Technical Meeting

September 9, 2025

Establishing Modeling Methodologies to Estimate a Baseline

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Technical Meeting Agenda

I. Goals for Today
II. Prior Public Engagements
III. Background for Establishing the “Baseline”
IV. Introduction to Input-Output (IO) Life Cycle Analysis (LCA)
V. Environmentally-Extended Input-Output Life Cycle (EEIO) Models
VI. U.S. Environmentally-Extended Input-Output (USEEIO) and StateIO Models
VII. Customizing USEEIO for the Embodied Carbon Program
VIII. Discussion and Feedback

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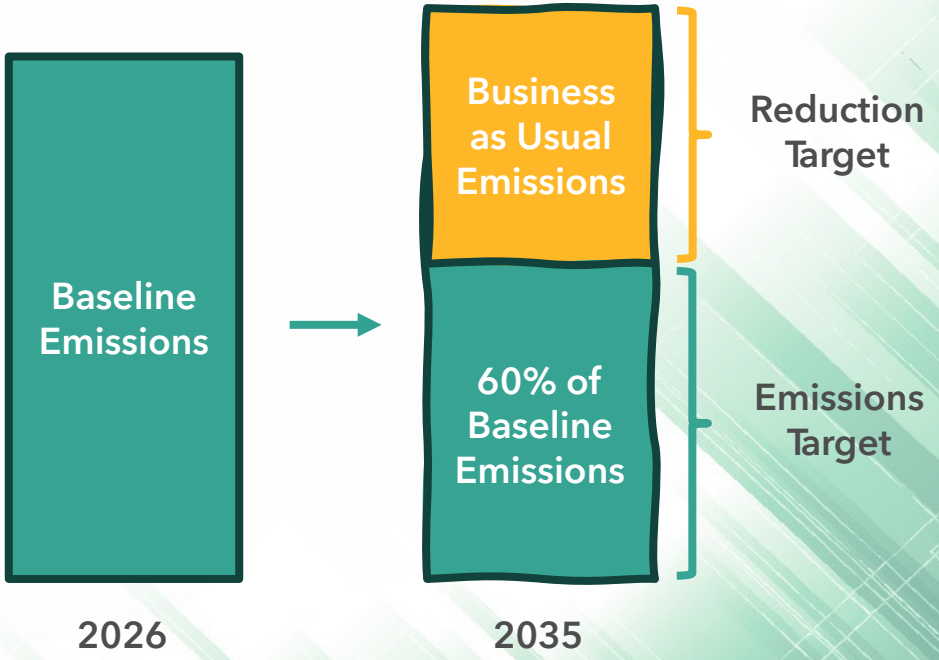
Goals for Today's Meeting

1. Discuss the purpose of developing a baseline
2. Review prior public engagement and staff thinking
3. Develop foundational understanding of input output analysis LCAs
4. Improve understanding of core datasets used by USEEIO and StateIO
5. Review staff's proposed modifications to the USEEIO model
6. Provide feedback on California Air Resources Board (CARB) staff's draft baseline emissions estimation model

What is the Emissions Baseline and How is it Used?

- A tool to guide planning
- A snapshot of building sector emissions in 2026 by sector and material
- Estimates the magnitude of the emissions reduction target
- Informs reporting priorities and reduction strategies



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Part II

Prior Public Engagement

Kick-off Workshop (September 2024)

- Introduced building embodied carbon concepts
- Consulted with the public about key topics in developing the framework, including the structure of a potential reporting system for building material embodied carbon
- Discussed the public engagement process moving forward

Staff Presentation

Research Presentation

Recording

Written Comments

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Reporting and Baseline Workshop (March 2025)

- Reviewed the statutory requirements
- Introduced staff concepts for:
  - Manufacturer reporting
  - Project reporting
  - Baseline emissions quantification
  - Emissions accounting

Presentation

Recording

Written Comments

Baseline Modeling: Statutory Requirements

Health and Safety Code (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."

Defining Key Terms

"Building material" refers to a physical product or system that is used or produced by the building sector and typically used in the construction of buildings and infrastructure.

"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 the total lifecycle greenhouse gas (GHG) emissions attributable to the consumption of building materials in California in 2026.

Challenges with Environmental Product Declarations (EPD)

Currently available 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

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 sector 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

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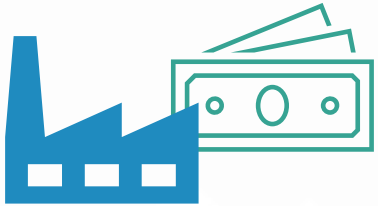
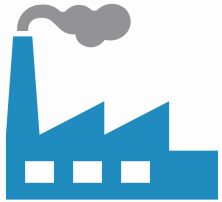
Staff Proposal for Baseline Estimation

- Economy-wide data is used to assess overall production and use of materials
- Emissions are allocated to each sector based on sector-specific emissions inventories.



California Building Sector Economic Demand ($)

x

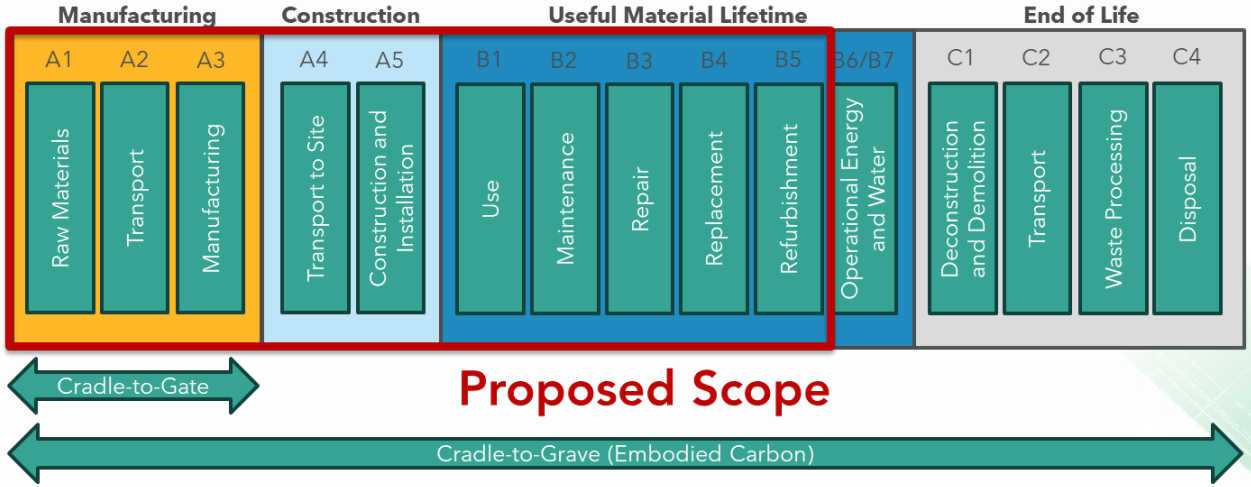


Emissions per Economic Output (CO_2e/$)

=

California Building Sector Emissions (CO_2e)

Suggested LCA Scope for the "Baseline"



- In life cycle analyses (LCA), **embodied carbon** is the total greenhouse gas (GHG) emissions associated with a material, product, or building
- **Cradle-to-Gate** and **Cradle-to-Grave** are two common scopes for embodied carbon LCAs
- Staff are proposing including A1-B5 in the scope of the baseline

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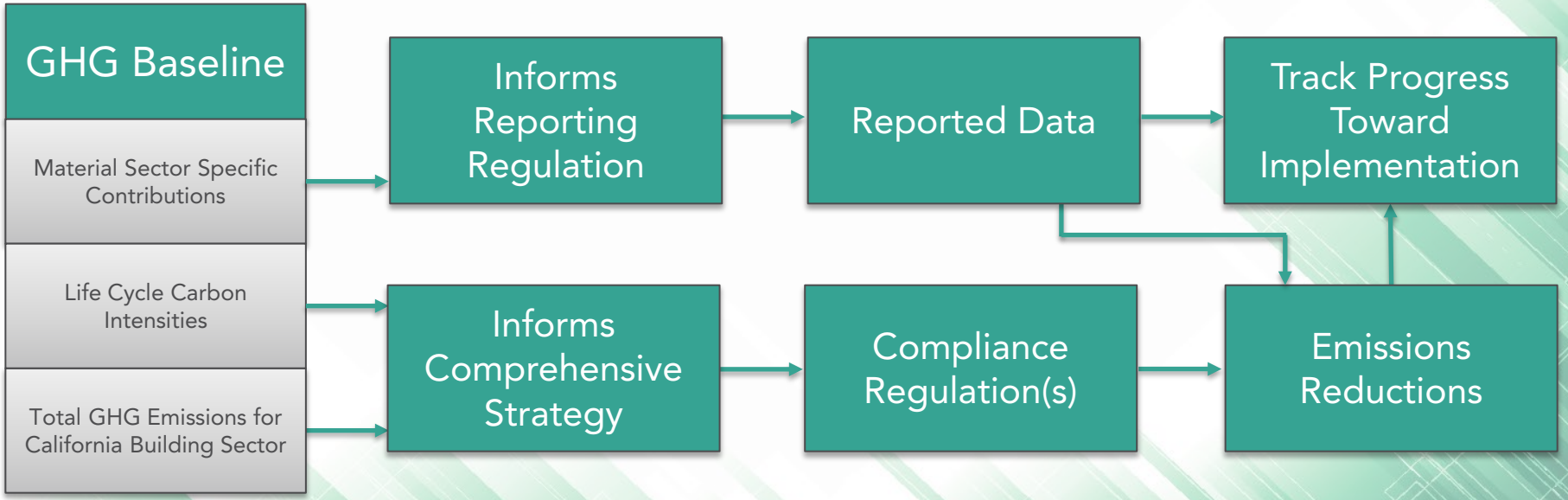
Part III

Baseline Stage Setting

How does the baseline connect to CARB's next steps on developing an Embodied Carbon Reporting Regulation?



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Building Sector Relevant LCA Tools

- GHG Protocol lists 88 relevant tools and databases for assessing product emissions and supply chain emissions
- Staff evaluated each tool and database for relevance toward assessing California building sector emissions

Best Applicability

- USEEIO Model

Some Applicability

- Athena Life Cycle Inventory tool & database
- OneClick LCA *
- Tally LCA *
- The International EPD System with Environdec
- Sphera (GaBi) Databases
- Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET)

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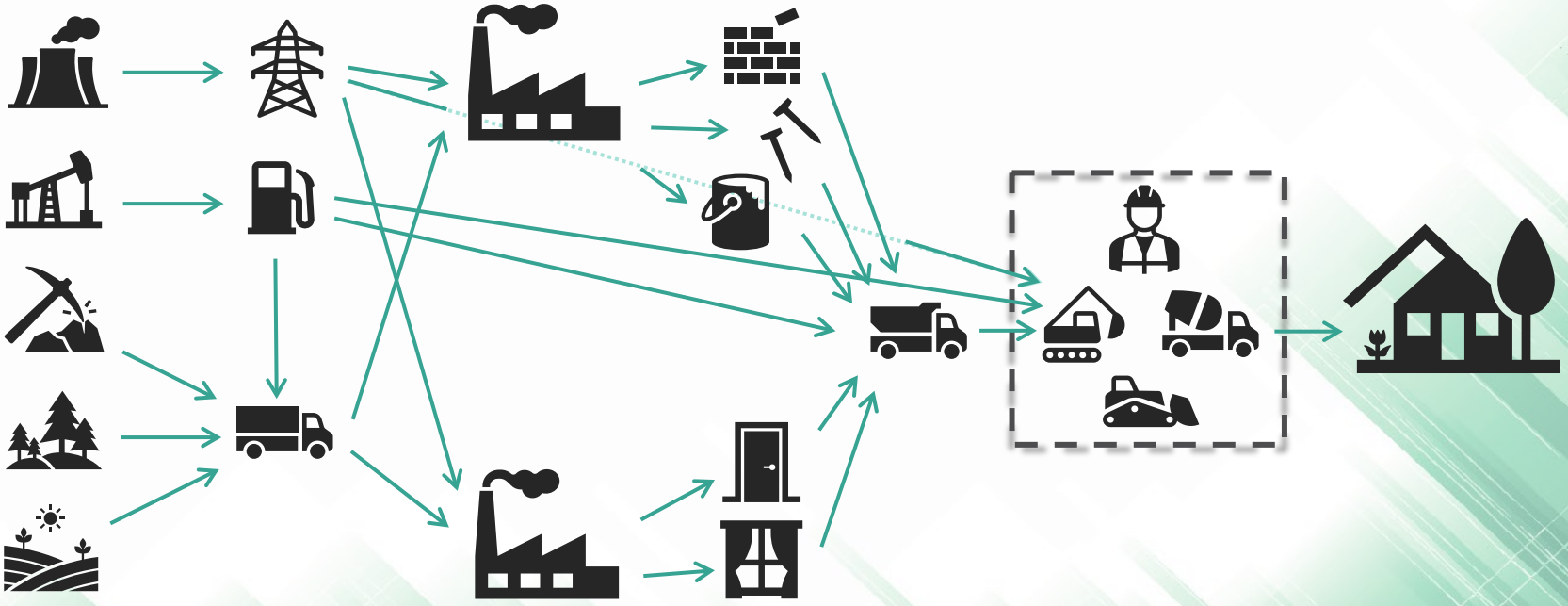
* Tool included to supplement GHG Protocol-listed tools

Example of Interconnected Sectors



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Part IV

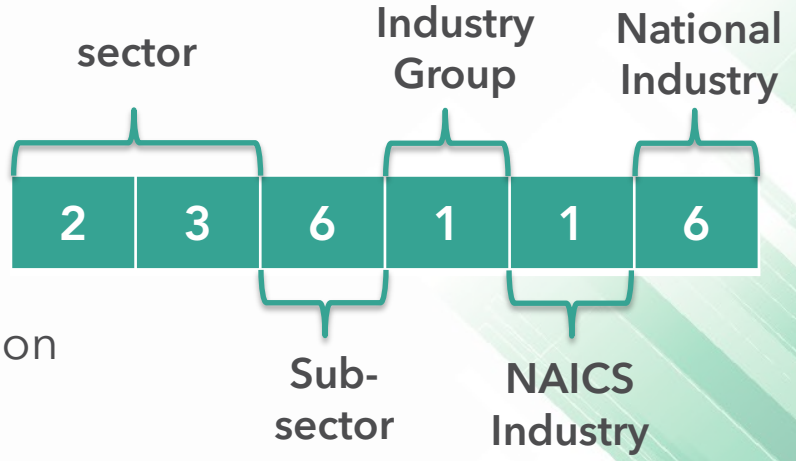
Introduction to Input-Output Analysis

Modeling the Baseline from an Economic Perspective

- The economy is a complex system of **interconnected sectors**
- Each sector produces **goods or services** using **inputs** from other sectors
- These **inter-sector flows** form the basis of economic activity
- The **total output** of each sector is either used by other industries or consumed as **final demand** (households, government, exports)
- Under comparable federal programs, sectors are organized by North American Industry Classification System (**NAICS**) Codes

Example of a 6 Digit NAICS Code

- **Sector**
  23 - Construction
- **Sub-Sector**
  236 - Construction of Buildings
- **Industry Group**
  2361 - Residential Building Construction
- **NAICS Industry**
  23611 - Residential Building Construction
- **National Industry**
  236116 - New Multifamily Housing Construction



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Introduction to Input-Output (IO) Models

- IO analysis calculates the **direct inputs** (e.g. steel used in cars) and **indirect inputs** (e.g. electricity used to make the steel) needed to produce one unit of output (e.g. cars) for a given sector
- CARB has used IO models for different applications, including:
  - A dynamic, hybrid IO model with multi-year forecasting to meet Administrative Procedure Act requirements for regulations (**REMI**)
  - A simpler IO model (**IMPLAN**) for research in support of the 2022 Scoping Plan Update

IO Models Run On Economic Data Tables

- IO models convert economic data tables into vector and matrix formats to perform linear algebra calculations
- The following types of data tables are fundamental to IO analysis:
  - Total Output Table
  - Inter-Sector Flow Table
  - Final Demand Table
- Data from the Total Output and Inter-Sector Flow Tables can also be combined to form a **Direct Requirements Table**

Total Sector Output Table

- The **Total Sector Output Table** shows the value (usually in dollars) generated by specific economic sectors
- This values includes all goods and services that are sold to other sectors or sold directly to consumers

Commercial Structures	Lumber	Sector [n] …
Total $ Produced for Other Sectors and Consumers	Total $ Produced for Other Sectors and Consumers	Total $ Produced for Other Sectors and Consumers

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Direct Requirements Table

- A **Direct Requirements Table** shows the direct inputs from other sectors needed to make $1 output for a given sector
- The values in this table are calculated by dividing the inter-sector flows (how much industries buy from each other) by the total sector output

	Commercial Structures	Lumber	Sector [n] …
Commercial Structures	$ of Commercial Structures consumed by Commercial Structures ÷ $ Commercial Structures sector output	$ of Commercial Structures consumed by Lumber ÷ $ Lumber sector output	$ of Commercial Structures consumed by [n] ÷ $ [n] sector output
Lumber	$ of Lumber consumed by Commercial Structures ÷ $ Commercial Structures sector output	$ of Lumber consumed by Lumber ÷ $ Lumber sector output	$ of Lumber consumed by [n] ÷ $ [n] sector output
Sector [m] …	$ of [m] consumed by Commercial Structures ÷ $ Commercial Structures sector output	$ of [m] consumed by Lumber ÷ $ Lumber sector output	$ of [m] consumed by [n] ÷ $ [n] sector output

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Final Demand Table

- The **Final Demand Table** shows the value of products and services produced by each sector that are purchased by end-consumers (i.e. private households and government consumption)
- It doesn't include goods or services that are bought by one business from another to make something else (those are inter-sector flows)

Commercial Structures	Lumber	Sector [n] …
$ from Commercial Structures to final consumers	$ from Lumber to final consumers	$ from sector [n] to final consumers

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The Basic Balance Equation

- **Basic Balance Equation:** The total output of a sector ($\vec{x}$) is equal to the inter-sector flow from that sector ($A\vec{x}$) plus the final demand of products from that sector to consumers ($\vec{y}$):

Eq. 1: $\vec{x} = A\vec{x} + \vec{y}$

Where:

- $\vec{x}$ is an **n×1 vector** version of the **Total Output Table**
- A is an **n×n matrix** version of the **Direct Requirements Table**
- $\vec{y}$ is an **n×1 vector** version of the **Final Demand Table**

Total Output Vector and L-Matrix

- Rearranging Eq.1 to solve for the Total Output Vector ($\vec{x}$):

$$\vec{x} = A\vec{x} + \vec{y} \quad \rightarrow \quad \vec{x} - A\vec{x} = \vec{y} \quad \rightarrow \quad \vec{x}(I - A) = \vec{y} \quad \rightarrow$$

Eq. 2: $\vec{x} = (\mathbf{I} - A)^{-1}\vec{y}$

- The $(\mathbf{I} - A)^{-1}$ term is called the **Leontief Inverse Matrix (L) (aka Total Requirements Matrix or L-Matrix)**, and $\mathbf{I}$ is an identity matrix

Eq. 3: $\vec{x} = L\vec{y}$

- The **L-Matrix** is the monetary value that every sector in the economy must contribute to generate 1 unit of final demand for a given sector

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Part V

Environmentally-Extended Input-Output Models

Modeling the Baseline with Environmentally-Extended Input-Output (EEIO) Models

- The economy generates waste and emissions, including:
  - **Air pollutants** from burning fossil fuels in factories or power plants
  - **Water pollutants** from industrial processes or agricultural runoff
  - **Solid waste** from manufacturing processes and resource extraction
  - **Greenhouse gasses (GHG)** such as carbon dioxide, methane, and nitrous oxide from industrial and agricultural activities
- These wastes and emissions are tracked by various state and federal agencies, and compiled into public datasets

Assigning Emissions to Economic Flows

- The Total Requirements Matrix (L-matrix) provides the total input requirements, across the entire economy needed to create one more unit of final demand from a sector
- Government datasets provide detailed environmental information on sector-based waste and emissions
- **EEIO models** assess the environmental impacts of products by linking **resource use and emissions data** to economic **input-output tables** to calculate the life-cycle environmental impacts associated with production

Example: Ready-Mix Concrete

Cement Manufacturing - 327310
$0.16 input per $1 output
Emissions: CO_2

Electricity Generation - 221100
$0.03 input per $1 output
Emissions: CO_2, N_2O

Limestone Mining- 212310
$0.03 input per $1 output
Emissions: Particulate, CO_2

Natural Gas Distribution - 221200
$0.006 input per $1 output
Emissions: CH_4

• • •

Input-Output Model (L)
+
Emissions coefficients

CO_2, CH_4, N_2O, PM2.5, etc.

Life-Cycle Emissions

$kgCO_2e$/$ of Ready-Mix Concrete

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Data taken from 2017 USEEIO output (L Matrix), NAICS sector 327320

EEIO Data Tables

- The following data tables are fundamental to EEIO:
  - **Environmental Satellite Tables**
  - **Life Cycle Impact Assessment Factor Tables**
- Data from the Satellite Tables and Life Cycle Impact Assessment Factor Tables can also be combined to form a **Life Cycle Emissions Factor Table**

EEIO Environmental Satellite Tables

- **Environmental satellite tables** measure annual quantities of emissions for GHGs, as well as other air pollutants and wastes
- The EPA's Greenhouse Gas Inventory and CARB's Mandatory Greenhouse Gas Reporting Regulation are two programs that collect emission data

Species	Annual Emissions (kg)
Carbon dioxide	1,197,891,260,056
HFC-125	4,015,677
HFC-134a	6,568,861
HFC-143a	1,097,641
HFC-236fa	13,161
HFC-32	2,742,122
Methane	708,712
Nitrous oxide	112,324

Example: 2022 EPA GHG Inventory Data for NAICS sector 236 (Construction of Buildings)

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Only species with emissions reported in the GHG_national_2022_m1.parquet file for NAICS 236 provided by the EPA are listed. Other inventoried species may not have sector-specific flows or may fall below reporting thresholds.

Life Cycle Impact Assessment (LCIA) Factors

- **Life Cycle Impact Assessment Factors (aka Indicator Values)** convert GHG emissions to carbon dioxide equivalent (**CO_2e**) units using Global Warming Potentials (**GWP**)
- The International Panel on Climate Change's **Annual Reports** and EPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (**TRACI**) are prominent LCIAs

Substance Name	Chemical Notation	GWP (kg CO_2e/ kg substance)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous Oxide	N_2O	298

Example: GHG Indicator Data Inputs (TRACI 2.1)

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Environmental Impact Vector

- EEIO modifies the Total Output Vector equation (Eq. 3) to solve for an **Environmental Impact Vector ($\boldsymbol{E}$)**:

$$\text{Let } E = CB\vec{x}$$

$$\text{Eq. 3: } \vec{x} = L\vec{y}$$

$$\textbf{Eq. 4: } \boldsymbol{E = CBL\vec{y}}$$

where:

- **Life Cycle Impact Assessment Factor Data ($\boldsymbol{C}$):** Matrix version of LCIA table (e.g., Global Warming Potentials)
- **Satellite Data ($\boldsymbol{B}$):** Matrix version of satellite tables (e.g., kg flow of N_2O)

Direct Impact Matrix

- The Environmental Impact Vector equation can be simplified by defining the product of the **Satellite Matrix ($\boldsymbol{B}$)** and the **Life Cycle Impact Assessment Factor Matrix ($\boldsymbol{C}$)** as a **Direct Impact Matrix ($\boldsymbol{D}$)**

$$\text{Let } D = CB$$

$$\text{Eq. 4: } E = CBL\vec{y}$$

$$\textbf{Eq. 5: } \boldsymbol{E = DL\vec{y}}$$

- **Direct Impact Matrix ($\boldsymbol{D}$) (aka D-Matrix)** is the weighted, direct (scope 1) environmental emissions per unit of output (e.g., kg CO_2e/$ economic output) from a sector

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Direct Impact Matrix

- For USEEIO, the **Direct Impact (aka intervention) Matrix (D)** is assembled from TRACI or other LCIA factors and includes the following datasets:

Agency	Datasets
US Environmental Protection Agency	National Emissions Inventory
	Toxics Release Inventory
	Greenhouse Gas Inventory
	Discharge Monitoring Report
	Advancing Sustainable Materials Management: 2014 Fact Sheet
US Energy Information Administration	Manufacturing Energy Consumption Survey
	Commercial Building Energy Consumption Survey
US Department of Agriculture	Agricultural Chemical Use Survey
US Geological Survey	Minerals Commodity Survey

Life Cycle Emissions Factor Matrix

- Equation 6 can be further simplified by multiplying the **Direct Impact Matrix ($\boldsymbol{D}$)** and the **Leontief Inverse Matrix (L)**

$$\text{Let } N = DL$$

$$\text{Eq. 6: } E = DL\vec{y}$$

$$\textbf{Eq. 7: } \boldsymbol{E = N\vec{y}}$$

- **Life Cycle Emissions Factor (aka Environmental Stressor) Matrix ($\boldsymbol{N}$)** is the life cycle emissions per unit of output (e.g., kg CO_2e/$ final demand)

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Life Cycle Emissions Factor Table

- **The Life Cycle Emissions Factor Matrix** can be represented as a table of sector-specific emission factors

sector	BEA Code	kg CO_2e/$ final demand
Health care buildings	233210/US-CA	0.13
Schools and vocational buildings	233262/US-CA	0.16
Residential building repair and maintenance	230302/US-CA	0.21
Multifamily homes	233412/US-CA	0.18
Manufacturing buildings	233230/US-CA	0.21
Utilities buildings and infrastructure	233240/US-CA	0.13
Single-family homes	233411/US-CA	0.17
Highways, streets, and bridges	2332C0/US-CA	0.21
Lumber and treated lumber	321100/US-CA	0.31
Plywood and veneer	321200/US-CA	0.31

Example: Life Cycle Emission Factors Used in the Baseline Assessment Tool

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Part VI

USEEIO and StateIO Models

U.S. Environmentally-Extended Input-Output (USEEIO) Model

- **Nationally-representative, single-region EEIO model** of the U.S. that calculates direct and indirect environmental impacts
- Developed by the federal Environmental Protection Agency (EPA) for life cycle assessment, policy analysis, and sustainable materials management
- Can be parametrized with varying **base years** and **sectoral resolution** (summary: ~70 sectors, detail: ~400 sectors), as well as user-defined environmental datasets
- Developed with IO Model Builder, flowsa, LCIAformatter (Python scripts), and useeior (R package)

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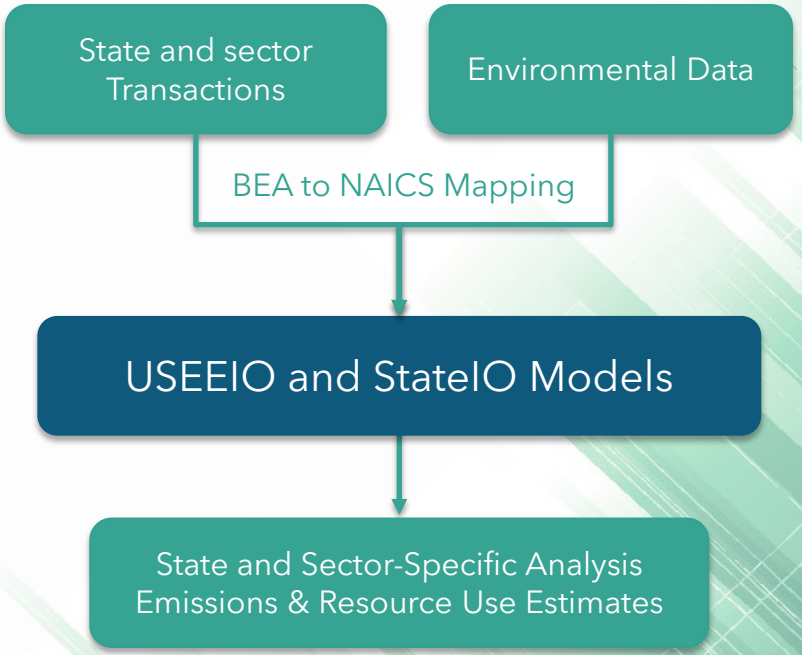
USEEIO and StateIO Model Approach

- **L-Matrix:** derived from Bureau of Economic Analysis (BEA) Input-Output Accounts and Gross Output by Industry tables
- **D-Matrix:** Assembled from various federal and state environmental datasets
- **Life Cycle Emissions:** L-matrix and D-matrix are mapped by BEA codes to facilitate life cycle emissions estimates for each sector



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BEA Make and Use Tables

- **BEA Make and Use Tables** are used by USEEIO model to calculate the Direct Requirements ($\boldsymbol{A}$) matrix
  - **Make Table ($\boldsymbol{V}$)**– Tracks which industries produce specific commodities
  - **Use Table ($\boldsymbol{U}$)**– Shows industry/sector purchase of intermediate products and how consumers purchase of final products
- **Data Lag:** Make and Use Tables are updated **annually** at 'sector' (most aggregated) and 'summary' (medium resolution) levels, and **every five years** at the 'detail' (most disaggregated) level of sectoral resolution
- Current sector and summary data is from **2023** and detailed data are from **2017** (released in **2024**)

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StateIO Model

- EPA model that facilitates the analysis of environmental impacts linked to a particular state, considering both in-state and rest-of-U.S. supply chains
- **Two-region model:** State of Interest (SoI) and the Rest of the U.S. (RoUS).
- Constructed using national IO tables and state-level industry and trade data from public sources, mapped into EEIO model using **flowsa,** which creates concordance between environmental flows and specific sectors
- Resolution at the BEA summary level (~73 commodities per region).
- Includes **Make (V)** and **Use (U)** tables at the state level.
- Developed using the open-source **stateior** R package

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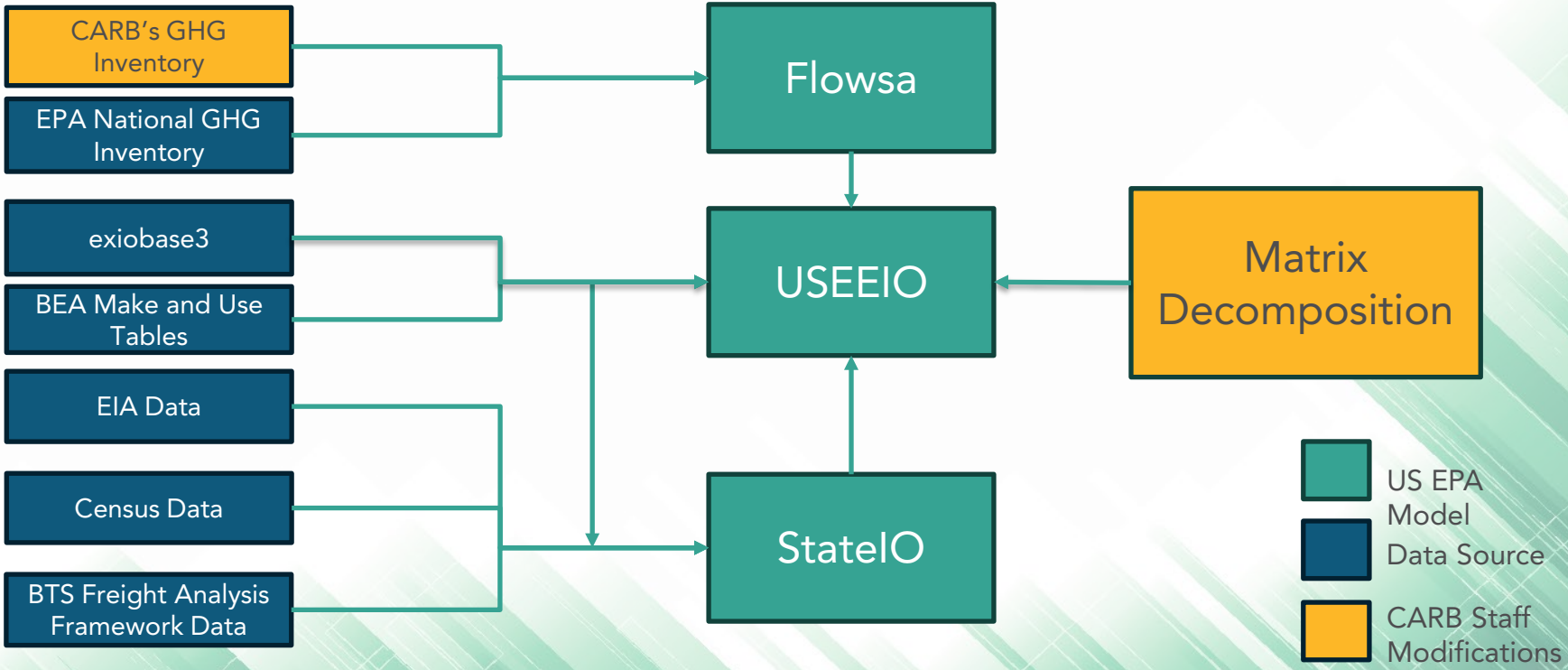
International Import Data

- USEEIO incorporates imported product data using external **Multi-Regional Input-Output** (MRIO) models such as **EXIOBASE**
- Environmental flow data is mapped to USEEIO determining import shares by nation for each commodity and then calculating the import emissions factors
- This approach adds import emissions factors to the D-Matrix
- The overall GHG intensity of imports is often higher than that of domestic commodities

Part VII

Customizing USEEIO for the Embodied Carbon Program

What Data Sets are Being Used?



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What are the Staff Modifications?

CARB's GHG Inventory

- Provides **California-specific Inventory emissions data** that replaces default EPA values integrated in flowsa
- Uses a **mapping by NAICS codes** which allows for more accurate attribution of emissions to California's industries

Matrix Decomposition

- Disaggregates coarse 71-sector outputs from the summary stateio model into **400+ detailed sectors for California**
- Uses **national-level ratios and scaling factors** to modify California's specific modeling results
- Allows for **improved precision in modeling emissions** from specific materials and industries relevant to buildings

Integrating CARB's GHG Inventory

- Each emission flow in CARB's inventory is **mapped to specific BEA sectors**, producing a custom satellite table that reflects California-specific emissions by industry

BEA Sector	CARB GHG Inventory Identifier
23	Industrial, Manufacturing, Construction, None, Fuel combustion, Natural gas
334	Industrial, Manufacturing, Electric & Electronic Equip., Fugitives, Fugitive emissions, NA
334	Industrial, Manufacturing, Electric & Electronic Equip., Semiconductors & Related Products, Semiconductor manufacture, NA
311	Industrial, Manufacturing, Food Products, Food Processing, Fuel combustion, Natural gas

- This table is incorporated in flowsa and generates a **CARB-specific satellite file** (GHGc_state_CA_2022.parquet) which replaces EPA's California state inventory
- This output is used in the **useeior configuration file** and used to calculate the direct emissions matrix for California, where D is direct emissions, C is the life cycle impact assessment (GWP), and B is the environmental flow (e.g., kg CO_2e) :

$$D_{CARB} = C \cdot B_{CARB}$$

Matrix Decomposition Approach

California input totals are preserved for an aggregate sector, but the values are redistributed to subsectors to align with detailed U.S. patterns. **Scaling is done based on national (US) inputs.** Additional detail is provided in the technical documentation released alongside this workshop.

For K and L summary sectors, and i and j detailed sectors such that $i \in K$ and $j \in L$ the general steps are:

- Get national detailed input matrix:
  - $A_{i,j}^{US} \times X_{j}^{US} = Input_{i,j}^{US}$
- Generate scaling factors:
  - $SF_{i,j}^{inputs} = \frac{Input_{i,j}^{US}}{\sum_{k \in K} \sum_{l \in L} Input_{k,l}^{US}}$
- Apply to California summary matrix:
  - $Input_{i,j}^{state} = SF_{i,j}^{inputs} \times Input_{K,L}^{state}$

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Matrix Decomposition Approach (cont.)

- We calculate the total emissions by multiplying the D matrix by the total inputs for each NAICS:
  - $Input_{i,j}^{US} \times D_j^{US} = Emission_{i,j}^{US}$
- Generate scaling factors:
  - $SF_{i,j}^{emission} = \frac{Emission_{i,j}^{US}}{\sum_{k \in K} \sum_{l \in L} Emission_{k,l}^{US}}$
- Apply to California summary matrix:
  - $Emission_{i,j}^{state} = SF_{i,j}^{emission} \times Emission_{K,L}^{state}$
- We can obtain the **detailed A, L and D matrices for California** (402 sectors):
  - $\boldsymbol{A_{i,j}^{state} = \frac{Input_{i,j}^{state}}{X_j^{state}}}$, $\boldsymbol{L_{i,j}^{state} = [(I - A^{state})^{-1}]_{i,j}}$ **and** $\boldsymbol{D_j^{state} = \frac{\sum_j Emission_{i,j}^{state}}{\sum_j Input_{i,j}^{state}}}$

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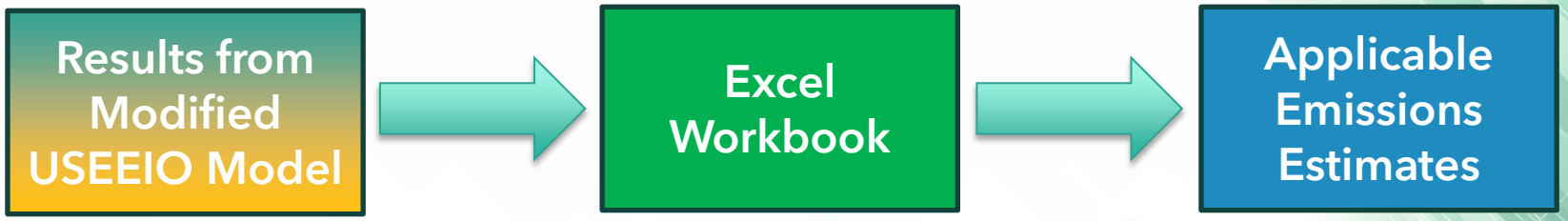
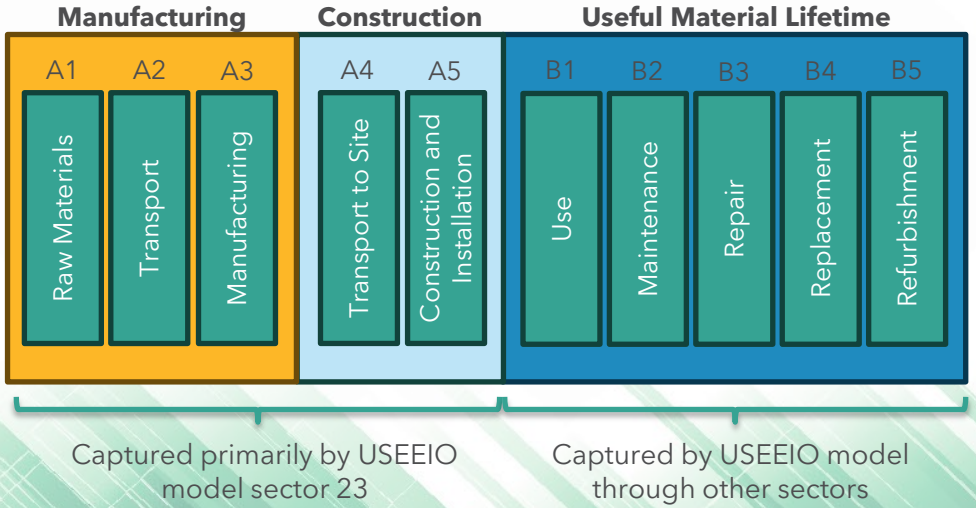
Baseline Assessment Tool

- The Baseline Assessment Tool is a simplified excel tool that incorporates relevant USEEIO model results to allow individuals to assess building sector inclusions and life cycle emissions



LCA Scope for Estimating "Baseline" Emissions

- 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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Staff Recommendation for Core Emissions

- The Building sector includes the final consumer demand for construction industry products (e.g., buildings)

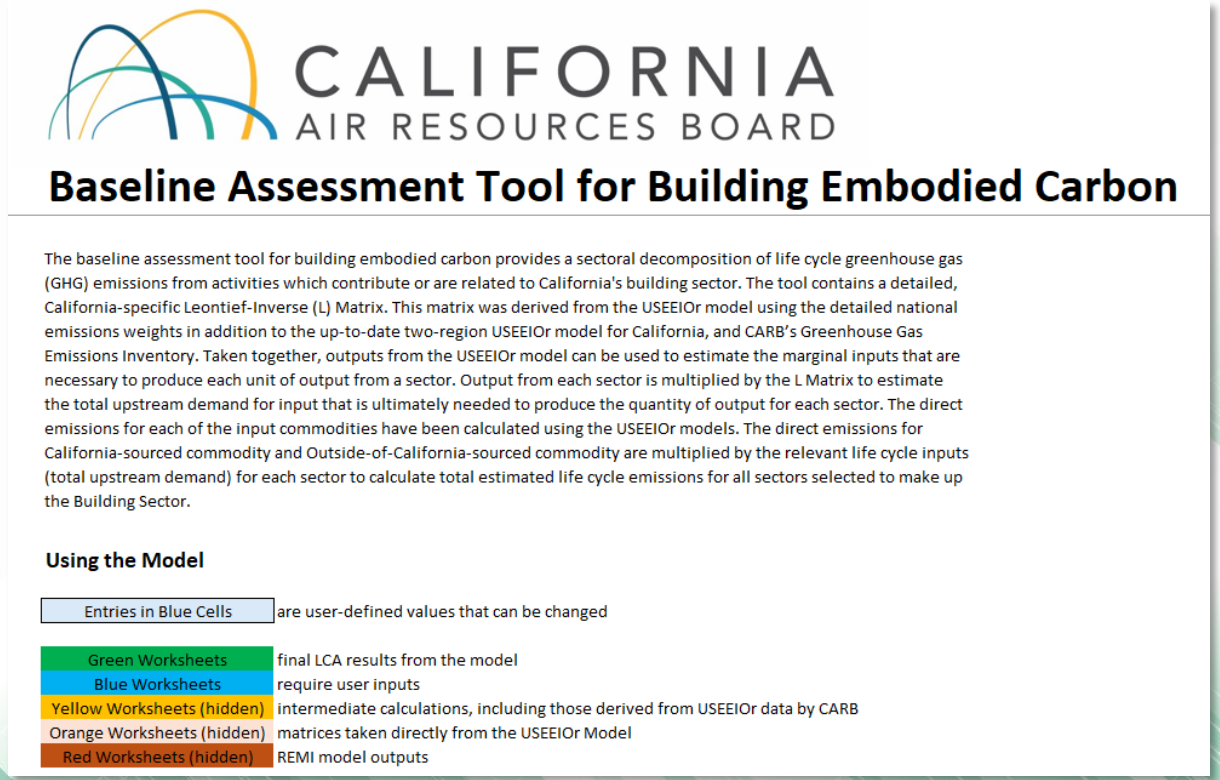
BEA Code	Description	Primary Product Stage Emissions
233210	Health care buildings	A1-A5
233262	Schools and vocational buildings	A1-A5
230301	Nonresidential building repair and maintenance	A1-A5
230302	Residential building repair and maintenance	A1-A5
2332A0	Commercial structures, including farm structures	A1-A5
233412	Multifamily homes	A1-A5
2334A0	Other residential structures	A1-A5
233230	Manufacturing buildings	A1-A5
2332D0	Other nonresidential structures	A1-A5
233240	Utilities buildings and infrastructure	A1-A5
233411	Single-family homes	A1-A5
2332C0	Highways, streets, and bridges	A1-A5

Staff Recommendation for Additional Emissions

- The Building sector includes the final consumer demand for some additional products purchased for final consumption (i.e. by private households). This helps estimate B1-B5 emissions

BEA Code	Description	Primary Product Stage Emissions
321100	Lumber and treated lumber	A1-A3, B1-B5
321200	Plywood and veneer	A1-A3, B1-B5
321910	Wooden windows, door, and flooring	A1-A3, B1-B5
3219A0	Veneer, plywood, and engineered wood	A1-A3, B1-B5
327100	Clay and ceramic products	A1-A3, B1-B5
327200	Glass and glass products	A1-A3, B1-B5
327991	Cut stone and stone products	A1-A3, B1-B5
332999	Misc. fabricated metal products	A1-A3, B1-B5
333120	Construction machinery	B1-B5
333414	Heating equipment other than warm air furnaces	A1-A3, B1-B5
333415	Air conditioning, refrigeration, and warm air heating equipment	A1-A3, B1-B5
531HSO	Owner-occupied housing	B1-B5
531HST	Tenant-occupied housing	B1-B5
541300	Architectural, engineering, and related services	B1-B5

Baseline Tool: "About" Worksheet



CALIFORNIA AIR RESOURCES BOARD

Baseline Assessment Tool for Building Embodied Carbon

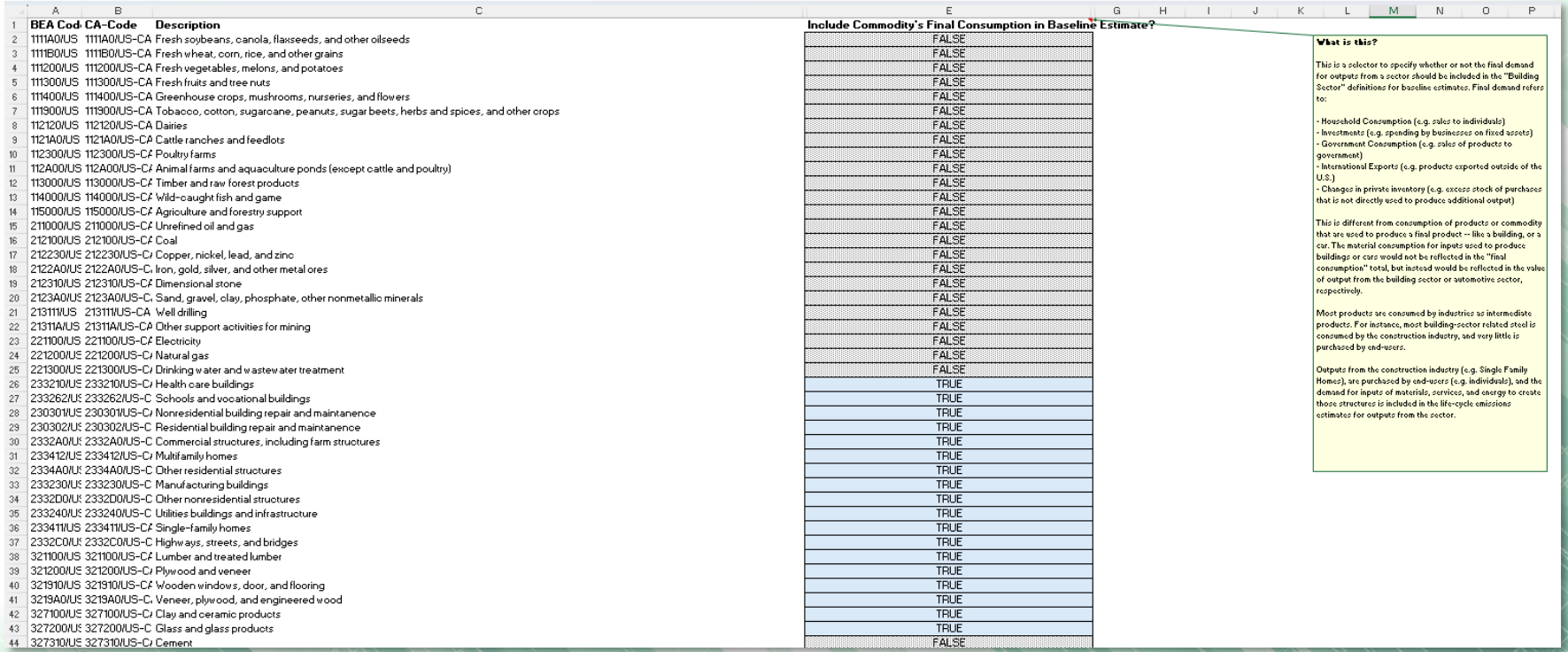
The baseline assessment tool for building embodied carbon provides a sectoral decomposition of life cycle greenhouse gas (GHG) emissions from activities which contribute or are related to California's building sector. The tool contains a detailed, California-specific Leontief-Inverse (L) Matrix. This matrix was derived from the USEEIOr model using the detailed national emissions weights in addition to the up-to-date two-region USEEIOr model for California, and CARB's Greenhouse Gas Emissions Inventory. Taken together, outputs from the USEEIOr model can be used to estimate the marginal inputs that are necessary to produce each unit of output from a sector. Output from each sector is multiplied by the L Matrix to estimate the total upstream demand for input that is ultimately needed to produce the quantity of output for each sector. The direct emissions for each of the input commodities have been calculated using the USEEIOr models. The direct emissions for California-sourced commodity and Outside-of-California-sourced commodity are multiplied by the relevant life cycle inputs (total upstream demand) for each sector to calculate total estimated life cycle emissions for all sectors selected to make up the Building Sector.

Using the Model

Entries in Blue Cells	are user-defined values that can be changed
Green Worksheets	final LCA results from the model
Blue Worksheets	require user inputs
Yellow Worksheets (hidden)	intermediate calculations, including those derived from USEEIOr data by CARB
Orange Worksheets (hidden)	matrices taken directly from the USEEIOr Model
Red Worksheets (hidden)	REMI model outputs

CARB

Baseline Tool: "Sector Selection" Worksheet



BEA Code	CA-Code	Description	Include Commodity's Final Consumption in Baseline Estimate?
1111A0/US	1111A0/US-CA	Fresh soybeans, canola, flaxseeds, and other oilseeds	FALSE
1111B0/US	1111B0/US-CA	Fresh wheat, corn, rice, and other grains	FALSE
111200/US	111200/US-CA	Fresh vegetables, melons, and potatoes	FALSE
111300/US	111300/US-CA	Fresh fruits and tree nuts	FALSE
111400/US	111400/US-CA	Greenhouse crops, mushrooms, nurseries, and flowers	FALSE
111900/US	111900/US-CA	Tobacco, cotton, sugarcane, peanuts, sugar beets, herbs and spices, and other crops	FALSE
112120/US	112120/US-CA	Dairies	FALSE
1121A0/US	1121A0/US-CA	Cattle ranches and feedlots	FALSE
112300/US	112300/US-CA	Poultry farms	FALSE
112A00/US	112A00/US-CA	Animal farms and aquaculture ponds (except cattle and poultry)	FALSE
113000/US	113000/US-CA	Timber and raw forest products	FALSE
114000/US	114000/US-CA	Wild-caught fish and game	FALSE
115000/US	115000/US-CA	Agriculture and forestry support	FALSE
211000/US	211000/US-CA	Unrefined oil and gas	FALSE
212100/US	212100/US-CA	Coal	FALSE
212230/US	212230/US-CA	Copper, nickel, lead, and zinc	FALSE
2122A0/US	2122A0/US-CA	Iron, gold, silver, and other metal ores	FALSE
212310/US	212310/US-CA	Dimensional stone	FALSE
2123A0/US	2123A0/US-CA	Sand, gravel, clay, phosphate, other nonmetallic minerals	FALSE
213111/US	213111/US-CA	Well drilling	FALSE
21311A/US	21311A/US-CA	Other support activities for mining	FALSE
221100/US	221100/US-CA	Electricity	FALSE
221200/US	221200/US-CA	Natural gas	FALSE
221300/US	221300/US-CA	Drinking water and wastewater treatment	FALSE
233210/US	233210/US-CA	Health care buildings	TRUE
233262/US	233262/US-CA	Schools and vocational buildings	TRUE
230301/US	230301/US-CA	Nonresidential building repair and maintanence	TRUE
230302/US	230302/US-CA	Residential building repair and maintanence	TRUE
2332A0/US	2332A0/US-CA	Commercial structures, including farm structures	TRUE
233412/US	233412/US-CA	Multifamily homes	TRUE
2334A0/US	2334A0/US-CA	Other residential structures	TRUE
233230/US	233230/US-CA	Manufacturing buildings	TRUE
2332D0/US	2332D0/US-CA	Other nonresidential structures	TRUE
233240/US	233240/US-CA	Utilities buildings and infrastructure	TRUE
233411/US	233411/US-CA	Single-family homes	TRUE
2332C0/US	2332C0/US-CA	Highways, streets, and bridges	TRUE
321100/US	321100/US-CA	Lumber and treated lumber	TRUE
321200/US	321200/US-CA	Plywood and veneer	TRUE
321910/US	321910/US-CA	Wooden windows, door, and flooring	TRUE
3219A0/US	3219A0/US-CA	Veneer, plywood, and engineered wood	TRUE
327100/US	327100/US-CA	Clay and ceramic products	TRUE
327200/US	327200/US-CA	Glass and glass products	TRUE
327310/US	327310/US-CA	Cement	FALSE

What is this?

This is a selector to specify whether or not the final demand for outputs from a sector should be included in the "Building Sector" definitions for baseline estimates. Final demand refers to:

- Household Consumption (e.g. sales to individuals)
- Investments (e.g. spending by businesses on fixed assets)
- Government Consumption (e.g. sales of products to government)
- International Exports (e.g. products exported outside of the U.S.)
- Changes in private inventory (e.g. excess stock of purchases that is not directly used to produce additional output)

This is different from consumption of products or commodity that are used to produce a final product -- like a building, or a car. The material consumption for inputs used to produce buildings or cars would not be reflected in the "final consumption" total, but instead would be reflected in the value of output from the building sector or automotive sector, respectively.

Most products are consumed by industries as intermediate products. For instance, most building-sector related steel is consumed by the construction industry, and very little is purchased by end-users.

Outputs from the construction industry (e.g. Single Family Homes), are purchased by end-users (e.g. individuals), and the demand for inputs of materials, services, and energy to create those structures is included in the life-cycle emissions estimates for outputs from the sector.

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Baseline Tool: "Dashboard Results" Worksheet

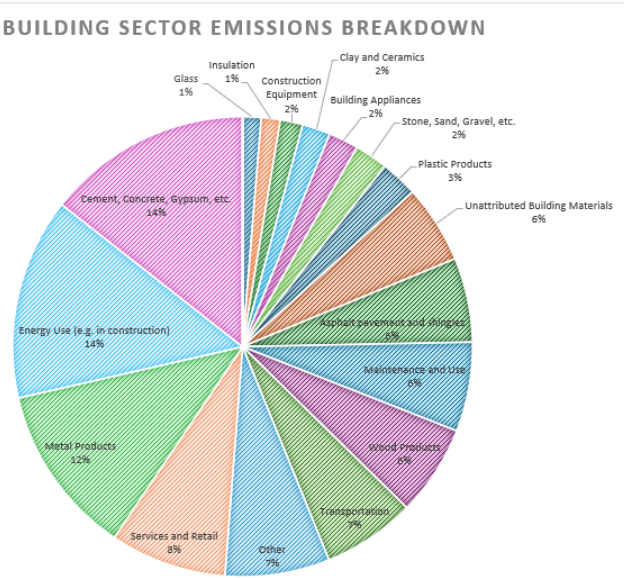
	A	B
1	Selected Analysis Year	2026
2		
3		Carbon Emissions ($MMT CO_2e$)
4	Building Sector Baseline Estimate	59
5	*from construction industry*	47
6	*from other relevant activity*	11
7		
8		
9	Building sector emissions if reduced by 40%	35
10	Emissions reductions needed to meet 40% reduction	24

Change Baseline Inclusions

What is this?

This graph shows an estimate for the brekadown of life cycle emissions for inputs purchased by the building sector.

Note: these emissions only reflect building



CARB

Baseline Tool: "Attributable Baseline Emissions" Worksheet

Relevant BEA Code	Sector Name	Life-Cycle Emissions (kg CO2e)	Life-Cycle Emissions (MMT CO2e)	% of Total Building Sector Life-Cycle Emissions	Economic Activity (Billion USD)
233210/US-CA	Health care buildings	1113273463	1.1	1.9%	8.85
233262/US-CA	Schools and vocational buildings	2948709589	2.9	5.0%	19.00
230301/US-CA	Nonresidential building repair and maintanence	0	0.0	0.0%	0.00
230302/US-CA	Residential building repair and maintanence	0	0.0	0.0%	0.00
2332A0/US-CA	Commercial structures, including farm structures	6201412634	6.2	10.5%	31.81
233412/US-CA	Multifamily homes	2451631818	2.5	4.2%	14.98
2334A0/US-CA	Other residential structures	11634635980	11.6	19.8%	46.30
233230/US-CA	Manufacturing buildings	2369138006	2.4	4.0%	13.27
2332D0/US-CA	Other nonresidential structures	3675112641	3.7	6.3%	23.14
233240/US-CA	Utilities buildings and infrastructure	2993234413	3.0	5.1%	23.22
233411/US-CA	Single-family homes	8492540109	8.5	14.4%	50.80
2332C0/US-CA	Highways, streets, and bridges	5602828074	5.6	9.5%	26.87
321100/US-CA	Lumber and treated lumber	0	0.0	0.0%	0.00
321200/US-CA	Plywood and veneer	0	0.0	0.0%	0.00
321910/US-CA	Wooden windows, door, and flooring	0	0.0	0.0%	0.00
3219A0/US-CA	Veneer, plywood, and engineered wood	328513664	0.3	0.6%	1.37
327100/US-CA	Clay and ceramic products	261076115	0.3	0.4%	0.29
327200/US-CA	Glass and glass products	720029921	0.7	1.2%	0.69
327991/US-CA	Cut stone and stone products	122465769	0.1	0.2%	0.40
332999/US-CA	Misc. fabricated metal products	104254419	0.1	0.2%	0.31
333120/US-CA	Construction machinery	778582113	0.8	1.3%	2.77
333414/US-CA	Heating equipment other than warm air furnaces	28287525	0.0	0.0%	0.11
333415/US-CA	Air conditioning, refrigeration, and warm air heating equipment	292780739	0.3	0.5%	1.02
531HSO/US-CA	Owner-occupied housing	4091155270	4.1	7.0%	305.99
531HST/US-CA	Tenant-occupied housing	1280685042	1.3	2.2%	92.14
541300/US-CA	Architectural, engineering, and Construction	612767011	0.6	1.0%	5.57

What is this?

This is the total life cycle emissions affiliated with final consumption of output from a sector (e.g. value of health care buildings constructed by the construction sector in a given year).

Total demand for commodity from each sector is multiplied by the total life cycle requirements to produce that commodity output from each sector. This reflects the complete production across the economy that is necessary to meet the total building sector requirements in California (e.g. building of all structures in the state in a given year).

Because this represents the total requirement, it aggregates quantities for both the direct inputs into the building sector, as well as the indirect (life cycle) inputs into the building sector, such as the coal and natural gas purchased by material manufacturers to produce products that are purchased by construction firms.

CARB

Baseline Tool: "Building Sector Breakdown" Worksheet

	A	B	C	D	I	J	K
1	**Inputs Purchased by Building Sector Firms**	MMT CO2	% of Tota	CARB Categorization	**Sector Aggregation**	**Pie Chart Labels**	**Total Percent**
2	All Other Emissions	1.07	2.0%	Other	Other	Other	0.073010795
3	Greenhouse crops, mushrooms, nurseries, and flowers	0.03	0.1%	Other	Wood Products	Wood Products	0.063273785
4	Tobacco, cotton, sugarcane, peanuts, sugar beets, herbs a	0.12	0.2%	Other	Energy Use in Construction	Energy Use in Construction	0.140795871
5	Timber and raw forest products	0.05	0.1%	Wood Products	Metal Products	Metal Products	0.119139464
6	Unrefined oil and gas	0.11	0.2%	Energy Use in Construction	Stone, Sand, Gravel, etc.	Stone, Sand, Gravel, etc.	0.023071652
7	Coal	0.06	0.1%	Energy Use in Construction	Unattributed Building Materials	Unattributed Building Materials	0.054592144
8	Iron, gold, silver, and other metal ores	0.04	0.1%	Metal Products	Maintenance and Use	Maintenance and Use	0.062357121
9	Dimensional stone	0.76	1.4%	Stone, Sand, Gravel, etc.	Clay and Ceramics	Clay and Ceramics	0.019573338
10	Sand, gravel, clay, phosphate, other nonmetallic mineral	0.24	0.4%	Stone, Sand, Gravel, etc.	Glass	Glass	0.01292643
11	Electricity	3.56	6.7%	Energy Use in Construction	Cement, Concrete, Gypsum, etc.	Cement, Concrete, Gypsum, etc.	0.142860402
12	Natural gas	0.04	0.1%	Energy Use in Construction	Insulation	Insulation	0.013205768
13	Drinking water and wastewater treatment	0.12	0.2%	Other	Construction Equipment	Construction Equipment	0.015759379
14	Nonresidential building repair and maintanence	0.11	0.2%	Maintenance and Use	Building Appliances	Building Appliances	0.020899138
15	Residential building repair and maintanence	2.09	3.9%	Maintenance and Use	Carpets, Rugs, Textiles	Carpets, Rugs, Textiles	0.002366243
16	Lumber and treated lumber	0.80	1.5%	Wood Products	Asphalt pavement and shingles	Asphalt pavement and shingles	0.058846296
17	Plywood and veneer	1.21	2.3%	Wood Products	Plastic Products	Plastic Products	0.026097208
18	Wooden windows, door, and flooring	0.44	0.8%	Wood Products	Finishes and Adhesives	Finishes and Adhesives	0.005175484
19	Veneer, plywood, and engineered wood	0.10	0.2%	Wood Products	Transportation	Transportation	0.064831983
20	Clay and ceramic products	1.05	2.0%	Clay and Ceramics	Services and Retail	Services and Retail	0.081217499
21	Glass and glass products	0.69	1.3%	Glass			
22	Cement	0.72	1.3%	Cement, Concrete, Gypsum, etc.			
23	Ready-mix concrete	3.79	7.1%	Cement, Concrete, Gypsum, etc.			
24	Concrete pipe, bricks, and blocks	0.33	0.6%	Cement, Concrete, Gypsum, etc.			
25	Other concrete products	0.61	1.1%	Cement, Concrete, Gypsum, etc.			
26	Lime and gypsum products	2.21	4.1%	Cement, Concrete, Gypsum, etc.			
27	Abrasive products	0.03	0.1%	Unattributed Building Materials			
28	Cut stone and stone products	0.24	0.4%	Stone, Sand, Gravel, etc.			
29	Ground or treated minerals and earth	0.03	0.1%	Other			
30	Mineral wool	0.57	1.1%	Insulation			
31	Other nonmetallic mineral products	0.35	0.7%	Other			
32	Primary iron, steel, and ferroalloy products	0.76	1.4%	Metal Products			
33	Secondary steel products	0.18	0.3%	Metal Products			

What is this?
This sheet is used to aggregate relevant data based on defined user parameters to create the graph shown on the dashboard results page.

CARB

Part VIII

Public Discussion and Feedback

Requested Feedback

1. Are there significant emissions associated with the “building sector” that the current staff approach does not adequately capture?
   - Should these emissions be included?
   - Are there suggestions for methods staff should consider for including these emissions in the baseline estimate?
2. Are there methods or approaches staff should consider for changing how A1-B5 emissions are estimated using USEEIO data? Should the scope be revised to better account for USEEIO limitations?
3. What additional tools or information would interested parties like to have access to in relation to the baseline?

CARB

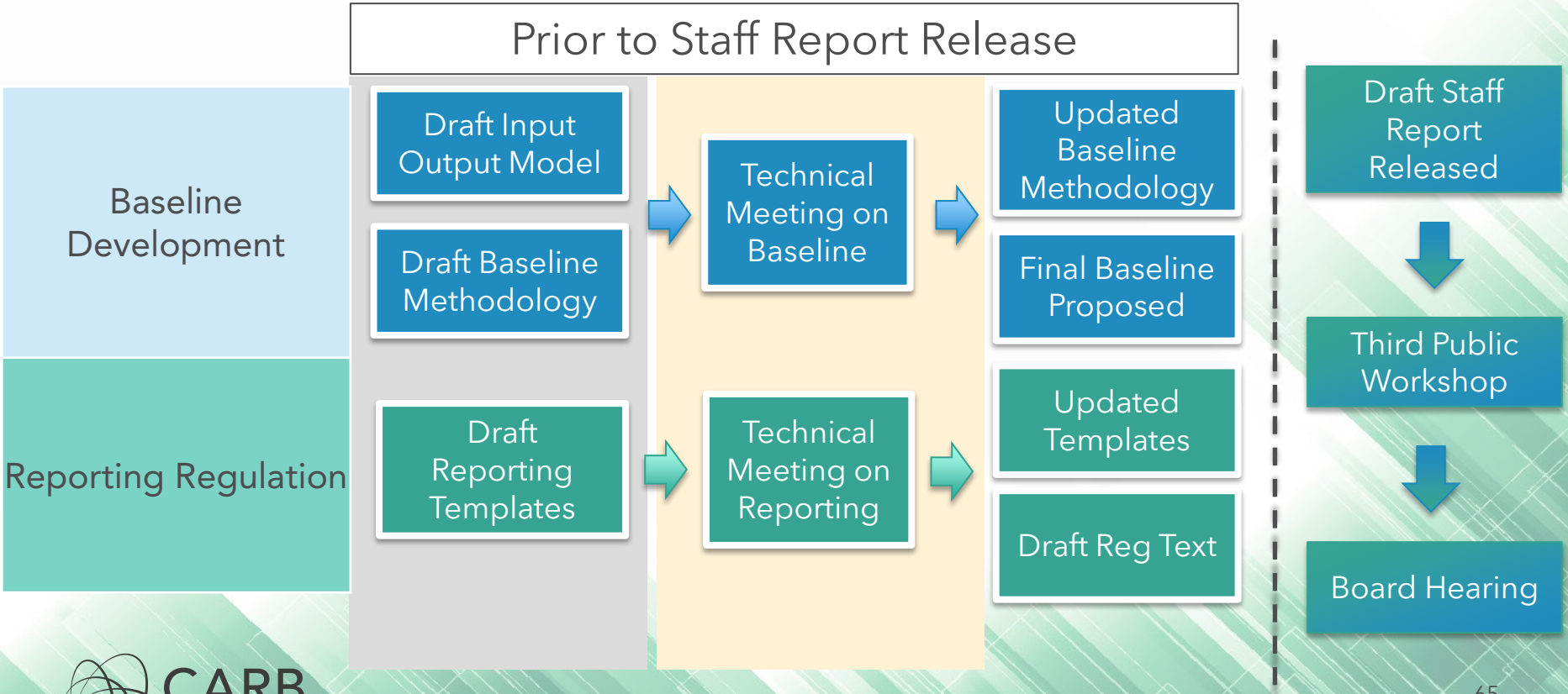
Requested Feedback (cont.)

4. Have staff excluded any sectors where final demand (e.g. commodity sold directly to end-consumers, such as private households) should be included as part of the "building sector"?
5. Have staff included any sectors where final demand should not be included as part of the "building sector"?
6. Are there different weighting approaches that staff should use for disaggregating coarse 71-sector outputs from the summary stateio model into the 400+ detailed sectors for California?

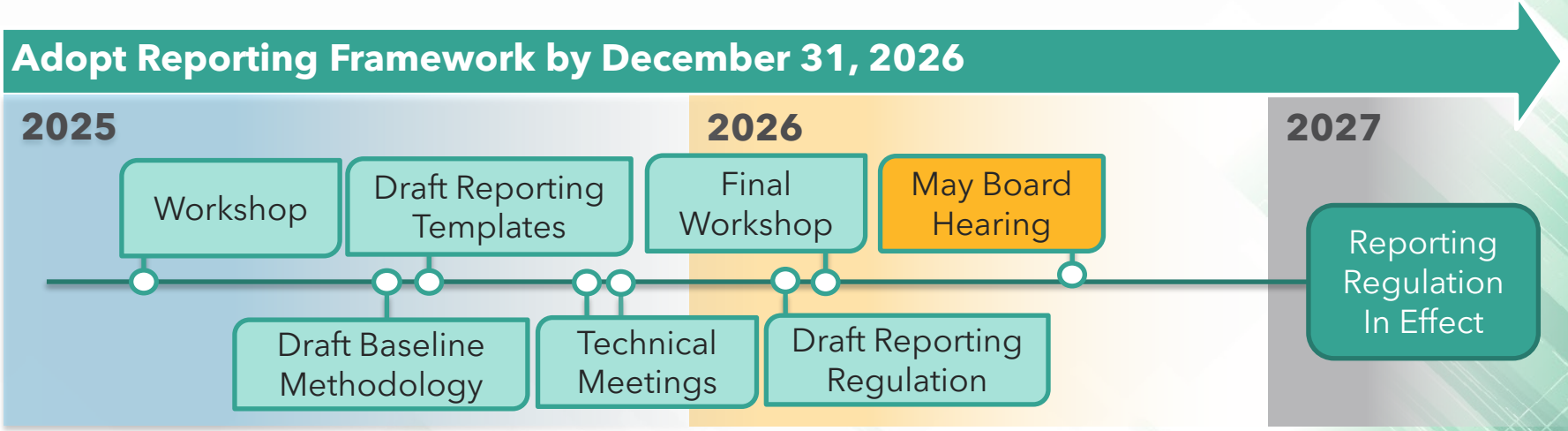
Submitting Feedback

- Provide feedback and review previous workshop content: https://ww2.arb.ca.gov/our-work/programs/building-decarbonization/embodied-carbon/embodied-carbon-meetings-and-workshops

Next Steps


Prior to Staff Report Release
Baseline Development
Reporting Regulation
Draft Input Output Model
Draft Baseline Methodology
Draft Reporting Templates
Technical Meeting on Baseline
Technical Meeting on Reporting
Updated Baseline Methodology
Final Baseline Proposed
Updated Templates
Draft Reg Text
Draft Staff Report Released
Third Public Workshop
Board Hearing

Program Timeline



Key References

- Ingwersen, Wesley W., Ben Young, Jorge Vendries, and Catherine Birney. 2024. **"USEEIO State Models V1.0: Environmentally-Extended Input-Output Models for U.S. States."** 600/R-23/228. Washington, D.C.: US Environmental Protection Agency, Office of Research; Development, Center for Environmental Solutions; Emergency Response. Read a description and download the report.

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- U.S. Environmental Protection Agency. 2024. **"Estimating Embodied Environmental Flows in International Imports for the USEEIO Model."** EPA 600/R-24/116. Read a description and download a copy of the report.

- Yang, Yi, Wesley W. Ingwersen, Troy R. Hawkins, Michael Srocka, and David E. Meyer. 2017. **"USEEIO: A New and Transparent United States Environmentally-Extended Input-Output Model."** Journal of Cleaner Production 158 (August): 308–18. Access the published paper.