European Commission

Novel Carbon Capture and Utilisation Technologies (CCU):
Research and Climate Aspects

17 September 2018 , Brussels

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STRUCTURE

EXECUTIVE SUMMARY

1 - INTRODUCTION

2 - AIM AND SCOPE

3 - METHODOLOGY

4 - POLICY AND LEGAL CONTEXT

5 - SCIENTIFIC EVIDENCE (SAPEA report)

6 - RECOMMENDATIONS

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OBJECTIVE OF THIS OPINION

Analyse the climate mitigation potential the CCU technologies for production of fuels, chemicals and materials in the mid- and long term.

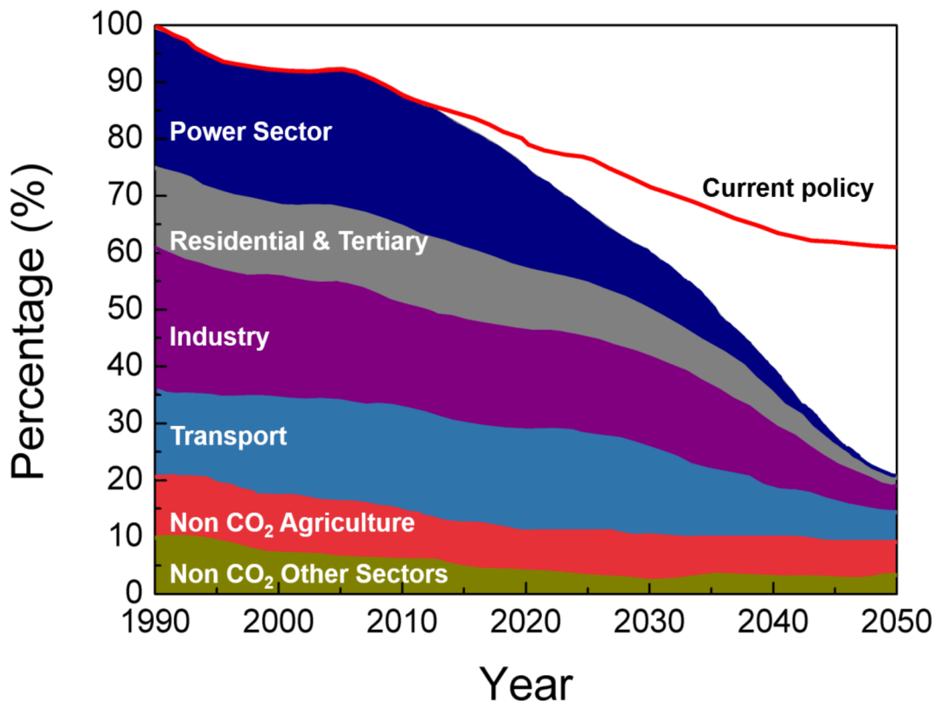
INTRODUCTION

The CCU technologies that are examined in this Opinion cover the family of technologies that, combined in a system, convert otherwise industrially emitted or airborne CO_2 into **fuels, chemicals and materials.**

This Opinion looks at **novel technologies** that can produce **added-value products** with ever-increasing efficiency by using renewable energy sources. These technologies use CO_2 as a raw material (feedstock) and integrate its carbon content in products for a shorter or longer period, i.e. until the product reaches its end-of-life and the carbon is released to the atmosphere or recaptured.

INTRODUCTION

EU has committed to an economy-wide domestic target of at least **40% GHG emission reduction for 2030** compared to 1990. By 2050, the EU aims to reduce its emissions by 80-95% compared to 1990 levels.



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AIM AND SCOPE

SAM High Level Group is asked to provide **scientific advice** based on existing research on the **climate mitigation potential of CCU technologies** to inform future policy decisions in this field over the next couple of years.

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AIM AND SCOPE

1. Under what circumstances CCU for production of fuels, chemicals and materials can deliver climate benefits and what are their **total climate mitigation potential in the mid- and long-run**?

2. How can the climate mitigation potential of CO_2 incorporated in products such as fuels, chemicals and materials **be accounted** for considering that the CO_2 will remain bound for **different periods of time and then may be released in the atmosphere**?

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METHODOLOGY

A scientific evidence gathering process on CCU was performed by SAPEA:

Chair: Robert Schlogl

Deputy Chair: Marco Mazzotti

The evidence gathering process consisted of three different elements:

The scientific literature review

Expert WG meetings

Organisation of a scientific expert workshop

Scientific Evidence Review

- A **scientific evidence report** was prepared by SAPEA#.
- EURO-CASE was in charge.
- Top scientists indicated by various European Academies have provided scientific evidence to the SAM HLG Scientific Opinion.

 # Search query on the WoS database: 18 600 papers and 350 000 citations

POLICY AND LEGAL CONTEXT

EU policy and legislation

CCU is a research priority under the Energy Union to allow the industrial and power sectors to reaching climate objectives in a cost-effective way (Emission Trading Scheme Directive).

This requires a wide range of legislative and policy initiatives:

- 61 EU projects running on CCU (FP7, H2020)
- Horizon Prize CO_2 Reuse (1.5 M€)
- Several directives on Energy/Transport sector:
  - *Energy Efficiency Directive (EED)*
  - *Renewable Energy Directive (RED)*

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Recommendations

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R1 - To develop a methodology to calculate the Climate Mitigation potential of CCU

- It is strongly recommended that EU develops a rigorous cross-sectorial methodology to calculate the CO_2 Climate Mitigation potential of CCU projects.

- Such a methodology should be preceded by the analysis of technologies (including full LCA assessment) required to achieve deep decarbonisation. Only projects that are beneficial to close gaps to achieve deep decarbonisation should be taken into account.

- This will constitute a powerful set of European guidelines and standards for the analysis of CCU projects.

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R2 - Eligibility criteria for CCU projects

A CCU project should be considered eligible for funding or to be further included in Climate Change Schemes, such as the Innovation Fund, if through the use of the described methodology, the project is able to demonstrate and to quantify its CO_2 mitigation potential.

The four following conditions must be fulfilled:

- The required energy has low-carbon origin, with high availability and low cost
- Other, simpler and more cost effective solutions do not yield comparable products available in sufficient quantities
- The readiness level of CCU projects will meet the objectives
- There are supplementary benefits of the CCU projects in addition to climate mitigation potential.

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R3 - CCU Novel Technologies

CCU technologies cover a wide spectrum of different technologies with a variety of TRLs. Some of the technologies are at the research and laboratory experimentation level (e.g., the case of nanomaterial catalysts), others at the demonstration level (e.g., the production of renewable methanol) and some technologies are already mature and have entered in the market (production of chemicals such as urea). **However, the majority of technologies are at a TRL 3-5.**

Since CCU technologies are not stand-alone but part of a system, apart from the TRL, also the IRL (**Integration Readiness Level**) should be considered to assess the readiness of and the contribution that CCU technologies can make.

R4 - Regulatory and investment framework

Due to the low TRL and the uncertainty about the mitigation potential, CCU technologies have been absent from the European and International Climate Change funding schemes. A stable regulatory and investment framework is necessary in order these technologies achieve a mature stage.

It is **strongly recommended** that European Commission develops a regulatory and investment framework for CCU applications comprising a set of clear rules and operational guidelines for CCU applications.

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R5 - International framework - Party to the Convention on Climate Change

The above methodology should be based on the described mechanisms indicated in this Opinion, and also be used as a selection criterion for CCU projects to be eligible in European and International schemes.

European Commission as a Party to the Convention on Climate Change, Kyoto Protocol and Paris Agreement is also recommended to propose this methodology in international arenas, in particular in the scope of the UNFCCC.

United Nations Climate Change

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Thank you

ec.europa.eu/research/sam

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"For CCU, the GWP varies widely depending on the utilisation option.

Mineral carbonation can reduce the GWP by 4–48% compared to no CCU.

Utilising CO_2 for production of chemicals, specifically, dimethylcarbonate (DMC) reduces the GWP by 4.3 times and ozone layer depletion by 13 times compared to the conventional DMC process."

Cuéllar-Franca, R. M.; Azapagic, A., Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts. ***Journal of CO2 Utilization*** **2015,** 9, 82-102.

GWP – Global Warming Potential

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The role of CO_2 capture and utilization in mitigating climate change

Niall Mac Dowell[1,2*], Paul S. Fennell[3], Nilay Shah[2,3] and Geoffrey C. Maitland[2,3]

To offset the cost associated with CO_2 capture and storage (CCS), there is growing interest in finding commercially viable end-use opportunities for the captured CO_2. In this Perspective, we discuss the potential contribution of carbon capture and utilization (CCU). Owing to the scale and rate of CO_2 production compared to that of utilization allowing long-term sequestration, it is highly improbable the chemical conversion of CO_2 will account for more than 1% of the mitigation challenge, and even a scaled-up enhanced oil recovery (EOR)-CCS industry will likely only account for 4–8%. Therefore, whilst CO_2-EOR may be an important economic incentive for some early CCS projects, CCU may prove to be a costly distraction, financially and politically, from the real task of mitigation.

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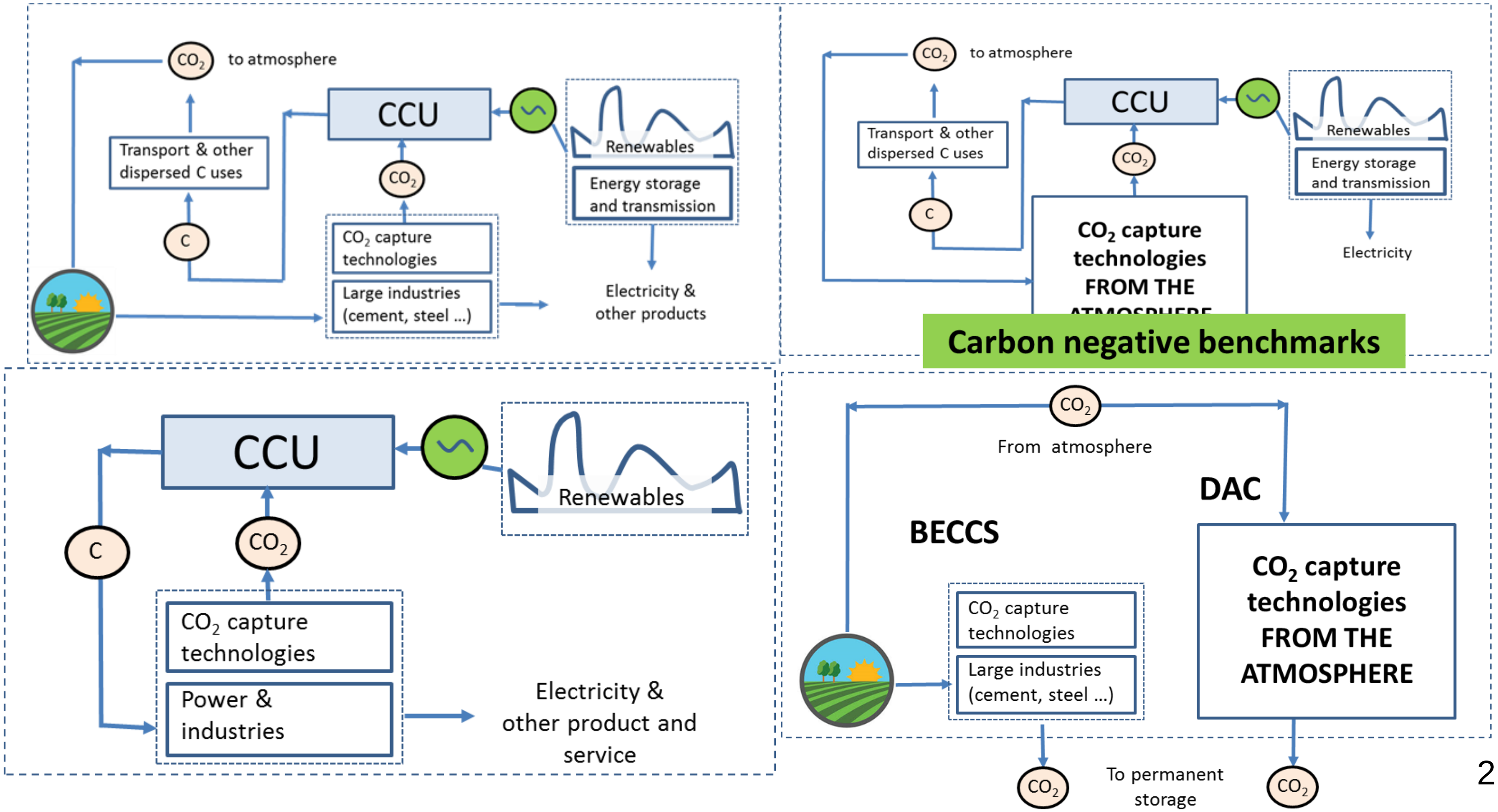
Fuel production from CCU



Technology facts

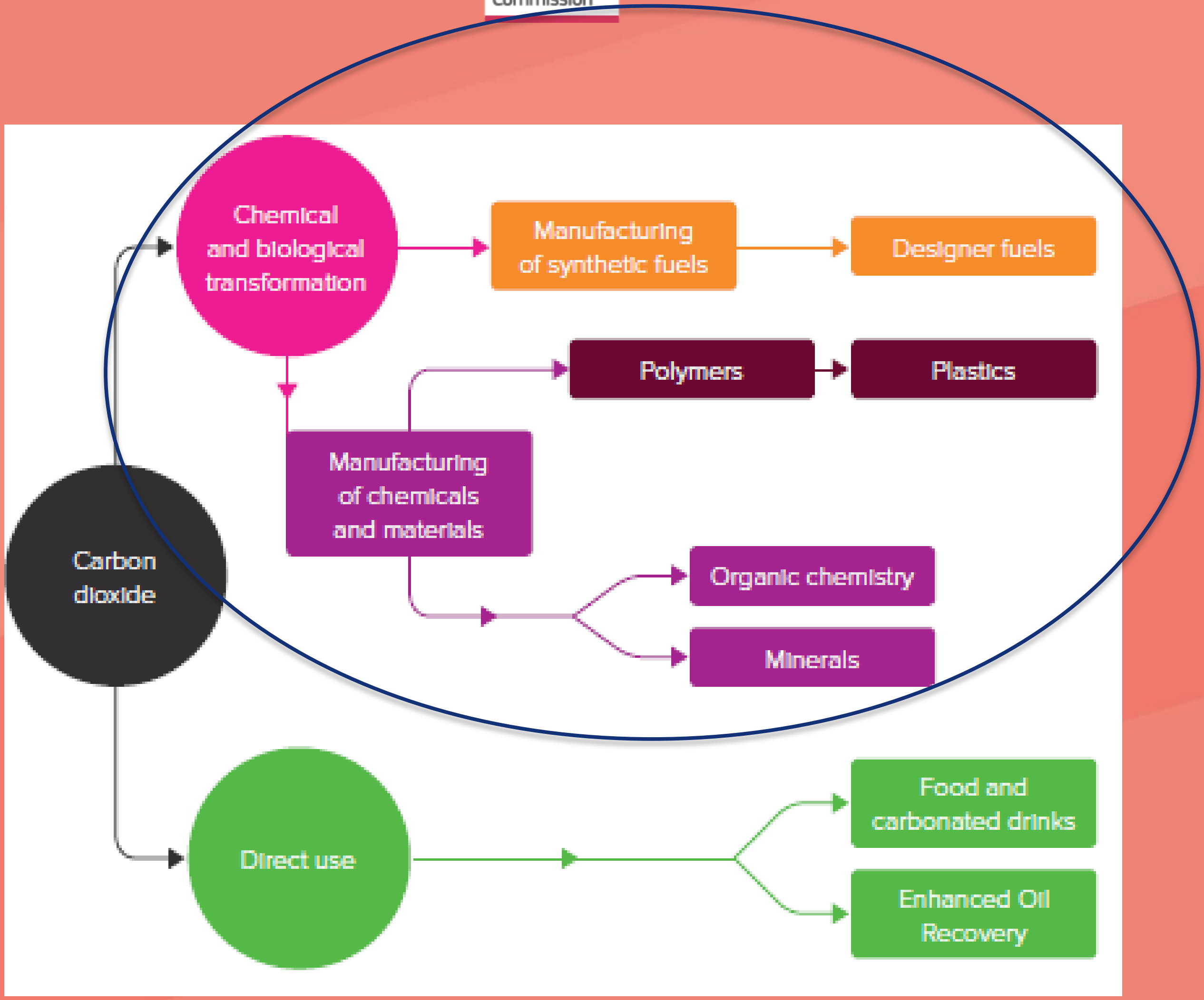
Nowadays, uses of CO_2 are in beverage carbonation, food industry, medical applications, urea synthesis, rubber/plastics or to mix gases/aerosols, among others [IHS CHEMICAL 2015].

Capture, transport, CO2 transformation and CO2 product consumption represents the value chain of the CCU technology.

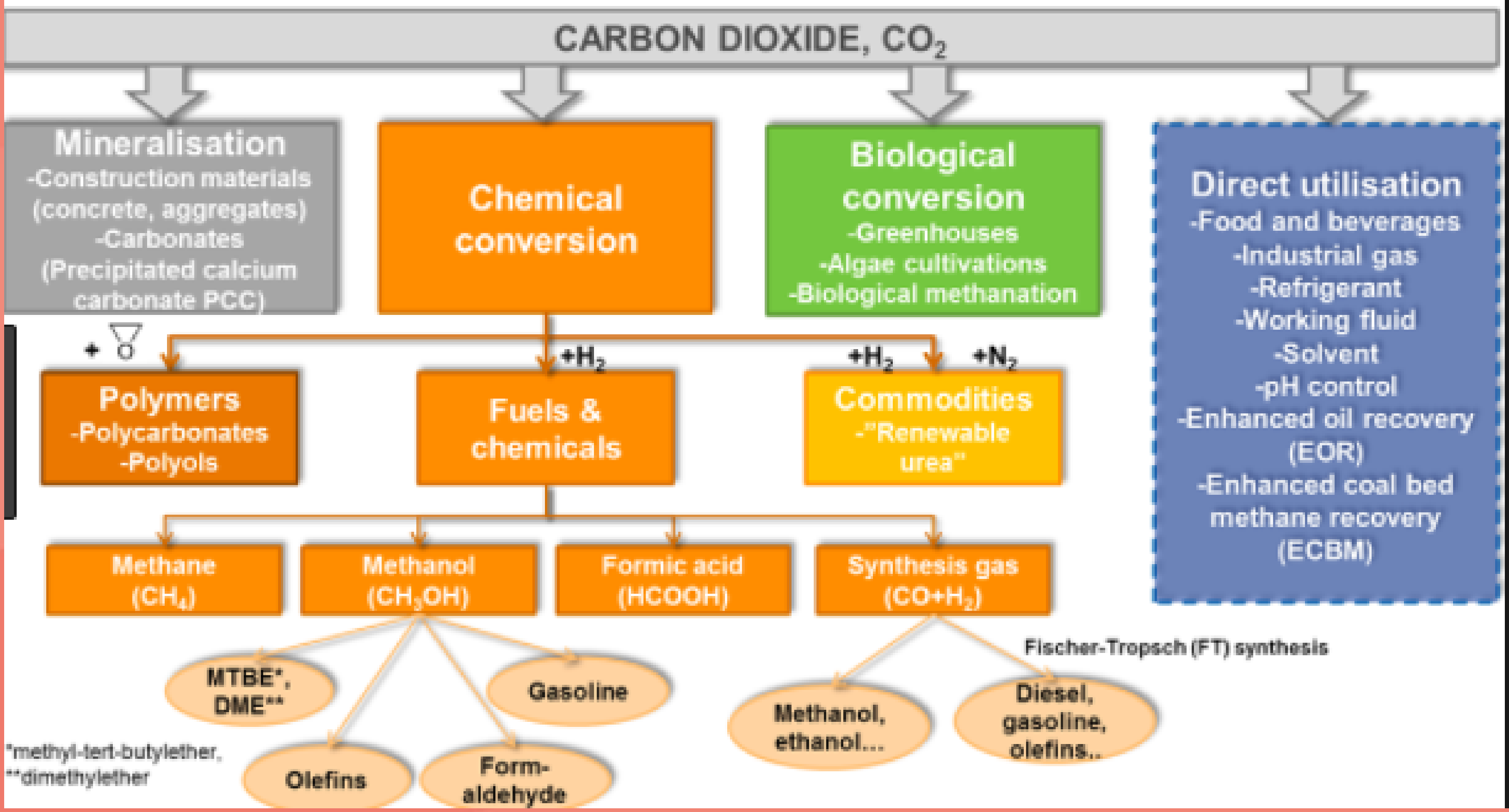
"Zero emission power plants" may capture at least 85% of the CO2 formed during the power generation process. Heavy industry emissions may have to use CO2 capture techniques to further decrease their carbon emissions. This captured CO2 will be either transported to suitable underground locations where it will be stored, or transported to be further used in industrial processes as a raw material or working fluid (so-called carbon capture and utilisation – CCU).

CCU fuels remains around factor 2 or 3 times more expensive than fossil fuel competitors. [Bio-based News 2015].

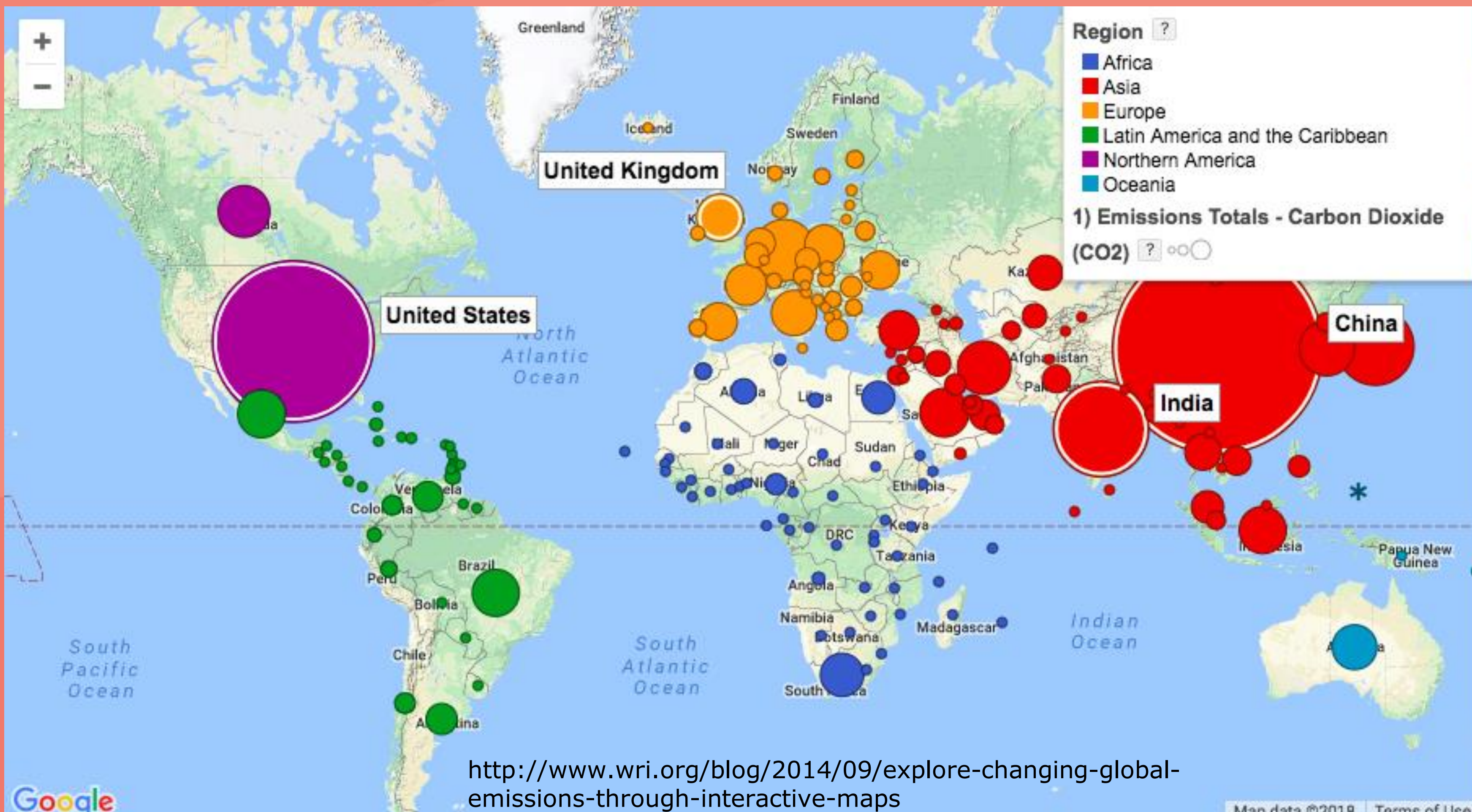
Iceland has the first semi-commercial plant, which is running with geothermal energy to produce methanol from CO2 [Bio-based News 2015].


Chemical and biological transformation
Manufacturing of synthetic fuels
Designer fuels
Polymers
Plastics
Manufacturing of chemicals and materials
Carbon dioxide
Organic chemistry
Minerals
Direct use
Food and carbonated drinks
Enhanced Oil Recovery

Main CO_2 utilisation routes and applications

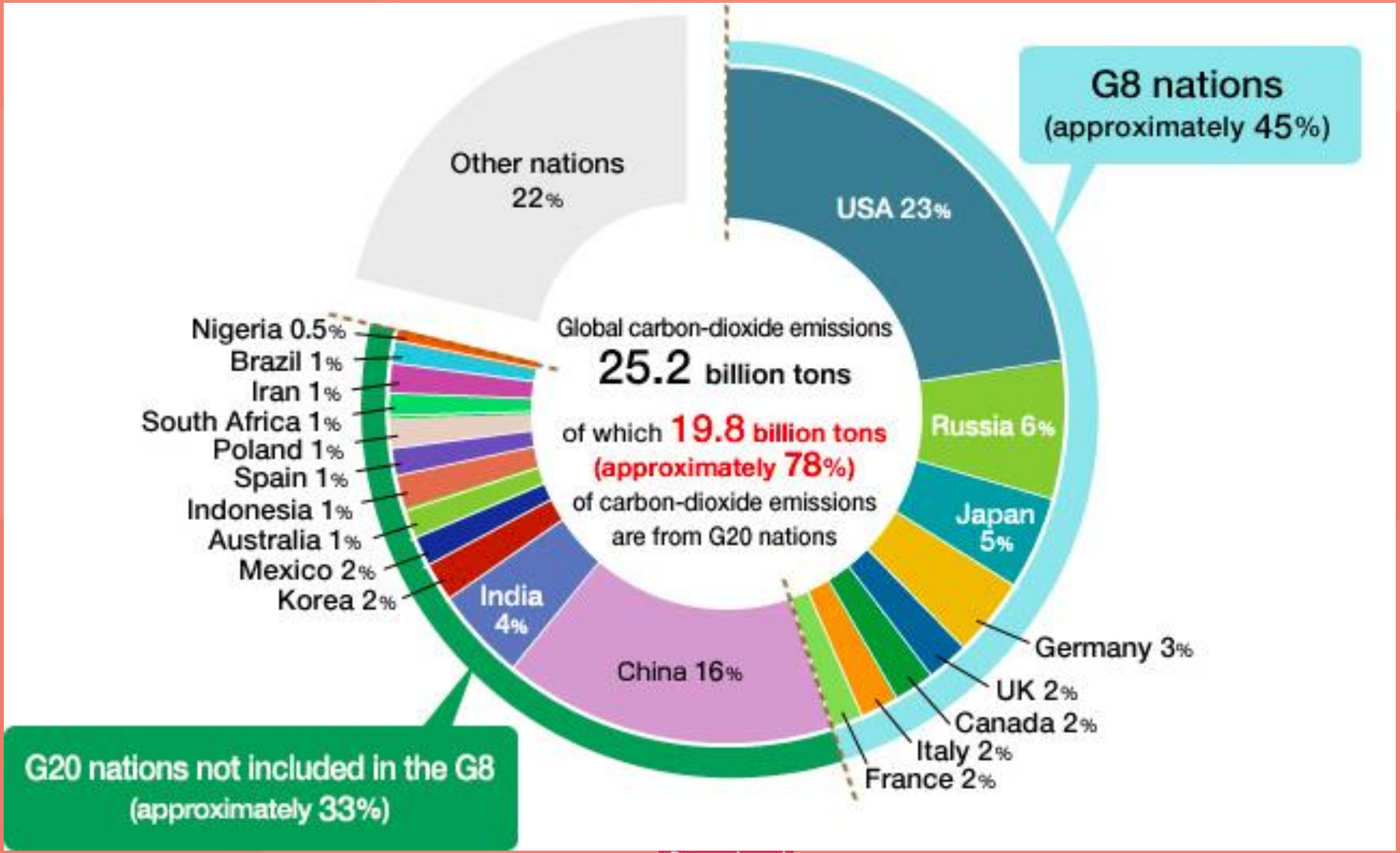


Introduction



http://www.wri.org/blog/2014/09/explore-changing-global-emissions-through-interactive-maps

The CO_2 Problem



http://www.constantinealexander.net/2012/07/global-co2-emissions-continue-to-increase.html

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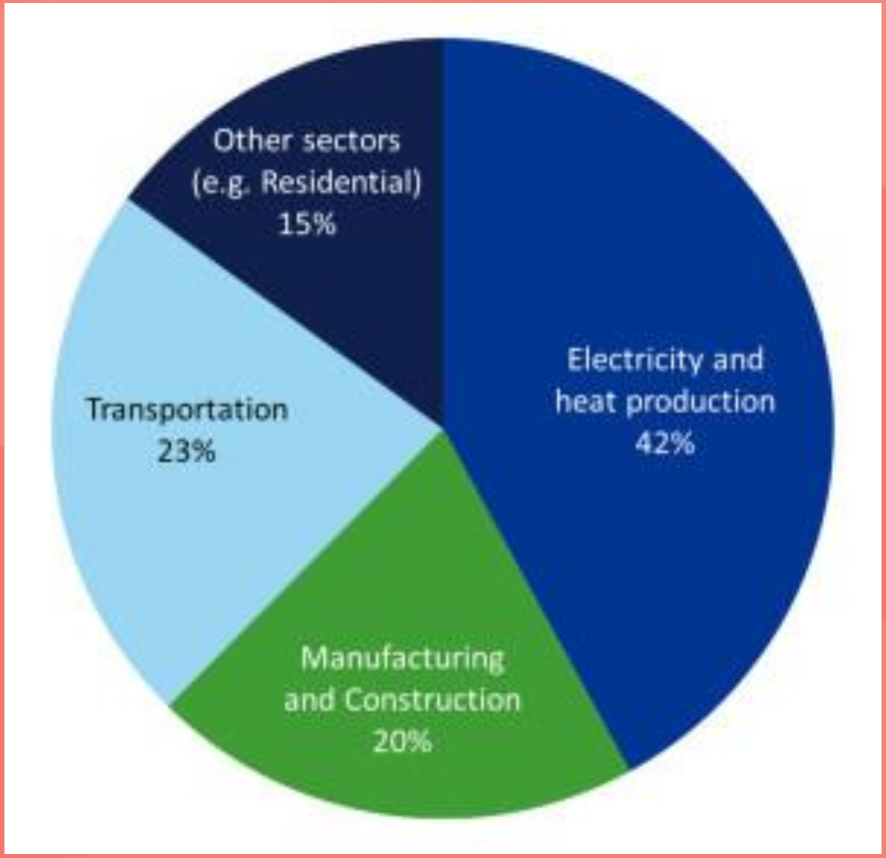
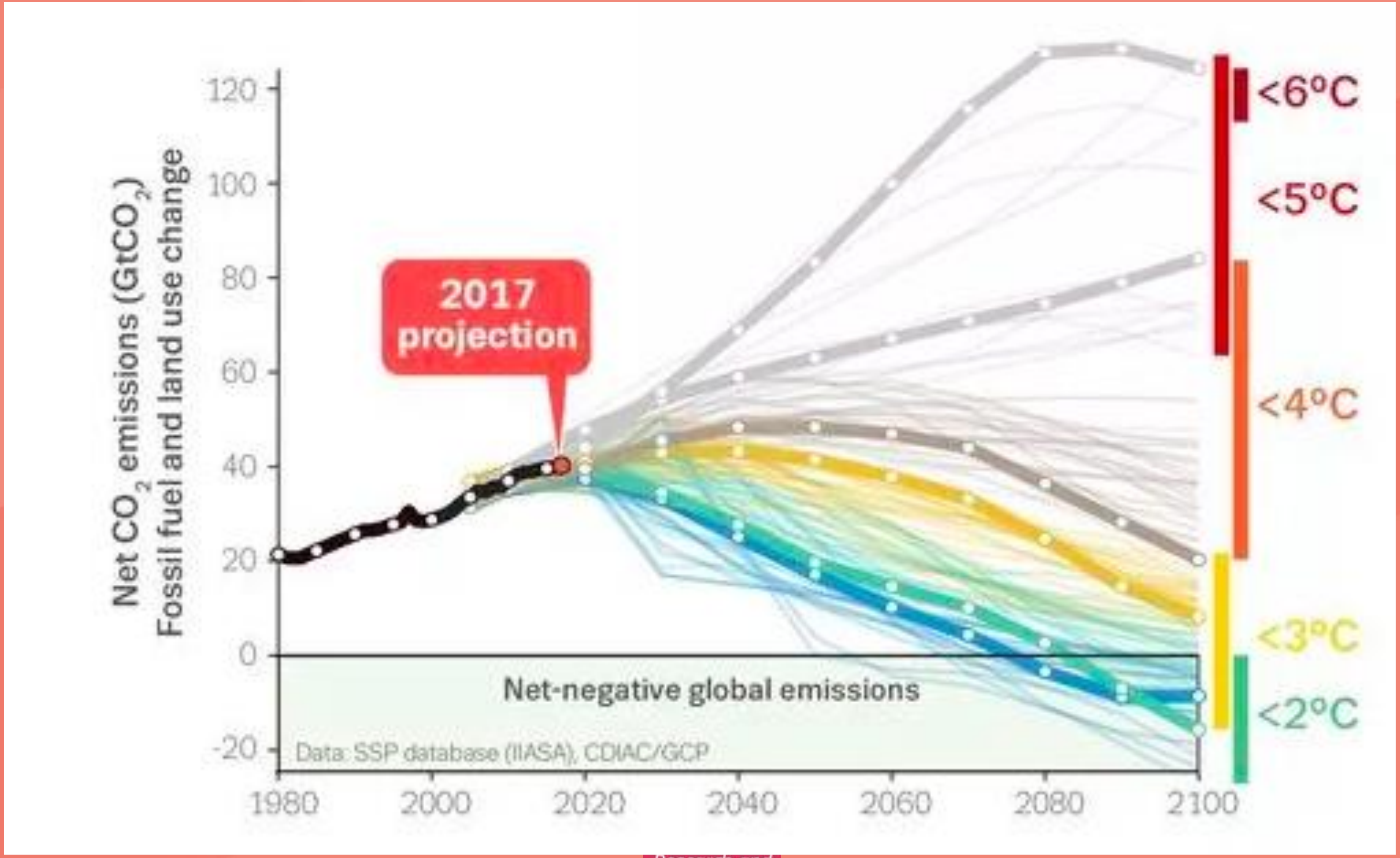
The CO_2 Problem



https://blogs.dnvgl.com/energy/us-clean-power-plan-and-global-emissions-what-difference-does-the-ccp-make-2

The CO_2 Solution Request



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Key issues identified by the SAM HLG currently under consideration

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The cyclical approach to CCU

- Decarbonisation is one of the main goals of the EU; multiple actions and instruments are needed.
- CCU may be an enabling technology for this purpose.
- CO_2 as a source (raw material) of potential valuable materials, products and services.
- CCU cyclical approach in the transition to a low carbon future (energy and industry) in the short and medium term.

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CCU and Renewable Energy Sources (RES)

- CCU require large amounts of energy.
- For climate change mitigation purposes, CCU technologies need energy that should be of renewable sources, e.g. surplus of RES.
- In addition, further efforts to improve energy efficiency the chain are needed.

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The concept of CCU services

- The contribution of CCU in climate change mitigation should be seen not only to reduce CO_2, but rather in terms of CCU energy-systems-services, e.g.:
  - Renewable Energy storage
  - Non-electricity energy vectors (aviation, maritime, etc)
  - Distribution through the existing infrastructures;
  - Manufacturing of carbon-containing industrial products.

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CCU Climate mitigation potential

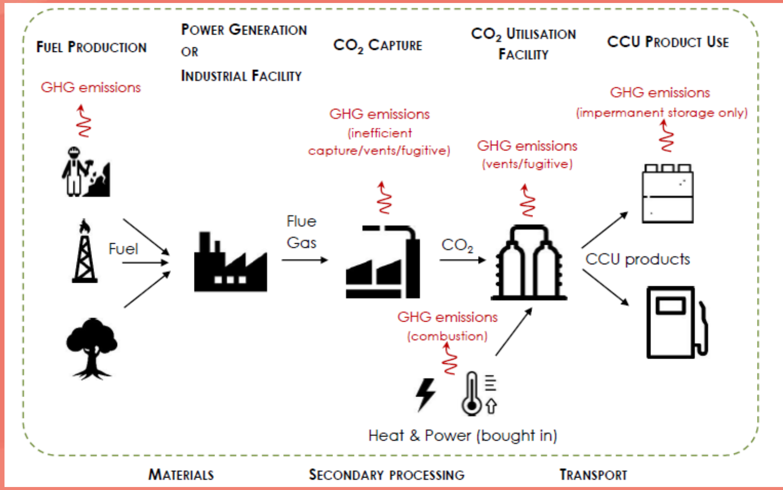
- The contribution of CCU in climate change mitigation should be seen not only to reduce CO_2, but rather in terms of CCU energy-systems-services.

- Nature and source of CO_2 are crucial for determining the climate change mitigation potential of different CCU systems.

- Resulting products can also be of very different nature and have different lifetimes.

Life Cycle Assessment (LCA) CCU boundaries

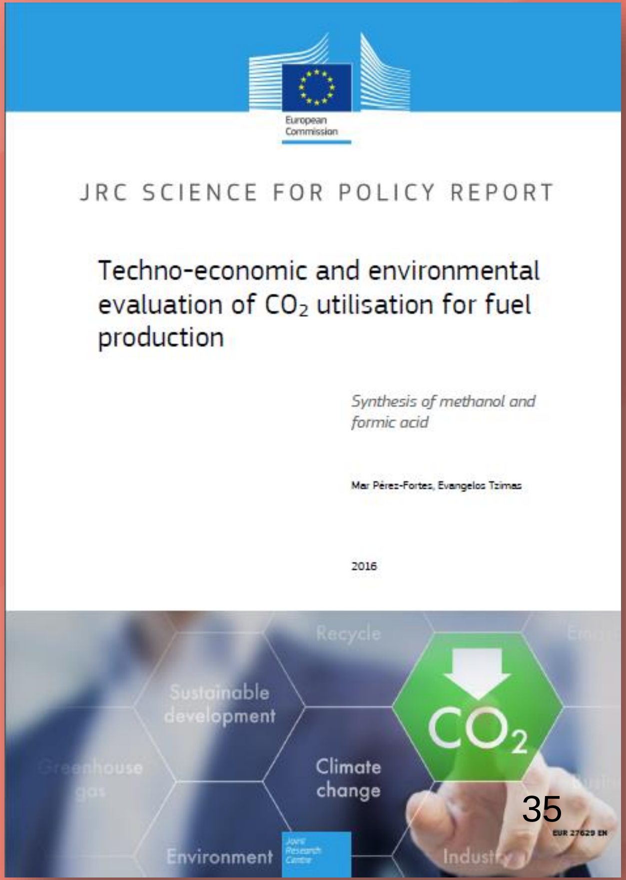
- To enable quantitative estimates of GHG emissions from cradle-to-grave requires a detailed definition of all the subsystems within the CCU system, following a standardised LCA methodology.



Source: CarbonCounts

CCU Climate mitigation potential - fuels

- "1 kg of methanol from CO_2 requires 10 kWh electricity"[1]
- CCU has little potential to mitigate climate change, unless the large amount of energy needed to manufacture the fuel comes from carbon-free sources.



[1] **SAPEA report 2018**

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CCU Climate mitigation potential - Chemicals

Global markets[1]

35.5 Gt of CO_2 are emitted/year

- Urea (160 Mt/yr)
- Methanol (61 Mt/yr)
- Formic acid (0.65 Mt/yr)

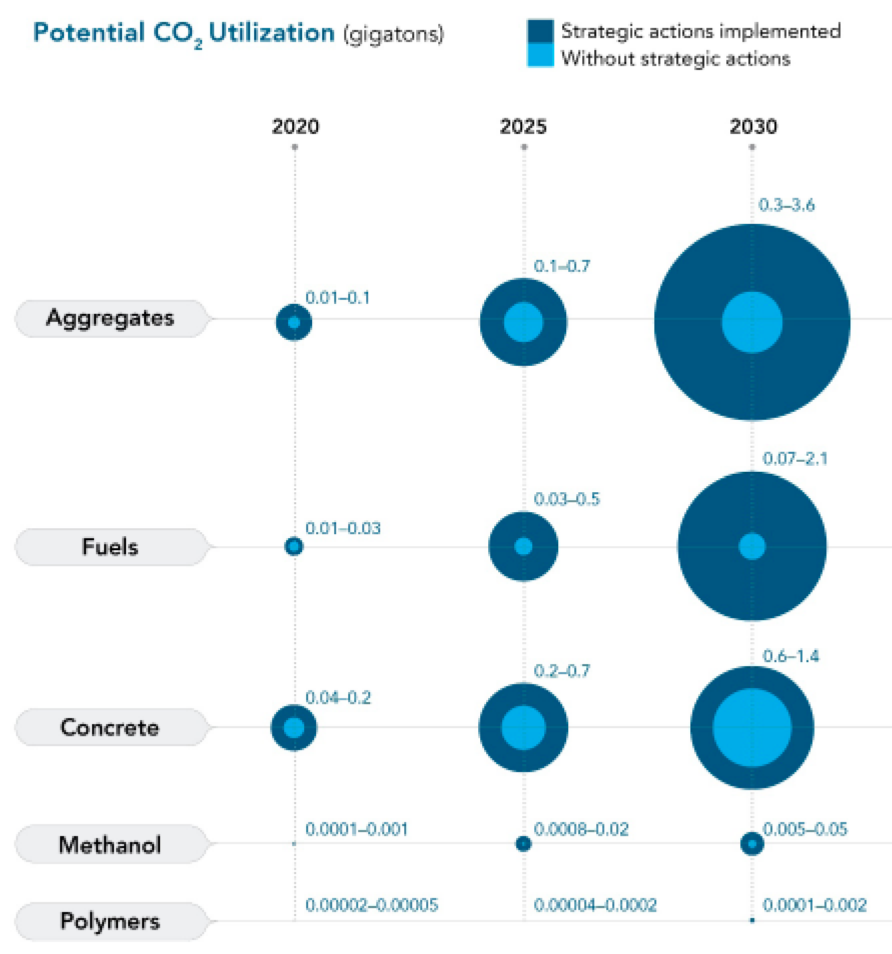
[1] SETIS-reports "CCU-synthesis of fuels, chemicals and materials"

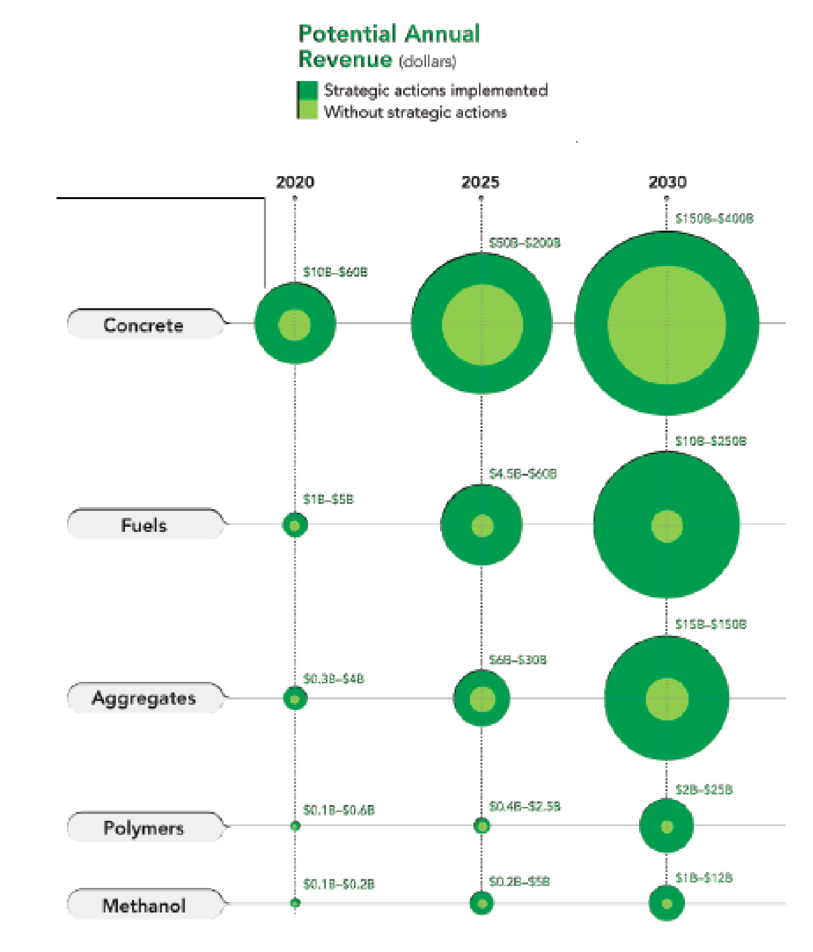
CCU Climate mitigation potential - Materials

- Building materials:
  - Concrete
  - Carbonate aggregates
- Polymers (polyols and polycarbonates)
  - Equivalent to 0.6% global emissions[1]
- Carbon materials?

[1] SETIS-reports "CO_2 as a feedstock for polymers"

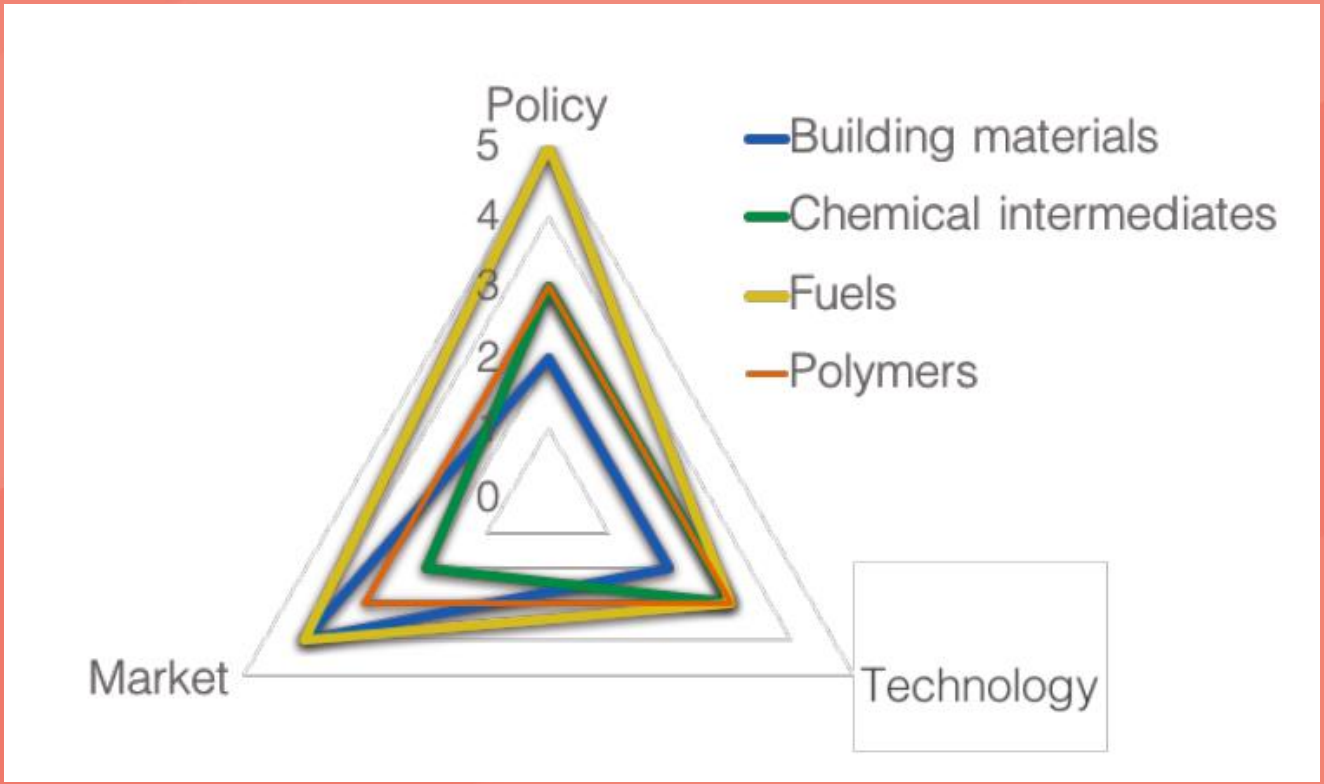
Potential CO_2 utilisation





Source: Global CO_2 Iniciative 2016 and ICEF

Policy/Market/Technology



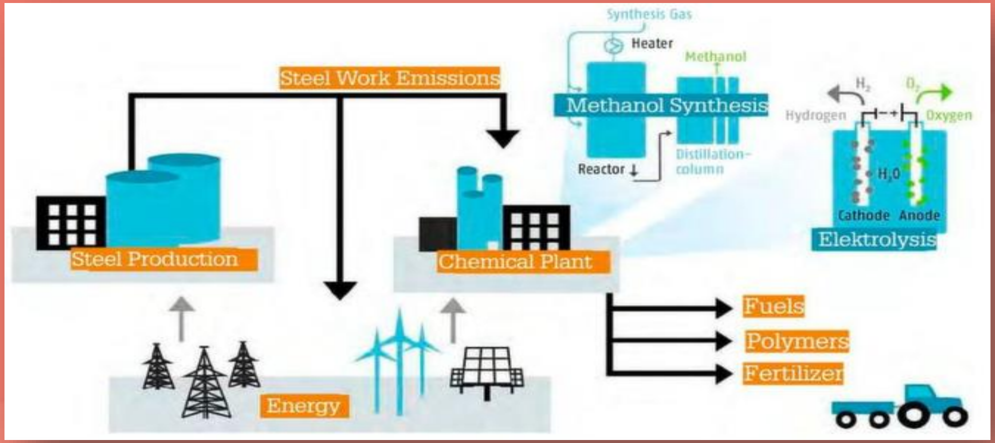
Source:Global CO2 Iniciative and ICEF

CCU and CO_2 unavoidable emissions

Cement Industry

1/3 of the CO_2 emitted by the cement industry comes from combustion, while 2/3 come from the limestone calcination.

Steel Industry



Period of CO_2 will remain bound

- The utilised CO_2 in most cases (except mineralization processes, where CO_2 may be stored over decades and centuries) is reemitted at a later point in time.
- However, if a cyclical approach is adopted, the period of time that CO_2 will remain bound is less relevant.

CO_2 Feedstock	CO_2 Storage: Permanent	CO_2 Storage: Not Permanent
Captured high concentration CO_2	EOR ECBM EGS Bauxite residue	Urea Polymers Renewable methanol Formic acid
Dilute CO_2 flue gas	ECBM Mineral carbonation Concrete curing Algae cultivation	Algae cultivation

Source: Global CCS Institute

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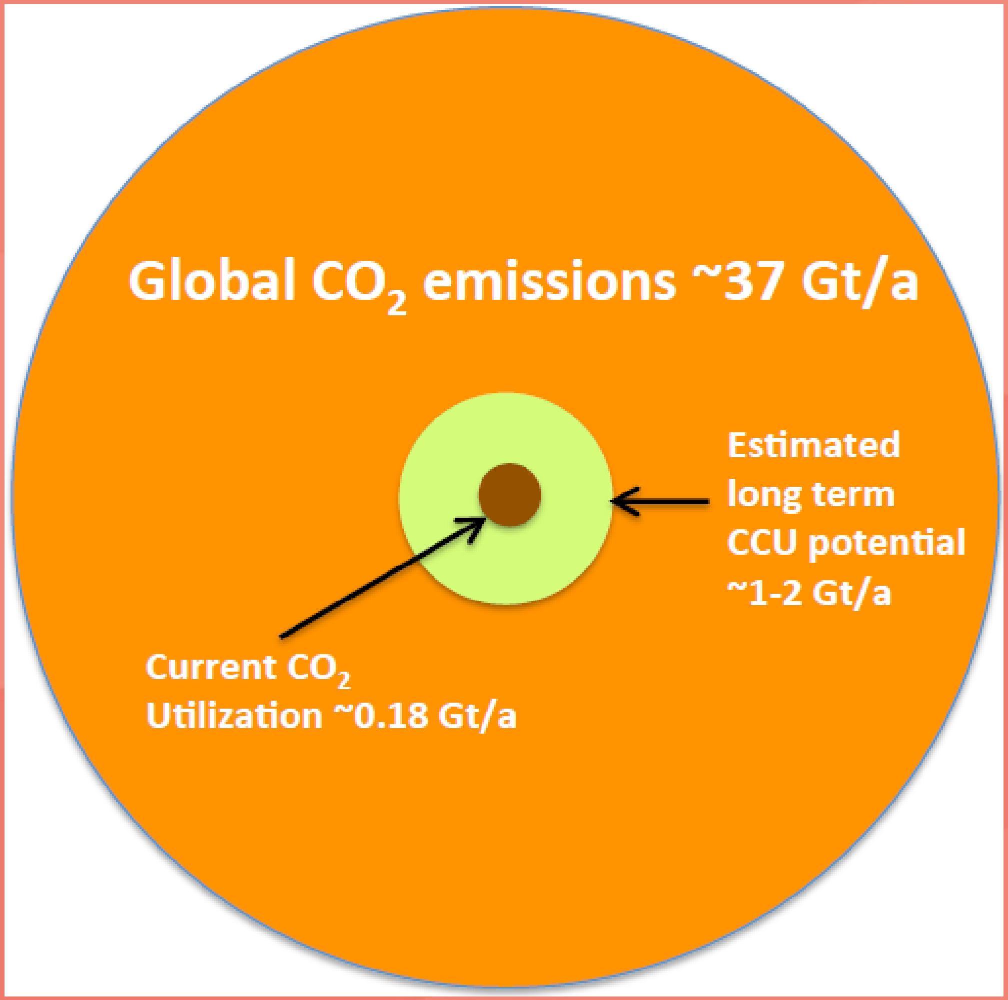
Period of CO_2 will remain bound

- Accountability of carbon emissions in CCU systems is strongly dependent on the relevant time scale for the release of CO_2 by the different CCU schemes.

- Any product that releases the carbon in a short time (e.g. days, weeks, months, or even decades) will not mitigate climate change unless the released carbon can be captured back from the air directly (DAC) or by means of biomass.



Fuels – XX%

Chemicals – YY%

Materials – ZZ%

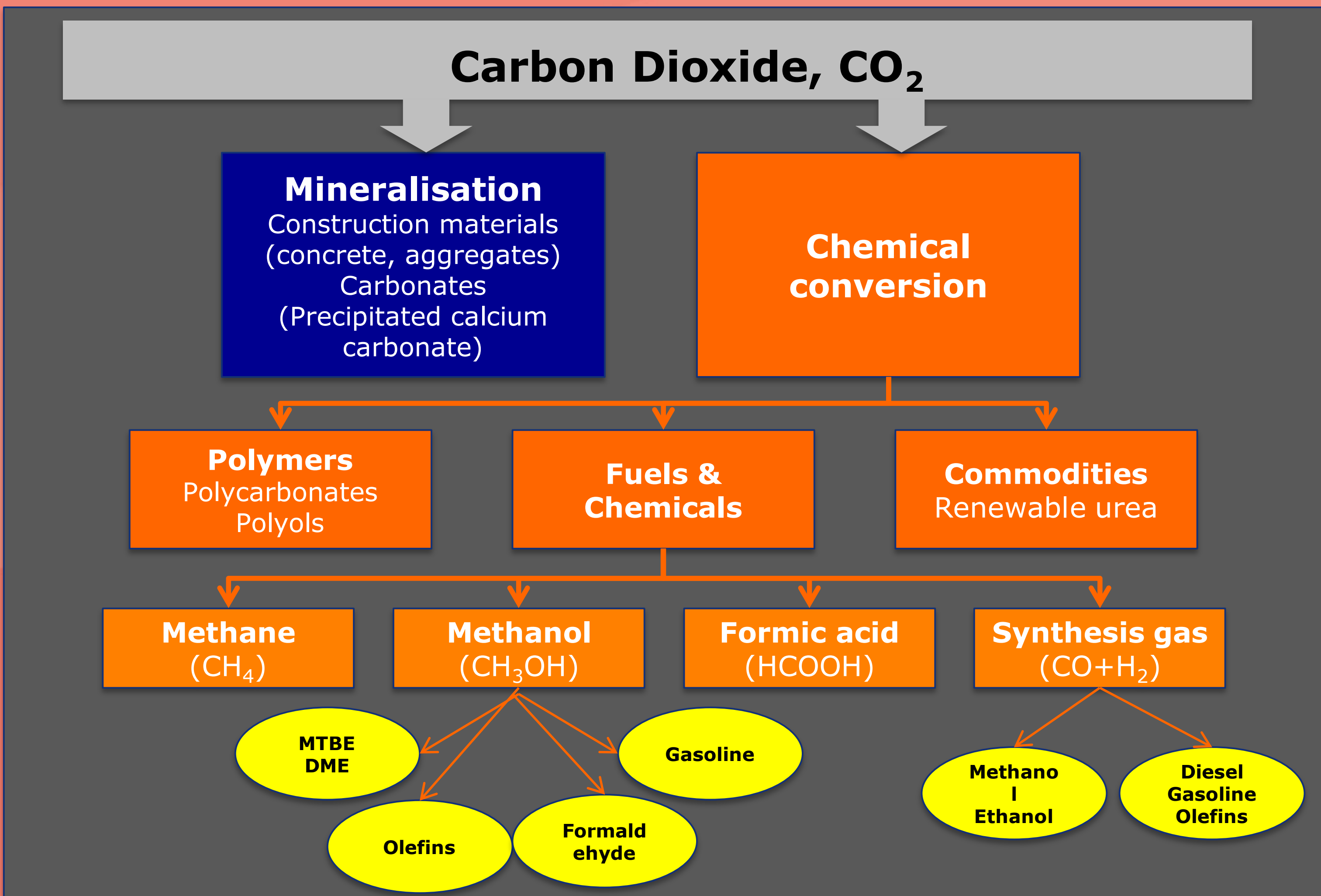
Conclusoes pag 11

A robust cross-sectoral and multi–disciplinary methodology should be developed to assess the benefits of climate change mitigation technologies, not only of CCU. Among the methodological components should be a rule-based Life

SCIENTIFIC
ADVICE
MECHANISM

**INDEPENDENT
SCIENTIFIC ADVICE
FOR POLICY MAKING**

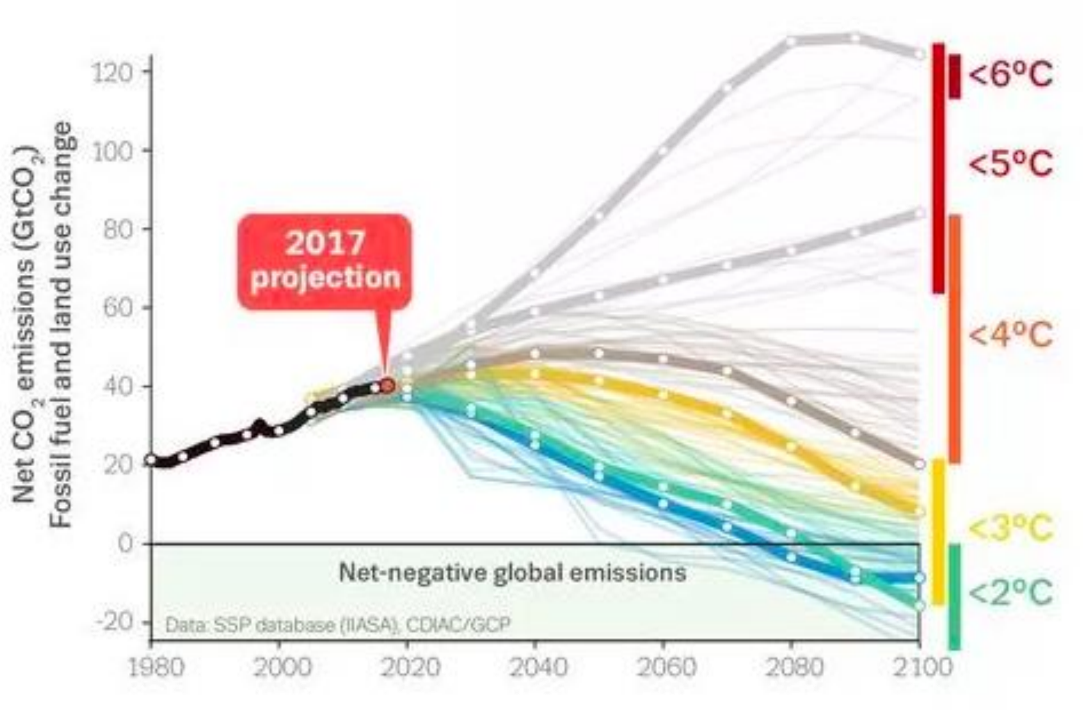
1 - INTRODUCTION



Main CO_2 utilization routes and applications

1 - INTRODUCTION

Representatives of 195 nations and the EU adopted the **Paris Climate Agreement** on December 2015.
The Agreement aims to respond to the global climate change threat by keeping a global temperature rise this century well **<2 °C** above pre-industrial levels.



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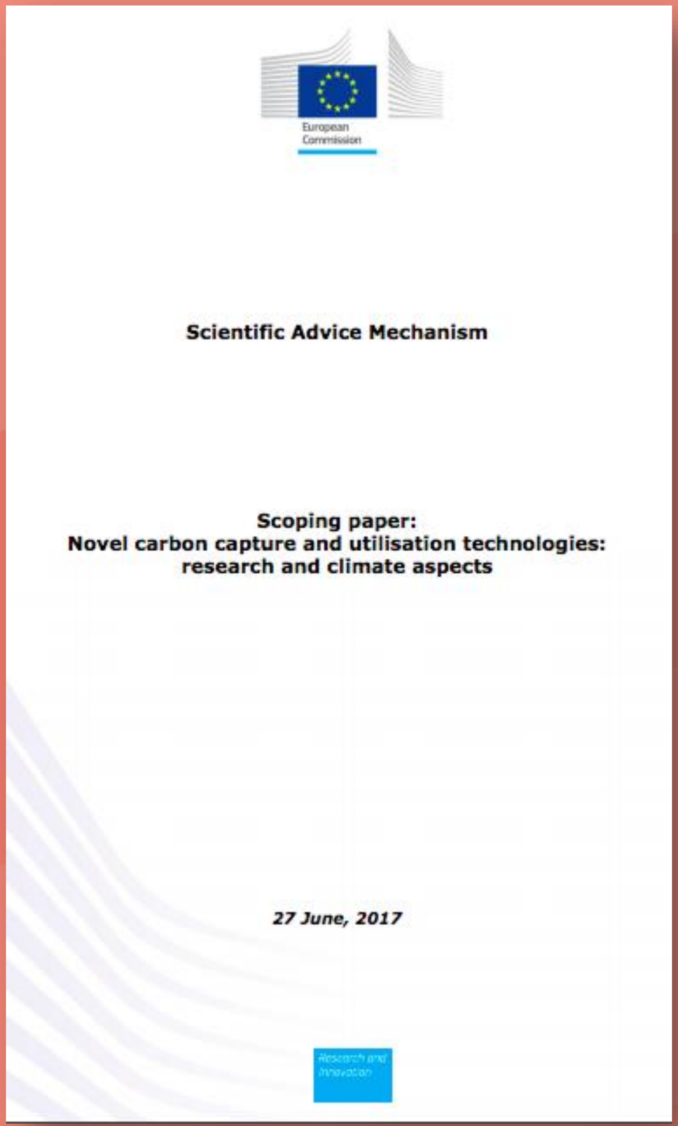
http://www.un.org/sustainabledevelopment/cop21/

2 – AIM AND SCOPE

Following a request for support by SAM, submitted by Commissioner Cañete to Commissioner Moedas, a **Scoping Paper** was prepared by DG Climate Action defining the exact scope and timing of the request.



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Scientific Advice Mechanism

Scoping paper:
Novel carbon capture and utilisation technologies: research and climate aspects

27 June, 2017

European Commission

2 – AIM AND SCOPE

CCU technologies offer a **number of opportunities for European industry** and the pursuit of EU policy objectives, including:

- Supporting **climate change** objectives, by replacing crude oil and gas in chemicals and fuels but also through fixation of the CO_2 in materials;

- Supporting the **circular economy**, by converting waste CO_2 to products, industrial innovation and competitiveness, particularly important for energy-intensive industries, developing new and more efficient processes and creating new market opportunities;

- Supporting **energy security** and renewable energy deployment, through utilising excess renewable electricity and providing energy storage alternatives;

- Supporting the evolution of CO_2 capture systems, which may help deployment of Carbon Capture and Storage (CCS) technology, which in turn provides permanent and large-scale storage of CO_2.

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Scientific Expert Workshop

Brussels|25.Jan.2018

Objective

To gather the views of top experts in the field of CCU on the questions asked to SAM.

Participants

- SAPEA experts
- Top researchers in the field
- Experts from European Academies

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Stakeholder Meeting
Brussels|20.Feb.2018

Objective

To gather the views of stakeholders in the field of CCU on the questions asked to SAM.

Participants

- Policy
- Business
- Consumers
- Civil society
- Scientific

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Timeline

11.05.2016	Request from Comr Cañete
28.06.2017	Final Scoping Paper agreed
July-Dec.2017	Evidence gathering by SAPEA
25.01.2018	Scientific expert workshop
20.02.2018	Stakeholder meeting
27.04.2018	(previous date)

Deliver SAM HLG Opinion (New date to de defined)

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4 – POLICY AND LEGAL CONTEXT

EU policy and legislation

Other policy and relevant clusters are relevant to CCU:

- *Products and labelling policy framework*
- *Waste and circular economy policy framework*
- *Environmental pollution and risk policy framework*
- *Financing programmes and instruments that do or can finance CCU*

4 – POLICY AND LEGAL CONTEXT

Current situation

No reliable estimates exist today for the total actual implementable savings of CO_2 emissions via CCU technologies. The amount of CO_2 that is useable varies with the technology employed and the energy to be spent for capture and conversion.

International climate obligations require reliable monitoring and reporting of real and calculated GHG emissions. Currently, the EU ETS provides derogation from GHG emissions accounting only for CCS in accordance with the Directive on the geological storage of CO_2.

This situation reflects the novelty of CCU technologies, the multitude of different products and of end-of-life scenarios.