

Carbon Dioxide (CO₂) Fact Sheet

Attribute	Specification
Description	A colorless, odorless gas composed of one carbon atom and two oxygen atoms. It is the primary long-lived greenhouse gas in Earth's atmosphere.
Atmospheric Lifetime	Variable (Centuries to Millennia). While some CO ₂ is absorbed quickly by plants/oceans, a significant portion remains for thousands of years.
Current Concentration	~425 ppm (parts per million) as of 2024, a 50% increase since 1850.

Global Emission Sources

Total annual global CO₂ emissions are approximately **40 to 42 Billion Tonnes (Gt)**.

- **Human (Anthropogenic) Sources (~90% of the "surplus"):** ~38.1 Gt/year (2025).
 - **Fossil Fuel Combustion:** Burning coal, oil, and gas for electricity, heat, and transport (the largest share).
 - **Industrial Processes:** Chemical reactions in cement, iron, and steel production.
 - **Land Use Change:** Deforestation and soil degradation release carbon stored in biomass and dirt.
- **Non-Human (Natural) Sources:** ~770 Gt/year (balanced by natural sinks).
 - **Respiration:** Animals and plants breathing.
 - **Ocean Release:** Outgassing from warmer waters.
 - **Volcanoes:** Contribute less than 1% of the amount humans emit annually.
 - *Note: Natural sources are usually balanced by "sinks" (forests/oceans). Human emissions create the "overflow" that causes warming.*

Potency & Baseline

- **Global Warming Potential (GWP): 1.0.**
CO₂ is the baseline against which all other gases (Methane, Nitrous Oxide) are measured.
- **Why it matters:** Even though it is less "potent" per molecule than N₂O, its sheer volume and long life make it **the most dangerous gas for long-term stability**.

Risks to Humanity

- **Temperature Rise:** Direct cause of melting ice caps, rising sea levels, and more frequent/intense heatwaves.
- **Ocean Acidification:** Oceans absorb ~25% of human CO₂, turning the water more acidic. This dissolves the shells of shellfish and destroys coral reefs (the "nurseries" of the sea).
- **Nitrous Oxide Connection:** You asked about N₂O risks here—the primary risk of N₂O (aside from warming) is **Ozone Layer Depletion**. It is currently the leading cause of the thinning ozone, increasing UV radiation exposure.

Mitigation Strategies

Quick Action (Near-Term):

- **Energy Efficiency:** Reducing the waste of heat in buildings and industrial motors.
- **Methane-to-CO₂ Flaring:** Burning methane leaks (GWP 28) converts the CH₄ to CO₂ (GWP 1), reducing the immediate warming impact by 28x (methane is 28x more potent than CO₂).
- **End Deforestation:** Protecting existing "carbon sinks" stops immediate massive releases.

Long-Term Strategy:

- **Electrification:** Moving cars and home heating to a grid powered by wind, solar, and nuclear.
- **Carbon Capture & Storage (CCS):** Stripping CO₂ from factory smokestacks and pumping it underground into rock formations.
- **Reforestation:** Large-scale planting to pull CO₂ back out of the air.

Metric Conversion Guide

Since CO₂ is the baseline, the conversion is 1:1.

- **1 Metric Tonne CO₂ = 1 Tonne CO_{2e}**

A Comparison of Renewable Energy vs. Carbon Capture in cost-per-tonne (metric ton, or 1.2 Imperial tons) of CO₂ avoided:

When comparing **Renewable Energy** (preventing emissions) to **Carbon Capture** (cleaning up emissions), the primary difference is the stage of the process and the current "price tag" per tonne.

Cost-Benefit: Renewables vs. Carbon Capture

Based on 2024-2026 Levelized Cost of Energy (LCOE) and IEA Carbon Capture cost benchmarks.

Strategy	Technology	Avg. Cost per Tonne CO ₂ Avoided	Best Use Case
Renewable Energy	Utility-Scale Solar & Wind	\$10 – \$50	Electricity generation (The "Low-Hanging Fruit").
Energy Efficiency	LEDs, Insulation, HVAC	Negative (\$)	Building retrofits; saves more money than it costs.
Point-Source CCS	Industrial Capture (e.g., Cement)	\$60 – \$120	Heavy industry where electricity alone can't fix the process.
Direct Air Capture	DAC (Giant Fans/Filters)	\$600 – \$1,000+	Removing CO ₂ already in the sky; currently very expensive.

1. Renewable Energy (The "Prevention" Model)

Renewables are currently the cheapest way to mitigate CO₂ because they replace expensive fossil fuels.

- **The Benefit:** In most parts of the world, building new wind or solar is now cheaper than continuing to run existing coal plants.
- **The Catch:** Renewables require **massive battery storage** (which adds cost) to handle times when the sun isn't shining or wind isn't blowing.

2. Carbon Capture & Storage - CCS (The "Filter" Model)

CCS is used at the "Point Source" (like a steel mill or gas power plant) to catch CO₂ before it leaves the chimney.

- **The Benefit:** It allows us to keep using existing industrial infrastructure while generating "near-zero" emissions.
- **The Catch:** It requires a lot of energy to run the "scrubbers," often reducing a power plant's efficiency by **20%**.

3. Direct Air Capture - DAC (The "Vacuum" Model)

This is a newer technology that pulls CO₂ directly out of the ambient air.

- **The Benefit:** It can be placed anywhere (like over an empty desert) and addresses CO₂ emitted by planes or old cars that we can't "catch" at the tailpipe.

- **The Catch:** It is currently **10x more expensive** than switching to solar power.

Summary Comparison

- **Renewables** are the **Fastest & Cheapest** way to stop *new* CO₂ from entering the atmosphere.
- **CCS** is a **Necessary Bridge** for "Hard-to-Abate" sectors like cement and steel where heat requirements are too high for today's batteries.
- **DAC** is the **Long-Term Safety Net** for lowering the total atmospheric concentration after we've stopped new emissions.

Hard to Abate Industries:

Industries labeled "Hard-to-Abate" are sectors where you can't just "plug in" a battery to solve the carbon problem. These industries usually require **extreme heat** (over 1,000°C) or specific **chemical reactions** that naturally release CO₂ as a byproduct.

The "Big Four" Hard-to-Abate Priorities

Industry	Why it's "Hard"	Role of Carbon Capture (CCS)
Cement	60% of its emissions come from the chemical reaction of heating limestone, not just the fuel used.	Critical. CCS is currently the only way to stop that chemical CO ₂ from entering the air.
Steel	High-grade steel requires "coke" (coal) as a chemical reducing agent to turn iron ore into metal.	High. While "Green Hydrogen" is an alternative, CCS on existing blast furnaces is a faster near-term fix.
Chemicals	Producing ammonia (for fertilizer) and plastics requires fossil fuels as "feedstock" (raw material).	High. Capturing CO ₂ at the ammonia plant turns it into "Blue Ammonia," a lower-carbon fuel/fertilizer.
Aviation	Batteries are currently too heavy for long-haul flights (a plane would need a battery larger than itself).	Indirect. Direct Air Capture (DAC) is used to offset "tailpipe" emissions that can't be caught mid-flight.

1. Cement: The #1 Priority for CCS

- **The Problem:** Cement is responsible for **~7-8% of global CO₂**. Even if you use 100% solar power to heat the kiln, the limestone itself releases CO₂ as it turns into lime.
- **The Fix:** Retrofitting cement plants with "Post-Combustion Capture."
- **Cost:** It currently adds about **\$50-\$100** to the cost of a single tonne of cement, but many governments are now subsidizing this to kickstart the market.

2. Steel: The "Coal-Free" Challenge

- **The Problem:** Traditional steelmaking uses coal to pull oxygen out of iron ore.
- **The Fix:** "Carbon Capture Storage" (CCS) at the smokestack or switching to **DRI (Direct Reduced Iron)** using Hydrogen.
- **Timeline:** Most major steelmakers (like ArcelorMittal) have committed to "Net Zero" by 2050 using a mix of CCS and Hydrogen.

3. Aviation: The "Fuel Switch"

- **The Problem:** Jet fuel is incredibly energy dense. Electricity just isn't there yet for a 12-hour flight.
- **The Fix: Sustainable Aviation Fuel (SAF).**
- **CCS Connection:** Some SAF is made by capturing CO₂ from the air (DAC) and combining it with Hydrogen to make "synthetic" kerosene. When burned, it just returns the CO₂ it took, making it **Carbon Neutral**.

Summary of the "Abatement Gap"

Without CCS, these four industries alone would make it impossible to hit global climate targets.

Metric	With Renewables Only	With Renewables + CCS
Cement Emissions	~10% Reduction	~90%+ Reduction
Steel Emissions	~20% Reduction	~85%+ Reduction

Top 5 Global CCS Projects in Hard-to-Abate Industries

1. Northern Lights

(Norway) — *Multisector / First "Open Source" Network*

1. **Industry:** Cement (**Heidelberg Materials**) and Waste-to-Energy (**Hafslund Celsio**).
2. **Status:** Successfully began storage operations in **August 2025**.
3. **Impact:** It is the world's first "merchant" CCS service, shipping liquified CO₂ from industrial sites across Europe to be injected under the North Sea. It currently handles 1.5 million tonnes per year, with plans to expand to over 5 million by 2028.

2. Petra Nova

(USA) — *Power & Industry Transition*

1. **Industry:** Fossil-fuel Power / Industrial.
2. **Status:** Operational; one of the largest post-combustion capture facilities in the U.S..
3. **Impact:** Captures approximately **1.4 million tonnes** of CO₂ annually. It serves as a key demonstration of how existing heavy energy infrastructure can be retrofitted with capture technology.

3. Shell Quest

(Canada) — *Chemicals & Hydrogen*

1. **Industry:** Bitumen Upgrading / Blue Hydrogen.
2. **Status:** Operational since 2015; has sequestered over **6 million tonnes** total to date.
3. **Impact:** It captures about **1.2 million tonnes** of CO₂ per year from a facility that processes oil sands, demonstrating CO₂ capture in the production of hydrogen—a key fuel for other hard-to-abate sectors.

4. Sinopec Qilu-Shengli

(China) — *Petrochemicals*

1. **Industry:** Chemicals and Petrochemicals.
2. **Status:** Fully operational as of 2024–2025.
3. **Impact:** Captures **1 million tonnes** per year from a fertilizer/chemical plant and uses it for Enhanced Oil Recovery (EOR), which helps fund the expensive capture process in its early stages.

5. [CF Industries Donaldsonville](#)

(USA) — *Ammonia & Fertilizer*

1. **Industry:** Primary Chemicals.
2. **Status:** Operational.

- Impact:** Captures approximately **2 million tonnes** of CO₂ per year specifically from ammonia production. Ammonia is critical for global food security, and this project proves that its high-carbon production process can be successfully mitigated.

Industrial Performance Summary (2026)

Project	Primary Hard-to-Abate Sector	Annual Capacity
Northern Lights	Cement / Waste-to-Energy	1.5 Mtpa (Phase 1)
Petra Nova	Power / Industrial	1.4 Mtpa
Shell Quest	Hydrogen / Bitumen	1.2 Mtpa
Sinopec Qilu	Chemicals	1.0 Mtpa
CF Donaldsonville	Chemicals (Ammonia)	2.0 Mtpa

New Policy Discussions Around the World

In 2026, climate policy has shifted from setting distant targets to implementing high-stakes financial mechanisms and trade regulations. Governments are now using "carrots" (massive subsidies) and "sticks" (border taxes) to force the hand of heavy industry.

1. The United States: Stabilizing the "One Big Beautiful Bill"

The U.S. policy landscape in early 2026 is dominated by the implementation of the **One Big Beautiful Bill (OBBBA)**, which streamlined and enhanced carbon management incentives.

- Unified Section 45Q Rates:** The tax credit has been simplified to **\$85 per metric tonne** for all industrial and power plant capture, regardless of whether the CO₂ is stored or utilized in products.
- Safe Harbor Provisions:** To prevent a "compliance gap" caused by proposed changes to EPA reporting rules, the IRS issued **Notice 2026-1** in early 2026. This allows companies to use independent certifications for their captured carbon, ensuring they don't lose access to tax credits while regulatory systems are updated.
- Industrial Retrofit Grants:** The Department of Energy (DOE) is currently deploying **\$5.8 billion** specifically to assist steel, cement, and chemical plants with the high cost of installing advanced capture technology.

2. European Union: The Industrial Accelerator Act (IAA)

The EU is moving aggressively to protect its industries from global competitors like China while enforcing strict decarbonization.

- **Industrial Accelerator Act (IAA):** Published in **March 2026**, this act aims to boost demand for "Made in Europe" low-carbon products (like green steel and cement) through public procurement and low-carbon labeling.
- **CBAM Enforcement:** As of **January 1, 2026**, the **Carbon Border Adjustment Mechanism (CBAM)** is fully operational. This "carbon tax" on imports (steel, cement, aluminum, etc.) ensures that foreign companies cannot undercut European manufacturers by producing goods with lower environmental standards.
- **Industrial Decarbonisation Bank:** The EU plans to propose a new bank in 2026 to support up to **€100 billion** in capital and operational expenses for energy-intensive sectors.

3. United Kingdom: The Track-2 Expansion

The UK is currently solidifying its position as a global leader in "cluster-based" carbon capture.

- **Track-1 and Track-2 Clusters:** Construction is underway for the **HyNet** and **East Coast** clusters. In early 2026, the government is launching a new selection process for projects to connect to these networks.
- **£9.4 Billion Funding:** The 2025 Spending Review confirmed massive capital for the sector, supporting the world's first carbon capture-enabled cement plant at **Padeswood**.
- **ETS Linking:** Negotiations are ongoing in 2026 to link the **UK and EU Emissions Trading Systems (ETS)**, which would allow for cross-border CO₂ storage and more competitive carbon pricing.

4. China: The Shift to "Dual Control"

- **Carbon Intensity Focus:** China's new five-year plan, expected in **March 2026**, is shifting from controlling total energy use to **"dual control" of carbon emissions**. This places a direct premium on industrial efficiency and CO₂ capture rather than just reducing power consumption.
- **Industrial Innovation:** Rather than symbolic leadership, China is focusing on **commercial expansion** of its clean tech, including large-scale carbon capture projects in the petrochemical and fertilizer sectors.