When will CCU go mainstream?

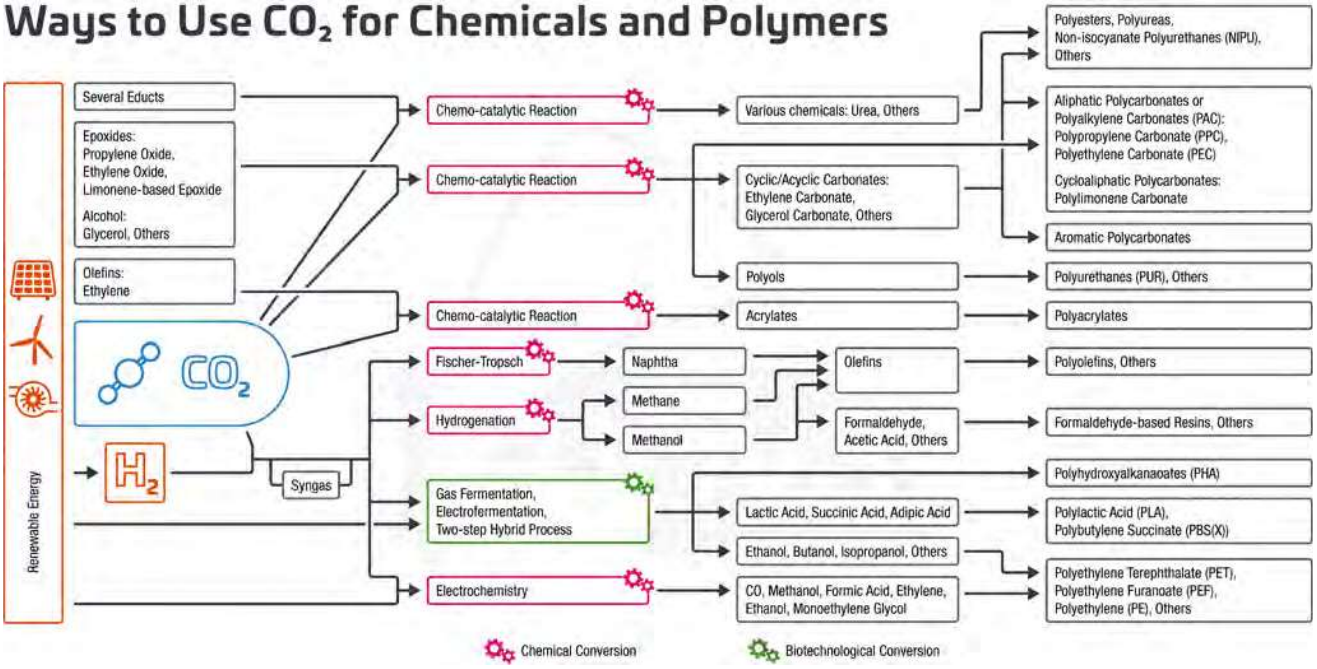
As soon as renewable energy becomes cheap and abundant, which is closer than we think.

The potential for carbon capture and utilisation (CCU) is tremendous. Utilising CO_2 from fossil and biogenic sources, and eventually from the air (direct air capture), could easily meet the entire demand for embedded carbon of the global chemical and plastics industry. There are many different chemical and biotech pathways; most rely on CO_2 plus hydrogen (H_2) to produce intermediates such as CO, syngas, methane, methanol, formic acid, and naphtha. Almost all chemicals and plastics can be produced in this manner. According to experts at nova-Institute, an area the size of Greece (135,000 km², equivalent to 1.5 % of the Sahara Desert or 0.8 % of all subtropical deserts combined) would be enough to produce sufficient green hydrogen via photovoltaics to meet the global chemical and plastics industry's demand for embedded carbon with CCU by 2050. This calculation assumes that the demand for embedded carbon in chemicals and plastics will double from 550 million tonnes to 1,150 million tonnes (of carbon) by 2050.

This simple calculation demonstrates the tremendous potential of CCU. It is also unlikely that it will ever be necessary to cover the demand for embedded carbon solely through CCU. Other sources of carbon, such as biomass and recycling, will remain available, and it is difficult to forecast the future shares of the different renewable carbon sources.

Latest innovations and implementations of CCU

- Eastern New Century Corporation from Taiwan has developed the world's first non-isocyanate polyurethane (NIPU) derived from CO_2, creating high-performance elastomeric materials for textiles and footwear. Second Winner of the "*Best CO_2 Utilisation 2025*"(nova-Institute).
- Blue Circle from the Netherlands aim to have a 200,000-tonne/a facility up and running by the end of 2029, transforming CO_2-based methanol to ethylene and propylene.
- Vioneo from Switzerland plans the first-of-its-kind plant with a capacity of 200,000 tonne/a for a wide range of polypropylene grades made from methanol, bio- and CO_2-based.
- NG Nordic from Finland will capture and utilise the CO_2 emissions from pulp plant to produce PHA polymers.
- Researchers from the South "*Korea Institute of Science and Technology (KIST)*" have succeeded in building the world's first functional electric motor without any metal components, replacing conventional copper coils with carbon nanotubes (CNTs). This innovation could revolutionise electric motors for vehicles, drones, and aerospace due to its ultra-light weight and improved electrical conductivity – and can be produced from CO_2.
- UP Catalyst from Estonia produces in a new electrochemical conversion technology battery-grade graphite and carbon nanotubes from CO_2. Winner of the "*Best CO_2 Utilisation 2025*" (nova-Institute).



Graphic © nova-Institute 2023 – available at www.renewable-carbon.eu/graphics

Article by:
Michael Carus
Founder and CEO
nova-Institute
Cologne, Germany

- The 2025 Nobel Prize in Chemistry was awarded to Susumu Kitagawa, Richard Robson, and Omar Yaghi for their pioneering work on metal–organic frameworks (MOFs), which are crystalline materials with vast internal surface areas that can be tailored to capture carbon dioxide and other gases. Their developments laid the foundation for powerful new approaches to industrial-scale carbon capture and environmental remediation.
- MOFs can be engineered to selectively trap CO_2 from large emission sources such as power plants or industrial facilities, offering a potentially more efficient and scalable alternative to traditional solvent-based and other capture methods.

Main bottlenecks for CCU going mainstream

There is a lack of suitable policy support frameworks for utilising CO_2, particularly for fossil CO_2 emissions. Although CCS is favoured in policy, CCU should be the preferred option instead. However, European policy is slowly shifting towards CCU.

Currently, there is insufficient cheap renewable electricity or green hydrogen available globally. This is due to a system failure. Renewable energy is expensive when implemented only partially; it is only cost-efficient when implemented fully. The existing electricity grid is not suitable for the fluctuating nature of solar and wind energy. There are insufficient battery storage or other solutions for storing fluctuating solar and wind energy. Once these issues have been resolved, CCU can become mainstream. When will this happen? In five to ten years?

EU CCU policy in motion

Clean Industrial Deal

- High-level flagship strategy to accelerate EU's green industrial transition while boosting competitiveness
- CCU is explicitly mentioned several times as a key clean technology

Net-Zero Industry Act

- Aims to strengthen European manufacturing capacity and address barriers for scale-up
- Parliament and Council agreed to include CCU as strategic net zero technology – CCU can now be referred to as net-zero in clean technology policies, which allows for accelerate permitting, national priority stats and advisory support

EU Emission Trading System (ETS)

- Permanent CCU Delegated Act: permanently stored emissions via CCU acknowledged (here, permanence refers to several centuries)
- EU ETS revision in 2026 ➤ The EC will assess inclusion of waste incineration and incentives for non-permanent

CCU-based products like plastics. There was currently a public consultation ongoing until 08 July 2025

Industrial Decarbonisation Accelerator Act (IDAA)

- Vital component of the Clean Industrial Deal, to accelerate decarbonisation of energy-intensive industries
- Central aim: Support lead market creation for low-carbon products ➤ Specific mention that incentives for uptake of renewable carbon feedstock (sustainable biomass, CCU, recycling of waste) is considered

Final Breakthrough for Renewable Energy in 2025?

There are two compelling reasons to take a closer look at the current state of renewable energy: (1) CCU can only become mainstream if there is enough cheap renewable energy available, and (2) the success story of renewable energy could provide a blueprint for the defossilisation of the chemical and plastics industry.

In the future, energy will increasingly be electric, with heating pumps replacing fossil fuel heating and electric cars replacing gasoline and diesel cars. Some experts expect, that in 2050 90 % of all energy demand will be met by electricity. Electricity will increasingly be produced by renewable energy sources such as solar, wind and hydro, which are net-zero emission. The transition from fossil to renewable energy systems is progressing well, particularly in China and other developing countries in Asia and Africa. The US is going back to fossil fuels, while Europe is progressing slowly.

The United States and other oil-producing countries are in their final throes, fighting a last battle for fossil fuels and against renewables, but the course has been set. And the facts tell a different story.

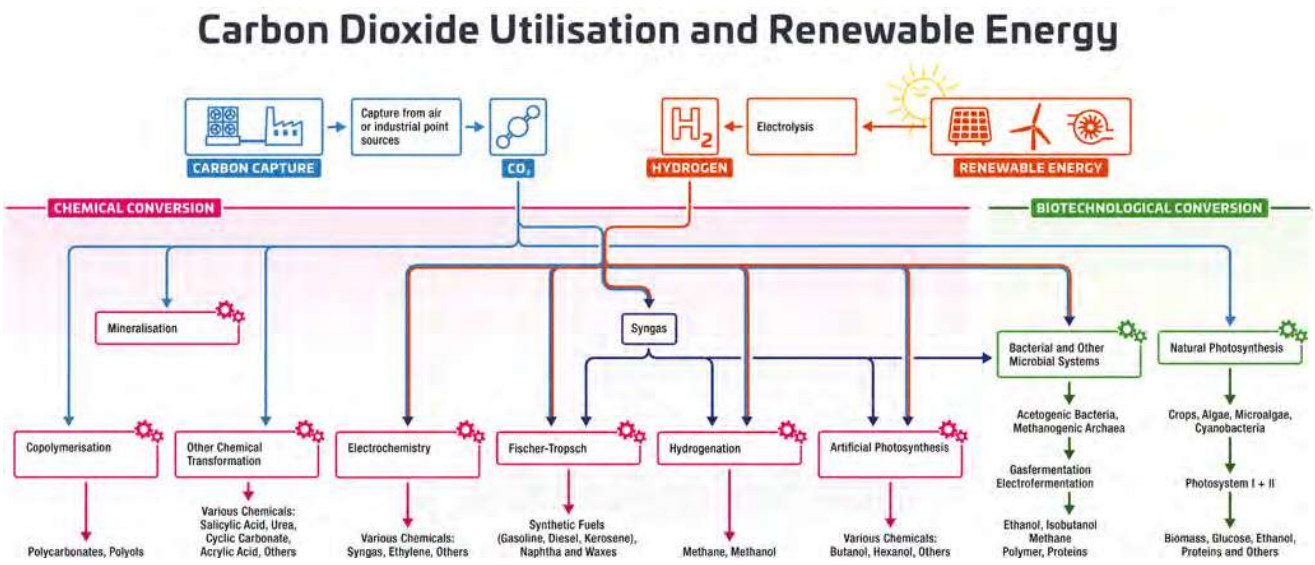
Europe and China are shifting their focus to renewable energy and carbon, recognizing that these are the key factors in ensuring a sustainable future. Solar and wind energy are the most sustainable forms of energy. They are also meanwhile the most cost-effective in most regions. Consequently, last year, 90 % of the global investment in new power plants went to renewable energy. The implementation of renewable energy and renewable carbon strategies contributes to the economic resilience and independence of the region. In the rapidly evolving global economy, this approach offers a reliable foundation for investment strategy.

Renewables overtake coal as world's biggest source of electricity – a crucial turning point

Renewable energy overtook coal as the world's leading source of electricity in the first half of the year 2025 – a historic first, according to new data from the global energy think tank Ember. Renewable energy contributed 34.3 % of all global electricity generated in the first half of 2025, while coal fell to 33.1 %. Renewable energies include solar, wind and hydro, as opposed to fossil fuels like coal and natural gas.

Electricity demand is growing around the world but the growth in solar and wind was so strong it met 100 % of the extra electricity demand including AI, even helping drive a slight decline in coal and gas use.

Developing countries, especially China, led the clean energy charge but richer nations including the US and EU relied more than before on planet-warming fossil fuels for electricity generation. Solar power delivered the lion's share of growth, meeting 83 % of the increase in electricity demand. It has now been the largest source of new electricity globally for three years in a row.



Graphic © nova-Institute 2023 – available at www.renewable-carbon.eu/graphics

Global solar generation grew by a record 31 % in the first half of the year, while wind generation grew by 7.7 %, the report by the energy think tank Ember found. More than 90 % of new renewable energy capacity is now cheaper than fossil fuels, study shows.

Solar energy is now so cost-effective that, in the sunniest countries, it costs as little as 2 to 2.5 EUR cent to produce one unit of power, making it cheaper than electricity generated from coal, gas or wind, according to a new study from the University of Surrey. Solar photovoltaic (PV) technology is now the key driver of the world's transition to clean, renewable power.

The research team also found that the price of lithium-ion batteries has fallen by 89 % since 2010, making solar-plus-storage systems as cost-effective as gas power plants. These hybrid setups, which combine solar panels with batteries, are now standard in many regions and allow solar energy to be stored and released when needed, turning it into a more reliable, dispatchable source of power that helps balance grid demand.

Despite many reasons to be optimistic, the research team points to several challenges – particularly connecting large amounts of solar power to existing electricity networks.

Solar in China

China is the global market leader and driving force for renewable energy. Within the 177 billion USD clean tech export figure for China, solar panels (236 GW) represent the largest single equipment category, with wind turbines (5.2 GW) much smaller, while EVs and batteries together also take a substantial share.

One reason why US President Trump is fighting against renewable energy and claiming that climate change does not exist could be China's position on renewable energy. China is far ahead of the US in this area and is very profitable and influential. So, fighting renewable energy might be a strategy to combat China. But this will not work. Renewables are too developed, too mature and too cost-competitive today, and they offer the prospect of greater independence from fossil fuel imports. Dependence on crude oil, natural gas, and coal could be risky in the future, making you vulnerable and economy expensive.

China's desert restoration strategy has become an ambitious, large-scale integration of renewable energy, ecosystem recovery, and land management. Through the Photovoltaic Desertification Control Plan (2025 – 2030), the country plans to install 253 gigawatts of solar capacity across its vast northern and western arid regions while restoring more than 670,000 hectares of degraded land by 2030.

Integrated Solar and Ecological Design: This *"sand-plus-solar"* model merges solar power generation with active desert rehabilitation, under the principle *"generate above, restore below."* Solar panels shield the ground from harsh sunlight, lowering surface temperatures by 3 – 5°C, decreasing evaporation, and improving soil moisture by up to 60 %, which helps native vegetation regrow – or to convert the desert in arable land.

China Three Gorges Corporation plant in China's target for 2027 is 180 GW of installed battery power. The battery capacity will be approximately 400 to 450 GWh by 2027, based on current GW/GWh expansion rates.

China's rational approach is that solar energy is the cheapest and most abundant energy source on our planet. The sun provides the Earth with around 6,000 times more energy than humanity consumes in a day. The problem is the fluctuation of solar and wind energy. China's main focus is to handle this in the most efficient way possible.

The existing electricity grid is not suitable for this, so there is a need for a next-generation electricity grid that can balance supply and demand and integrate with AI different short- and long-term storage systems, such as lithium-ion battery farms for short-term storage and pumped hydropower, hydrogen, or liquid air. China's new liquid air project in the Gobi Desert is part of an accelerating international effort to find scalable long-duration storage solutions that go beyond lithium-ion batteries.

Outlook

Thirty years ago, studies forecast that solar and wind power would only be able to cover less than 5 % of electricity demand. Now, it is expected that renewable energy will cover 80 – 90 % of the electricity demand in most regions in the future.

For CCU, this means two things: Firstly, the availability of cheap renewable energy is key to making CCU mainstream. If the current speed of energy transformation continues, this could happen within the next 10 years.

Secondly, highly recognised energy experts have consistently underestimated the growth of solar and wind energy; they have had to correct their forecasts every year, as it always happens faster than expected.

This could be a blueprint for the defossilisation of the chemical and plastic sector via renewable carbon: with the right policy framework in place, CCU, as well as biobased products and recycling, could become real success stories with rapidly growing market shares replacing fossil carbon, such as renewable energy replaces fossil energy. ■

i www.nova-institut.de