Embodied Carbon Program

Baseline Assessment Tool for Building Sector Embodied Carbon

User Guide

August 20, 2025

Contents

Introduction

Health and Safety Code §38561.3(b) directs the California Air Resources Board (CARB) to establish a baseline for building sector emissions and to develop a reduction strategy:

> *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.*

To inform this baseline and strategy, CARB staff have *recommended* a top-down modeling approach that combines sector-based emissions data with an environmentally-extended input-output (EEIO) framework. Specifically, staff have proposed using a modified version of the U.S. Environmental Protection Agency's (US EPA) *USEEIO model*, calibrated with California-specific data.

To support this work, CARB has developed **a baseline assessment tool for building sector embodied carbon.** This tool incorporates outputs from the USEEIO model and allows users to define which economic sectors, industries, activities, and products should be considered part of California's building sector.

USEEIO

The USEEIO model is built on economic data from the U.S. Bureau of Economic Analysis (BEA), capturing both:

- The **inputs** (materials and services) required by each sector
- The **outputs** (commodities and products) each sector produces

The model attributes greenhouse gas (GHG) emissions to products and industries across three scopes:

- **Scope 1**: Direct emissions from a sector's operations
- **Scope 2**: Emissions from purchased energy
- **Scope 3**: Indirect emissions across the upstream supply chain

USEEIO supports regional customization. For California, CARB has configured the model to incorporate state-specific emissions factors based on CARB's Greenhouse Gas (GHG) Emissions Inventory. This allows for the development of life cycle emissions estimates tailored to California's unique economic and environmental profile.

At the center of USEEIO is the Leontief-Inverse matrix (also called the Total Requirements matrix, or L-Matrix). This matrix quantifies the full economic output (both direct and indirect) needed across all sectors to produce one unit of output in a specific sector.

By multiplying this L-Matrix with emissions factors, the model produces estimates of the total life cycle GHG emissions associated with producing one dollar of final demand for any given sector.

Example: Direct Requirements and Total Requirements

Direct Requirements

To produce $1 worth of concrete, a concrete manufacturer directly requires inputs such as:

- $0.16 of cement from the cement manufacturing sector.
- $0.10 of aggregates (sand, gravel, crushed stone) from the mining sector.
- $0.07 of truck and rail transport

Indirect Requirements

To produce the direct requirements for the concrete manufacturer, additional inputs will need to be sourced by those upstream entities that are providing the direct requirements for the concrete manufacturer. For instance:

- To produce cement ($0.16), the cement manufacturing sector requires raw materials like limestone, energy (often from coal and electricity), and transportation.
- To produce aggregates ($0.10), the mining sector requires fuel, explosives, and machinery.
- To provide transportation services ($0.07), the transportation sector needs fuel, vehicles, and infrastructure.

Total Requirements

The Leontief inverse matrix (L) captures all these direct and indirect requirements. The column for concrete in the L-matrix would show the total dollar value of output required from every sector in the economy (including aggregates, cement, electricity, transportation, mining, energy production, etc.) to ultimately deliver $1 of concrete to final demand.

The total requirement value will be greater than or equal to the corresponding direct requirements because they include the entire upstream supply chain.

California-Specific Adjustments to USEEIO Model

CARB has developed a California-customized implementation of the USEEIO model.[1] With several key modifications:

Blue Cell	User-defined value that can be changed
Blue Worksheet	User inputs required
Yellow Worksheet	Intermediate calculations, often derived from USEEIO
Orange Worksheet (hidden)	USEEIO model matrices
Green Worksheet	Final LCA results from the USEEIO model
Burnt Orange (hidden)	REMI model outputs

About

This worksheet introduces the baseline assessment tool layout.

Sector Selection

This worksheet allows users to define which economic sectors, activities, and commodities are considered part of California's building sector. Selections are based on U.S. Bureau of Economic Analysis (BEA) codes, which are also mappable to North American Industry Classification System (NAICS) codes.

To include a sector in the baseline emissions calculation, use the dropdown in column E to select "**TRUE**." This will include the final demand for that sector's commodities in the baseline. Selecting "**FALSE**" will exclude that sector from the calculation.

Reducing the number of included sectors will lower the total emissions attributed to the building sector.

[1] *https://github.com/leoal2/USEEIO_CARB_Runner?tab=readme-ov-file*

Dashboard Results

This worksheet displays the baseline emissions associated with the selected sectors.

- **Cells B5–B6**: Emissions are categorized into two groups:
    - Emissions from the construction industry (BEA and NAICS sector code 23-)
    - Emissions from all other included industries, materials and activities potentially attributable to the building sector
- **Cells B9–B10**: Emissions reduction required to achieve a 40% net reduction target.
- **Cells B10:** Selected year for estimating commodity demand

A dynamic pie chart provides a visual summary of emissions by BEA sector and updates automatically based on sector selections. **Note**: The baseline assessment tool should automatically update calculations. If updates do not occur, check that "**Calculation Options**" in the "**Formulas**" toolbar of Microsoft Excel is set to "**Automatic**."

Attributable Baseline Emissions

This worksheet shows life cycle emissions attributable to final demand for each selected sector, based on outputs from a California-specific implementation of the USEEIO model. Only sectors marked as "**TRUE**" in the *Sector Selection* worksheet will be displayed.

Demand Scaling

This worksheet shows the scaling factors the tool will use for different commodity demand. The scaling factor is calculated based on the chosen analysis year in the Dashboard worksheet and is calculated based on projections in the Regional Economic Models, Inc. (REMI) model. The REMI model is a model that CARB uses for assessing economic impacts for proposed regulations.

CA_L_Detailed_Estimate

This worksheet contains the **L-matrix**, derived from USEEIO and CARB data.

- **Rows** represent the economic sectors supplying output
- **Columns** represent sectors with one unit of final demand

- Each cell shows the **total economic output ($)** required from each row-sector to support **one unit of final demand ($)** for the column-sector

Direct Emission Factors

Direct emission factors represent the emission factors (kg CO_2e per dollar of output) associated with the direct requirements for a given sector. This emissions data is generated by the USEEIO model and parameterized with CARB's *GHG Emissions Inventory data.*

Life Cycle Emissions Factors

This worksheet provides **life cycle emissions factors** (kg CO_2e per dollar of output), accounting for both **direct and indirect** emissions across the supply chain. These are calculated by multiplying the **L-matrix** by the **Direct Emission Factor** matrix.

Hidden Worksheets

Several hidden worksheets support intermediate calculations and enhance tool functionality. These sheets do not accept user input or display final outputs and have been hidden to streamline the user interface.

Hidden Sheet Name	Description
Emissions Factor Scaling	Placeholder for future functionality. Entered values are multiplied by USEEIO-derived emissions factors. 1 means no scaling occurs.
REMI Scaling	This worksheet performs the calculations necessary to estimate the REMI scaling factors for commodity demand for the chosen analysis year
REMI_Trade Shares_CA	This worksheet is taken directly from REMI and estimates the trade share for commodity demand for California-produced commodity
REMI_Demand	This worksheet is taken directly from REMI and projects the demand for commodity in California over time

Hidden Sheet Name	Description
Building Sector Breakdown	Sheet used for aggregating results displayed in the chart on the Dashboard worksheet.
Final Demand Vector	Shows detailed final demand values based on any scaling that was enabled.
A_state_detailed	The calculated direct requirements matrix at a detailed BEA code level.
Sector Disambiguation	This worksheet provides additional data classifications from the BEA economic dataset.
SectorCrosswalk	This sheet provides a crosswalk table between Summary and Detailed NAICS and BEA codes.
2017_US_Consumption_Complete	This worksheet lists the national final consumption values ($) for each detailed BEA sector using 2017 data.
2022_US-CA_Consumption_Complete	This worksheet lists California's final consumption values ($) for each summary BEA sector using 2022 data.
Direct Inputs for Sector	This is an intermediate matrix that pulls the direct requirements vectors for each sector chosen to make up the building sector.
LCA of Direct Inputs to Sector	This worksheet estimates the life cycle emissions affiliated with all direct inputs into the selected sectors. This is done by multiplying values found in 'Life Cycle Emission Factors' by the direct requirement matrix ('A_state_detailed')
Aggregate LCA Direct Inputs	This matrix aggregates life cycle emissions estimates to specific BEA designations whether the material sourced is produced inside California or elsewhere.