Climate effects of various CCU and CCS measures

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The CCU and CCS comparison
From a climate perspective, the extent to which a CCU process can contribute towards climate change mitigation depends on the lifecycle of the product and whether and when the captured CO$_2$ is released into atmosphere. Treating all forms of CCU as de facto CO$_2$ abatement could have serious detrimental impacts on efforts to reduce emissions.

**Short term storage:** 10 years or less before release of utilised CO$_2$.

**Medium term storage:** 10 to 100 years before release of utilised CO$_2$.

**Long term or permanent storage:** CO$_2$ prevented from entering the atmosphere for a century or more.
Converting H₂ into products:
Carbon capture and use
Types of CCU

Applications range from chemicals and fuels, to fertilisers and enhanced oil extraction. “From fluffy pillows to concrete” (BBC, 2017)

Sources: Zheng et al. 2017
Chemicals and Fuels


2. Headlines, research and support from member states such as Germany
Methane production from syngas goes back more than 100 years of research and process development. *(Ronsch et al. 2016)*

![Table 3. Overview of the most promising European CCU technological pathways and the DG JRC CO2 reuse shortlisted technologies showing the CO2 uptake potential (based on GCCSI/Parsons & Brinckerhoff, 2011), the research and industrial engagement and the TRLs.](source: Bocin-Dumitriu et al. 2013, Joint Research Centre)

<table>
<thead>
<tr>
<th>CO2 re-use technology</th>
<th>Uptake potential (Mt/y)</th>
<th>Research &amp; Industrial engagement</th>
<th>TRLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol production</td>
<td>&gt; 300</td>
<td>++ +</td>
<td>4-6</td>
</tr>
<tr>
<td>(Carbonate) Mineralisation</td>
<td>&gt; 300</td>
<td>++ +</td>
<td>3-6</td>
</tr>
<tr>
<td>Polymerisation</td>
<td>5 &lt; demand &lt; 30</td>
<td>++ +</td>
<td>8-9</td>
</tr>
<tr>
<td>Formic acid</td>
<td>&gt; 300</td>
<td>++ +</td>
<td>2-4</td>
</tr>
<tr>
<td>Urea</td>
<td>5 &lt; demand &lt; 30</td>
<td>++ +</td>
<td>9</td>
</tr>
<tr>
<td>Enhanced coal bed methane recovery</td>
<td>30 &lt; demand &lt; 300</td>
<td>+ - -</td>
<td>6</td>
</tr>
<tr>
<td>Enhanced geothermal systems</td>
<td>5 &lt; demand &lt; 30</td>
<td>++ -</td>
<td>4</td>
</tr>
<tr>
<td>Algae cultivation</td>
<td>&gt; 300</td>
<td>+ - -</td>
<td>3-5</td>
</tr>
<tr>
<td>Concrete curing</td>
<td>30 &lt; demand &lt; 300</td>
<td>++ -</td>
<td>4-6</td>
</tr>
<tr>
<td>Bauxite residue treatment</td>
<td>5 &lt; demand &lt; 30</td>
<td>++ -</td>
<td>4-5</td>
</tr>
<tr>
<td>Fuels engineered micro-organism</td>
<td>&gt; 300</td>
<td>++ -</td>
<td>2-4</td>
</tr>
<tr>
<td>CO2 injection to methanol synthesis</td>
<td>1 &lt; demand &lt; 5</td>
<td>+ - -</td>
<td>2-4</td>
</tr>
</tbody>
</table>
CO₂ is a minor input in CCU – Energy and Resources Dominate

CCU Fuels / CCU chemicals – A high energy reactant such as H₂ is the major resource requirement. e.g. for CCU with electrolytic H₂ and under favourable assumptions, the use of 1 tonne of CO₂ in the formation of methanol requires some 6.5 MWh of zero carbon electricity. Manufacturing diesel fuel would double the electricity requirement.

The amount of CO₂ that can be converted to chemicals and materials is relatively small compared to the amount of anthropogenic CO₂ emitted from fossil fuel combustion. (Song et al. 2012)

Source: Breyer (2017) Synthetic Methanol and Dimethyl Ether Production based on Hybrid PV-Wind Power Plants
Carbon dioxide is a molecule of low thermodynamic potential.

".../it is known that the activation of C-O bonds in \( \text{CO}_2 \) molecules is hindered by its nature from a thermodynamic and kinetic standpoint. The high chemical/electrochemical stability of \( \text{CO}_2 \) is a basic contradiction for conversion." — Zheng et al. 2017

*used to calculate the maximum of reversible work that may be performed by a thermodynamic system at a constant temperature and pressure (isothermal, isobaric).
This is all the electricity produced in Europe. It’s used for everything from lighting, air-conditioning, heating, industry etc.

If all passenger cars in Europe were electric, the increase in electricity is significant — but not world changing. It would amount to approximately 800 TWh.

Electrifying EU base industrial chemicals - 140% additional electricity!

Adding the production of synthetic fuels increases electricity demand beyond all reality.

CCU: using CO₂ for the production of chemicals

~ 3,200 TWh

CCU fuels: Using CO₂ to produce synthetic fuels

~ 7,600 TWh

~ 14,400 TWh

Accounting for emissions reductions in the current EU legislation
What about the climate?

It’s complicated:

"The process of making such products involves some chemical voodoo"

German Environment Agency
Dr. Harry Lehmann, General Director of Division Environmental Planning and Sustainability Strategies
In comparison to permanent storage, CCU does not have significant emissions abatement potential.

The MeOH analysis shows CCU to be an inferior mitigation option compared to a system with CCS producing the same fuel without CO₂ utilization. The generalized analysis further reveals that the mitigation potential of CCU for fuels production is limited to 50% of the original emissions of the reference system without CCU. We further highlight that the main challenge to CCU cost reduction is not the CO₂-to-fuel conversion step but the production of required carbon-free electricity at very low cost.

The life cycle of the product

The key to accounting for emissions reductions

Re-use of the CO₂ molecule means a maximum 50% emissions reduction in ideal conditions.

The standard emissions reduction target for low-carbon fuels is 70% (target for 2021).

Source: Benedikt Stefansson, Director of Business Development - Carbon Recycling International
The life cycle of the product

Available LCA studies (for example a recent JRC publication on “Methanol using captured CO2” [2]) refer to very narrow process boundaries, where CO2 and H2 are entering the boundaries. However, to assess the real mitigation potential of any CCU process it is essential to consider much wider system boundaries.

Source: Abanades et al. 2017 (Peres-Fortes et al. 2016)

"If you can use the industrial carbon dioxide, the only CO2 emissions attached to it are the purification, compression and transport – because otherwise it would be released to the atmosphere."

Classifying CO2 streams as unavoidable waste

Robert Edwards, DG JRC, ISPRA, "Proposed principles for calculating emissions from RES fuels of non-biological origin and CCU fuels", presented during the official LCA workshop organised by the European Commission
## Counting the CO₂

- If the overall CO₂ reduction of a CCU fuel system amounts to a theoretical maximum of 50%, where do we account the emissions reduction?

- It is impossible for both parties (CO₂ supplier & CO₂ user) to be decarbonised. Any CO₂ reduction must be split or given to one party.

- Thus CO₂ recycle (CCU Fuels) can not reduce emissions from industry & transport simultaneously.

<table>
<thead>
<tr>
<th>CO₂ supplier</th>
<th>Fuel/Chem producer</th>
<th>CO₂ supplier</th>
<th>Fuel/Chem producer</th>
<th>CO₂ supplier</th>
<th>Fuel/Chem producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>~50% CO₂ reduction</td>
<td>Zero CO₂ reduction</td>
<td>CO₂ avoided shared. Both see a reduction of ~35%</td>
<td>Zero CO₂ reduction</td>
<td>~50% CO₂ reduction</td>
<td></td>
</tr>
<tr>
<td>CO₂ emissions abatement at CO₂ supplier.</td>
<td>Full carbon fuel made with renewable electricity</td>
<td>Small CO₂ reduction</td>
<td>Small CO₂ reduction</td>
<td>No abatement of emissions from where CO₂ is captured</td>
<td>Low carbon fuel made with renewable electricity –</td>
</tr>
<tr>
<td>CO₂ emission now distributed in transport fleet</td>
<td>No rationale for fuel as not compatible with CO₂ reduction performance of REDII</td>
<td>Low CO₂ abatement – CO₂ scattered, not possible to reduce emissions further</td>
<td>Not sufficient abatement to reach reduction performance of REDII</td>
<td>Emitter must surrender EUA. CO₂ emissions now scattered, no abatement potential</td>
<td>CO₂ emissions from fuel still accounted at industrial source.</td>
</tr>
</tbody>
</table>
CCU and the ETS

• CCU can link emissions from one sector to another
• CO$_2$ captured and use in one sector can then be emitted in another
• Different CO$_2$ reduction policies can become entangled or short-circuited
• Danger of double counting – who gets the credit?
The Renewable Energy Directive

<table>
<thead>
<tr>
<th>Recycled carbon fuels</th>
<th>Renewable fuels of non-biological origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuels produced from unavoidable gaseous waste streams of non-renewable origin, including waste processing gases and exhaust gases</td>
<td>Liquid or gaseous fuels which are used in transport other than biofuels whose energy content comes from renewable energy sources other than biomass</td>
</tr>
</tbody>
</table>

- **No double counting**

  “By 31 December 2021, the Commission shall adopt delegated acts in accordance with Article 32 to specify the methodology to determine the share of biofuel resulting from biomass being processed with fossil fuels in a common process, and to specify the methodology for assessing greenhouse gas emission savings from renewable liquid and gaseous transport fuels of non-biological origin and recycled carbon fuels, which shall ensure that **no credit for avoided emissions be given for carbon dioxide whose capture already received an emission credit under other legal provisions.**”

- **Minimum savings**

  “Appropriate minimum thresholds for greenhouse gas emission savings of recycled carbon fuels shall be established through life cycle assessment that takes into account the specificities of each fuel. The threshold shall be set by the Commission at the latest by 1 January 2021 by the means of a delegated act.”
Creating a clean market instead of supplying the fossil one

Carbon free H2 use replaces unsustainable infrastructure

Using clean H2 to turn it back to a gas or other hydrocarbons supplements unsustainable infrastructure
Thank you for your attention!

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References


https://doi.org/10.1016/j.apenergy.2015.07.067