Chemical valorisation of CO_2

Carbon is an essential element of most products needed by society, and carbon is part of the structure of most chemicals. Recycling carbon from CO_2 (and CO from 'industrial waste gases') is one of the options that can be considered by the chemical industry to reduce the environmental footprint of chemicals and polymers, develop the use of alternative carbon feedstock and improve carbon circularity.

Summary

The chemical valorisation of CO_2 (and CO from 'industrial waste gases') refers to a specific type of utilisation of CO_2, while CCU (Carbon Capture and Utilisation) has a much broader scope including the physical utilisation of CO_2. The chemical valorisation of CO_2 is subject to intense research and innovation activities that:

- build on a broad portfolio of materials and process technologies (e.g. catalyst) developed by the chemical industry;
- can find applications in various sectors including the production of chemicals, polymers, materials, alternative fuels, and can provide solutions for energy storage.

For the chemical valorisation of CO_2 to effectively support the development of a more circular and climate neutral economy, with industrial leadership of Europe in related technologies, it is essential to define at European level:

- a clear terminology with regard to the types of utilisation of CO_2;
- guidelines enabling a common understanding of how to evaluate the environmental impacts of CO_2 valorisation technologies for various applications;
- an appropriate European policy framework that supports the utilisation of CO_2 as carbon feedstock with environmental benefits;
- risk-sharing measures to facilitate investment in Europe in related technologies;
- support to research and innovation at EU and national level to develop the next generation of CO_2 valorisation technologies.

CO_2 as an alternative source of carbon for Europe

CO_2 is available in abundance in Europe including from industrial production sites that provide point sources at various CO_2 concentrations. Although fossil industrial emissions are planned to decrease in the EU political context, some process emissions and other sources will remain available (e.g. bio-based CO_2 emissions, CO_2 from air with the development of Direct Air Capture technologies in the long-term).

The chemical valorisation of CO_2 has the potential to contribute to major EU priorities and related SDGs such as:

- Circular economy and resource efficiency, through sustainable production and consumption (SDG 12);
- GHG emission reduction for a climate-neutral economy (SDG 13);
- Renewable energy targets through power-to-X technologies;
- Reduction of Europe's dependence on imports of fossil resources;
- Leadership of the European industry in innovative technologies towards a climate neutral and circular economy.

How can the European chemical industry contribute?

European chemical companies are developing advanced materials and process technologies for:

- efficient capture and purification of CO_2 from various sources;
- the production of chemicals and polymers with a lower carbon footprint, through a broad portfolio of CO_2 conversion pathways;
- the sustainable production of hydrogen with a low carbon footprint which is required for the production of some large volume chemical building blocks from CO_2;
- possible large-scale chemical storage of renewable electricity through power-to-X technologies that can contribute to renewable electricity storage and grid stabilisation;
- the production of advanced CO_2-based fuels with a lower carbon footprint than current fuels (e.g. for some transport sectors such as aviation).

What is needed to succeed?

The development and deployment of CO_2 valorisation technologies entail huge investments with high risk. New innovative technologies, with a reduced environmental footprint (including carbon footprint) have to compete globally against established processes which have achieved a high degree of efficiency. Novel CO_2-based materials (with new properties) also have to overcome barriers to market entry.

Based on technologies available today, the production of large volume chemicals from CO_2 would require a high volume of climate-friendly hydrogen[1] that would entail a high demand for climate-neutral electricity with current water electrolysis technologies. Therefore, in addition to the development of efficient CO_2 valorisation processes, existing and novel options to access climate-friendly hydrogen should be considered based on a proper environmental assessment, including the development of breakthrough technologies

[1] *When referring to "climate-friendly hydrogen", Cefic means hydrogen produced with a low greenhouse gas (GHG) emissions compared to unabated hydrogen from natural gas with Steam Methane Reforming (SMR), e.g. with fossil-free energy or from natural gas with CO_2 emissions being either captured or transformed into solid carbon.*

such as methane pyrolysis and water photolysis (for a complete overview see the section on ‘Energy demand and access to climate-friendly hydrogen’ in the annex).

To define business opportunities for the European industry in the context of global competition, it is essential for Europe to develop:

- Dedicated guidelines enabling a common understanding of how to evaluate the environmental impacts of CO_2 valorisation technologies. Such guidelines:
  - are essential to the design of an appropriate policy framework and the evaluation of project proposals, and
  - would avoid the utilisation of non-relevant indicators such as carbon retention time of carbon in CO_2-derived chemicals (see annex);
- A clear terminology to avoid confusion created for instance by acronyms such as CCU and CCUS (see annex);
- An appropriate policy framework ensuring that existing and future policies adequately recognise CO_2 valorisation technologies taking into account the abovementioned guidelines;
- The recognition in the Emissions Trading System (ETS) Monitoring and reporting regulation (MRR) (and any future regulation in this area) based on carbon accounting principle of CO_2 emission avoidance resulting from the utilisation of CO_2 as alternative carbon feedstock (chemical valorisation of CO_2). Policy recommendations on MRR are addressed in a specific Cefic position paper*;*
- Risk-sharing measures through appropriate financial instruments such as the Innovation Fund and Important Projects of Common European Interest (IPCEI). Appropriate funding for technology development along the value chains at all Technology Readiness Levels (TRLs) in Europe at EU and national level will be key, in particular Horizon Europe including with the continuation of the SPIRE PPP.

Understanding the impact of CO_2 valorisation is critical

While a comprehensive evaluation of the impacts of CO_2 valorisation technologies require the consideration of the three pillars of sustainability, agreement on how to evaluate the environmental impacts is essential in the context of technological projects evaluation and policy design.

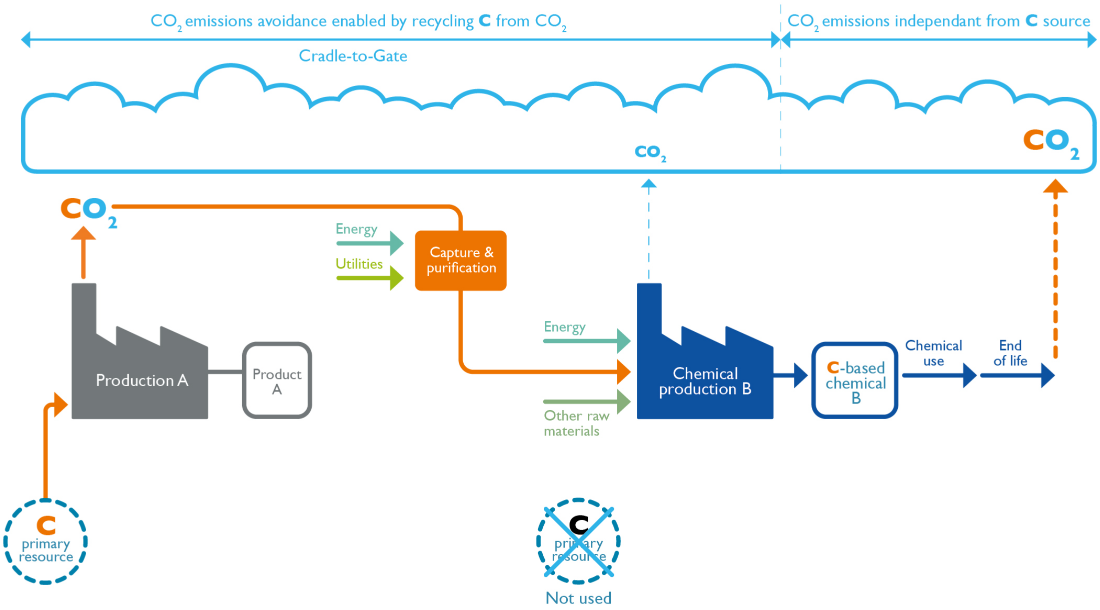
The overall environmental impact of CO_2 valorisation technologies should be evaluated based on an appropriate life cycle approach taking into account the specificities of the application of CO_2 valorisation (e.g. chemical production, fuel production, renewable electricity storage) and not limited to an evaluation of the impact on GHG emissions. While the carbon footprint is key other environmental impacts cannot be neglected.

Recycling carbon from CO_2 for the production of chemicals and polymers can avoid the utilisation of an additional virgin carbon (that would result in an additional CO_2 emission) and can effectively contribute to permanent CO_2 emissions avoidance that should be evaluated with an appropriate methodology.

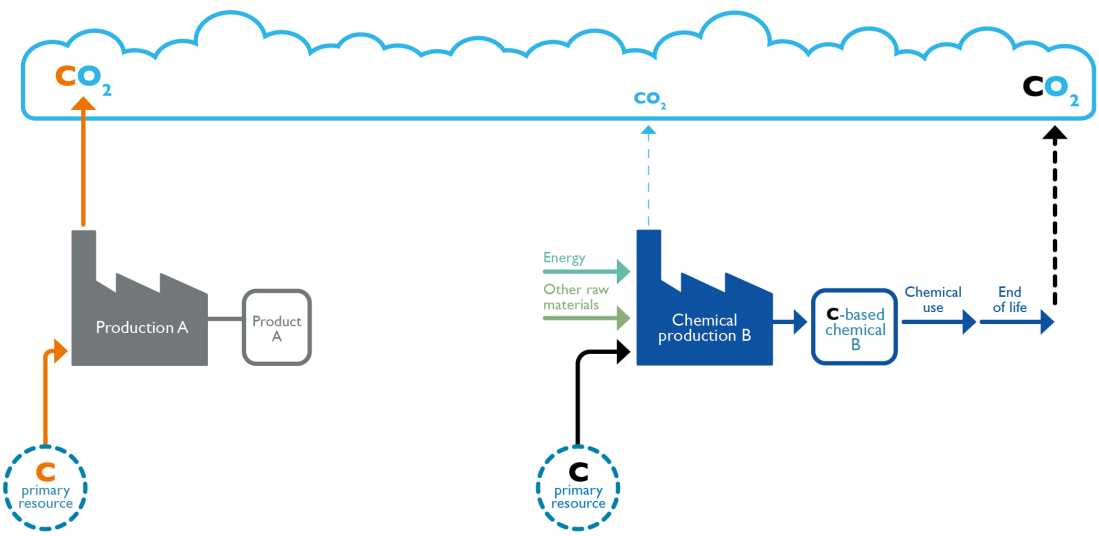
Since CO_2 emissions in the use phase and end of life (EoL) of a chemical are independent of the carbon source, the net CO_2 emissions avoidance - resulting from the implementation of a CO_2-based production compared to the standard production route of the same chemical (for its utilisation in the chemical and materials related value chains) - can be evaluated on a Cradle-to-Gate basis with the appropriate definition of system boundaries and methodology taking into account all relevant elements including the utilisation of energy and other raw materials.

Comparison between CO_2-based production of a chemical (1) and conventional production of the same chemical (2), with schematic representation of carbon flows related to the use of CO_2 as feedstock

(1) CO_2-based production of chemical product B



(2) Conventional production of chemical product B



The retention time of carbon in chemicals is not a relevant assessment criterion: recycling a carbon atom from CO_2 can avoid the utilisation of an additional virgin carbon (that would result in an additional CO2 emission) while the GHG emissions related to the use and End-of-Life (EoL) of a chemical product is independent from the carbon source.

While a cradle-to-gate approach is relevant for the comparison of two production routes of the same chemical for its utilisation in the same chemical and materials related value chains, it is not valid:

- For the production of CO_2-derived molecules for other services (e.g. energy storage). This requires the comparison of the CO_2 valorisation option with other technologies providing the same service;
- For a new chemical structure generating new properties. Here a full life cycle evaluation should be considered.

In such cases, beyond the CO_2 emissions avoided in the production phase, a comprehensive evaluation of the impacts of CO_2 valorisation is needed. Therefore, agreement on how to evaluate the overall environmental impact is essential in the context of technological projects evaluation and policy design.

For polymers, the recyclability potential could be a relevant criterion for the evaluation of a more sustainable option (through multiple carbon loops). Indeed, collecting plastics and recycling them (via mechanical recycling, chemical recycling, or through capture and valorisation of CO_2 from waste incineration) may be easier than for most other CO_2-derived products.

European policy context

CO_2 valorisation has been included in the development of various recent initiatives and proposals from the European Commission. Cefic supports that CO_2 valorisation is now included in policy developments, and recommends that the principles summarised in this paper be considered for:

- the revision of the ETS Monitoring and Reporting Regulation (MRR) planned in 2019; the Directive on the promotion of the use of energy from renewable source that requires the adoption by 31 December 2021 of Delegated Acts to specify the methodology for assessing GHG savings for two types of CO_2 and CO derived fuels for transport: ‘renewable liquid and gaseous transport fuels of non-biological origin’ and ‘recycled carbon fuels’;
- the Joint Research Center (JRC) study on alternative feedstock for plastics launched in the framework of the European Strategy for Plastics in a Circular Economy;
- decisions and developments related to the Communication ‘A Clean Planet for All’ which refers to ‘CCU’ in the circular economy scenario and as a contribution to the deployment of renewables, the use of electricity, and the production of e-fuels;
- the development of the European Green Deal and the related circular economy action plan;
- the development of funding instruments, in particular:
    - Horizon Europe including the continuation of the SPIRE Public Private Partnership;
    - The Innovation Fund which will require an appropriate methodology to assess GHG avoidance in the evaluation of project proposals, including CO_2 valorisation projects;
    - Important Projects of Common European Interest.

Annex

Important clarifications about CO_2 valorisation

CCUS and CCU

Acronyms such as CCUS (Carbon Capture Utilisation and Storage) and CCU contribute to the development of misleading statements based on inappropriate indicators. The U of CCUS encompass both the 'physical' utilisation of CO_2 with no chemical conversion of CO_2 (e.g. CO_2 as industrial fluid, utilisation of CO_2 for Enhanced Oli Recovery (EOR)), and the chemical conversion of CO_2 resulting in products where the Carbon from CO_2 is chemically bound in a desired product.

CO_2 emission avoidance vs. CO_2 sequestration and retention time

The technologies enabling the utilisation of CO_2 as an alternative carbon source for the production of chemicals do not aim at CO_2 sequestration, but at a more sustainable production of desired carbon-based products. The retention time of carbon is therefore not a relevant indicator to assess the impact of such technologies. Recycling a carbon atom from CO_2 can avoid the utilisation of an additional virgin fossil carbon feedstock, and CO_2 valorisation technologies can effectively contribute to CO_2 emission avoidance in the chemical industry. The CO_2 emissions reduction of such CO_2 valorisation technologies needs to be evaluated against existing production routes with an appropriate methodology and definition of system boundaries.

CO_2 sources

Like for all technological options, Direct Air Capture (DAC) technologies require an appropriate evaluation, including the higher energy demand required for capture and purification of CO_2 from air vs. CO_2 from concentrated point sources. The development of DAC technologies can be considered as a longer-term option. However, such DAC options cannot be treated preferentially to the utilisation of concentrated point sources, as long as these are available, based on the principle of type of CO_2 source, since the overall impact compared to the conventional production should always be evaluated based on an appropriate life-cycle assessment; the same applies to the utilisation of CO_2 from bio-based production.

Energy demand and access to climate-friendly hydrogen

Large scale production of hydrocarbons based on CO_2 and hydrogen will require large amounts of climate-friendly hydrogen and therefore climate-neutral electricity based on the technologies available today. With regard to energy demand (and climate-neutral electricity demand), it should be noted that:

- not all CO_2 valorisation routes require climate-friendly hydrogen (for instance technologies using CO_2 as a co-monomer for some specific polymers);
- access to climate-friendly hydrogen does not necessarily require low-carbon electricity to the level required for the production of hydrogen from water electrolysis (e.g. utilisation of hydrogen by-product in the context of industrial symbiosis, hydrogen from steam methane reforming coupled with carbon capture and storage, or alternative breakthrough technologies for the production of climate-friendly hydrogen such as methane pyrolysis or water photolysis).

The high energy demand required by many CO_2-based routes stems from the fact that CO_2 is a very low energy content feedstock compared to the conventional fossil feedstock.

Comparison of technology options

Comparison of technology options using appropriate methodologies to assess their respective environmental impact should take into account:

- the type of application of CO_2 valorisation technologies (e.g. production of chemicals for the chemical value chains, production of fuels, energy storage);
- forward-looking comparison of CO_2 conversion pathways to conventional production routes, considering either routes that do not require hydrogen, or routes that are based on climate-friendly hydrogen.

Technology development and scenario

Concerning the contribution of CO_2 valorisation technologies to climate neutrality by 2050 in Europe, as for other technologies, 2050 scenario should not be based only on technologies available today, as breakthrough technologies could be real game changers.

As for all carbon recycling options, the impact can be influenced by the specific local/regional characteristics.

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About Cefic
Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 16% of world chemicals production.