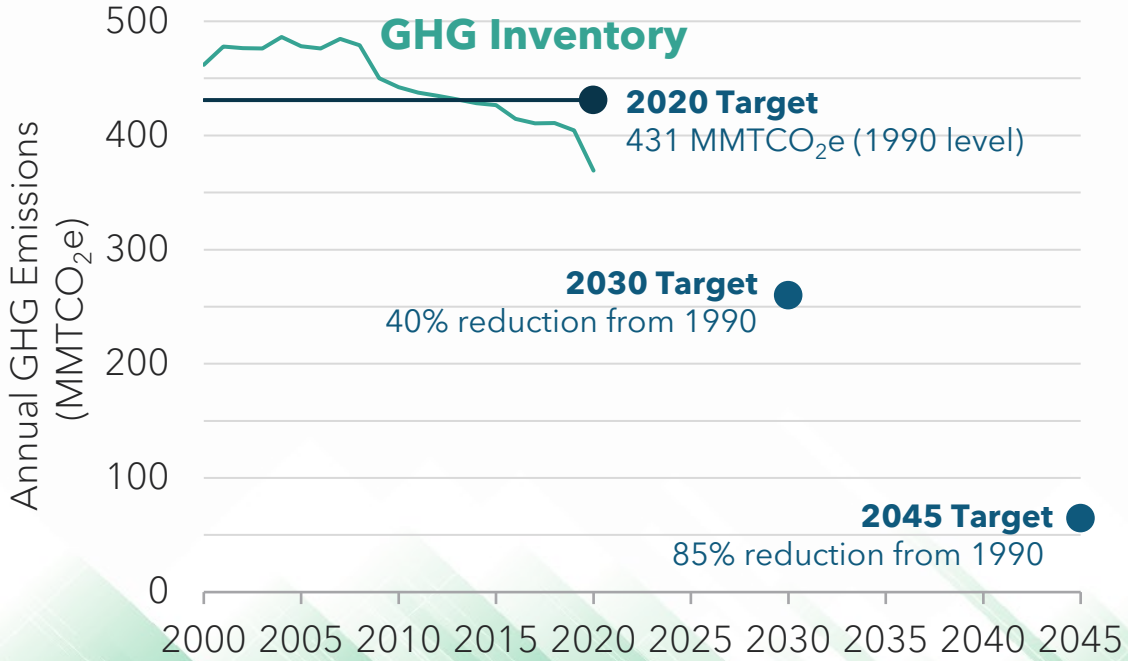
California's Statutory Greenhouse Gas (GHG) Reduction Targets



ACHIEVING CARBON NEUTRALITY BY 2045

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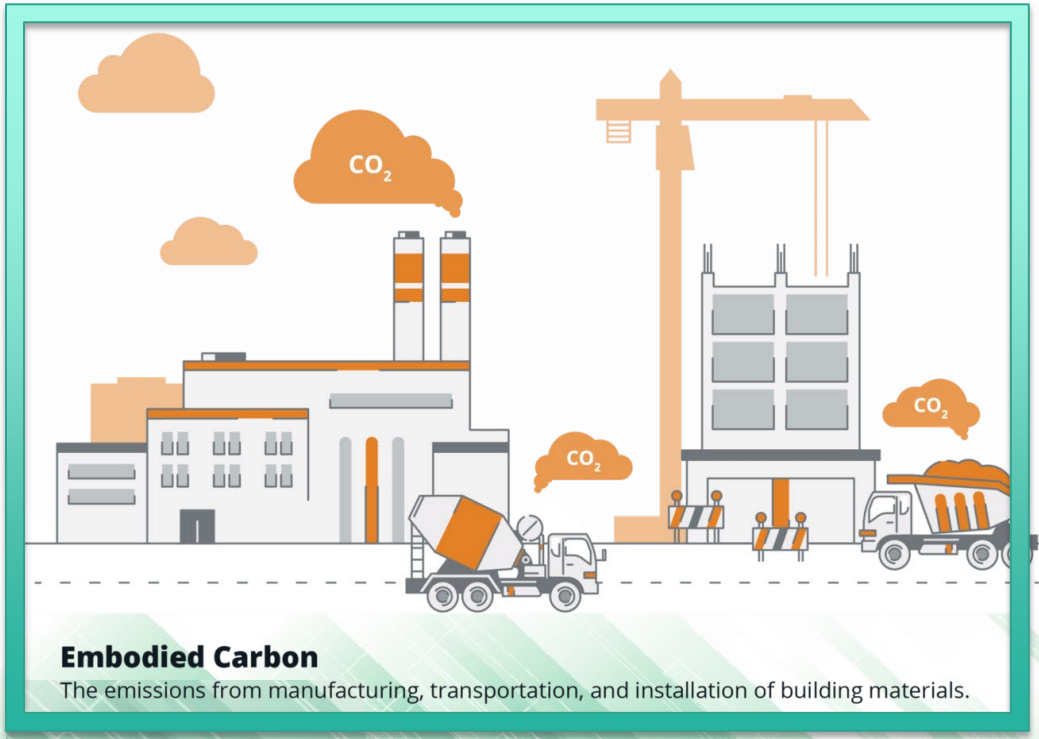
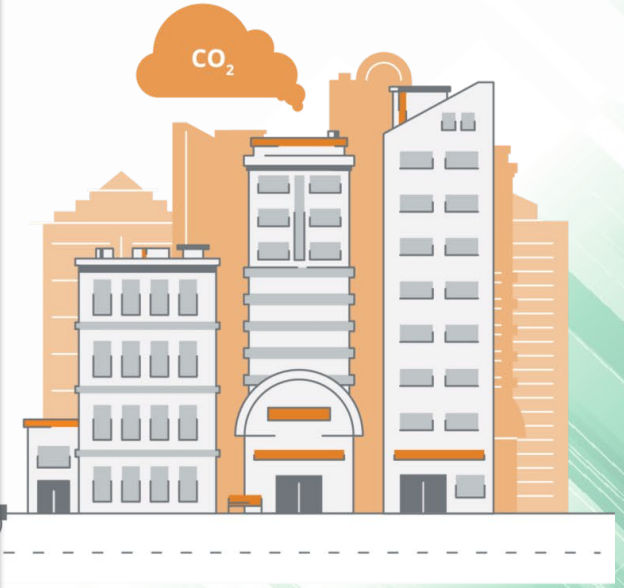
Building Decarbonization: Embodied + Operational

Today's Workshop



Embodied Carbon
The emissions from manufacturing, transportation, and installation of building materials.

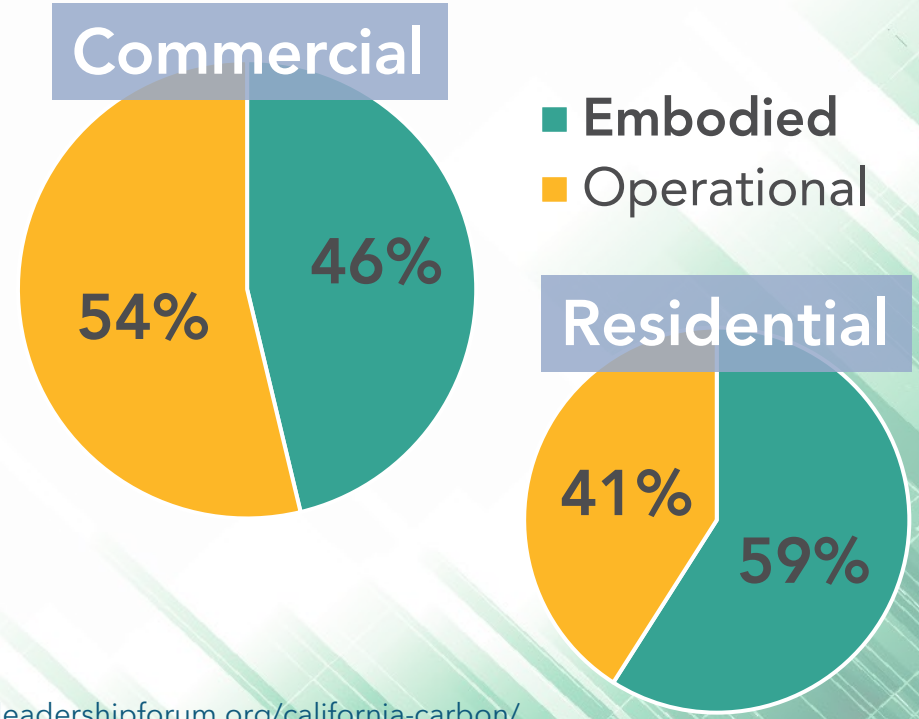


Operational Carbon
The emissions from a building's energy consumption.

Retrieved from: https://www.carboncure.com

Embodied Carbon is Critical

- As operational emissions go down, embodied carbon (EC) becomes increasingly important
- Over half of the carbon footprint of new buildings in California is attributable to embodied carbon



Adapted from https://carbonleadershipforum.org/california-carbon/

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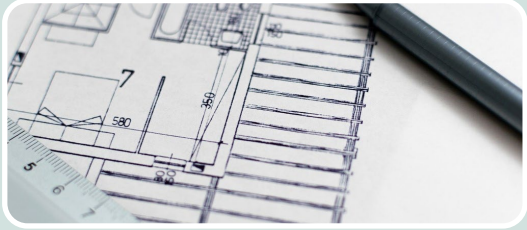
What Drives Emissions from Buildings?

Materials

Energy and non-energy related emissions from extraction, refining, manufacturing, transport, use, and disposal of building materials



Design

Building design influences the types and quantity of building materials used, as well as operational energy requirements

Location

Building site impacts material availability, operational energy needs, travel behavior, land-use, and construction processes

Previous Workshop: Summary

- In September, CARB staff welcomed over 300+ attendees to the first workshop on Embodied Carbon in Buildings
- Today's workshop will discuss staff concepts for the reporting regulation and build upon some concepts introduced in the first workshop:
  - Embodied carbon
  - Life Cycle Assessment and Whole-building LCA (LCA and WBLCA)
  - Environmental Product Declarations (EPD)
  - Building materials and building sector activity
  - Reporting
  - Baseline modeling

Previous Workshop: Participant Feedback

- 80+ questions and comments on topics including:
  - EPD/LCA collection standards and methods
    - Whether data must be specific to a facility or product
    - Which entities will be required to report
    - Opportunities for standardizing and streamlining reporting
    - LCA accounting practices and system boundaries
  - Scope of covered building materials
  - Stakeholder education and outreach

Key Pieces of GHG Reduction Programs

Baseline for Emissions	Reductions Target	Policies to Reduce Emissions	Tracking Progress Towards Targets
Being developed as part of the framework for measuring the carbon intensity of building materials	Set in statute: a 40% reduction in net GHG emissions of building materials by 2035	Developed or identified as part of the strategy development, after the reporting regulation	Reported data under new or existing programs allows CARB to track progress toward emissions reduction targets

Statutory Requirements and Dates

By December 31, 2026

Adopt a framework for measuring carbon intensity of building materials

By December 31, 2028

Develop a comprehensive strategy to reduce GHG emissions

By December 31, 2035

Achieve a 40% net reduction in GHG emissions of building materials by 2035

Today's Workshop:

Reporting Regulation
Baseline Methodology

Statute: California HSC Sections 38561.3 and 38561.6

Definitions for Reference

- **Life Cycle Assessment (LCA)**: Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle (e.g., from cradle-to-grave)
- **Environmental Product Declaration (EPD):** A document that discloses the results of a life cycle assessment of the environmental impacts of a product based on defined rules
- **Embodied Carbon:** The carbon dioxide equivalent emissions associated with a product as determined using a life cycle assessment
- **Carbon Intensity (CI):** The carbon dioxide equivalent emissions associated with a product based on a comparable functional unit (e.g., kg CO_2e per kg)

CARB Staff Presentation

Baseline Emissions Modeling

Purpose of Baseline Emissions Quantification

- Estimates the greenhouse gas emissions attributable to building materials used in the state
- Identifies key sectors for emissions reporting
- Estimates total emissions from which to establish a 40% net reduction target
- Informs emissions reduction strategy development

Baseline Modeling: Statutory Requirements

- **HSC §38561.3 (b)**: "The state board shall also develop, by December 31, 2028, a comprehensive strategy for the state's **building sector** to achieve a 40-percent net reduction in greenhouse gas emissions of **building materials** as soon as possible, but no later than December 31, 2035. **The baseline** for the 40-percent net reduction shall be established based on an industry average of environmental product declarations reported for the 2026 calendar year, or the most relevant, up-to-date data that is available, as determined by the state board."

Initial Staff Thinking: Defining Key Terms

- Staff propose to adopt the following definitions:
  - "Building material" refers to a physical product or system that is used or produced by the building sector that is intended to become an integral and inseparable part of the completed structure
  - “Building sector” includes all economic activity related to product manufacturing and the construction, renovation, maintenance, design, and siting of buildings and infrastructure
  - The “baseline” is an estimate of total GHG emissions attributable to the estimated use of building materials in California in 2026

Illustrative Emissions Baseline for Building Materials

Total amount of building materials used in California

Life cycle GHG emissions of materials (e.g., kg-CO_2e)

Total emissions from which to assess a 40% net reduction

Baseline Methodology Options

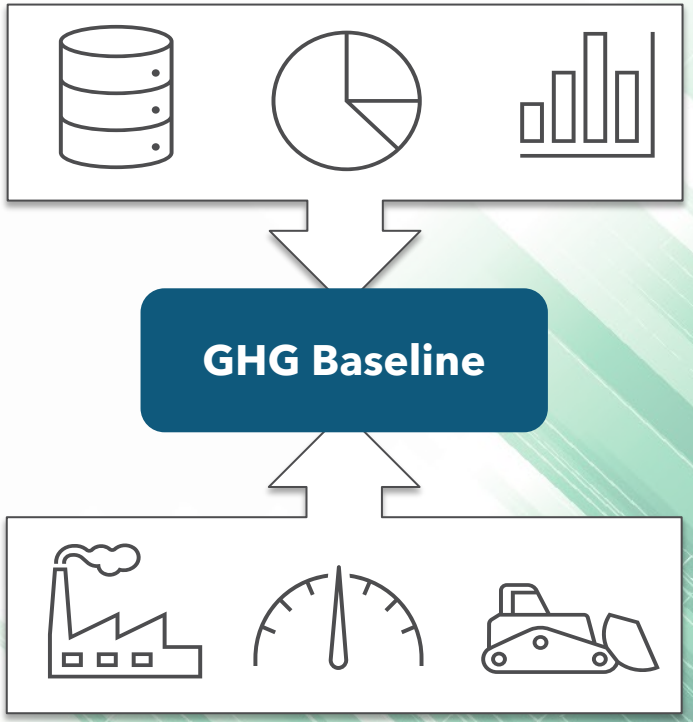
Top-Down Method

- Baseline emissions allocated from economy-wide datasets

versus

Bottom-Up Method

- Baseline emissions extrapolated from a subset of facility and project data



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Baseline Methodology: Pros and Cons

	Top-Down	Bottom-Up
+	• Economy-wide models capture most emissions • Data readily available • Rapid implementation	• Detailed accounting of emissions for specific projects and specific manufacturing facilities
−	• Lags in collection and release of data from third parties	• Data not yet available • Difficult and costly to gather all data • Data will require significant extrapolation due to imperfect response rate and bias

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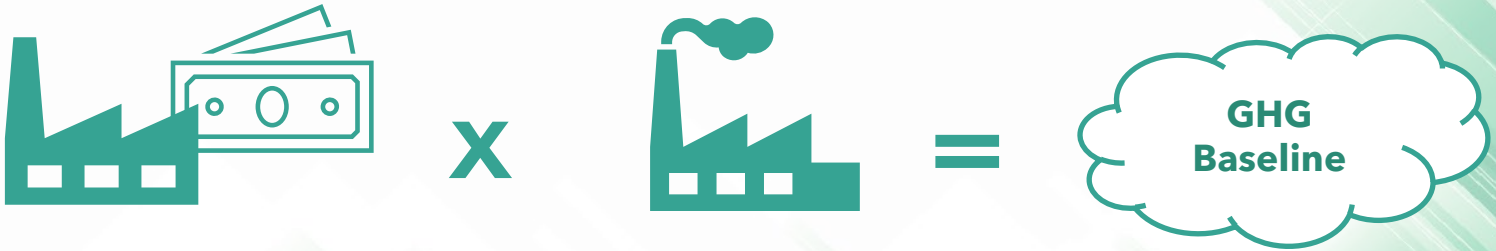
Staff Concept for Baseline Estimation

- **Initial Staff Thinking:** Use a top-down baseline. Options include:
  - EPA US Environmentally-Extended Input-Output (USEEIO) Models
  - Industry-average emissions for major product classes from EPDs and existing LCA databases combined with other economic output data



California Building Sector Economic Demand ($)

Emissions per Economic Output (MT CO_2e/$)

California Building Sector Emissions (MT CO_2e)

Top-Down Baseline Option 1: USEEIO Model

- The Model links the movement of goods through the US economy to environmental outcomes, including GHG emissions
- Economic data are from the Bureau of Economic Analysis (BEA) Input-Output (IO) accounts, which groups industries by NAICS code*
- GHG emissions are from facilities reporting under EPA's Greenhouse Gas Reporting Program (GHGRP)

* The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was developed under the auspices of the Office of Management and Budget (OMB) and adopted in 1997.

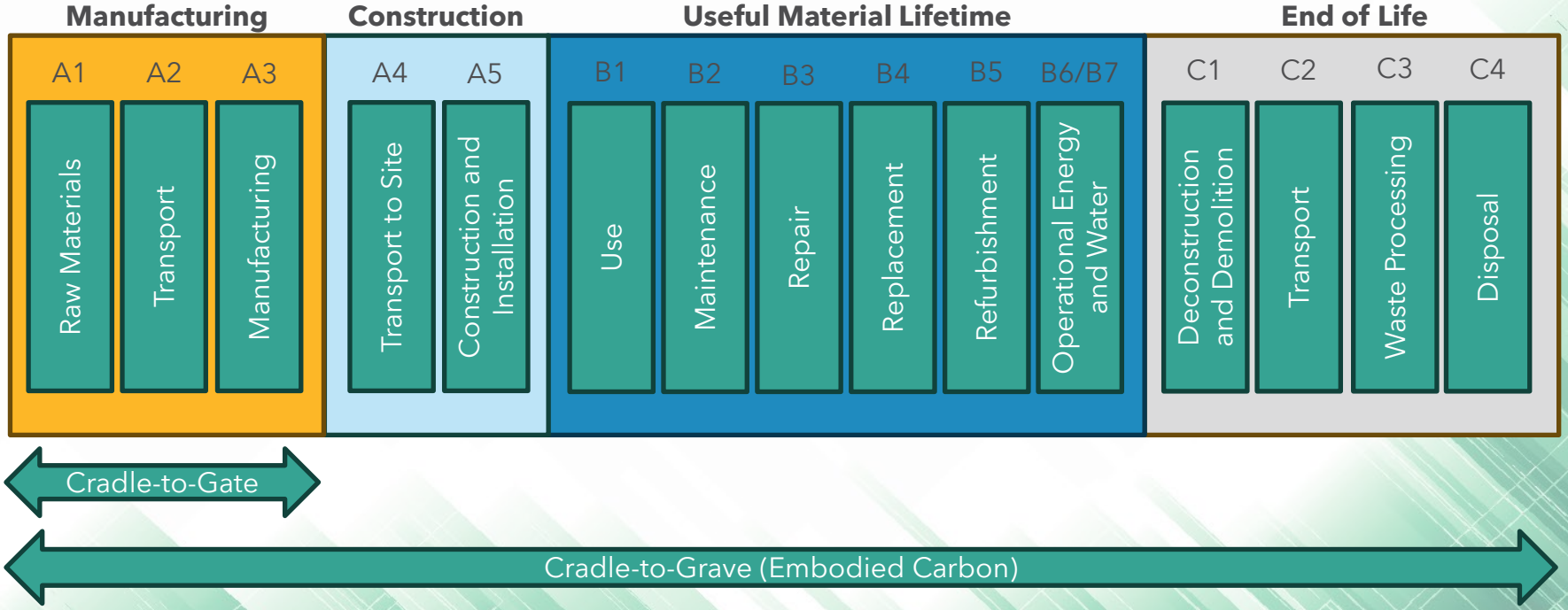
Top-Down Baseline Option 2: EPDs and LCAs

- Gather industry average EPDs and LCAs for all major building materials
- Take total consumption of major building materials from economic models
- Convert EPD and LCA functional units to homogenized units associated with Input and Output consumption
- Multiply these together to estimate total GHG emissions of the building sector in California

Top-Down Baseline Options: Pros and Cons

	USEEIO Model	Existing EPDs and LCAs
+	• Covers entire building sector • Minimal omissions or double-counting concerns • Summary data published yearly	• Emissions can be matched to specific products
−	• Disaggregation possible only to the NAICS level • Fully detailed data is published every 5 years	• Few products have EPDs or PCRs • Existing EPDs may create data bias • Difficult to convert to IO units ($) • EPD data may be up to 5 years old, and background data may be older

Complete Life Cycle Assessment Scope for "Building Materials"



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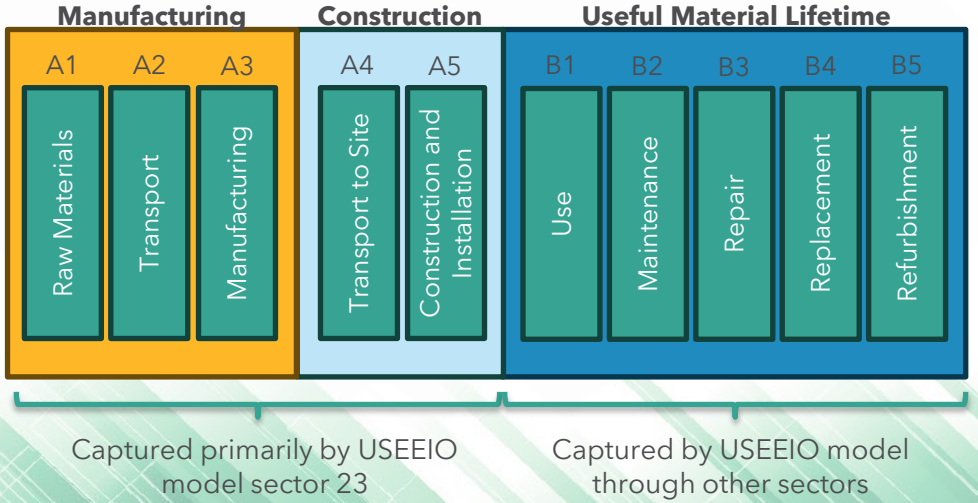
ISO 21930:2017 LCA boundaries

Suggested LCA Scope for the "Baseline"

- **Initial Staff Thinking:** Baseline includes life cycle emissions affiliated with the manufacture of building materials and the subsequent use or installation in all structures located in California created by the construction industry, as well as maintenance and repair (A1-B5 life cycle emissions)



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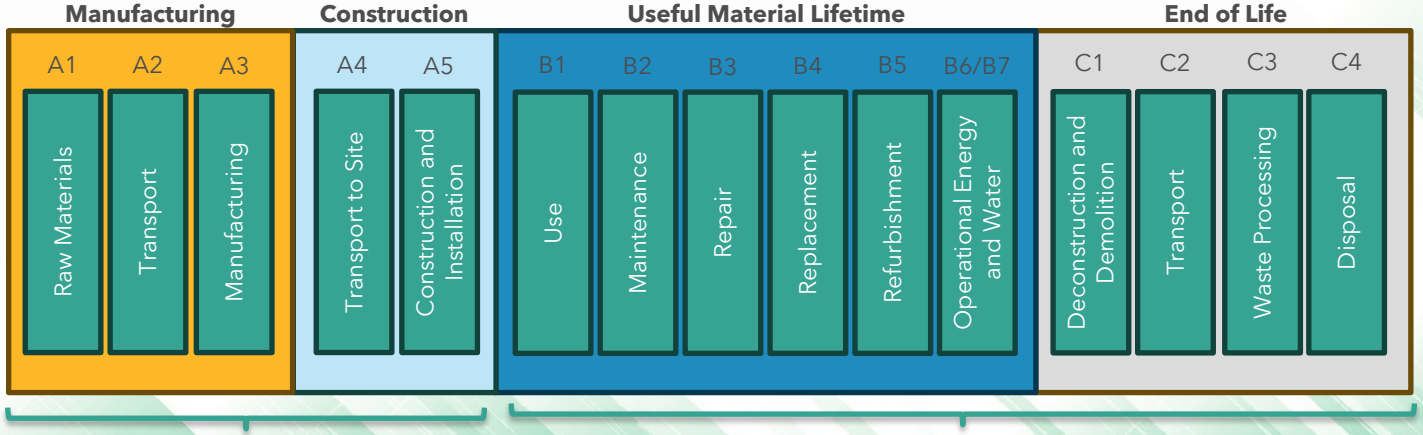
Alternative 1: LCA Scope for the "Baseline"

- Baseline includes life cycle emissions affiliated with the manufacture of building materials and the subsequent use or installation in all structures located in California created by the construction industry, as well as maintenance, repair, and end-of-life (A1-C4 life cycle emissions)



Will require new methods and analysis to attribute end-of-life emissions to building materials. Construction and demolition wastes are also insignificant methane generators.

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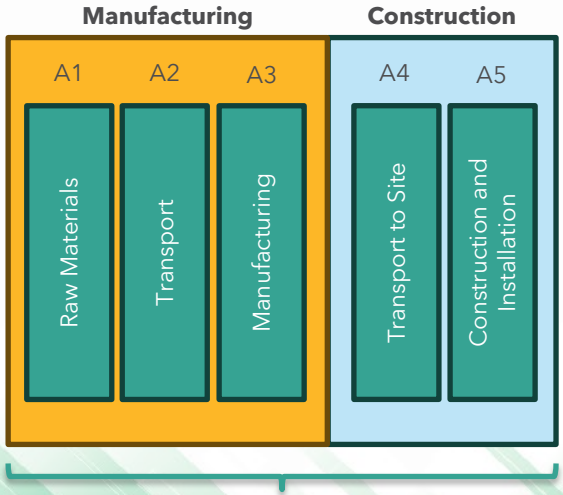
Alternative 2: LCA Scope for the "Baseline"

- Baseline includes life cycle emissions affiliated with the manufacture of building materials and the subsequent use or installation in all structures located in California (A1-A5 life cycle emissions)



Captured primarily by USEEIO model sector 23

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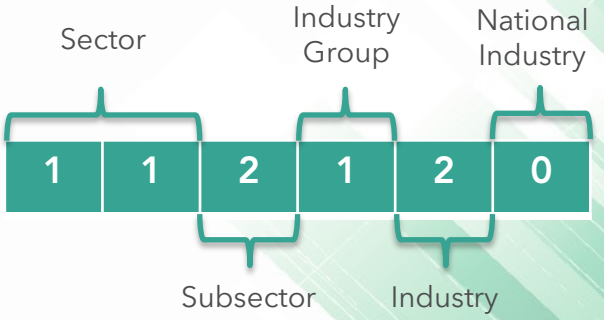
U.S. Environmentally-Extended Input-Output Models

- The USEEIO model has been **developed by the EPA** to assess environmental impacts across industry sectors
- Integrates **economic transactions with environmental emissions data** to provide a life cycle-based assessment of industry activities
- **Supports GHG accounting**, life cycle analysis, sustainable materials management and climate policy development
- Can be used by CARB to **estimate sector-based emissions** and help guide California's embodied carbon strategies

Tracking Commodity Flows Between Industries

- **The Bureau of Economic Analysis (BEA) input-output tables record monetary transactions** between industries, illustrating interdependencies within the economy:
  - **Make Table** – Tracks which industries produce specific commodities
  - **Use Table** – Shows how industries and consumers purchase goods and services
- BEA categorizes industries using **NAICS codes**, ensuring standardization across sectors
- 3 levels of detail exist: Sector (15 industries), Summary (71 industries), and Detailed (405 industries)
- BEA updates summary and sector tables annually to reflect changes in production, trade, and industrial activity



Example of a 6 digits NAICS Code

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Understanding Environmental Satellite Tables

- Environmental Satellite Tables contain **emissions factors** for GHGs, air pollutants, energy, land and water use, and waste generation
- These tables in the USEEIO model are derived from EPA's State and National Emissions Inventories, the U.S. Geological Survey (USGS), the Department of Energy (DOE), and other environmental datasets
- The model quantifies direct and indirect environmental impacts, showing how emissions propagate through supply chains
- Example: A steel manufacturer's emissions include:
  - Direct emissions – from steel production
  - Indirect emissions – from electricity use, mining, and material transport

National Industry	Oil and gas extraction (211000)	Coal mining (212100)	Electric power generation, transmission and distribution (221100)	Natural gas distribution (221200)
Iron, gold, silver, and other metal ore mining (2122A0)	6	35	447	119
Single-family residential structures (233411)	-	-	465	161
Commercial structures, including farm structures (2332A0)	-	-	207	63
Veneer, plywood, and engineered wood product (321200) manufacturing	7	4	389	289

Energy Use Table for the US (MJ per USD output)

Data from USEEIOv1.1 - Satellite Tables - Catalog

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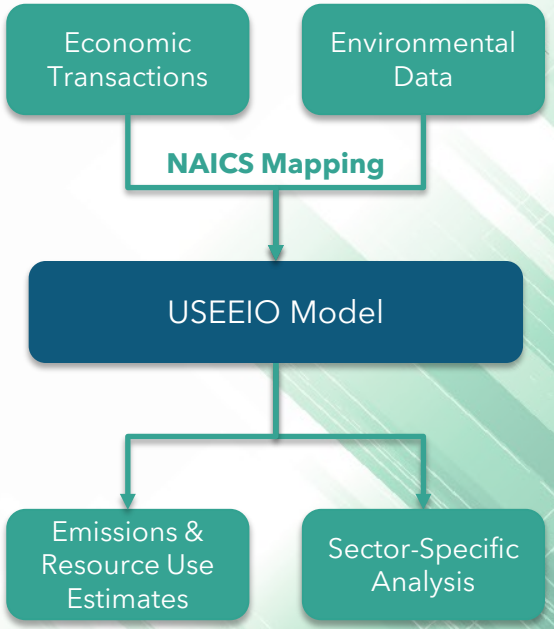
Economic Transactions to Environmental Impacts

- **USEEIO links economic activities to emissions factors from the environmental satellite tables,** enabling sector-specific sustainability analysis
- The model generates (among other outputs):
  - **Final Demand & Consumption Vectors** which account for imported vs. domestic products to refine emissions calculations
  - **Life Cycle Impact Assessment Factors** which convert raw emissions data into standardized impact categories (e.g., CO_2-equivalents)



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Emissions Incorporated into USEEIO GHG Emissions Factors

- **GHG emissions are quantified and converted to CO_2e** using GWP factors (AR4) from **TRACI**, a tool developed by the EPA to assess chemical and other environmental impacts. The greenhouse gases considered in the model are:
  - Carbon Dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous Oxide (N_2O)
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur Hexafluoride (SF_6)
  - Nitrogen Trifluoride (NF_3)
- USEEIO ensures consistency with official US inventories, including NEI, GHGRP, GHGI

National Industry	CO_2 Emissions (MMT CO_2e)	CH_4 Emissions (MMT CO_2e)	N_2O Emissions (MMT CO_2e)	Total GHG Emissions (kg CO_2e)
Iron, gold, silver, and other metal ore mining (2122A0)	8.6	0.02	0.13	8.8
Single-family residential structures (233411)	24.4	0.02	0.03	24.5
Commercial structures, including farm structures (2332A0)	10.7	0.007	0.01	10.7
Veneer, plywood, and engineered wood product (321200) manufacturing	2.2	0.001	0.002	2.2

GHG Table for the US

Data from USEEIOv1.1 - Satellite Tables - Catalog

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USEEIO's Application for California

- **State-Level Customization**
  - USEEIO is implemented using the open-source **useeior** R package, enabling state or national emissions modeling
  - The **stateior** R package supports multi-regional input-output modeling, splitting emissions factor estimates into California-specific & Rest-of-U.S. emissions
- **Applications for Embodied Carbon Accounting**
  - CARB can use USEEIO to **estimate embodied carbon in materials** like concrete, steel, and wood (from manufacturing, transportation, and installation)
  - Possible to disaggregate life cycle emissions factors into **detailed state-level** estimates to estimate **Scope 1, 2 & 3 emissions** from California's building sector

Request for Feedback

1. Staff are requesting feedback on the definitions staff have presented for “building material,” “building sector,” and “baseline.”
2. Staff are requesting feedback on the LCA scope and system boundary for the baseline. Are there additional considerations?
3. What is an acceptable cutoff year for historic data that should be used to estimate the 2026 baseline?
4. Are there other models or platforms that CARB should consider using for estimating a top-down baseline other than USEEIO?

Public Comments via Zoom

Online Attendees

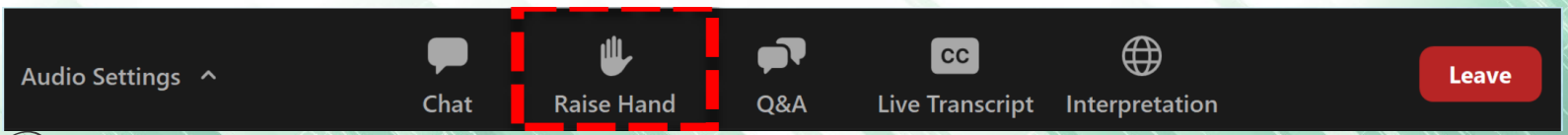
- Use the "**Raise Hand**" feature in the Zoom toolbar.
- When staff call your name, please "**Unmute**" yourself by clicking the red button and proceed to introduce yourself.

Phone Attendees

- Dial *9 to raise or lower your hand
- Dial *6 to mute or unmute

Technical Difficulties

- If you have technical difficulties, please email: embodiedcarbon@arb.ca.gov



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CARB Staff Presentation

Reporting Regulation for Covered Projects and Building Material Manufacturers

California Health and Safety Code (HSC) Summary of Key Reporting Requirements

- **HSC §38561.3(c)**

  (1) Specific building construction projects must submit a life cycle assessment (LCA) to CARB

  (2) Building material manufacturers must submit Environmental Product Declarations (EPD) or equivalent

- **HSC §38561.3(i)**

  (2) Specified **building construction projects** must report data to support cost impact and feasibility determinations

  (5) **Building material manufacturers** must report data to ensure their products comply with reduction targets

(1) Manufacturer Reporting Regulations

Statutory Requirements

- **HSC §38561.3 (c)(2):** "A requirement for the submission by the **manufacturer of a building material** of an Environmental Product Declaration [...] or similarly robust material life-cycle assessment approaches that have uniform standards in data collection consistent with ISO Standard 14025"
- **HSC §38561.3 (j):** "This section **does not apply to appliances**"

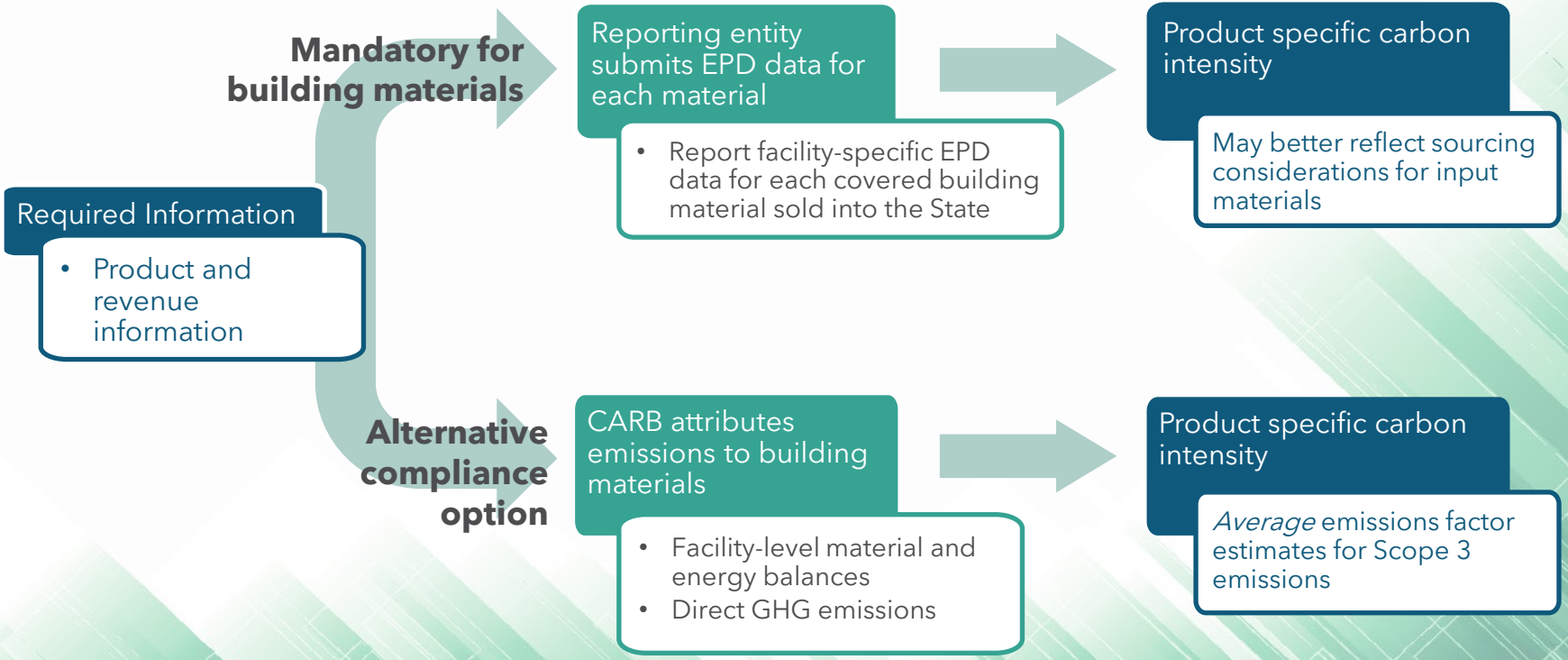
Who Reports?

- **Initial Staff Thinking:** Any firm which sells, supplies, offers for sale, or produces covered "building materials" for use in the State of California are subject to the requirement of **HSC §38561.3 (c)(2)** hereafter "building material manufacturers"
- **Potential Exemptions:** Building material manufacturers are exempt from reporting if they meet certain requirements:
  - Manufacturers under minimum annual revenue thresholds
  - Manufacturers that produce only appliances, as defined by CA 2021 Appliance Efficiency Regulations (Title 20, Part 6§1601)

What is Reported?

- **Initial Staff Thinking:** Building material manufacturers submit to CARB on a quarterly basis:
  - A detailed list of each covered building material, including product quantities and attributable revenue, sold into the State by that entity
  - **EITHER** valid, facility-specific EPD data for each covered building material **OR** facility-level production data

Graphical Representation of Staff Concept for Building Material Manufacturer Reporting



Challenges with EPDs

- Current EPDs present the following **comparability, consistency, and data quality issues**:
  - Many building materials currently lack EPDs
  - Limited LCA data transparency
  - Opaque data verification standards
  - Bundled environmental attribute concerns (e.g., voluntary offsets)
  - System boundaries may vary by Product Category Rules (PCR)
  - Inconsistent or outdated data periods
  - No unified emissions factor database

Concepts for EPD Data Reporting

Initial Staff Thinking: EPD type data submitted to CARB by building material manufacturers must meet the following requirements:

- Recent primary and background data (<2 years old) specific to the manufacturing facility and product
- Clearly delineated and disaggregated information about actual emissions without adjustments for environmental attributes
- Energy and material inputs to the manufacturing facility must use CARB-approved default emission factors (consistent with MRR where applicable)

Alternative Compliance: Facility Level Reporting

- **Initial Staff Thinking:** In lieu of submitting valid, facility specific EPD data – building material manufacturers may report to CARB facility level production data, which will include:
  - A facility-level material and energy balance that clearly delineates commodity inputs, outputs, and quantities
  - Product-specific revenue totals
  - Total direct facility-level GHG emissions
  - An attestation that total direct facility-level emissions were calculated using appropriate GHGRP Subparts or MRR calculation methods

Concept for Phase-in of Manufacturer Reporting

- Manufacturing Sector Reporting (Required in 2026)*:
  - Cement and concrete
  - Iron, steel, and ferroalloy products
  - Glass and glass products
  - Asphalt pavement and shingles
  - Insulation
  - Wood and wood products
- Phased-in Manufacturing Sector Reporting (Required starting in 2028):
  - Aluminum
  - Clay and ceramics
  - Lime and gypsum products
  - Additional sectors not currently part of state or federal buy clean programs

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* this first phase of reporting covers products likely to account for a significant share of total embodied carbon emissions

Request for Feedback

1. How should the agency approach data collection for manufacturers *and* downstream supply chain entities (e.g., resale, retail, wholesale) to enable chain-of-custody tracking?
2. What annual revenue thresholds should be considered for exemption?
3. Staff is seeking feedback on the concepts presented for the data reporting regulations. How might any concerns be addressed?
4. How long do manufacturers expect it to take to meet any or all proposed EPD data submittal requirements discussed today?
5. Is an alternative-reporting pathway to EPD data submission desirable?
6. Do manufacturers have concerns about reporting timelines and phase-in approaches outlined in the presentation?
7. What other data sources and programs administered by the state should be leveraged for reporting needs under this program (MRR, SB 253, other)?

(2) Project Reporting Regulations

Statutory Requirements

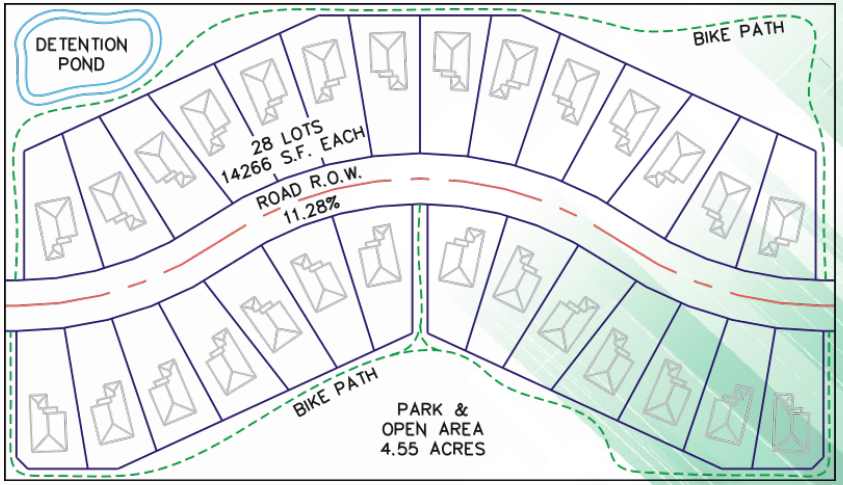
- **HSC §38561.3 (c)(1):** "A requirement for the submission by an entity undertaking the construction of a project with a minimum size of five new residential units or 10,000 square feet of nonresidential building space of **a life-cycle assessment**, as defined in the International Organization for Standardization (ISO) 14040 series of standards with a focus on the Product Stage phases (A1-A3), to determine the **carbon intensity** of the materials used in new residential and nonresidential buildings. "
- **HSC §38561.3 (i)(1):** "For buildings covered by this section, the incorporation of lower carbon materials shall be limited or excluded to the extent that it has a cost impact or is unfeasible."

Can Property Owners Delegate Reporting Responsibility?

- **HSC §38561.6(a)(5)** "Entity undertaking the construction of a project" means a person or entity who owns the real property that is the subject of a development agreement is the primary reporting entity
- **HSC §38561.3(g):** "The state board shall allow the entity undertaking the construction of a project to use the same persons as those responsible for the Certificate of Installation pursuant to paragraph (3) of subdivision (a) of Section 10-103 of Title 25 of the California Code of Regulations in submitting, reporting, notifying, tracking, or otherwise conveying information to the state board"
- **Initial Staff Thinking:** The project owner may delegate reporting responsibilities to any architect, engineer or contractor who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the building design

Which Residential Projects Report?

- **HSC §38561.3 (c)(1):** "A requirement for the submission by an entity undertaking the construction of a project with a minimum size of five new residential units […] of a life-cycle assessment"
- **Initial Staff Thinking:** A project, per this statute, is the construction of five or more residential units by the same project owner within a single building or single land subdivision map submitted pursuant to California Gov. Code § 66426



Covered Project Example:
Subdivision with >5 Residential Units

Retrieved from: https://californialanddevelopment.com/blog-posts/whats-a-tentative-map-and-why-does-it-matter/

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Which Non-Residential Projects Report?

- **HSC §38561.3 (c)(1):** "A requirement for the submission by an entity undertaking the construction of a project with a minimum size of […] 10,000 square feet of nonresidential building space of a life-cycle assessment"
- **Initial Staff Thinking:** "Nonresidential building space" includes all buildings and structures listed in the 2022 California Building Code, Title 24, Part 2, Section 302 "Occupancy Classification and Use Designation," except for Residential Group R

Staff Concept for Covered Project Reporting

- All covered projects meet **"Basic Reporting"** requirements within one year of issuance of a building permit
  - CARB estimates a default carbon intensity for the covered projects using "basic reporting" information and standardized, conservative emissions factors
  - Default covered project carbon intensity may be replaced by verified "WBLCA Reporting" data
- Whole Building LCA Reporting (**"WBLCA Reporting"**) will begin with larger projects, with requirements expanding over time

Concepts for “Basic Reporting” Requirements

Initial Staff Thinking: All covered projects report

- Building Type
- Building occupancy
- Project location
- Site area
- Gross floor area
- Built floor area
- Developer, designer, and contractor contacts
- Project costs
- Project schedule
- Bill of materials
- Material suppliers

Bill of materials must include all elements of the project's structure, enclosure, interior construction and finishes, site hardscape and walls at a level of detail equivalent to OmniClass Level 3 or higher

Concepts for "WBLCA Reporting"

- **Initial Staff Thinking:** Projects of more than 30 residential units or more than 100,000 square feet of non-residential building space will report the results of a WBLCA
  - WBLCA Reporting expands to all covered projects by 2030

- **Initial Staff Thinking:** WBLCA must be prepared according to identified methodologies, data quality standards, and CARB specific submittal requirements

Potential WBLCA Submittal Concepts

- **Initial Staff Thinking:** Potential requirements for scope and data quality of the submitted WBLCA
  - Utilize a Cradle-to-grave (modules A-C) system boundary, inclusive of operational stages
  - Include all elements of the project's structure, enclosure, interior construction and finishes, site hardscape and walls in the scope of the LCA
  - Consistent reference study period (60 years)
  - Adheres to identified methodologies and standards

Request for Feedback

1. Staff are requesting feedback on the initial concept for delegating reporting responsibility.
2. What concerns are there with the initial concept presented for inclusion considerations for residential and non-residential projects?
3. What are the barriers to producing WBLCAs for more projects?
4. How could the proposed reporting requirements impact the cost, timeline, or feasibility of projects you conduct?
5. Are there specific occupancy types that face unique reporting challenges?
6. At what stage of the project schedule should covered projects report?
    a) Planning permit? Building Permit Issuance? Obtaining certificate of occupancy? Other milestones?
7. Are there specific WBLCA standards and methodologies staff should review?

Public Comments via Zoom

Online Attendees

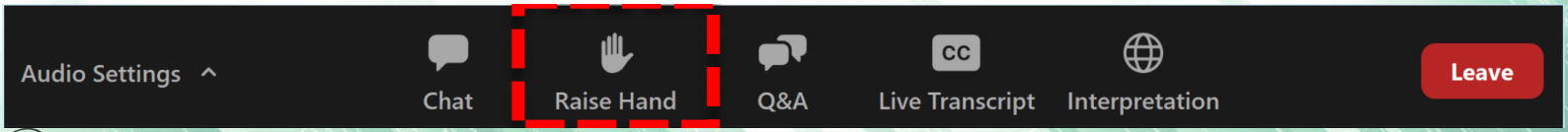
- Use the "**Raise Hand**" feature in the Zoom toolbar.
- When staff call your name, please "**Unmute**" yourself by clicking the red button and proceed to introduce yourself.

Phone Attendees

- Dial *9 to raise or lower your hand
- Dial *6 to mute or unmute

Technical Difficulties

- If you have technical difficulties, please email: embodiedcarbon@arb.ca.gov



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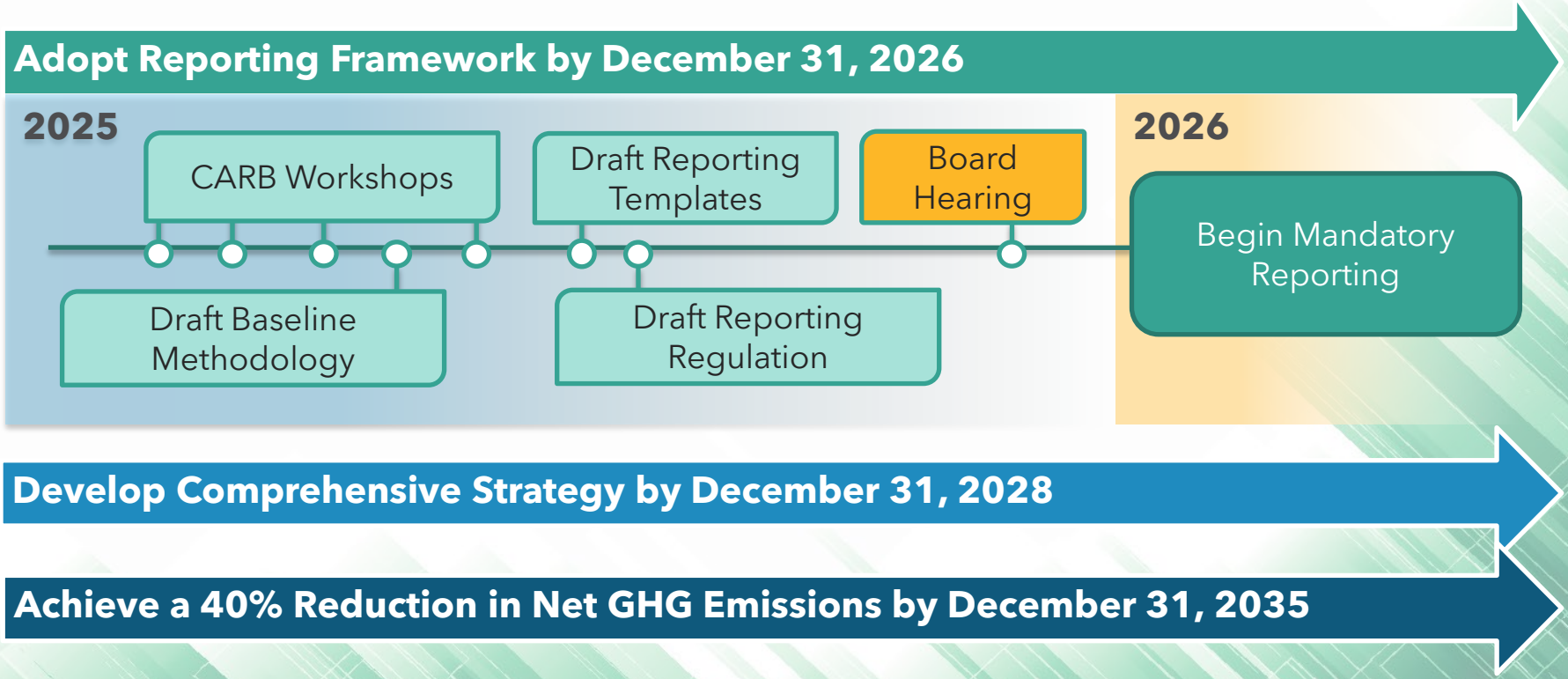
Wrapping Up

- Feedback
- Next workshop topics
- Reporting reg timeline

Timeline and Key Milestones



Next Steps

- Submit public comments in writing by April 14, 2025, at https://ww2.arb.ca.gov/our-work/programs/building-decarbonization/embodied-carbon/embodied-carbon-meetings-and-workshops
- Subscribe to the Embodied Carbon Listserv for updates on future workshops