

# Carbon Dioxide

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## Abstract

Because of its unique properties, carbon dioxide is a versatile compound with many different applications in gaseous, liquid, and solid states. It is used as a chemical building block (mainly for urea synthesis from ammonia), as an acidifier in beverage and water treatment applications, as a supercritical solvent (e.g., in enhanced oil recovery and caffeine extraction from coffee), as a shielding and inerting gas (e.g., in metalworking or food preservation), and as a chilling and cleaning agent while in a solid state (it sublimates from solid directly to gaseous state).

On the other hand, carbon dioxide is regarded as the number one climate issue for its role in accelerating global warming. CO<sub>2</sub> is produced by the burning of fossil fuels (coal, natural gas, crude, or refined oils) to generate electricity and heat, or for transportation purposes; via the production of cement (the transformation from limestone or calcium carbonate to lime or calcium oxide releases CO<sub>2</sub>); and by various other industries. In 2016, China was estimated to be the largest CO<sub>2</sub>-producing nation (28% of global CO<sub>2</sub> emissions), followed by the United States and India with 16% and 6%, respectively.

Attempts are ongoing to limit and reduce CO<sub>2</sub> emissions while collecting and sequestering carbon dioxide from the atmosphere. The chemical conversion and fixation of carbon dioxide, however, has limited applications for bulk use. Therefore, long-term geological storage including usage for enhanced oil recovery is probably the only practical way to reduce global carbon dioxide levels in the Earth's atmosphere. As current carbon capture and storage technologies for enhanced oil recovery are not cost-competitive with low oil prices, more than two-thirds of planned carbon capture, utilization, and storage projects have been cancelled over the past five years.

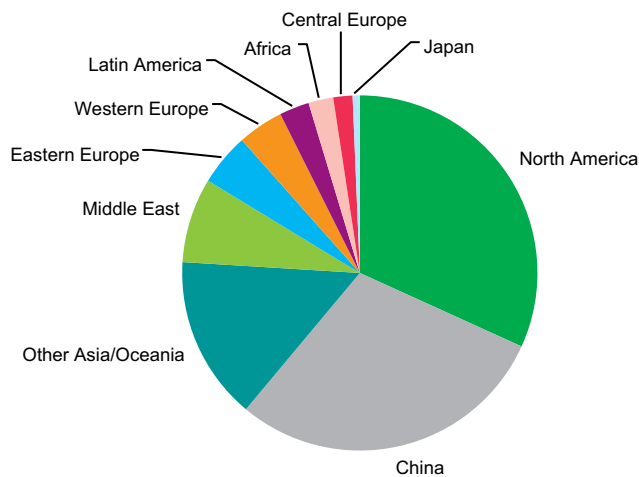
While atmospheric carbon dioxide has been identified as a contributor to global warming, this is relevant primarily to industries that generate and release carbon dioxide into the atmosphere. The companies covered in this report recover and distribute by-product carbon dioxide or naturally occurring carbon dioxide, but do not produce carbon dioxide.

The following pie chart shows world consumption of carbon dioxide:

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World total consumption of carbon dioxide—2017



Source: IHS Markit

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The carbon dioxide business is traditionally thought of as the recovery and distribution of liquid carbon dioxide, since this is the most commonly traded product. Liquid carbon dioxide is usually recovered as a gaseous by-product of industrial operations, such as hydrogen production by the steam reforming of natural gas or the production of ethanol by fermentation. The gaseous carbon dioxide is liquefied for sale as a merchant product because liquid carbon dioxide can be transported more economically than gas. Many consumers also use carbon dioxide for the physical properties associated with its being a refrigerated liquid. Liquid carbon dioxide reaches end users through a network of highway tankers, resupply depots, and railcars. Carbon dioxide is also traded as dry ice in the solid state, with its main end use being transport refrigeration. As a result of these circumstances, the carbon dioxide business is highly regional.

China is the major market for carbon dioxide, accounting for about 29% of global demand in 2017, followed by the United States, Other Asia and Oceania, and the Middle East, accounting for about 28%, 15%, and 8%, respectively. Out of the total global merchant market for carbon dioxide, about 24% each are for the beverage and food industries, followed by fabricated metal products at 15%.

There is a substantial market for gaseous carbon dioxide for use in enhanced oil recovery. Another large use for gaseous carbon dioxide is on-site chemical manufacturing. For example, many ammonia manufacturers generate by-product carbon dioxide and consume it at the same site for urea production.

The major issue in the carbon dioxide market is balancing regional supply and demand. Carbon dioxide sources may or may not exist where demand is greatest. In addition, chemical manufacturing operations that produce a gaseous carbon dioxide by-product run according to demand for the primary product, as opposed to demand for the by-product carbon dioxide. For example, ammonia plants typically run at full capacity in the fall and winter seasons in preparation for spring fertilizer requirements. Carbon dioxide demand, in contrast, tends to be highest during the warm summer months when ammonia plants may be closed for turnaround, so supplies are not often balanced with demand.

In the past few years, there have been growing concerns about greenhouse gases (and the impact of corn-based ethanol production) and profitability that have somewhat dampened interest in corn-based ethanol. However, federal mandates for ethanol blending in gasoline in the United States will continue to support corn-based ethanol production. In the future, the primary sources of carbon dioxide are expected to be ethanol fermentation plants, as ammonia plants are being shut down as a result of less-expensive offshore production or lower-cost import replacements.

The total global carbon dioxide market is expected to grow at an average annual rate of 1.7%. The highest growth rates are forecast for Africa at 8.8% per year, followed by Eastern Europe and China, both of which are expected to grow at about 2% per year through 2022.

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