Decomposition of Energy-related Carbon Emissions: California's Manufacturing Sector 2000-2021

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What's driving carbon emissions?

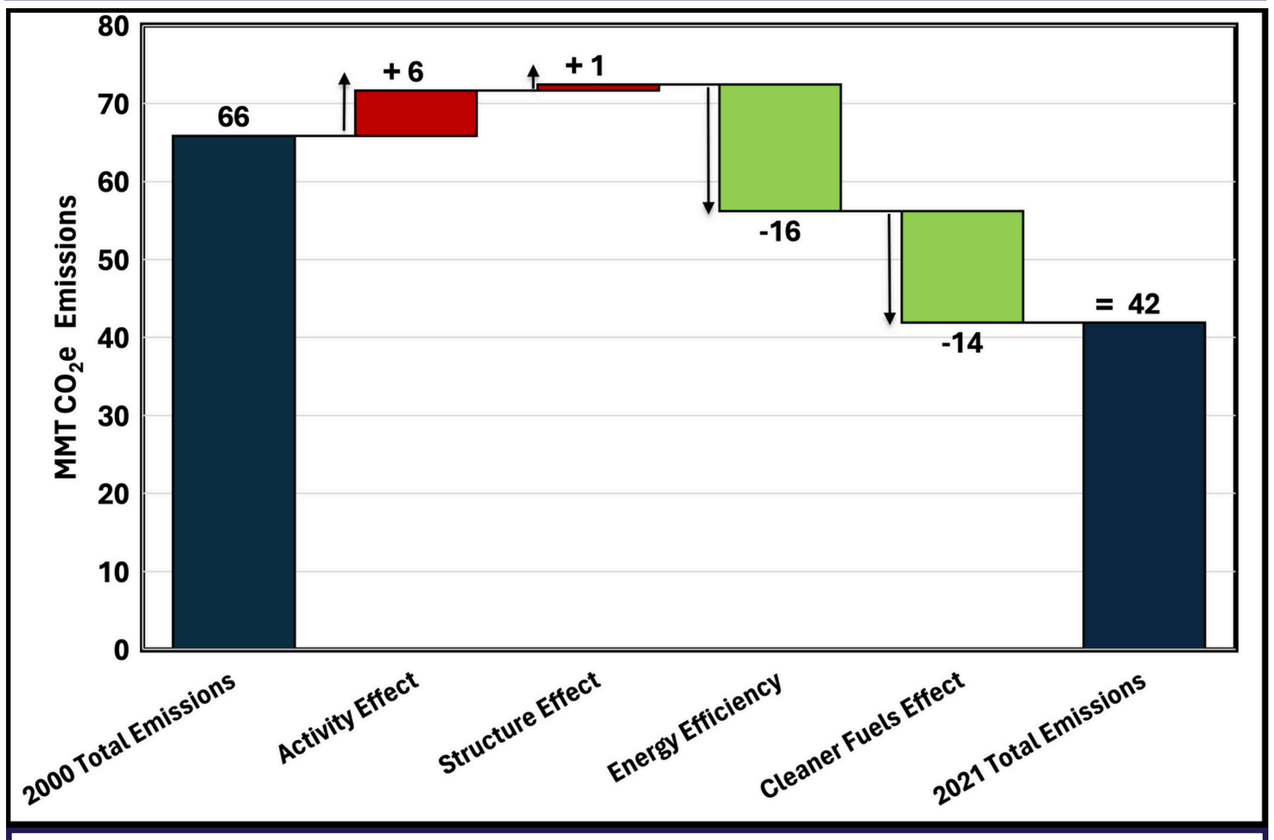
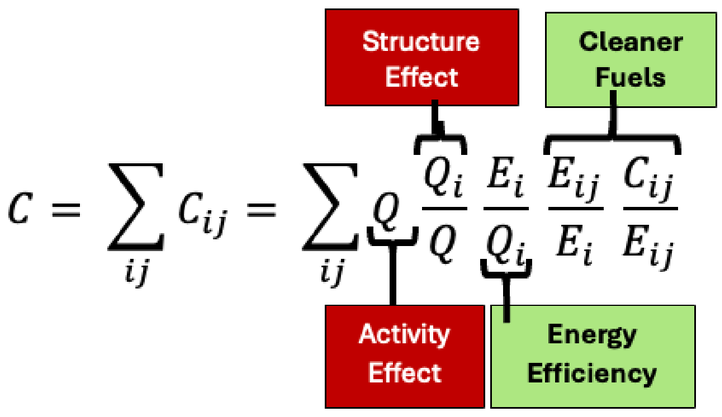


Figure 1: LMDI Decomposition of CA's Manufacturing Sector's Energy-Related Carbon Emissions 2000-2021.

Methodology And Data



This study uses an additive **Logarithmic Means Divisia Index (LMDI)** to decompose the carbon emissions of California's manufacturing sector for **2000-2021**. Additive LMDI is a widely used index decomposition analysis (IDA) method that starts with an identity expressing an aggregate quantity (energy or CO2) as a product of factors affecting it. The identity above expresses 2000 and 2021 CO2e emissions for each manufacturing sub-sector for each fuel as a product of the total manufacturing output **(Activity Effect)**, the sub-sector's share in it **(Structural Effect)**, the energy intensity of the sub-sector's output **(Energy Efficiency)**, and the carbon intensity of its fuel mix **(Cleaner Fuels Effect)**. To estimated the values for these effects, the relative change in the effects' quantitative indicators between the base year and the future year is weighted with the log mean of CO2e emissions in 2021 and 2000. The LMDI method leaves no residual and perfectly decomposes the change in CO2e emissions as a sum of the underlying effects.

The energy consumption data at the fuel level for each sub-sector was derived either directly **(U.S. EIA)** or indirectly by dividing CO2 emissions for each sub-sector and fuel combination **(CARB's GHG Emissions Inventory)** with the fuel's emissions factor **(U.S. EIA, CARB Inventory, and U.S. EPA)**. The data on manufacturing output for each sub-sector came from the **U.S. Bureau of Economic Analysis**. Data on 15 manufacturing sub-sectors (mostly with NAICS codes in 311 - 337 range) for 15 fuels was obtained from the sources above. For the ease of interpretation, the **15 sub-sectors were categorized as "energy-intensive" or "non energy-intensive"** and the **15 fuels were classified as fossil fuels or electricity**.

Ang, B. W. (2005). The LMDI approach to decomposition analysis: A practical guide. Energy Policy, 33(7), 867–871. https://doi.org/10.1016/j.enpol.2003.10.010

Silva, M., & Michaelis, C. (2019). IEA: An introduction to decomposition analysis. https://iea.blob.core.windows.net/assets/imports/events/613/7.IntroductiontodecompositionanalysisIEA.pdf

Discussion

Key Findings (Figure 1):

- Energy-related CO2e emissions decreased by 14 MMT between 2000 and 2021 (~21%).
- **Activity effect contributes to emissions increase:** The 11% growth in manufacturing output (real GDP) pushed emissions upwards. **Structural changes had a small but positive effect** in the emissions increase and a ~4% increase in the output share of energy-intensive sectors (Chemicals and Petroleum and Coal Products) contributed to the increase in emissions.
- **Energy Efficiency had the largest contribution to the decline in emissions, followed by cleaner fuels:** The fall in the energy intensity of manufacturing output and the lowered carbon intensity of fuels consumed drive all the decrease in emissions between 2000 and 2021.
- **Without energy efficiency measures and cleaner fuels**, the hypothetical **emissions in 2021 would have been ~11% higher** than 2000 (Figure 2).

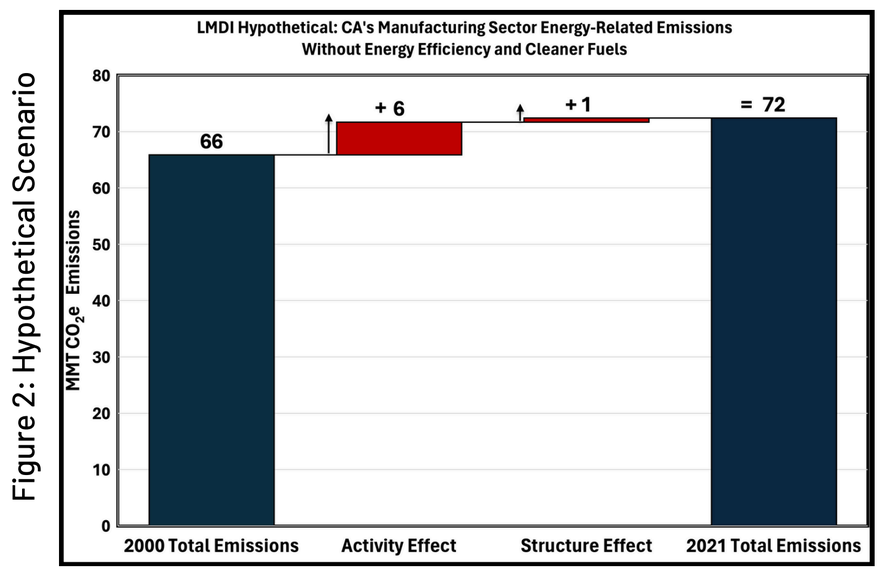


Figure 2: Hypothetical Scenario

Caveats & Considerations

The choice of a different analysis period can reveal variations in the magnitude and direction of effects driving CO2e emissions changes. Figure 3 decomposition of the more recent **2010-2021** period highlights **a structure effect contributing to a small decline in emissions**. This was primarily linked to the decline in the output share of energy-intensive industries. Nonetheless, **energy efficiency and cleaner fuels still dominate what drives the decline in emission**.

Caveats:

- Estimates of the structure effect could also be sensitive to what sub-sectors are labelled "energy-intensive".
- Electricity use data not available from CARB; estimated using U.S. EIA MECS West Region and CA industrial electricity use data.

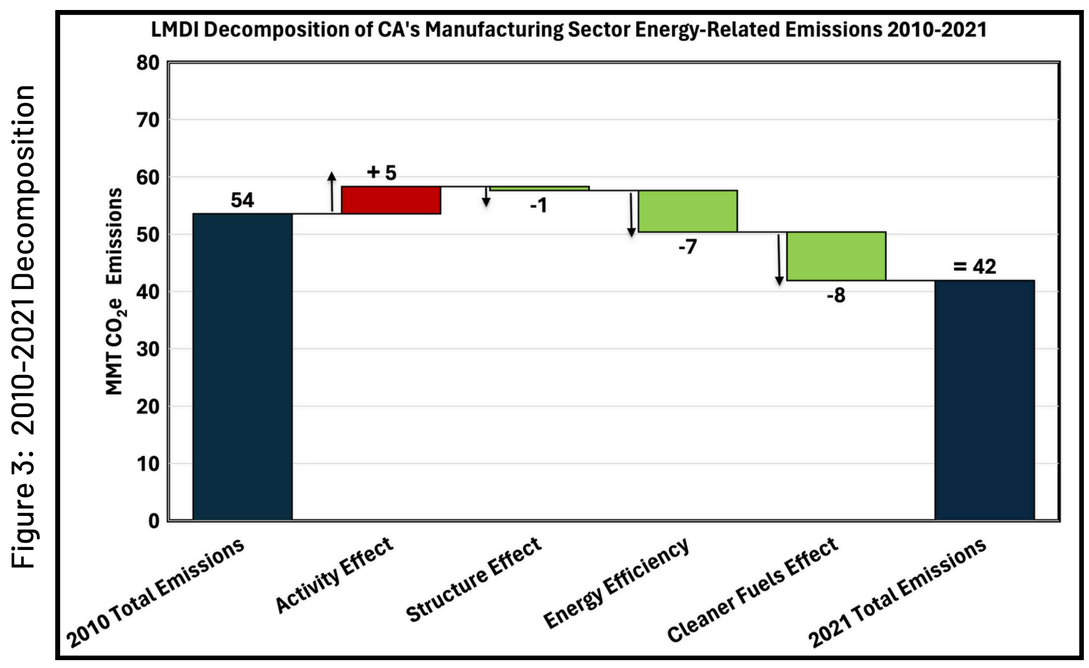


Figure 3: 2010-2021 Decomposition