CO2 Emissions in 2022

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Key messages

- **Global energy-related CO_2 emissions grew by 0.9% or 321 Mt in 2022, reaching a new high of over 36.8 Gt.** Following two years of exceptional oscillations in energy use and emissions, caused in part by the Covid-19 pandemic, last year's growth was much slower than 2021's rebound of more than 6%. Emissions from energy combustion increased by 423 Mt, while emissions from industrial processes decreased by 102 Mt.
- In a year marked by energy price shocks, rising inflation, and disruptions to traditional fuel trade flows, **global growth in emissions was lower than feared**, despite gas-to-coal switching in many countries. Increased deployment of clean energy technologies such as renewables, electric vehicles, and heat pumps helped prevent an additional 550 Mt in CO_2 emissions. Industrial production curtailment, particularly in China and Europe, also averted additional emissions.
- **Specific challenges in 2022 contributed to the growth in emissions.** Of the 321 Mt CO_2 increase, 60 Mt CO_2 can be attributed to cooling and heating demand in extreme weather and another 55 Mt CO_2 to nuclear power plants being offline.
- **CO_2 growth in 2022 was well below global GDP growth of 3.2%**, reverting to a decade-long trend of decoupling emissions and economic growth that was broken by 2021's sharp rebound in emissions. Improvements in the CO_2 intensity of energy use were slightly slower than the past decade's average.
- **Emissions from natural gas fell by 1.6% or 118 Mt**, following continued tightening of supply exacerbated by Russia's invasion of Ukraine. Reductions in emissions from gas were particularly pronounced in Europe (-13.5%). The Asia Pacific region also saw unprecedented reductions (-1.8%).
- **Increased emissions from coal more than offset reductions from natural gas**. Amid a wave of gas-to-coal switching during the global energy crisis, CO_2 emissions from coal grew by 1.6% or 243 Mt, far exceeding the last decade's average growth rate, and reaching a new all-time high of almost 15.5 Gt.
- **Emissions from oil grew even more than emissions from coal, rising by 2.5% or 268 Mt to 11.2 Gt.** Around half of the increase came from aviation, as air travel continued to rebound from pandemic lows, nearing 80% of 2019 levels. Tempering this increase, electric vehicles continued to gain momentum in 2022, with over 10 million cars sold, exceeding 14% of global car sales.
- **The biggest sectoral increase in emissions in 2022 came from electricity and heat generation,** whose emissions were up by 1.8% or 261 Mt. In particular, global emissions from coal-fired electricity and heat generation grew by 224 Mt or 2.1%, led by emerging economies in Asia.
- **A strong expansion of renewables limited the rebound in coal power emissions**. Renewables met 90% of last year's global growth in electricity

generation. Solar PV and wind generation each increased by around 275 TWh, a new annual record.

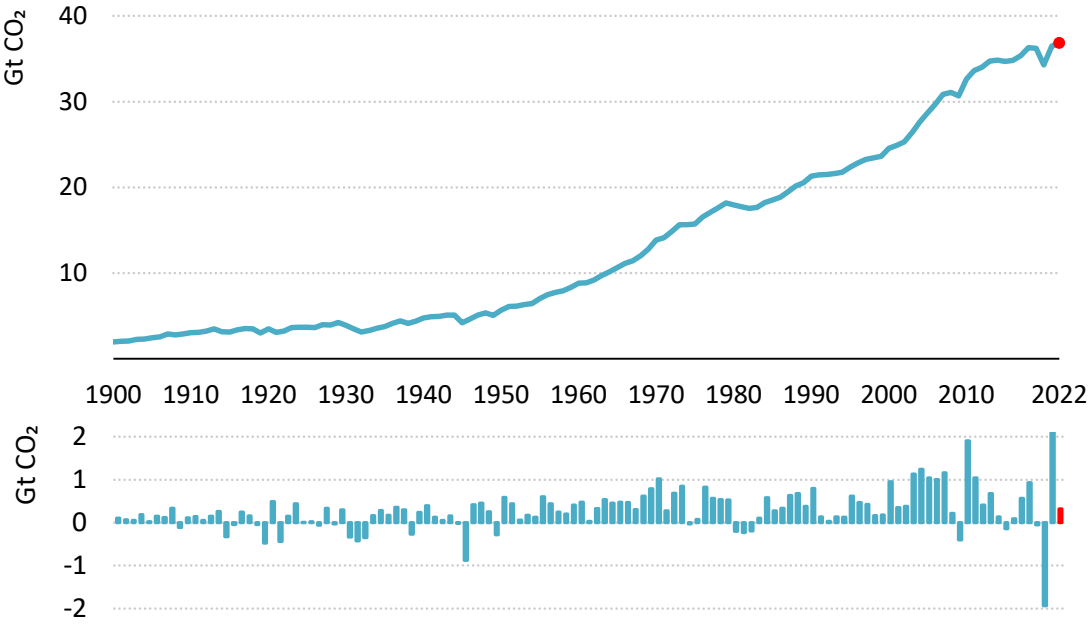
- **Emissions from industry declined by 1.7% to 9.2 Gt last year**. While several regions saw manufacturing curtailments, the global decline was largely driven by a 161 Mt CO_2 decrease in China's industry emissions, reflecting a 10% decline in cement production and a 2% decline in steel making.
- **China's emissions were relatively flat in 2022, declining by 23 Mt or 0.2%.** Growing emissions from combustion were offset by declines from industrial processes. Weaker economic growth, declining construction activity, and strict Covid-19 measures led to reductions in industrial and transport emissions. Power sector emissions growth slowed compared with the average of the past decade but still reached 2.6%.
- **The European Union saw a 2.5% or 70 Mt reduction in CO_2 emissions** despite oil and gas market disruptions, hydro shortfalls due to drought, and numerous nuclear plants going offline. Buildings sector emissions fell markedly, helped by a mild winter. Although power sector emissions increased by 3.4%, coal use was not as high as anticipated. For the first time, electricity generation from wind and solar PV combined exceeded that of gas or nuclear.
- **US emissions grew by 0.8% or 36 Mt. The buildings sector saw the highest emissions growth, driven by extreme temperatures.** The main emissions reductions came from electricity and heat generation, thanks to unprecedented increases in solar PV and wind, as well as coal-to-gas switching. While many other countries reduced their natural gas use, the United States saw an increase of 89 Mt in CO_2 emissions from gas, as it was called upon to meet peak electricity demand during summer heat waves.
- **Emissions from Asia's emerging market and developing economies, excluding China, grew more than those from any other region in 2022,** increasing by 4.2% or 206 Mt CO_2. Over half of the region's increase in emissions came from coal-fired power generation.
- This report is the first in the **IEA's new series, the *Global Energy Transitions Stocktake***. The new tracker consolidates the IEA's latest analysis in one place, making it freely accessible in support of the first Global Stocktake in the lead-up to COP 28.

Energy-related CO_2 emissions grew by 0.9% to over 36.8 Gt in 2022

Global carbon dioxide (CO_2) emissions from energy combustion and industrial processes[1] grew 0.9% or 321 Mt in 2022 to a new all-time high of 36.8 Gt. This estimate is based on the IEA's detailed region-by-region and fuel-by-fuel analysis, incorporating the latest official national statistics and publicly available data on energy use, economic indicators, and weather.

Last year's increase follows two years of exceptional oscillations in energy-related emissions. Emissions shrank by more than 5% in 2020, as the Covid-19 pandemic cut energy demand. In 2021, emissions rebounded past pre-pandemic levels, growing more than 6% in tandem with economic stimulus and the roll-out of vaccines.

Figure 1: Global CO_2 emissions from energy combustion and industrial processes and their annual change, 1900-2022



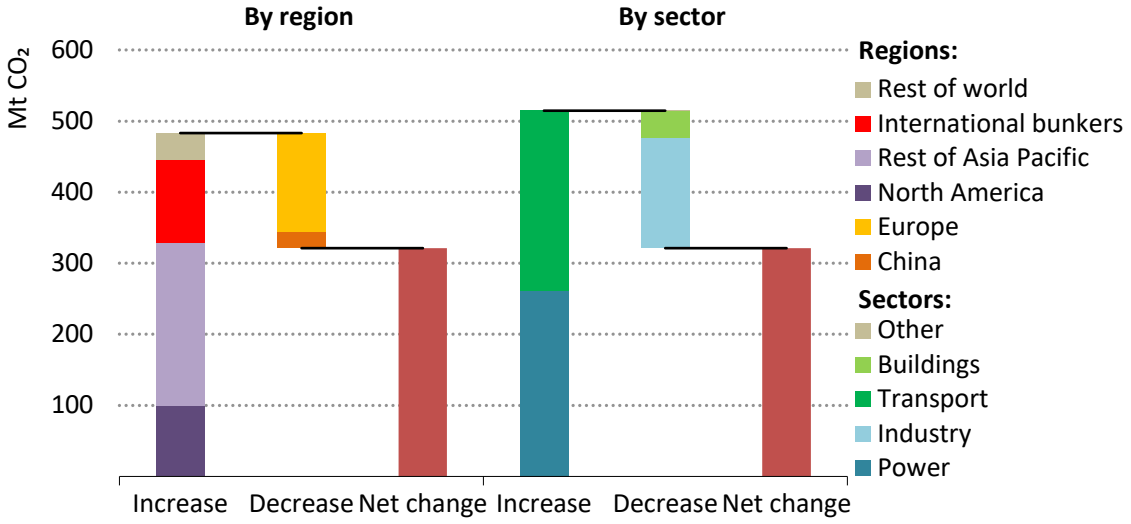
CO_2 emissions from energy combustion grew by around 1.3% or 423 Mt in 2022, while CO_2 emissions from industrial processes declined by 102 Mt. Emissions growth in 2022 was below global GDP growth (+3.2%), reverting to a decades-long trend of decoupling emissions and economic growth that was broken in 2021.

[1] All subsequent mentions of CO_2 emissions refer to CO_2 emissions from energy combustion and industrial processes, unless otherwise specified. Further details about methodology are at the end of the report.

Meanwhile, improvements in CO_2 intensity of energy use were slightly slower than the past decade's (2012-2021) annual average.

There were divergent trends between regions and sectors. CO_2 emissions grew in North America and Asia (excluding People's Republic of China ["China" hereafter]), outweighing reductions from Europe and China. At a global level, CO_2 emissions from power and transport (including international bunkers) grew by 261 Mt and 254 Mt, respectively, more than offsetting reductions from industry and buildings.

Figure 2: Change in CO_2 emissions by region and by sector, 2021-2022



Note: Transport includes international bunkers.

Greater deployment of clean energy technologies helped prevent further emissions growth amid crises

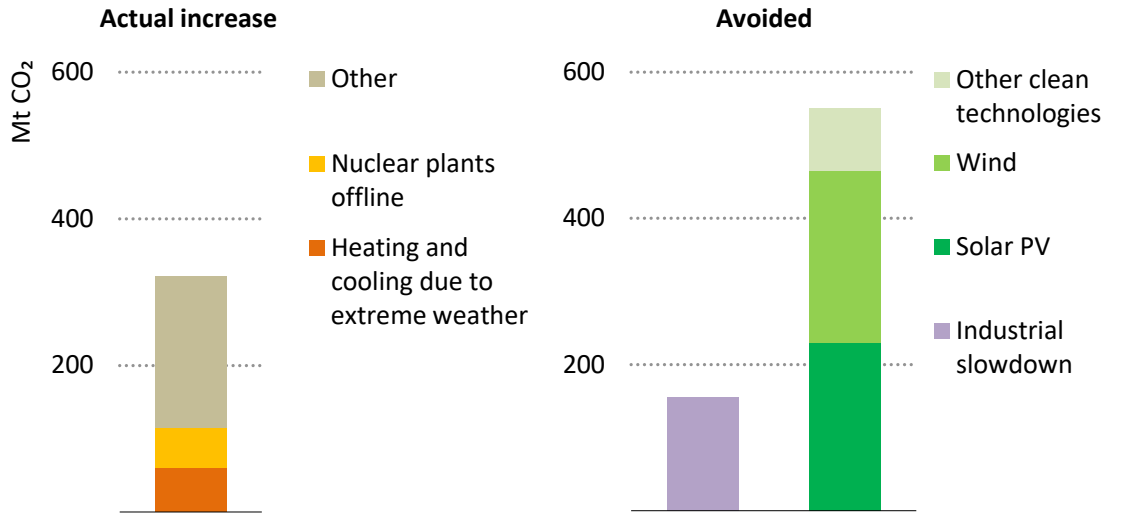
In an exceptionally turbulent year with Russia's invasion of Ukraine, energy price shocks, rising inflation, and major disruptions to traditional fuel trade flows, global growth in emissions was lower than anticipated.

Impressive growth of solar PV and wind generation helped prevent around 465 Mt CO_2 in power sector emissions. Other clean energy technologies, including other renewables, electric vehicles, and heat pumps, helped prevent an additional roughly 85 Mt CO_2. Without this increased growth in clean energy deployment, the annual increase in energy-related emissions would have been almost triple. Emissions reductions also resulted from economic slowdowns, including

155 Mt CO_2 from decreases in energy-intensive industrial production, mainly in China, the European Union, Japan, Korea and North America.

Specific challenges in 2022 also contributed to the global increase in emissions. Of the overall increase of 321 Mt CO_2, extreme temperatures contributed 60 Mt from heating and cooling for buildings. The decline in nuclear power generation, due to both maintenance and continued phase-outs, led to another 55 Mt CO_2.

Figure 3: Change in global CO_2 emissions by driver, 2021-2022



Notes: Solar PV and wind refer to the annual growth in generation. Other clean technologies is the annual growth in use of other renewables, electric vehicles, and heat pumps. In this figure, industry includes iron and steel, chemicals, non-metallic minerals, and non-ferrous metals.

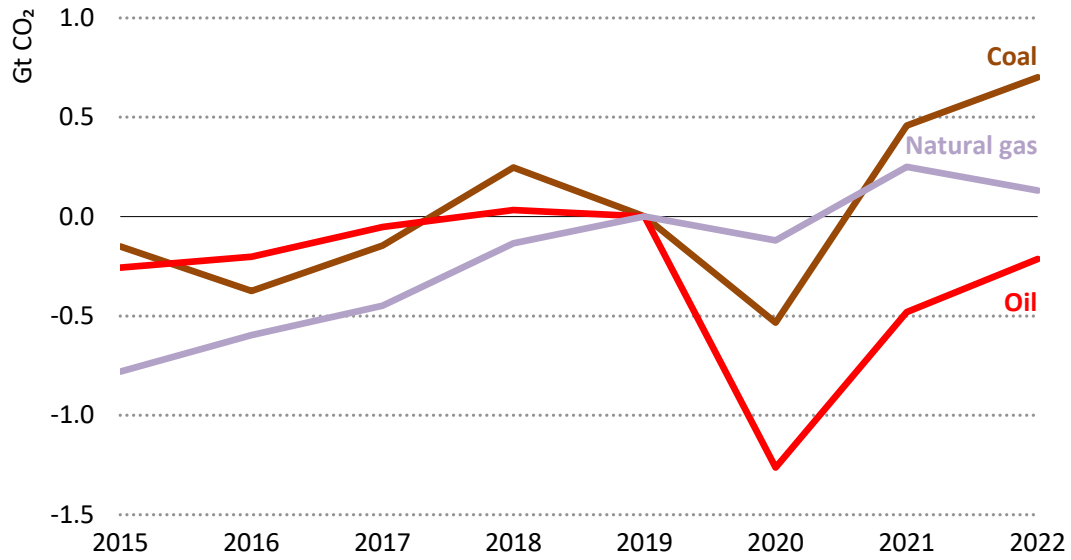
Reductions in emissions from natural gas were more than replaced by emissions from coal

Emissions from natural gas decreased by 1.6% or 118 Mt in 2022, as an already tight gas supply was exacerbated by Russia's invasion of Ukraine and the widespread trade disruptions that followed.

Emissions reductions were particularly pronounced in Europe, where they fell by 13.5%, with the strongest year-on-year reductions coming in the last months of the year. European gas prices reached record highs in 2022 following a sharp decline in Russian gas flows. However, a mild start to winter helped reduce household heating demand. In the Asia Pacific, LNG spot prices also spiked, and natural gas emissions declined by 1.8%, the largest year-on-year decline ever seen in the region. By contrast, natural gas demand remained robust in the United States and Canada, where emissions from gas increased by 5.8%.

Coal emissions grew 243 Mt to a new all-time high of almost 15.5 Gt. This 1.6% increase was faster than the 0.4% annual average growth over the past decade.

Figure 4: Change in global CO_2 emissions by fuel, relative to 2019 levels, 2015-2022



Oil emissions grew the most last year

Emissions from oil grew by 2.5% (or 268 Mt) to 11.2 Gt in 2022. Around half of the year-on-year increase came from aviation as air travel continued its recovery from pandemic lows. The rebound to pre-pandemic emissions levels was faster in advanced economies, where last year's aviation emissions reached 85% of 2019 levels, compared with 73% in emerging market and developing economies.

Total transport emissions increased by 2.1% (or 137 Mt), also driven by growth in advanced economies. Nonetheless, emissions would have been higher without the accelerating deployment of low-carbon vehicles. Electric car sales surpassed 10 million in 2022, making up over 14% of global sales. If all new electric cars on the road had been typical diesel or gasoline cars, global emissions last year would have been another 13 Mt higher.

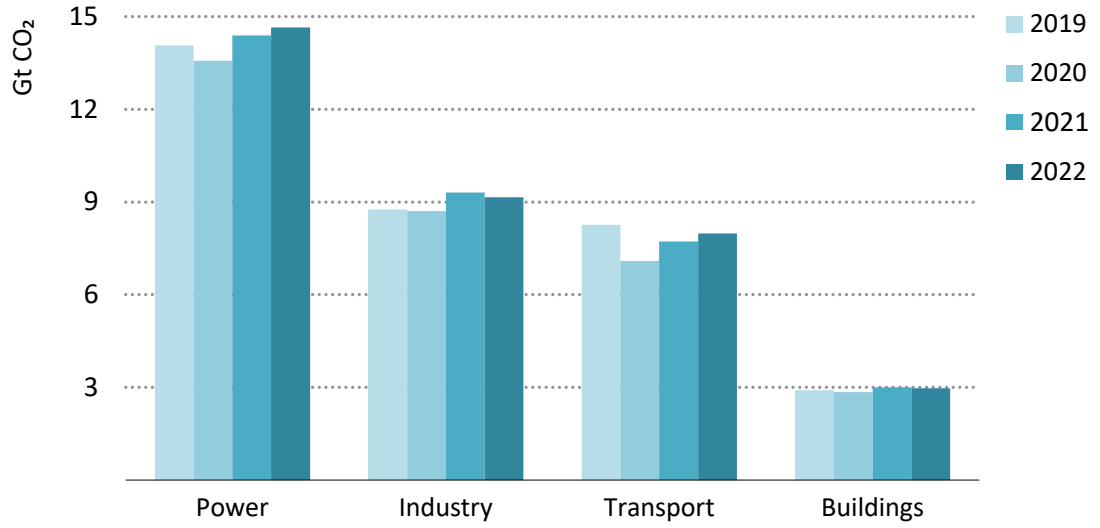
Despite promising growth in renewables, power sector emissions had the largest sectoral growth

The largest absolute sectoral increase in emissions in 2022 was from electricity and heat generation. Electricity and heat sector emissions increased by 1.8% (or 261 Mt), reaching an all-time high of 14.6 Gt. Gas-to-coal switching in many regions was the main driver of this growth: CO_2 from coal-fired power generation grew by 2.1%, led by increases in Asian emerging market and developing economies. Natural gas emissions in the power sector remained close to 2021 levels, propped up most significantly by an increase in the United States.

Global electricity demand increased by 2.7%, and overall carbon intensity of the electricity generation declined by 2.0%, resuming a nine-year trend that had been broken in 2021.

The resumed decline in carbon intensity resulted from the fast deployment of renewables across all regions, with renewables meeting 90% of global growth in electricity demand. Solar PV and wind generation each increased by around 275 TWh, helping to avoid around 465 Mt in power sector emissions. Although several countries registered severe droughts in 2022, global hydro generation grew by 52 TWh from 2021's levels, which were low because of water shortages in many regions.

Figure 5: Global CO_2 emissions by sector, 2019-2022



Note: Transport includes international bunkers.

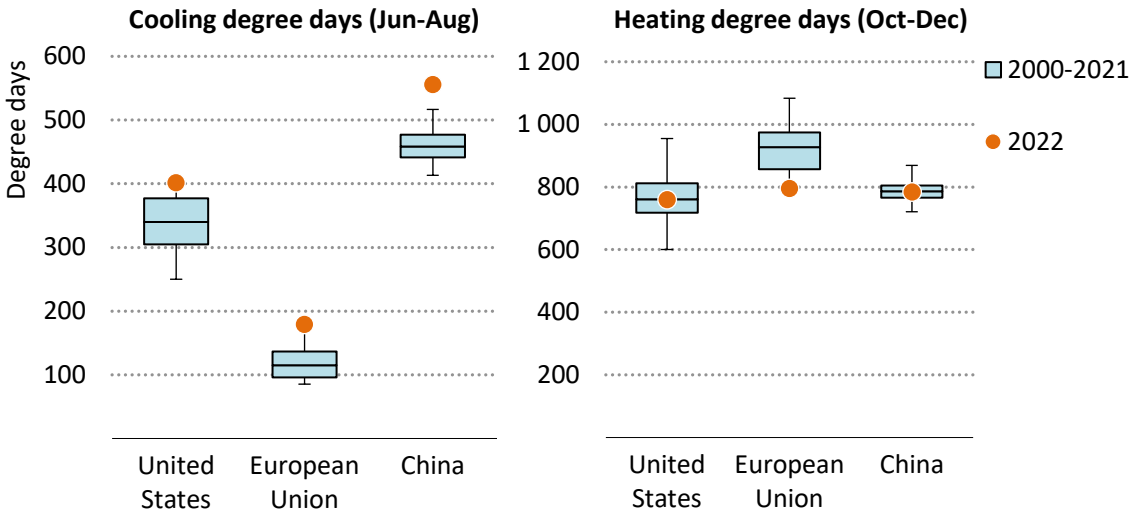
Reliance on coal- and gas-fired power in extreme weather drove up emissions across regions

Emissions were pushed up by reliance on fossil fuel power plants to meet excess cooling demand during extreme summer heat, with cooling degree days across several regions in 2022 exceeding typical levels or even the maximum seen between 2000 and 2021. In the United States, the share of natural gas in the power fuel mix surpassed 40% in July and August. Coal power generation in China increased in August by around 15% year-on-year to exceed 500 TWh. In both countries, emissions levels for the first half of the year were lower than in 2021, before summer heat waves reversed the trend.

Europe saw the second warmest start to winter in the last 30 years, and as a result, emissions from buildings were lower than anticipated.

For the full year, cooling and heating demand from extreme weather pushed up global emissions by around 60 Mt CO_2, around two-thirds of which came from additional cooling needs, and the remaining third from heating needs. This accounted for almost one-fifth of the total global increase in CO_2 emissions.

Figure 6: Cooling degree days in summer months and heating degree days in winter months for selected countries/regions, 2000-2022



Notes: Cooling degree days illustrate how hot average daily temperatures were and are measured relative to 21 ºC. Heating degree days illustrate how cold average daily temperatures were and are measured relative to 18 ºC.

China's emissions barely changed from 2021 to 2022, amid Covid-19 lockdowns and a real estate slump

Energy-related emissions in China were relatively flat between 2021 and 2022, decreasing by 0.2% or 23 Mt to around 12.1 Gt. Emissions from energy combustion alone grew by 88 Mt, entirely due to increased use of coal, but this was more than offset by declines in emissions from industrial processes. The overall yearly decline was the first since structural reforms drove emissions lower in 2015.

While China significantly ramped up domestic coal production and coal power capacity additions last year, actual coal consumption did not fully keep pace. Tempered by a large increase in solar PV and wind generation, coal accounted for around three-fifths of the fuel mix in electricity generation. Total electricity demand grew much slower than the average seen over the last decade. As such, emissions from coal-fired power increased by around 3%, in part due to the ramp-up of coal power plants during heat waves, as well as to increasing reliance on electricity or district heating fuelled by coal.

Industry sector emissions declined, but the effects of China's crackdown on debt-financed property and the ongoing real estate slump were not fully reflected in 2022 industry emissions. Construction new starts were down by around 40% year-on-year, while the production of steel and cement were just 2% and 10% lower than in 2021, respectively. As a result, China's industry sector emitted 161 Mt less than the year before, with a large share of this decline from process emissions. China's unprecedentedly large year-on-year decline pulled down global industry emissions.

In contrast to the global growth in transport sector emissions, China's transport emissions registered a 3.1% decrease in 2022. Covid-19 measures were strongly reinforced in comparison to 2021, including total lockdowns in major cities and restrictions on crossing prefecture or province boundaries. At the same time, electric car sales reached 6 million in 2022, preventing further emissions from diesel and gasoline cars.

United States emissions grew in 2022, driven by rising natural gas consumption

US emissions grew by 0.8% (or 36 Mt) to 4.7 Gt in 2022. The annual growth was much slower than 2021's spurt but still a deviation from the previous decade's declining trend. While most other countries shifted away from natural gas in the face of last year's price spikes, the United States increased its consumption.

Emissions from natural gas increased 89 Mt, more than supplanting the 69 Mt decline in coal emissions.

Emissions grew the most in the buildings sector, rising 26 Mt and far exceeding the last decade's annual average growth (around 7 Mt per year). The jump was mostly caused by cold weather during the early months of the year.

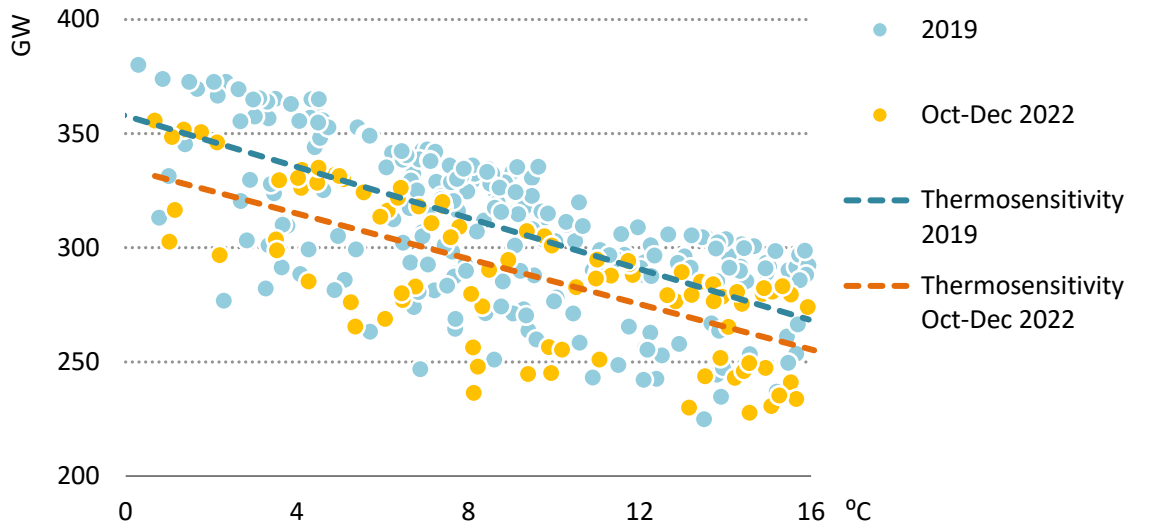
Power sector emissions decreased by 20 Mt, in large part thanks to solar PV and wind generation increasing by around 95 TWh. Without last year's rise in renewables, power sector emissions would have been around 65 Mt CO_2 higher. However, power generation contributed more than half of the growth in natural gas emissions, as the trend of coal-to-gas switching resumed after a strong coal rebound in 2021, with natural gas power plants meeting peak cooling demand during the summer's heat waves.

Energy crisis pushed European Union to cut emissions through clean power and demand reduction measures

Despite the coinciding challenges of oil and gas market disruptions, hydro shortfalls due to drought, and numerous nuclear plants going offline, the European Union reduced its emissions by 2.5% (or 70 Mt), thanks to a mild winter, effective energy conservation measures, fuel switching, behaviour changes, and industrial production curtailments. Reduced natural gas emissions more than offset increases in emissions from coal and oil.

Buildings sector emissions declined the most, by 60 Mt, enabled by exceptionally mild weather from October to December 2022 – the second warmest start to winter in the last 30 years – and collective energy conservation measures. Average electricity consumption was lower, even accounting for weather, and electricity use was less sensitive to temperature changes in 2022 than in 2019, pointing to the role of behaviour change. EU heat pump sales reached 2.8 million, more than doubling in several countries from the previous year. Meanwhile industry sector CO_2 emissions declined by 42 Mt.

Figure 7: Daily average electricity load at different temperatures in the European Union, 2019 and 2022



Notes: Thermosensitivity shows the line of best fit between average daily electricity load and average daily temperature. 2019 is shown as an indicative historic year before the pandemic.

Source: Analysis based on IEA Weather for Energy Tracker and Real Time Electricity Tracker.

Power sector emissions increased by 28 Mt even though electricity demand declined, as a temporarily higher reliance on coal increased carbon intensity. A 15% increase in wind and solar PV generation helped prevent further coal use with wind and solar PV for the first time jointly overtaking gas as well as nuclear as the top source of Europe's electricity generation. This record-breaking increase in solar PV and wind generation avoided almost 75 Mt CO_2 of emissions. Without hydro generation decreasing by 21% year-on-year and nuclear by 17%, another 80 Mt could have been averted.

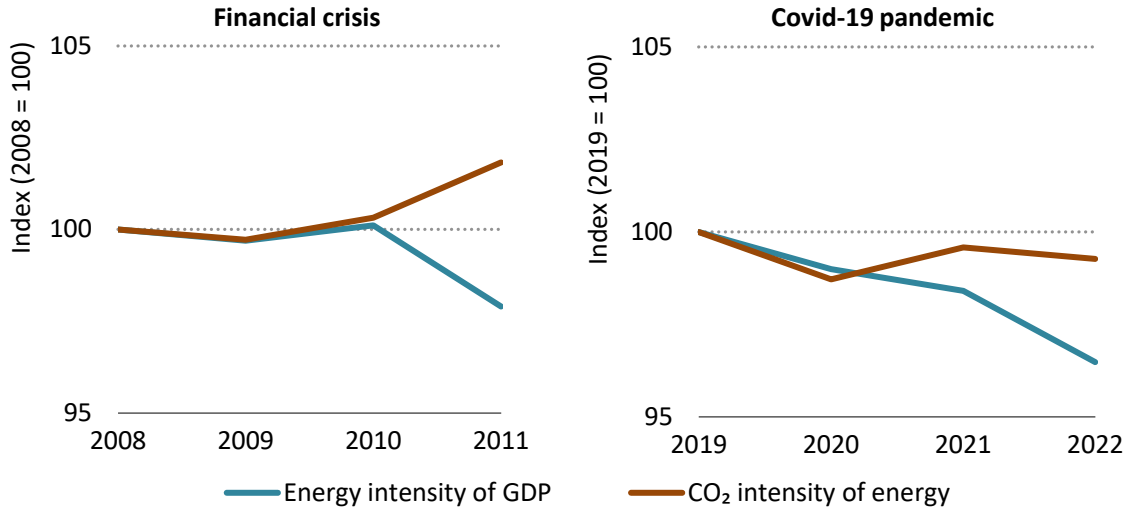
Despite the global energy crisis, recovery from the Covid-19 pandemic is proving more sustainable than past crises

Countries responded to the high energy prices and energy security concerns caused by Russia's invasion of Ukraine with energy conservation measures, fuel switching, and an acceleration of clean energy technology deployment.

Emissions trends now stand in contrast to those seen after the 2008 global financial crisis. Energy intensity of GDP is now 3.5% below 2019 pre-pandemic levels, compared to 2% below three years after the onset of the financial crisis. CO_2 intensity of energy use in 2022 was lower than before the pandemic, after a short-lived rebound in 2021, unlike the increase that emerged in the early 2010s.

The large green spending component of stimulus packages appears to be making a lasting impact on controlling emissions growth. Between April 2020 and October 2022, economic recovery packages enacted by governments worldwide included USD 1 215 billion in clean energy investment support, as detailed in the IEA's Government Energy Spending Tracker. This is well over twice the financial commitments made to green recovery measures after the financial crisis.

Figure 8: Global emissions intensity of energy use and energy intensity of economic activity, 2008-2011 and 2019-2022

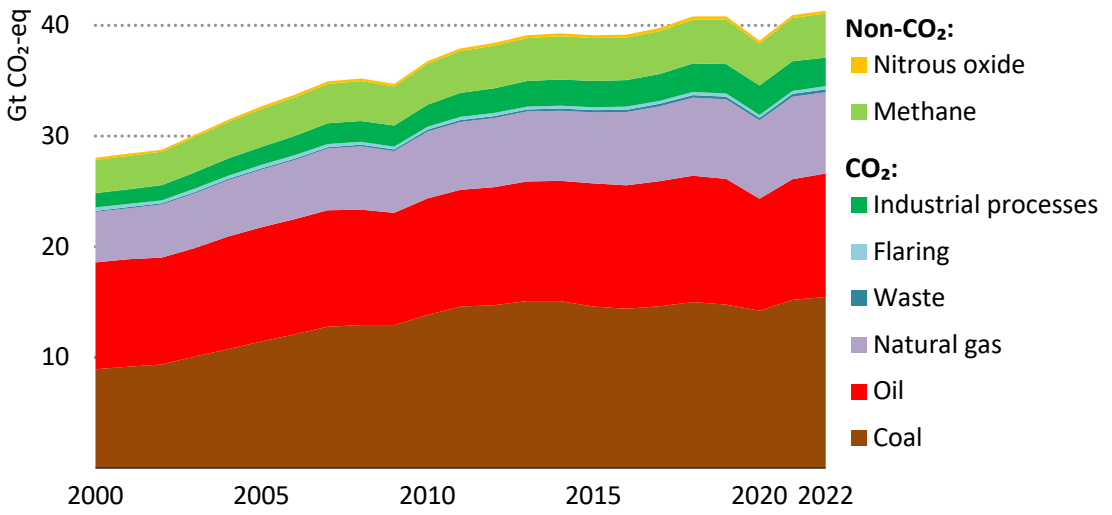


Energy-related greenhouse gas emissions reached 41.3 Gt CO_2-eq in 2022

Total energy-related greenhouse gas emissions increased by 1.0% to an all-time high of 41.3 Gt CO_2-eq (see "Data sources and method" for global warming potential values). CO_2 emissions from energy combustion and industrial process accounted for 89% of energy-related greenhouse gas emissions in 2022.

Methane from energy combustion, leaks and venting represented another 10%, mostly coming from onshore oil and gas operations as well as steam coal production. Methane emissions rose to nearly 135 Mt CH_4 or around 4 Gt CO_2-eq in 2022, despite high natural gas prices that increased the cost effectiveness of methane abatement technologies.

Figure 9: Global energy-related greenhouse gas emissions, 2000-2022



Source: Flaring emissions are from IEA analysis based on the World Bank Global Gas Flaring Reduction Programme.

This report is the first in the IEA's new series called the Global Energy Transitions Stocktake. The new tracker consolidates the IEA's latest analysis in one location, making it freely accessible in support of the first Global Stocktake in the lead-up to COP28 Climate Change Conference in November.

Data sources and method

The IEA draws upon a wide range of respected statistical sources to construct estimates of energy demand, energy-related CO_2 and other greenhouse gas emissions for the year 2022. Sources include the latest monthly data submissions to the IEA Energy Data Centre, real-time data from power system operators across the world, statistical releases from national administrations, and recent data from the IEA Market Report series that covers coal, oil, natural gas, renewables, electricity and energy efficiency. Where data are not available on an annual or monthly basis, estimates are used.

The scope of CO_2 emissions in this report includes emissions from all uses of fossil fuels for energy purposes, including the combustion of non-renewable waste, as well as emissions from industrial processes such as cement, iron and steel, and chemicals production. Estimates of industrial process emissions draw upon the latest production data for iron and steel, clinker for cement, aluminium, and chemicals. CO_2 emissions from the combustion of flared gases are also included in estimates of global energy-related greenhouse gas emissions.

Non-CO_2 greenhouse gas emissions include fugitive emissions from oil, gas and coal supply. Methane and nitrous oxide emissions related to energy combustion are also evaluated, based on typical emissions factors for the corresponding end uses and regions. When converting non-CO_2 greenhouse gas emissions to equivalent quantities, a global warming potential over a 100-year period is used, with global warming potential values of 30 for methane and 273 for nitrous oxide.

Economic growth rates underlying this analysis are those published by the International Monetary Fund's January 2023 *World Economic Outlook* update. All monetary quantities are expressed in USD (2021) in purchasing power parity (PPP) terms.

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