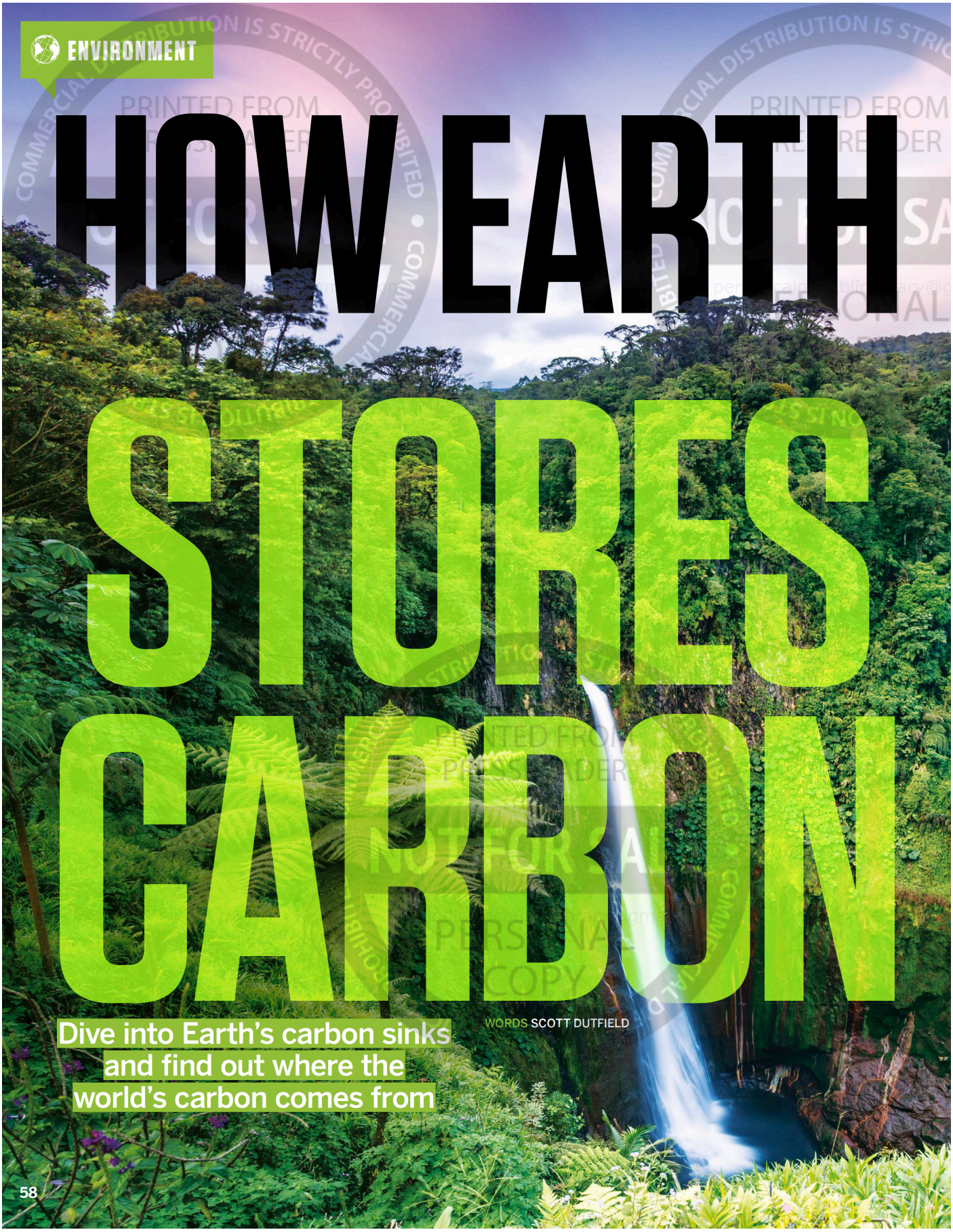
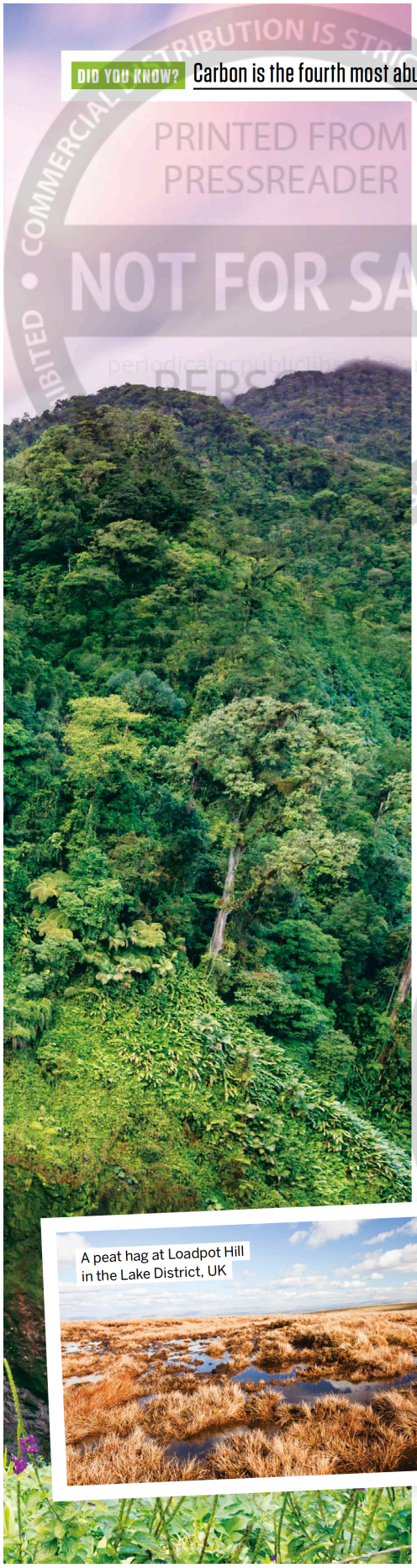
- Carbon sink / Reservoirs



DID YOU KNOW? Carbon is the fourth most abundant element in the known universe



Carbon is one of the fundamental elements of life on Earth. It can be found in the atmosphere, forms part of the biological building blocks of every living organism on Earth and is trapped in the structures of rocks that form our planet's crust. Scientists estimate that Earth contains 1.85 quintillion tonnes of carbon, all of which moves through what's known as the carbon cycle. Through countless mechanisms of carbon storage and release, the planet has evolved a complex exchange system that continually cycles this essential element to sustain life.

During the billions of years that our planet has existed, this complex and intricate carbon cycle has formed to maintain atmospheric harmony. Several major players in the carbon cycle keep the exchange of 'carbon stock' ticking over. 'Carbon sinks', such as forests and oceans, commonly exchange carbon atoms in the form of atmospheric carbon dioxide. A carbon sink becomes a 'carbon pool' when it absorbs more carbon stock than it releases into the atmosphere. When the release of carbon is greater than its absorption, this is known as a 'carbon source' – a volcano being a good example. The process of taking carbon from one source and storing it for long periods is called carbon sequestration.

There are several ways that the world sequesters carbon. For example, one of the most well-known examples of carbon exchange is through photosynthesis and respiration. Plants extract carbon from the atmosphere, in the form of carbon dioxide, and use it to build more plant cells to grow. Similarly, when they need to break down sugars for energy, plants release carbon dioxide through respiration. Plants, like all life, hold onto the carbon in their biomass until they die and it is released into the soil through decomposition, or is passed into the bodies of other organisms that eat them. One plant can't store that much carbon, but together the world's forests absorb around 15.6 billion tonnes of carbon dioxide each year. Congo's tropical rainforest alone sequesters 600 million tonnes of carbon dioxide each year.

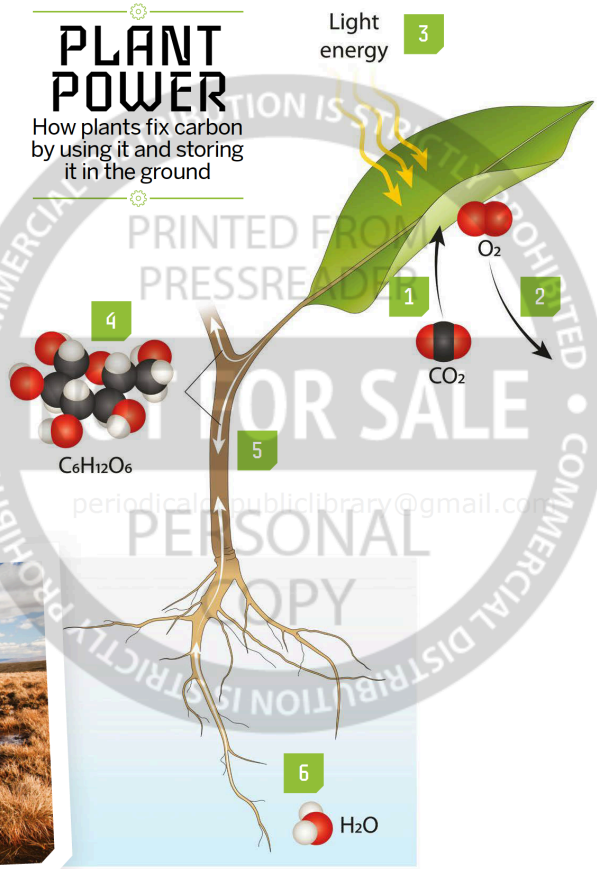
Plants aren't the only living things with carbon-fixing powers. Phytoplankton drifting through the world's oceans also trap carbon

Did you know?
You are around 18 per cent carbon

A peat hag at Loadpot Hill in the Lake District, UK

PLANT POWER

How plants fix carbon by using it and storing it in the ground



1 UPTAKE
Carbon dioxide enters plants through tiny holes on the underside of leaves called stomata.

2 OXYGEN RELEASE
As a byproduct of photosynthesis, oxygen is released into the atmosphere.

3 LIGHT ENERGY
The energy of sunlight stimulates tiny organelles called chloroplasts in the plants to convert the carbon dioxide and water into sugar.

4 GLUCOSE
Glucose is a simple sugar, each molecule of which contains six carbon atoms.

5 STORAGE
Glucose is used to build the bodies of plants, in which carbon atoms are stored.

6 ROOTS
When roots die or leaves fall to the ground and decay, carbon is released into the soil and becomes sequestered.

© Getty / Alamy

ENVIRONMENT

through photosynthesis. Plankton are part of a marine carbon storage system called the 'biological carbon pump', whereby the carbon they collect is passed through a chain of other organisms, gradually filtering down to the bottom of the ocean where it is stored. The world's oceans make up the largest carbon sink on the planet and hold a whopping 60 times more carbon dioxide than the atmosphere. All in all, it's estimated that around 100 billion tonnes of carbon is released and recaptured annually through the planet's different carbon sinks.

Maintaining harmonious levels of carbon stock in the global cycle is essential for life on Earth, especially in our atmosphere. Although the concentration of carbon dioxide in the atmosphere is just 0.04 per cent, it's our planet's most important greenhouse gas, absorbing radiation from the Sun for warmth. However, when levels of carbon dioxide become unbalanced, Earth's climate drastically changes. Should the world's supply of carbon dioxide suddenly be depleted, then Earth would be plunged into freezing temperatures of around -18 degrees Celsius at the surface. Too much carbon dioxide and Earth would burn up with an atmosphere of around 400 degrees Celsius, similar to the surface of Venus.

Levels of carbon stock at each point in the cycle can naturally fluctuate. However, since the Industrial Revolution in the 18th century, human activity has offset the balance in the carbon cycle. By tapping into the world's underground carbon pools in the form of fossil fuels, humankind has become an additional and prolific carbon source. Oil and coal are packed with the carbon from decayed prehistoric animals that died millions of years ago. When these materials are burned, the trapped carbon is released into the carbon cycle.

Industrial gas pollution isn't the only way that humans have been increasing atmospheric


The bodies of plankton send trapped carbon down to the depths of the ocean floor

Did you know?

From 2000 to 2022, global tree coverage shrank by an eighth

BLUE VERSUS GREEN

The plants and trees that build the world's forests are often referred to as 'green' carbon sinks, relating to their ability to store carbon in their green biomass. But in recent years marine scientists have discovered the importance of 'blue' carbon sinks. Along tropical coastlines near the equator, mangrove forests act as a blue carbon sink. Unlike green carbon forests, these plants store the majority of their carbon in the soil and sediment around them. Scientists estimate that mangrove forests can store up to five times more carbon than some tropical forests and currently store around 10 billion tonnes of carbon globally.

Mangrove forests, along with seagrass and salt marshes, can store more carbon that tropical and boreal forests

DID YOU KNOW? Carbon makes up just 0.032 per cent of Earth's crust and upper mantle

WHERE IS IT CAPTURED?

The sources, sinks and pools that keep carbon moving through the world

CARBON DIOXIDE TRANSFER

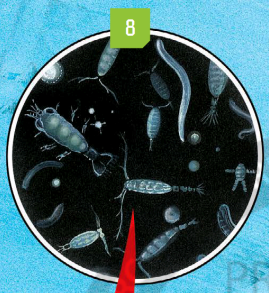
PHOTOSYNTHESIS

1 OCEANS
More than 40,000 billion tonnes of carbon is stored in the ocean.

10 INDUSTRY
Globally, humans release around 37 billion tonnes of carbon dioxide into the atmosphere by burning fossil fuels.



8 PLANKTON
Carbon-capturing phytoplankton, along with the zooplankton that consume them, fall to the seafloor and store carbon as sediment.



7 VOLCANOES
Carbon-rich molten rock is ejected through Earth's crust as volcanoes, releasing carbon dioxide into the atmosphere.





6 INTO THE EARTH
The carbon trapped in rocks and sediments on the seafloor is fed beneath the Earth's crust into the mantle at points where tectonic plates pass over each other.

9 FROZEN SINKS
Around 6 billion tonnes of carbon is locked up in the world's frozen ice sheets and glaciers.

11 SOIL
There are 1,500 billion tonnes of carbon in the first metre of soil worldwide, in the form of organic matter.

"Levels of carbon stock at each point in the cycle can naturally fluctuate"

© Getty / Science Photo Library



One of the world's largest forest carbon sinks, the Amazon

carbon dioxide. By removing or altering carbon pools, humans prevent them from doing their job and leaving carbon in the air. For example, the world's peatlands are some of the most efficient carbon sinks around. Formed from waterlogged land and humid rainforests, these boggy areas create an environment in which plant matter doesn't completely decay, trapping all the plant's carbon with it. For peatlands to remain as carbon pools, they need to stay wet. However, deforestation in the tropical peatlands especially causes peatlands to dry up and release their carbon back into the atmosphere. Similarly, due to its high carbon content, peat has been used as a fuel source and burned, releasing fossil fuel levels of carbon into the atmosphere.

The world's natural carbon sinks can't keep up with the excess of carbon dioxide being released into the atmosphere, currently around 47 per cent higher than levels before the Industrial Revolution. The consequences of this are changing climates and increasing global temperatures due to carbon dioxide's warming greenhouse effect. Scientists have estimated that we would theoretically need an additional billion hectares of trees to store excess carbon and stop the global temperature increasing beyond 1.5 degrees Celsius by 2050. If the average global temperature exceeds that of pre-industrial times by more than 1.5 degrees Celsius, the world would face drastic climatic changes, such as increases in extreme weather and rising sea levels.

To combat the effects of human-produced carbon dioxide and reduce its levels in the atmosphere, scientists have made many attempts to artificially sequester carbon. In 1999, the Southern Ocean Iron RElease Experiment (SOIREE) explored the impact of iron fertilisation on phytoplankton growth and subsequently increased carbon capture. Iron fertilisation naturally occurs when strong winds blow sediment from arid deserts into coastal waters. Phytoplankton use iron as a micronutrient to grow and reproduce. However, the phytoplankton off in the South Ocean near Antarctica aren't exposed to natural iron fertilisation, something

THE IMPORTANCE OF PEAT

The consequences of peatland destruction



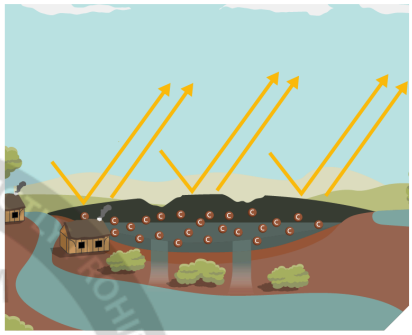
1 PEAT BOGS
Peat is formed from partially decayed plants and other organic matter accumulating over thousands of years.



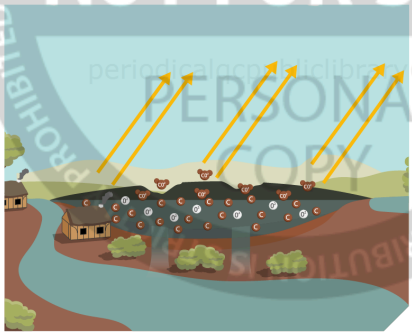
2 DESTRUCTION
Peat bogs are destroyed for fuel or for agricultural space. In some parts of the world, such as Indonesia, peatland relies on trees to shelter it from sunlight's heat.



3 DRAINAGE
The removal of plant life and intentional drainage of peatlands leaves them dry and exposed to the Sun.



4 WARMING UP
Exposed and dry peatland heats up under direct sunlight. An increase in temperature allows atmospheric oxygen to enter the peatland and bind with the locked-up carbon.



5 RE-IGNITING DECOMPOSITION
The newly introduced oxygen causes the undecayed plant life to restart decomposition and release the carbon as carbon dioxide.



6 PEAT FIRES
The combustible nature of carbon-packed peatlands means they are also at risk of igniting, accelerating the release of carbon dioxide.

DID YOU KNOW? The word 'carbon' comes from the Latin word 'carbo', which means 'charcoal'

scientists saw as an opportunity to increase plankton populations.

The experiment involved dumping large amounts of iron into the polar waters of the Southern Ocean and watching a plankton bloom. A bloom that could be seen from space formed in the Antarctic waters and persisted for 40 days, which suggested that iron fertilisation could help facilitate the capture of carbon. However, subsequent studies have called the practice of iron fertilisation into question. Fears over its impact on other ecosystems that rely on the micronutrients guzzled up by artificially fertilised blooms and their carbon-fixing efficiency have largely halted further iron fertilisation.

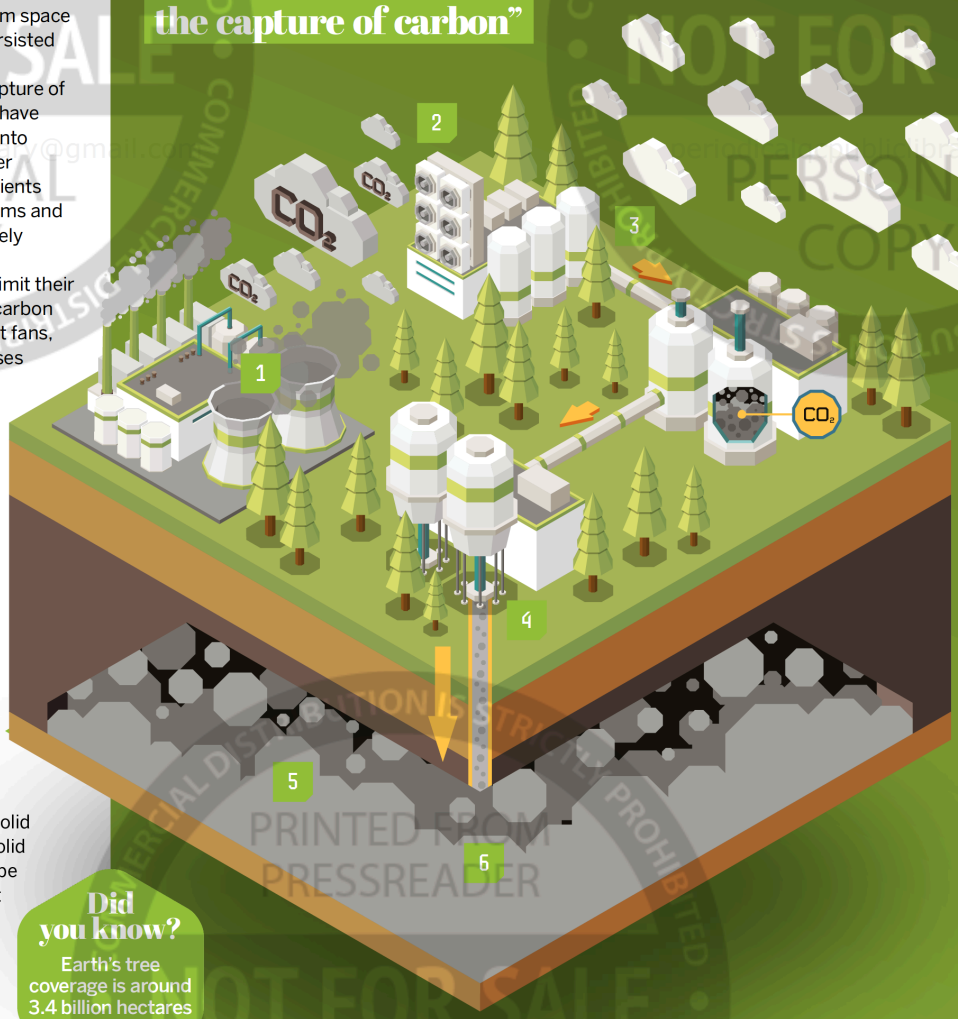
Heavy industries are attempting to limit their environmental impact through direct carbon capture and storage (CCS). Using giant fans, air is pumped into containers and passes through a material called a sorbent. Sorbents are designed to absorb specific molecules in liquids and gases, such as carbon dioxide, and hold onto them. Once the sorbent is saturated with carbon dioxide it is heated up to 100 degrees Celsius. By heating the sorbent, the trapped carbon dioxide is released and re-directed into storage tanks. The stored carbon dioxide can either be permanently stored underground or used as an ingredient in other industries, such as making plastics and graphene construction.

Similarly, emerging 'calcium looping' technology uses calcium oxide sorbents in the flues of cement plants to convert carbon dioxide into solid calcium carbonate. Not only can the solid carbonate be physically stored, it can be converted back into a gas by heating it to around 950 degrees Celsius. In 2023 there were around 395 CCS facility projects in the works globally, with just 43 fully operational. The largest is the Alberta Carbon Trunk Line (ACTL) in Canada, which can capture and store 14.6 million tonnes of carbon each year.



Shell's carbon capture and storage facility in Alberta, Canada

"Iron fertilisation could help facilitate the capture of carbon"



Did you know?

Earth's tree coverage is around 3.4 billion hectares

ARTIFICIAL STORAGE

How humans are mimicking carbon sinks

1 INDUSTRY
Burning fossil fuels for energy production and metal manufacturing are among the largest emitters of carbon dioxide in the world.

2 CAPTURE
Fans around industrial areas gather carbon dioxide and 'capture' the molecules in filters called sorbents.

3 COMPRESSION
Once the carbon dioxide is released from the fan's sorbents, it's heated and compressed to a fluid state for transport.

4 INJECTION
Through a network of pipes, pressurised carbon dioxide is injected into rock formations underground.

5 STORAGE
Carbon dioxide is often stored in natural gas reservoirs, saline aquifers or depleted oil stores.

6 DEPTH
Captured carbon is typically stored at least 0.62 miles underground.

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