



CO₂ Utilization in the Industry: overview, prospects and recommendations

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Agenda



1. Brief review of CO₂ Utilization technologies
2. Current actions of Club CO₂'s French CO₂ Utilization Working Group
3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop (Lyon, France, Oct. 21st 2016)
4. Prospects and challenges of the CO₂ Utilization: focus on Mission Innovation



1. Brief Review of CO₂ Utilization Technologies

Definitions

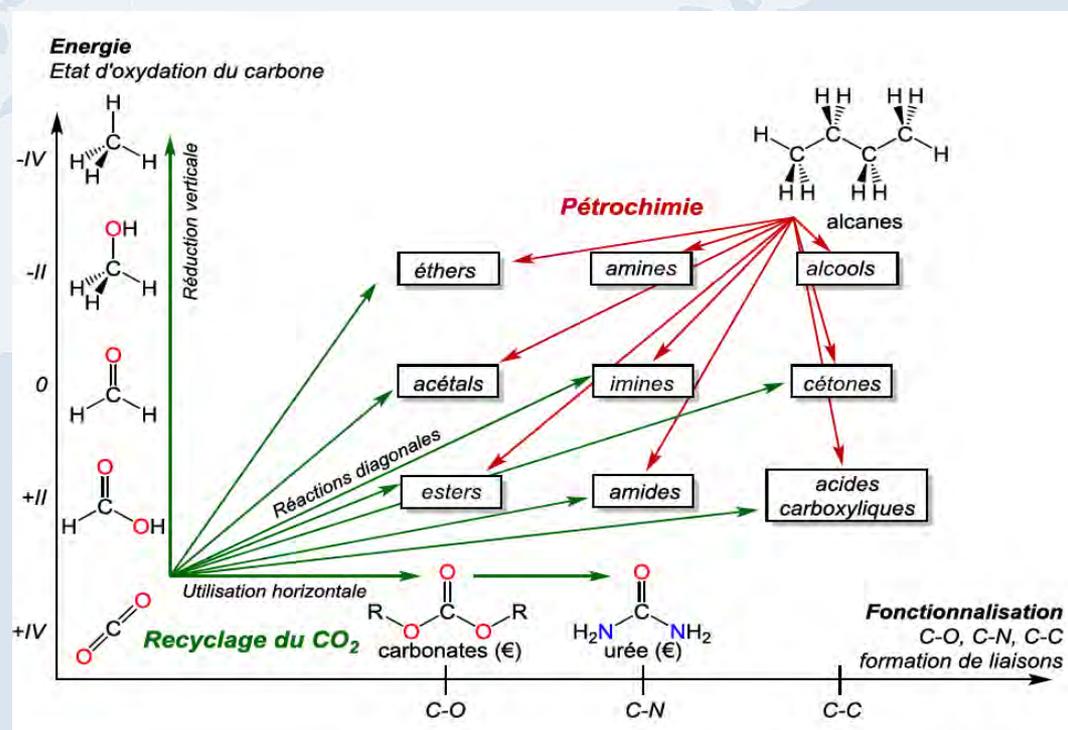
- CO₂ Utilization:
 - **Genuine utilization of CO₂**, diluted, partially concentrated or highly purified, depending on the utilization processes
 - Based on **physical, chemical** or **biological** processes (Detailed hereafter)
- CO₂ Valorization: giving added-values to the Utilization (a step forward):
 - CO₂ Valorization addresses the three pillars of **Sustainable Development**.
 - **An environmental value**: by avoiding CO₂ emissions, limiting fossil fuel and raw materials requirements and improving the carbon footprint of products,
 - **An economic value** with strong and reliable business models. Could be a way to deploy circular economy.
 - **A societal value**, by protecting human health (mitigation of CO₂ emissions and other pollutants) and developing employment.



1. Brief Review of CO₂ Utilization Technologies

Processes

- **Physical CO₂ Utilization routes:**
 - EOR, EGR, CO₂-Fracturing for Hydrocarbon Recovery,
 - CO₂-Assisted geothermal (cf. “Task Force on Utilization Options for CO₂: Phase 2 Report”)
- **(Mineral and Organic) Chemical CO₂ Utilization routes:**
 - Reduction of C,
 - Functionalization,
 - Mix reduction/functionnalization (« diagonal approach ») with catalysts
- **Biological CO₂ Utilization routes:** utilization of organisms to convert CO₂ into chemicals (microalgae, bacteria,...)



Source : Blondiaux, "Recyclage du CO₂ : une alternative à la pétrochimie pour la synthèse de molécules azotées", 2015

Adapted from Cantat et al., "A Diagonal Approach to Chemical Recycling of Carbon Dioxide: Organocatalytic Transformation for the Reductive Functionalization of CO₂", *Angew. Chem. Int. Ed.* 2012, 51, 187–190



1. Brief Review of CO₂ Utilization Technologies

Quantities

- CO₂ Emissions:
 - In 2014, CO₂ emissions from fossil fuel combustion and industry reached 35.9±1.8 Gt CO₂, +60% since 1990.
 - **In 2015, emissions stabilized at 35.7±1.8 Gt CO₂** (Source: Global Carbon Project)
- CO₂ Utilization in the global mitigation initiatives and efforts:
 - Current Utilization:
 - **180 Mt CO₂**(mainly for urea and inorganic carbonates manufacture) (Source: Armstrong & Styring, 2015)
 - **+ 70 Mt CO₂ for EOR** (Source: CO₂ Utilization Summit, San Antonio, 2015)
 - **= 250 Mt CO₂/yr utilization (0.7% 2014's emissions) could be reused**
 - If business models are relevant and regulations are in place: **max 2 to 4% overall emissions could be utilized (eg: C₁-building blocks, mineral carbonation...)** → It is a way to deploy **circular economy** based on a robust industrial sector and infrastructure.
 - It will act as a **complement to other solutions** (efficiency, renewable energies,...) with a potential that should be carefully assessed.



1. Brief Review of CO₂ Utilization Technologies

CCU is drawing attention from many stakeholders, eg:

Science-based

8TH CARBON DIOXIDE UTILIZATION SUMMIT 22ND-23RD FEBRUARY 2017 SAN ANTONIO TEXAS USA

Korea CCUS International Conference

CDUK UK Centre for Carbon Dioxide Utilisation

5th Conference on CO₂ Carbon Dioxide as Feedstock for Fuels, Chemistry and Polymers

11-15 September 2016 ICCDU XIV Sheffield, UK

CHEMSUSCHEM

eit Climate-KIC

EnCO₂re is enabling CO₂ re-use

National-level networking

CO₂Chem An EPSRC Grand Challenge Network

ClubCO₂

pteCO₂

International activities

CO₂ Forum Fuels & Materials Resource & Energy EFFICIENCY

ieaghg

nrg | cosia CARBON XPRIZE

ERA GRAND CHALLENGE: INNOVATIVE CARBON USES

MISSION INNOVATION Accelerating the Clean Energy Revolution



2. Current actions of Club CO₂'s French CO₂ Utilization Working Group

Stakeholders and Objectives:

- Working Group of Club CO₂
- 24 members: industries (Majors and SMEs), public bodies (national and regional-level), public research
- Started in 2013
- Objective:
 - **Sharing** on CO₂ utilization technologies and their potential
 - **Aligning** on key learnings
 - **Mainstreaming** recommendations on CO₂ Valorisation for France





2. Current actions of Club CO₂'s French CO₂ Utilization Working Group

11 actions done or ongoing:



SWOT
Analyses



Recommendations
for COP21

Task 7 – Public
Events watch &
feedback

Task 9 – Video on
explaining CCU

Task 11 – Support to
other WG



2 CO₂ Util^{on}
Workshops
(2015, 2016)



Mapping of
Stakeholders

Task 10 – Assessment of
Environmental benefits of
CCU



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Facts & Figures

- **Lyon, Oct. 21st 2016; 71 attendees**
- A 360° overview of CO₂ Utilization, for France and Europe, bringing together French institutions (at local level and national level), competitiveness clusters, universities and public research labs, small and big companies from industrial and service sectors.
- Agenda:
 - 1 Plenary Session :
 - Current position and prospects for the **policy-making, regulatory and economic** aspects of CO₂ Utilization.
 - Analyses of the **economic and environmental benefits** of different CO₂ conversion processes, based on industrial applications (methanol, polymers, mineral aggregates).
 - 1 Workshop Session to highlight the **conditions for the successful emergence of CO₂ transformation technologies** from:
 - A business perspective
 - A territorial perspective



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Conclusions drawn

- Research, Development, Innovation
- Environment
- Industries and Business
- Markets and Finance
- Economics
- Territories
- Regulation
- Stakeholders



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Research, Development and Innovation

- **Valorization of CO₂ is supported at all stages of development**, from the proof-of-concept at lab scale to the pre-industrial scale within:
 - French Programs (ANR, FUI, ADEME PIA, BPI PIAVE)
 - European Program and Actions (Energy Union, SET Plan, H2020, ERANET)
 - International initiatives (Mission Innovation)
- France has less visibility than other countries regarding its support in term of funding, but the country invested **42 M€** (over a total of 95 M€ budget for projects) over the five last years.
- **Demo-scale plants** must be rolled out to remove technological locks and limit the risks linked to the industrialization.
- Developments must rely upon **public-private collaborations**



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Environment

- Valorization of CO₂ :
 - Presents a **potential of mitigation of CO₂ emissions that must be carefully assessed**
 - Should not only be considered in terms of organic or inorganic chemicals production: **services have to be considered:**
 - Lever for managing the intermittency of renewable energies
 - Substitution to more impacting solutions
 - Needs **significant amounts of renewable energies** (e.g. for green H₂ production)
- About environmental assessments:
 - Need a **clear, rigorous and agreed way, as soon as first developments start**
 - **Lack of data** in LCA databases about captured CO₂
 - **How to allocate environmental benefits** between CO₂ and other by-products?
 - Avoid any **transfer of impact** (land use, water use,...)



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Industries & Business

- The attendance of many industrial companies to the event highlighted the **willingness to mitigate emissions** and/or to valorize them.
- **Valorization of CO₂ is a reality** for some pathways, illustrated by CRI (methanol), COVESTRO (polyether polycarbonate polyols) and Carbon 8 (Mineral aggregates): it is a **growth driver**
- But technologies still need **technical and environmental improvements**; the sector also need a **regulatory support** to transform some successes into a wide deployment
- Prospects:
 - **Integration is a key**: CO₂ valorization units must be integrated within industrial parks to decrease conversion costs (materials, thermal exchanges, shared services).
 - The **allocation of constraints and benefits** on the entire value chain must be defined over 4 axis: level of [CO₂] to be valorized, avoided CO₂, energy requirements, economic benefits.
 - Major companies could be a driver of CO₂ utilization: initiatives could emerge, **requesting lower carbon footprints of products and services**



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Markets & Finance

- Financial flows and initiatives:
 - With UNFCCC COP21, a real change is going on
 - **New financial initiatives are emerging:** Financial Stability Board, Institutional Investors Group on Climate Change, Portfolio Decarbonization Coalition...
 - It is an opportunity for CO₂ valorization to be supported by the **reorientation of financial flows** (5000 G\$ needed for complying with the 2°C scenario by 2100)
- Price & Tax:
 - The trend of a **low carbon price will reverse in the next years** thanks to the momentum initiated at COP21.
 - **Carbon price must be stable and globalized** so as to prevent distortion of competition.
 - In France, the Contribution Climat Energie targets a CO₂ tax of 56 €/t by 2020 and **100 €/t by 2030**.



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Economics

- **Business models are difficult to set up** for many pathways of valorization due to:
 - The high cost of the decarbonized energy (eg: hydrogen)
 - The high cost of captured CO₂ (specifically for mineral carbonation)
 - The current low prices of fossil resources
- There is **no financial incentive to purchase a low carbon-based product** compared to a reference product
- **Investors must be reassured** with respect to risks (long-term securing of raw materials and CO₂)



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Territories

- Seek to **maintain their competitiveness** while reducing their impacts on the environment.
- **Promote the installation of CCU plants** in terms of financial support, ease of contacts between stakeholders.
- Examples:
 - Le Havre Développement offers CO₂ capture solutions (from 1 kg/h to 1 t/h) that could be combined with R&D devices of valorization of CO₂ .
 - The Marseille's Industrial Port Area seeks to mitigate its CO₂ emissions in particular with CCU technologies (project VASCO2 (biological conversion), project JUPITER 1000 (methanation)).
- To mitigate emissions at a region level, there is a need to couple:
 - **Multimodal connections** (transport, energy) of the **different level of territories** (industrial port area, cities, countryside, homes)
 - **Multi-vector smart grids** (methane ex CO₂, H₂, heat, renewable electricity)
 - **CO₂ capture and Utilization**



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Regulation

- Focus on France:
 - In France, the **Law of Energy Transition for a Green Growth** (LTECV) provides the framework for technological innovations that contribute to reduce energy consumptions and CO₂ emissions. It is an opportunity for CO₂ valorization.
 - Since 2016 the **Public Procurement Reform** is in place and criteria of LCA is now taken into account.
- Prospects & Questions:
 - There is a need to **homogenize regulations** at European level
 - A **label** could contribute to support the sector
 - There is a **lack of clarity or adverse regulation** regarding the benefit of CO₂ abatement between stakeholders: how to recognize stakeholders' efforts for capturing and valorizing their CO₂?



3. Conclusions and recommendations of the 2nd CO₂ Utilization Workshop

Stakeholders

- **CCU projects must include as soon as possible all stakeholders** in addition to industrial companies, public research and national-level public bodies:
 - Economic development agencies
 - Civil society actors
 - NGO
- A **European Association of CO₂ transformation is in the process of being set up**
 - Objective: merge efforts of all stakeholders interested in speeding up research, innovation and market development of CO₂ valorization solutions in Europe.
- There is a need to:
 - Increase **awareness**
 - **Reassure**
 - **Convince** the civil society with demo-scale projects



4. Prospects and challenges of the CO₂ Utilization

Focus on France's Proposals for Mission Innovation's Challenge 3

- **Improve life cycle analyses (LCA) for innovative processes and products:** A simple, moderately resource-intensive and widely acceptable LCA methodology needs to be developed to assess the environmental impacts of manufactured products involving CO₂ utilization.
- **Direct use of CO₂ flue gases:** One of the issues to be overcome is the **high cost of obtaining CO₂**. As lower-cost options develop, including **direct capture from flue gas**, it will be possible to increase the CO₂ content of the CO₂-based products. The direct use of CO₂ captured from flue gases and appropriately treated should be given priority to keep down the costs of its use: algae production, greenhouses and mineral carbonation are some of the applications to be targeted as a priority.
- **Reduce the energy consumption:** The most CO₂ applications imply high energy consumption. To decrease this energy consumption, a fundamental work is needed for **catalysis** (design of catalyst). Also **mineralisation** is a promising process: identification of key parameters to accelerate the reaction in order to reduce energy consumption is also required.



Questions ?

