Carbon Dioxide (CO_2) 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.

I. Global Emission Sources

Total annual global CO_2 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.*

II. Potency & Baseline

- **Global Warming Potential (GWP): 1.0**.

  CO_2 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 N_2O, its sheer volume and long life make it **the most dangerous gas for long-term stability**.

III. 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 CO_2, turning the water more acidic. This dissolves the shells of shellfish and destroys coral reefs (the "nurseries" of the sea).

IV. Mitigation Strategies

Quick Action (Near-Term):

- **Energy Efficiency:** Reducing the waste of heat in buildings and industrial motors.
- **Methane-to-CO_2 Flaring:** Burning methane leaks (GWP 28) converts the CH_4 to CO_2 (GWP 1), reducing the immediate warming impact by 28x (methane is 28x more potent than CO_2).
- **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 CO_2 from factory smokestacks and pumping it underground into rock formations.
- **Reforestation:** Large-scale planting to pull CO_2 back out of the air.

V. Metric Conversion Guide

Since CO_2 is the baseline, the conversion is 1:1.

- **1 Metric Tonne CO2 = 1 Tonne CO2*e***

VI. A Comparison of Renewable Energy vs. Carbon Capture in cost-per-tonne (metric ton, or 1.2 Imperial tons) of CO_2 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 CO_2 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 CO_2 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 CO_2 directly out of the ambient air.

- **The Benefit:** It can be placed anywhere (like over an empty desert) and addresses CO_2 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* CO_2 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 CO_2 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 CO_2**. Even if you use 100% solar power to heat the kiln, the limestone itself releases CO_2 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 CO_2 from the air (DAC) and combining it with Hydrogen to make "synthetic" kerosene. When burned, it just returns the CO_2 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*

a. **Industry:** Cement (**Heidelberg Materials**) and Waste-to-Energy (**Hafslund Celsio**).

b. **Status:** Successfully began storage operations in **August 2025**.

c. **Impact:** It is the world's first "merchant" CCS service, shipping liquified CO_2 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*

a. **Industry:** Fossil-fuel Power / Industrial.

b. **Status:** Operational; one of the largest post-combustion capture facilities in the U.S..

c. **Impact:** Captures approximately **1.4 million tonnes** of CO_2 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*

a. **Industry:** Bitumen Upgrading / Blue Hydrogen.

b. **Status:** Operational since 2015; has sequestered over **6 million tonnes** total to date.

c. **Impact:** It captures about **1.2 million tonnes** of CO_2 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*

a. **Industry:** Chemicals and Petrochemicals.

b. **Status:** Fully operational as of 2024–2025.

c. **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*

a) **Industry:** Primary Chemicals.

b) **Status:** Operational.

c) **Impact:** Captures approximately **2 million tonnes** of CO_2 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 CO_2 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 CO_2 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 CO_2 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.