Climate Leadership Council

Country-Level Analysis of Traditional Air Pollution Intensity

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OVERVIEW

The Climate Leadership Council has developed a body of research examining the relative emissions intensity of U.S. industry compared to major trading partners around the world. Building on that prior work—which focused on carbon and greenhouse gas emissions—this analysis offers similar insights into traditional air pollutants, including SO_2, NO_x, CO, and PM2.5.

This memorandum summarizes the results and methodology behind the Council's country-level analysis of air pollution intensity. It describes the data and steps taken to estimate how "pollution efficient" the U.S. is relative to other countries.

Results

Across the four major pollutants examined, the U.S. industrial sector produces significantly less pollution per dollar of output than most of the countries examined (Figure 1).

Figure 1 – Pollution Intensity by Substance (Metric Tons Pollutant / $1billion industrial value add)

	U.S.	Mexico	Canada	China	Taiwan	Germany	Japan	Vietnam	S. Korea	Ireland	India
SO2	167	1,712	608	1,093	115	180	272	5,815	202	7	7,938
NOx	366	847	740	1,357	272	230	382	3,756	422	41	3,092
CO	441	1,125	1,830	8,360	391	935	892	12,860	311	50	7,817
PM2.5	138	162	278	949	151	63	49	1,794	129	18	2,768

The Council also developed a multi-pollutant index for the industrial sector, which gives a composite view of pollution that considers the relative harm of different substances. The results are summarized in Figure 2 and methodology is described later in this paper. In the multi-pollutant analysis, we set the U.S. at a benchmark of 1.0. A country with a level above 1.0 signifies that the country has higher pollution per dollar of value added.

Figure 2 – U.S. Industrial Sector Pollution Advantage (U.S. = 1.0)

Country	Level
Mexico	2.5
China	7.1
Canada	2.5
Germany	0.8
Japan	0.9

Country	Level
Vietnam	19.3
South Korea	2.1
Taiwan	1.4
Ireland	0.2
India	25.0

METHODOLOGY

The sections below describe the data sources and calculation steps underlying these results.

Emissions data

Emissions data (usually in a unit like metric tons, "MT") is sourced from two places:

1. **A Community Earth-Atmosphere Data System (CEDS) for Historical Surface Fluxes** – CEDS[1] is a database maintained by the Pacific Northwest National Laboratory ("PNNL") with country- and sector-level pollution emissions.
   a. Aerosols = Black Carbon (BC) and Organic Carbon (OC)
   b. Aerosol Precursors and Reactive Compounds (SO_2, NOx, NH_3, CH_4, CO, NMVOC) as well as nitrous oxide (N_2O)
2. **Emissions Database for Global Atmospheric Research (EDGAR)** – EDGAR[2] is a database maintained by the European Commission. EDGAR has data on many of the same compounds as CEDS; the only additional compounds added to this analysis from the EDGAR database were PM2.5 and PM10.

Macroeconomic data

Calculating the pollution advantage requires both a numerator (the emissions data from CEDS and EDGAR) and a denominator, which in this case is measuring national-level economic activity with either gross domestic product (GDP) or industrial output in dollars.

The main data sources for the macroeconomic data in this analysis include:

1. **World Bank GDP**[3]
2. **World Bank Industrial Value-Added (VA)**[4]
3. **Federal Reserve Economic Data (FRED)**[5]
4. **OECD's input-output (IO) tables**[6] **and intercountry input-output tables (ICIO)**[7]
5. **Taiwanese Directorate General of Budget, Accounting, and Statistics (DGBAS)** – used to fill data for Taiwan not included by the World Bank

Total pollution intensity

Calculating a macroeconomic pollution intensity by compound involves taking national emissions of a compound in a year (e.g., NO_x, etc.) across all sectors and dividing it by total GDP. The resulting quotient yields a product in a unit like metric tons per $1 billion. Products across countries are then compared with the U.S. estimate.

Figure 3 – Flowchart Summarizing the Calculation Process for Economywide Emissions

National-level GDP (World Bank, etc.) + **National-level pollutants** (CEDS, EDGAR) = **Pollutants** (metric tons) per $1 billion GDP

For example, Figure 4 shows the U.S. has an advantage over most major world economies outside Europe in terms of metric tons of NO_x per dollar of GDP.

Figure 4 – U.S. NO_x Pollution Advantage (U.S. level = 1.0)

Country	Level
Australia	1.8
Brazil	4.0
Canada	2.2
China	3.5
France	0.7
Germany	0.6
India	9.2
Indonesia	14.2

Country	Level
Italy	0.8
Japan	1.0
Mexico	2.6
Russia	8.6
South Korea	1.4
Spain	1.3
Turkey	2.0
U.K.	0.6

This calculation is straightforward but looks at the entire national economy, including both the emissions and economic activity associated with the nonindustrial portions of the economy like agriculture, residential and commercial activities, and transportation.

To compare the pollution intensity of industrial sectors across countries, further calculations must be made to determine the level of total national emissions attributable to the industrial sector through direct use, electricity purchases, and fugitive emissions.

Industrial pollution intensity

CEDS reports emissions by detailed use. For example, within transportation, CEDS includes international aviation, domestic aviation, road, rail, international shipping, oil tanker loading, domestic navigation, and other transportation. To perform this analysis, these data should be aggregated into industrial, electricity, and fugitive by fuel type.[8]

The calculation process then follows:

1. “Own” industrial emissions are 100% attributable to the industrial sector.

2. “Indirect” purchase of power (equivalent to Scope 2 emissions in the GHG Protocol[9]) create pollution through power generation, transmission, and distribution. These emissions from the electricity sector are attributed to national-level industrial sectors based on the industrial sector’s share of total electricity load.

   Industrial load as a share of total load could be sourced from different places, but the most available and straightforward source is the “World Energy Balances” published by the International Energy Agency (“IEA”).[10] The IEA data show energy production and consumption across national economies starting with primary energy via intermediate transformations (e.g., natural gas for electricity or hydrogen, etc.) before eventually flowing to end-use customers by their economic sector.

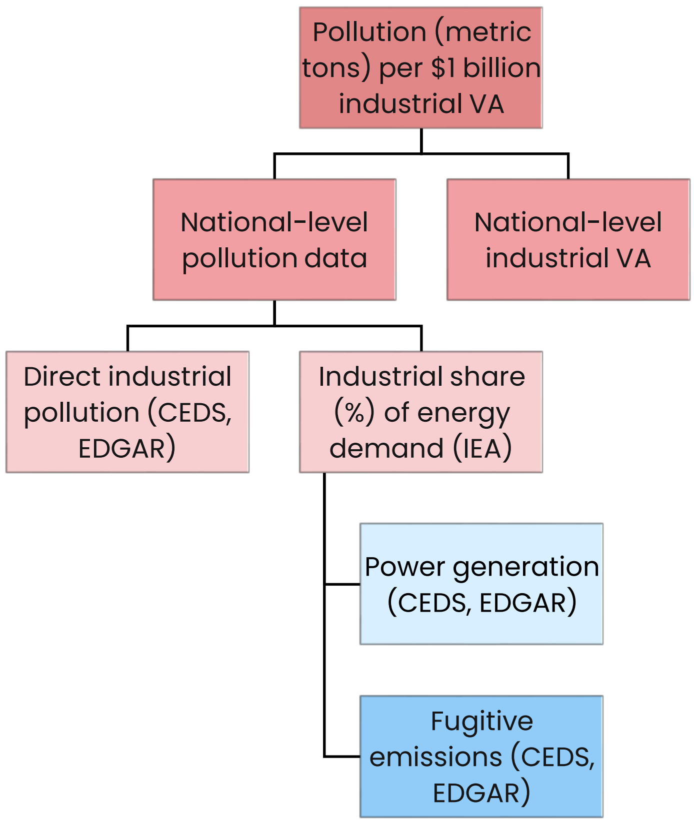
   The electricity flowing “into” the industrial sector is divided by total load and is multiplied by power sector emissions in order to perform the allocation.

3. Fugitive emissions are attributed to the industrial sector in a similar manner based on the industrial share of total coal, natural gas, and petroleum consumption.

Figure 5 summarizes this process. Starting from the bottom of the flowchart, pollution related to the power sector and fugitive emissions are attributed to the industrial sector based on the sector’s share of total demand by category. These results are then added to the total from the industrial sector’s direct use to produce attributable emissions.

The industrial-related pollution is then divided by industrial VA (industrial contribution to GDP) creating the pollution intensity in a unit like metric tons per $1 billion.

Figure 5 – Flowchart Summarizing the Calculation Process for Industrial Emissions

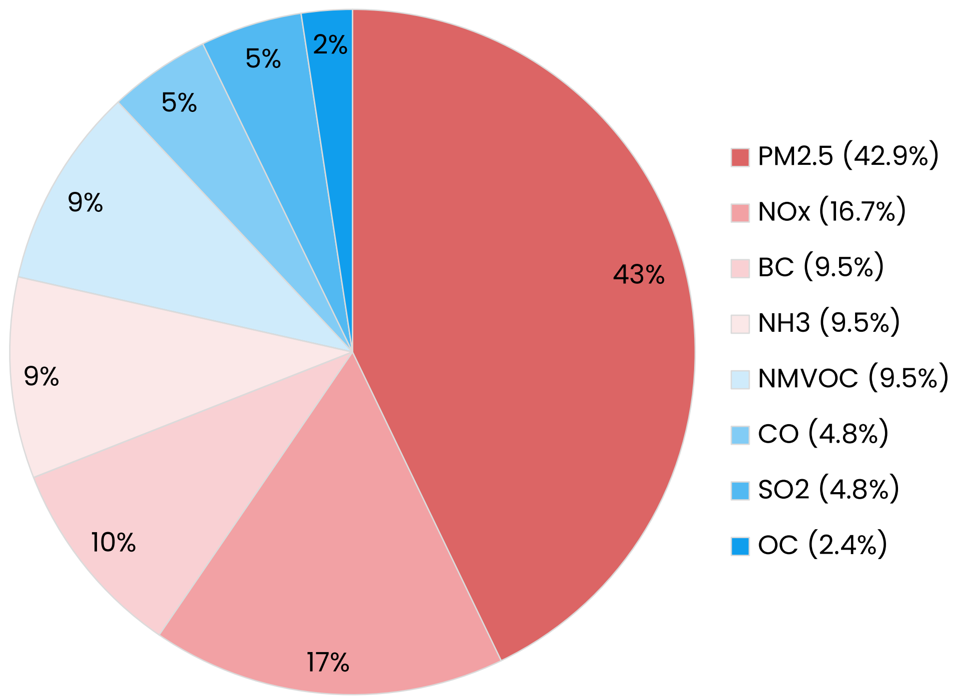


Multi-Compound Index

So far, the methodology only handles the pollution intensity and advantage for an individual compound—not a single comparison across the compounds. The most straightforward way to create a multi-compound index is a weighted average across compounds based on their relative impact on human health and quality of life as air pollution.

Different scientific papers could serve as potential sources for the weights, though the Council narrowed its focus on the Environmental Performance Index from Yale University.[11] Figure 14-2 on Page 189 has a sunburst chart showing the weights used in their index when analyzing the environmental quality by country. Figure 6 shows our focus on air quality.

Figure 6 – Weights from the Environmental Performance Index for a Multi-Compound Index



After adjusting for the weights, a clearer picture of the average U.S. industrial sector pollution advantage emerges in Figure 2 (recopied below).

Figure 2 – U.S. Industrial Sector Pollution Advantage (U.S. = 1.0)

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Ireland	0.2
India	25.0

The U.S. industrial sector produces significantly less pollution than most other countries.

Endnotes

[1] "A Community Earth-Atmosphere Data System (CEDS) for Historical Surface Fluxes," *Pacific Northwest National Laboratory*, https://www.pnnl.gov/projects/ceds
[2] "EDGAR – Emissions Database for Global Atmospheric Research," *European Commission*, https://edgar.jrc.ec.europa.eu/
[3] "Gross domestic product (GDP) in constant US$," *Our World in Data*, https://ourworldindata.org/grapher/gdp-worldbank-constant-usd
[4] "Industry (including construction), value added (constant 2015 US$)," *World Bank*, https://data.worldbank.org/indicator/NV.IND.TOTL.KD
[5] "Industrial Production: Total Index," *Federal Reserve Economic Data*, https://fred.stlouisfed.org/series/INDPRO
[6] "Input-Output Tables," *OECD*, https://www.oecd.org/en/data/datasets/input-output-tables.html
[7] "Intercountry Input-Output Tables," *OECD*, https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html
[8] Coal, Gas, Oil, and Other
[9] Mary Sotos, "GHG Protocol Scope 2 Guidelines," *World Resources Institute*, https://ghgprotocol.org/sites/default/files/2023-03/Scope%202%20Guidance.pdf
[10] "World Energy Balances," *International Energy Agency*, https://www.iea.org/data-and-statistics/data-product/world-energy-balances
[11] "Environmental Performance Index, 2024," *Yale University*, https://epi.yale.edu/downloads/2024-epi-report-20250106.pdf