

**Understanding the Decline in Japan's CO2  
Emissions: Evidence from Factor  
Decomposition**

**Report**

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# Understanding the Decline in Japan's CO2 Emissions: Evidence from Factor Decomposition<sup>†</sup> (Report)

March 2026

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## 1. Introduction

The Paris Agreement was adopted at the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, France, in 2015. It established a shared long-term global goal to “pursue efforts to limit the global average temperature increase to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C.” Furthermore, at COP26 in Glasgow, UK, in 2021, the Glasgow Climate Pact was adopted, incorporating the commitment to “pursue efforts to limit the global average temperature increase to 1.5°C above pre-industrial levels by the end of the 21st century.”

In response to these developments, the United States has set a 2030 target to reduce greenhouse gas (GHG) emissions by 50–52% below 2005 levels and to achieve carbon neutrality (net zero) by 2050. The European Union has set a 2030 target to reduce GHG emissions by at least 55% below 1990 levels and to achieve carbon neutrality by 2050.<sup>1</sup> Similar trends have been reported worldwide.

In October 2020, Japan declared its aim to achieve carbon neutrality by 2050.<sup>2</sup> In April

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<sup>1</sup> GHGs comprise CO<sub>2</sub>, methane, nitrous oxide, fluorinated gases, and others. CO<sub>2</sub> emissions account for 92.3% of Japan's total GHG emissions (FY2023), making CO<sub>2</sub> the predominant component. Carbon neutrality refers to the concept of balancing the emissions and absorption of GHGs such as CO<sub>2</sub>, thereby reducing emissions to “net zero.”

<sup>2</sup> Prime Minister Suga declared Japan's commitment to achieving carbon neutrality by 2050 in his policy address on October 26, 2020. Furthermore, at the Headquarters for Global Warming Prevention Policy and the U.S.-hosted Climate Summit in April 2021, Prime Minister Suga stated: “As an ambitious target consistent with the 2050 goal, we aim to reduce greenhouse gas emissions by 46% from fiscal year 2013 levels by fiscal year 2030. We will continue to strive toward the higher target of

2021, it announced a target to reduce GHG emissions by 46% compared to fiscal year (FY) 2013 levels by FY2030 and further stated its aspiration to aim for a 50% reduction. In February 2025, the Cabinet approved the “Global Warming Response Plan,” setting ambitious targets on a linear path toward achieving carbon neutrality by 2050: a 60% reduction by FY2035 and a 73% reduction by FY2040. This new resolution constitutes “Japan’s Nationally Determined Contribution (NDC)” to the UNFCCC Secretariat.

In recent years, driven by the government’s Green Transformation (GX) policies and heightened national awareness of climate change, Japan’s carbon dioxide (CO<sub>2</sub>) emissions have been decreasing. This shift is evident in the transition from fossil fuel-based power generation to renewable energy. This study examines trends in Japan’s CO<sub>2</sub> emissions and attempts to clarify the factors contributing to their increase and decrease.

**2. Trends in CO<sub>2</sub> Emissions**

Figure 1 shows the trend in Japan’s CO<sub>2</sub> emissions using the “direct emissions” calculation method, which includes CO<sub>2</sub> emissions from power generation by electric utilities under the energy transition sector.<sup>3</sup>

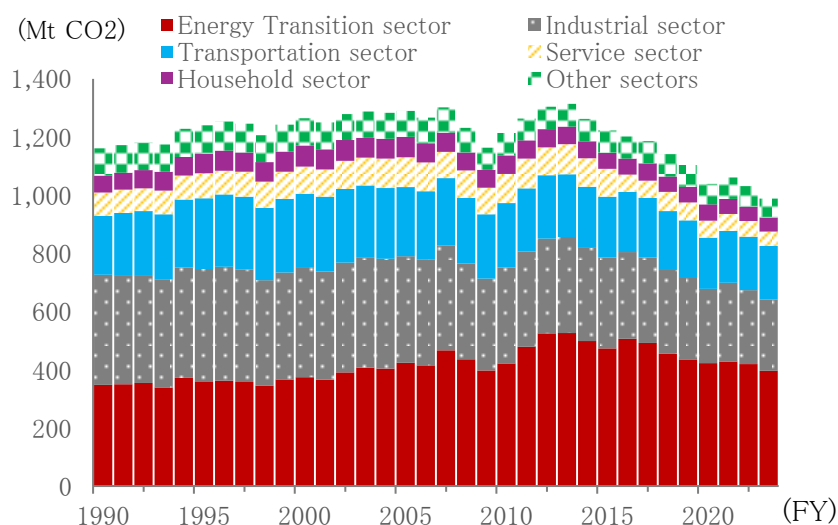
After 1990, CO<sub>2</sub> emissions gradually increased. However, following the economic downturn triggered by the Global Financial Crisis in September 2008, emissions decreased in FY2009. During the Great East Japan Earthquake in March 2011, the shutdown of nuclear power plants led to a significant increase in emissions from the energy transition sector (red bars), including power companies converting coal, oil, and other fuels into electricity between FY2011 and FY2012 (Figure 1). Subsequently, emissions peaked in FY2013 and began to decline, primarily in the industrial sector (gray bars), which comprises manufacturing, construction, agriculture, forestry, fisheries, and mining.

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50%.”

<sup>3</sup> There are two methods for calculating CO<sub>2</sub> emissions: “direct emissions” and “indirect emissions.” The “direct emissions” calculation method attributes CO<sub>2</sub> emissions from power generation by utilities to the energy transition sector. In contrast, the “indirect emissions” calculation method attributes CO<sub>2</sub> emissions from power generation by utilities to the respective sectors that consume the electricity. As the industrial sector, primarily manufacturing, consumes large amounts of electricity, under the indirect emissions method, CO<sub>2</sub> emissions from the industrial sector are estimated to be approximately 30% attributable to power companies.

**Figure 1: Japan’s CO2 Emissions (Direct Emissions)**



(Source) National Institute for Environmental Studies

### 3. CO2 Emission Factor Decomposition Formula

Changes in CO2 emissions are analyzed by decomposing them into factors such as fluctuations in economic activity (economic output), progress in energy conservation, and shifts to renewable energy. As shown in the following equation, known as the “Kaya Identity,” “CO2 emissions” are represented by the product of three factors: economic activity (real GDP), the energy efficiency of economic activity (energy consumption divided by real GDP), and CO2 emissions per unit of energy consumption (CO2 emissions divided by energy consumption).<sup>4</sup>

$$CO2\ Emissions = Real\ GDP \times \frac{Energy\ Consumption}{Real\ GDP} \times \frac{CO2\ Emissions}{Energy\ Consumption}$$

The first term on the right-hand side is real GDP, a proxy variable for economic activity (economic output). During economic booms, increased consumer demand leads to higher factory production, thereby increasing CO2 emissions. In contrast, during recessions, such as the 2008 Global Financial Crisis or the COVID-19 pandemic, reduced consumer demand leads to lower production in factories and decreased CO2 emissions.

<sup>4</sup> The Kaya Identity was reported by Professor Yoichi Kaya of the University of Tokyo to the Energy and Industry Sub-Committee established under Working Group III of the Intergovernmental Panel on Climate Change (IPCC) to discuss global warming countermeasures. It was also included in the IPCC’s First Assessment Report published in 1990 (Nikkei, December 22, 2018, “My Resume: Yoichi Kaya (21) Kaya Identity—Simplifying CO2 Emissions, Decomposing into Three Elements, Forming the Basis of Analysis” [in Japanese]).

The second term on the right-hand side indicates the energy consumption required to generate one unit of real GDP (economic output) and is referred to as “energy intensity (energy intensity per unit of economic output).” By developing and utilizing energy-saving technologies—such as switching to LED lighting and high-efficiency air conditioning, improving insulation, and adopting industrial and automotive motors with high energy efficiency—energy consumption can be reduced while maintaining production levels. This lowers energy intensity and consequently reduces CO2 emissions.

The third term on the right-hand side represents the amount of CO2 emitted per unit of energy consumed and is referred to as “carbon intensity (CO2 emission intensity).” Carbon intensity can be reduced, thereby decreasing CO2 emissions, by switching from CO2-emitting coal- and oil-fired power generation to CO2-free renewable energy and nuclear power generation.

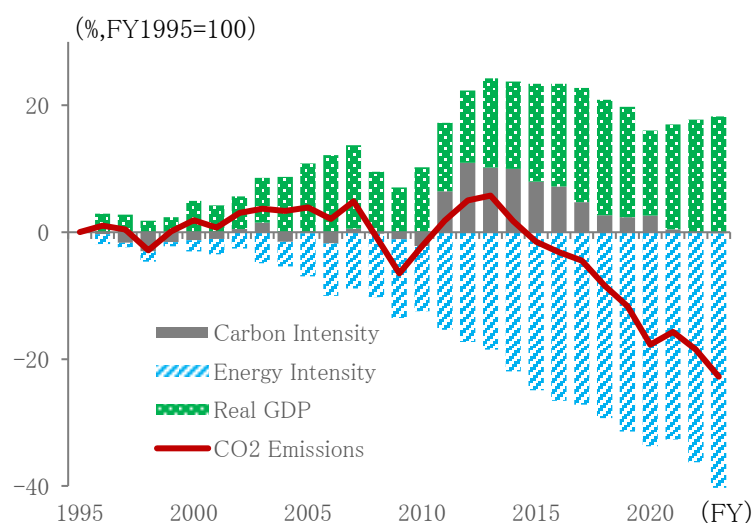
This factor decomposition enables a quantitative assessment of whether the reduction in CO2 emissions since 2014 is attributable to (1) economic fluctuations, (2) progress in energy conservation, or (3) a shift to renewable energy sources (decarbonization of energy sources).

#### **4. Factor Decomposition of CO2 Emissions**

The red line in Figure 2 shows the rate of change in CO2 emissions relative to the FY1995 baseline. Positive and negative values indicate, respectively, an increase and a decrease in emissions compared to 1995. The rate of change in CO2 emissions relative to 1995 declined after FY2014, widening the negative margin and reaching a decrease of 20% compared to 1995 in the most recent FY (FY2023).

Furthermore, this rate of change is decomposed into the following factors using the above formula: real GDP (green bars), energy intensity (blue bars), and the carbon intensity of energy consumption (gray bars).

**Figure 2: Factor Decomposition of Japan's CO2 Emissions**



First, as Japan's economy continues to grow, real GDP contributes to an increase in CO2 emissions. However, during recessions, such as the Global Financial Crisis (FY2008) and the COVID-19 pandemic (FY2020), the negative growth rate of real GDP slows, contributing to a decrease in CO2 emissions.

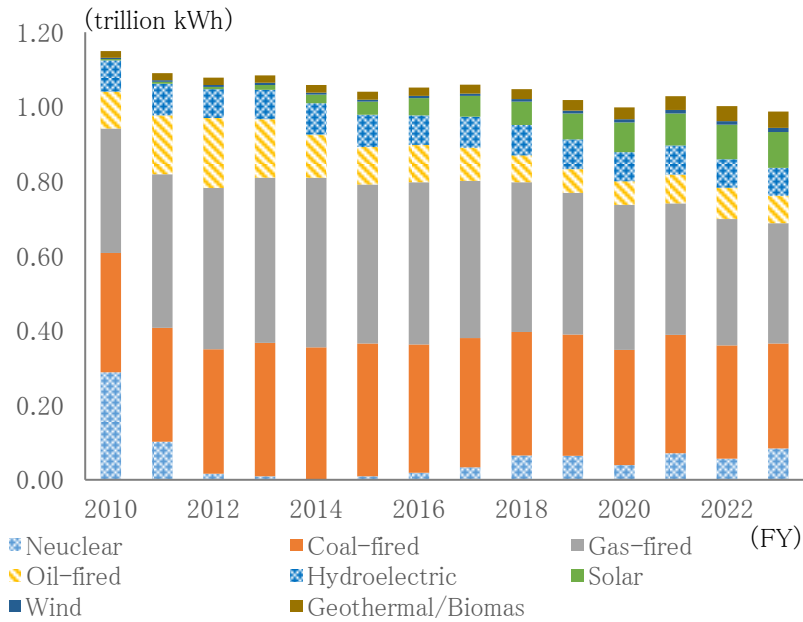
Second, energy intensity has consistently widened its negative margin, significantly contributing to CO2 emission reductions. Energy conservation has progressed through measures such as switching to LED lighting and introducing hybrid vehicles. Coupled with vigorous energy-saving advances in the industrial sector (discussed later), energy consumption has remained flat or declined relative to real GDP growth. The 1998 revision of the Act on the Rational Use of Energy (Act on Rationalization of Energy Use and Shift to Non-fossil Energy, enforced in April 1999) also contributed to progress in energy conservation. This revision introduced (1) the Top Runner Program for machinery, equipment, and automobiles and (2) medium- to long-term energy conservation targets requiring an average annual reduction of at least 1% in factories and similar facilities (discussed later).<sup>5</sup>

Finally, the carbon intensity of energy consumption increased in FY2011, contributing to higher emissions. This increase was due to a shift from non-CO2-emitting nuclear power to CO2-emitting coal-, oil-, and gas-fired power generation following the Great East Japan

<sup>5</sup> The Top Runner Program sets standards aiming to exceed the values of the most energy-efficient equipment available at the time the standard is established (maximum standard method). Specifically, if a car achieves 15 km/L, efficiency is assumed to be the most fuel-efficient "top runner" among vehicles sold in the year the standard is set, and the standard for the following year is set at 15 km/L. From the next year, manufacturers advance energy-saving development with the goal of achieving 15 km/L fuel efficiency. If the standard is not met by the target year, manufacturers are obligated to report the reasons for non-compliance and their future countermeasures.

Earthquake in March 2011. Subsequently, the positive margin of carbon intensity narrowed because of the shift toward renewable energy sources, contributing to a reduction in CO2 emissions. Figure 3 shows trends in Japan’s power generation by source. Over the last decade, power generation from renewable energy sources—comprising hydroelectric, solar, wind, and geothermal/biomass power—has increased (share of total power generation: FY2012, 10% → FY2023, 23%). Nuclear power generation has also increased since the restart of reactors (share of nuclear power generation in total: FY2012, 1% → FY2023, 9%).

**Figure 3: Japan’s Power Generation by Source**



(Source) Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry

**5. Factor Decomposition of CO2 Emissions in the Industrial Sector**

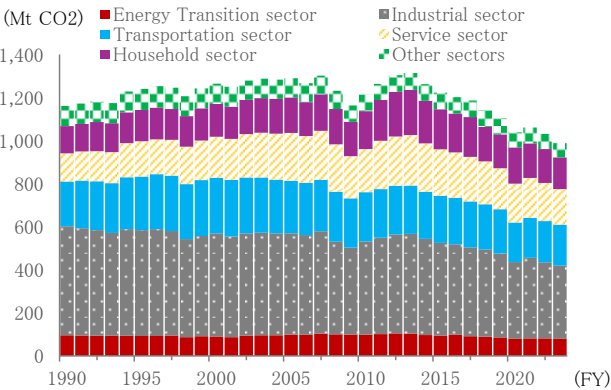
We analyzed differences in trends between Japan as a whole and the industrial sector (manufacturing, construction, agriculture, forestry, fisheries, and mining) by decomposing the factors behind increases or decreases in CO2 emissions from this sector, which had the second-highest CO2 emissions after the energy transition sector.

Figure 4 shows the trend in CO2 emissions using the aggregation method for “indirect emissions,” in which CO2 emissions from power generation by utilities are attributed to electricity users. As the industrial sector, centered on manufacturing, uses electricity for economic activities (production), analyzing CO2 emissions, including electricity purchased from utilities, allows for a comprehensive analysis of the flow from energy consumption-based production to production-based CO2 emissions.

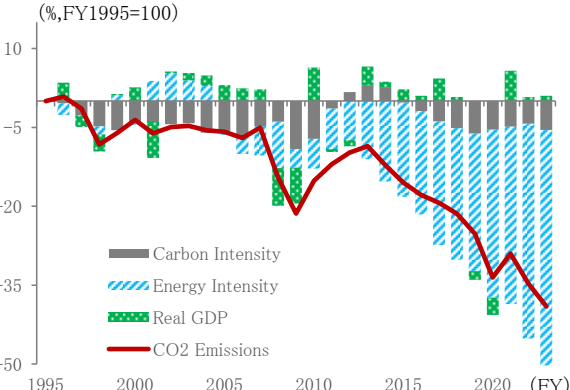
Considering each sector, first, the industrial, service (including wholesale/retail and

accommodation/food services), and household sectors all use significant amounts of electricity for economic activities. Consequently, the share of CO2 emissions from these three sectors is larger compared to the “direct emissions” calculation method shown in Figure 1.<sup>6</sup> Next, the increase in CO2 emissions resulting from the shutdown of nuclear power plants following the Great East Japan Earthquake between FY2011 and FY2012 is reflected in the increased CO2 emissions from these three electricity-consuming sectors. Finally, as shown by the “direct emissions” calculation method in Figure 1, CO2 emissions from the industrial sector peaked in FY2013 and have been declining continuously since then.

**Figure 4: Japan’s CO2 Emissions (Indirect Emissions)**



**Figure 5: Factor Decomposition of CO2 Emissions in the Industrial Sector**



(Source) National Institute for Environmental Studies

Figure 5 shows the rate of change in CO2 emissions in the industrial sector relative to the FY1995 baseline.<sup>7</sup> CO2 emissions relative to FY1995 (red line) show a larger negative change (-32% in FY2023) than Japan’s overall emissions (-20% in FY2023), as shown in Figure 2.

Considering the decomposition of factors affecting CO2 emission changes, we examined the background behind the larger negative change compared to Japan as a whole.

First, real GDP (green bars) shows a smaller positive margin than Japan’s overall real GDP in Figure 2 because of factors such as reduced exports resulting from the overseas relocation

<sup>6</sup> In the aggregation method for “indirect emissions,” CO2 emissions from power companies account for approximately 30% in the industrial sector, approximately 70% in the commercial and other sectors, and approximately 60% in the residential sector.

<sup>7</sup> In the calculations, CO2 emissions from “Industrial Processes and Product Use” were added to the industrial sector. This is because, for example, in cement manufacturing, energy-derived CO2 emissions account for 40% and limestone-derived CO2 emissions account for 60% (Cement Association) of total CO2 emissions. However, in the statistics, limestone-derived CO2 emissions are recorded under “Industrial Processes and Product Use” rather than the “Industrial Sector.”

of manufacturing production.

Second, energy intensity (blue bars) shows a significant negative margin, contributing substantially to the reduction in CO<sub>2</sub> emissions. However, the notable expansion in the negative margin of energy intensity occurred in the early 2010s, which was slightly later than the expansion seen in Figure 2 for Japan's overall energy intensity. This is because the 1998 revision of the Energy Conservation Law (enforced in April 1999) required that "energy consumption intensity (energy consumption/economic output, i.e., energy intensity) be reduced by an average of at least 1% per year over the medium to long term for each factory or business operator." However, the 2013 revision of the Act on the Rational Use of Energy (enforced in December 2013) added the goal of "reducing the electricity demand leveling evaluation unit (calculating energy consumption by multiplying energy consumption during peak electricity demand periods by 1.3 to determine energy intensity) by an average of at least 1% per year." This amendment likely required factories and businesses to further intensify their energy conservation efforts. Against this background, energy intensity has been decreasing, particularly in the chemical industry, because of (1) the introduction of cogeneration systems that utilize steam and hot water generated from waste heat in blast furnaces and coal-fired power plants within the steel industry for manufacturing processes, absorption chillers for air conditioning, and hot water supply and (2) the adoption of energy-saving technologies such as the "gas diffusion electrode electrolysis method" in caustic soda production.<sup>8</sup>

Finally, the carbon intensity of energy consumption (gray bars) generally follows the same trend as Japan's overall carbon intensity, as shown in Figure 2. This similarity is partly because power companies account for approximately 30% of total CO<sub>2</sub> emissions. Carbon intensity turned positive after the Great East Japan Earthquake and then turned negative again following the shift toward renewable energy.

However, a recent difference can be observed in the slight narrowing of the negative margins of carbon intensity. This may be influenced by sectors such as steel, chemicals, cement, and paper within the industrial sector, which require high-temperature chemical reactions in their manufacturing processes and thus generate their own CO<sub>2</sub> emissions using coal-fired power generation. To achieve carbon neutrality by 2050, the industrial sector must also develop and implement new technologies that do not emit CO<sub>2</sub> (fuel switching).

By decomposing CO<sub>2</sub> emissions by sector, it is possible to discuss detailed policy responses.

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<sup>8</sup> The "Gas Diffusion Electrode Electrolysis Method" is reported to have reduced required power consumption by nearly 40% compared to the then-conventional "Ion Exchange Membrane Electrolysis Method" by using a gas diffusion electrode, catalyzed by silver or similar materials, as the cathode in the salt electrolysis cell.

## 6. Conclusion

The factor decomposition of CO<sub>2</sub> emissions growth and decline indicates that Japan's CO<sub>2</sub> emissions are decreasing owing to the significant negative contribution of energy intensity, reflecting substantial progress in energy conservation. Furthermore, in recent years, the positive contribution of carbon intensity has been shrinking, suggesting that shifts toward renewable energy are contributing to reductions in CO<sub>2</sub> emissions.

To achieve Japan's target of "reducing GHG emissions by 46% compared to fiscal 2013 levels by fiscal 2030," it will be necessary to (1) further advance energy conservation and (2) shift to renewable energy sources centered on solar and wind power, as well as CO<sub>2</sub>-free power generation such as nuclear energy (decarbonizing energy sources).

Moreover, to achieve carbon neutrality by 2050, from the perspective of developing new technologies for CO<sub>2</sub>-free power generation under point (2), the following are potential avenues for reducing CO<sub>2</sub> emissions: (a) establishing implementation and mass production technologies for film-type perovskite solar cells; (b) developing floating offshore wind power; and (c) developing and implementing power generation using co-firing or dedicated firing of hydrogen and ammonia at existing coal- and gas-fired power plants, leveraging Japan's comparative technological advantages. Additionally, developing and implementing carbon capture and storage (CCS) technology to separate and capture CO<sub>2</sub> emitted from thermal power generation and other sources and then stably store it underground over the long term is also a foreseeable prospect.

Furthermore, the industrial sector (manufacturing, construction, agriculture, forestry, fisheries, and mining), which has the second-highest CO<sub>2</sub> emissions after the energy transition sector, requires strong advancements toward carbon neutrality. This can be achieved through measures such as AI-driven energy savings in factories, a shift from blast furnaces to electric furnaces and the adoption of hydrogen-based steelmaking in the iron and steel industry, fuel switching in self-generated coal-fired power plants to hydrogen or ammonia, and feedstock conversion from naphtha-derived materials.

Recently, large-scale projects such as offshore wind power construction and hydrogen/ammonia supply chain development have commenced. Given the substantial funding required for these projects, financial institutions are expected to further leverage project financing and other financial tools to supply risk capital and stimulate GX investments.

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