Climate Accounts for various CCUS measures

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Source: Thinkstock

Agenda

1. Types of Carbon Capture and Use
2. The inputs
   I. Electricity use
   II. Resource efficiency

3. Accounting for emissions reductions in the current EU legislation
   I. Interlinking sectors
   II. Deployment potential and knock-on effects
   III. The Renewable Eneregy Directive

4. Q&A

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Types of Carbon Capture and Use

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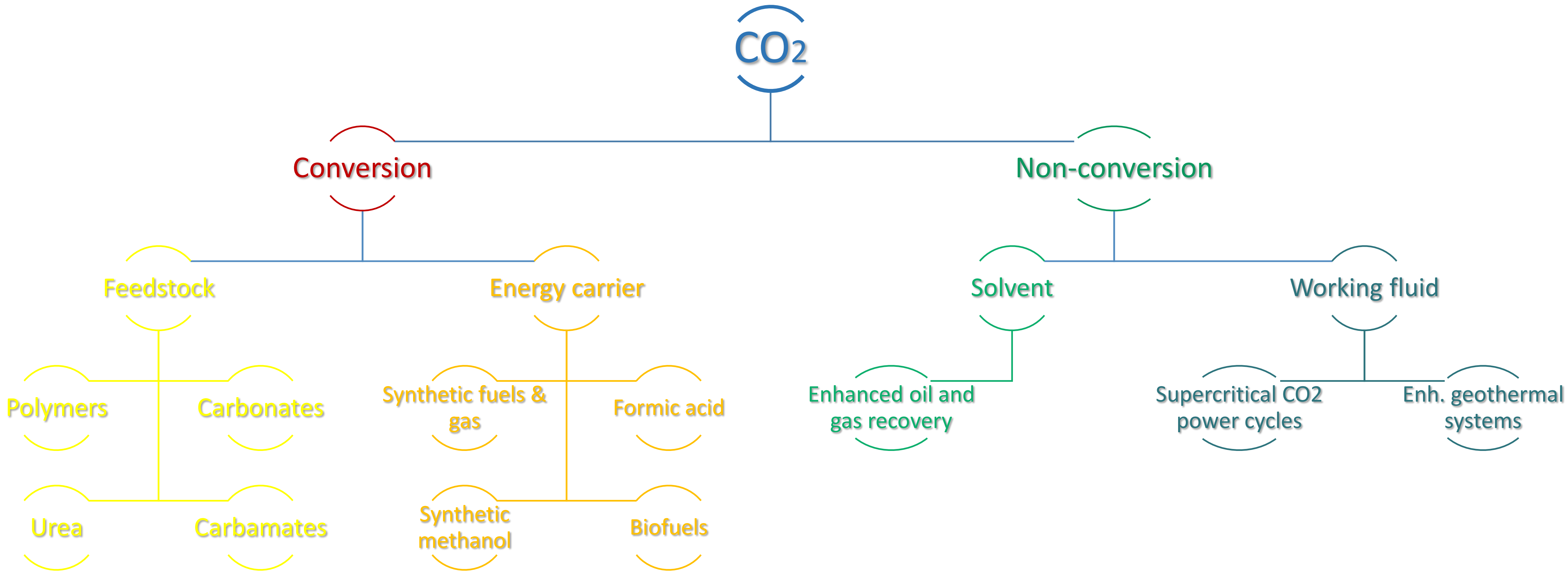
Types of CCU



The CO_2 molecule is transformed into a new compound by chemical transformation, breaking down with enzymes (photosynthesis) or a process where a catalyst is used.

Sources: Zheng et al. 2017

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Types of CCU

Source: Thinkstock

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Source: Thinkstock

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

Sources: Zheng et al. 2017

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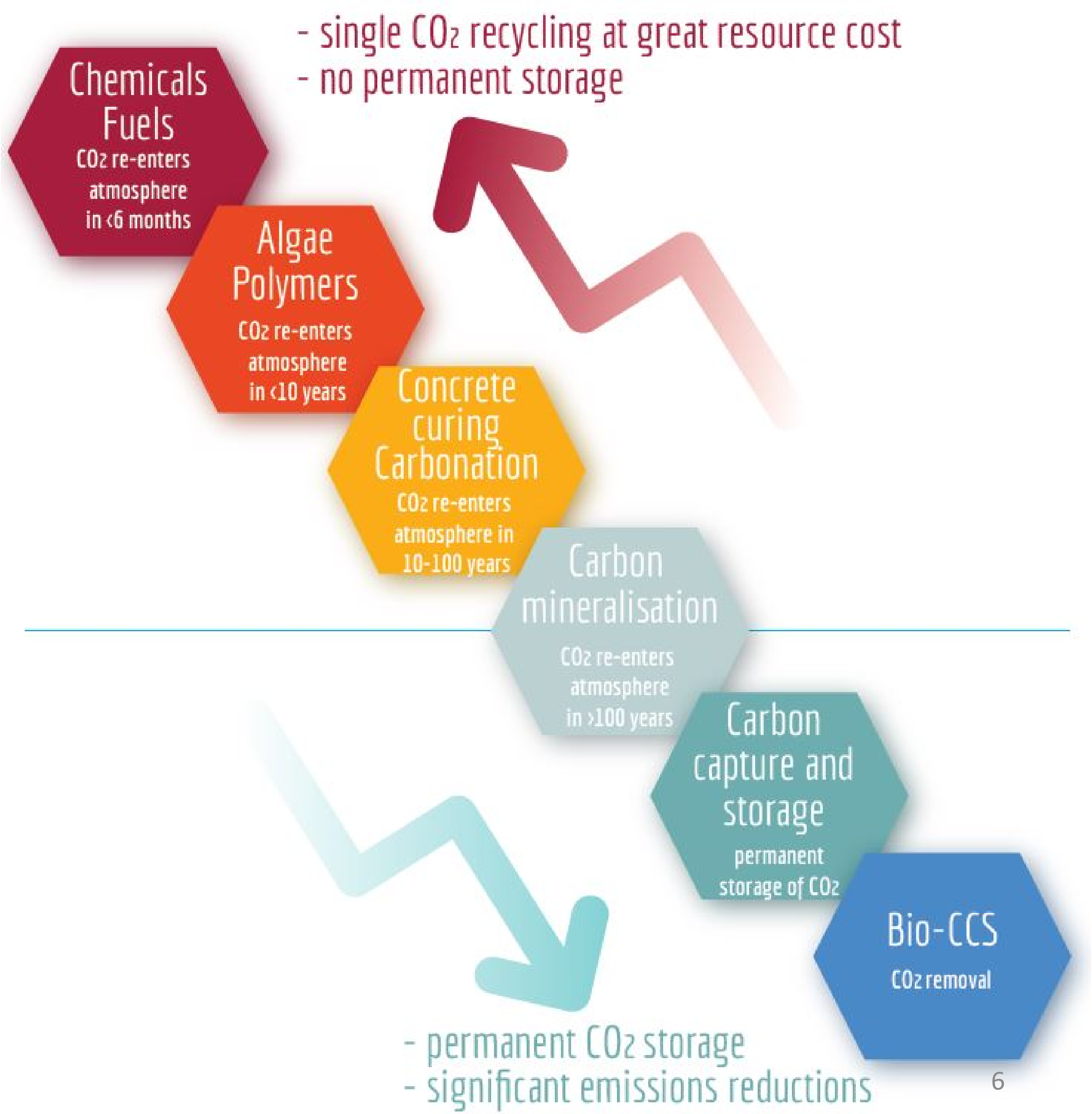
Types of CCU

Storage potential and comparison to CCS

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.

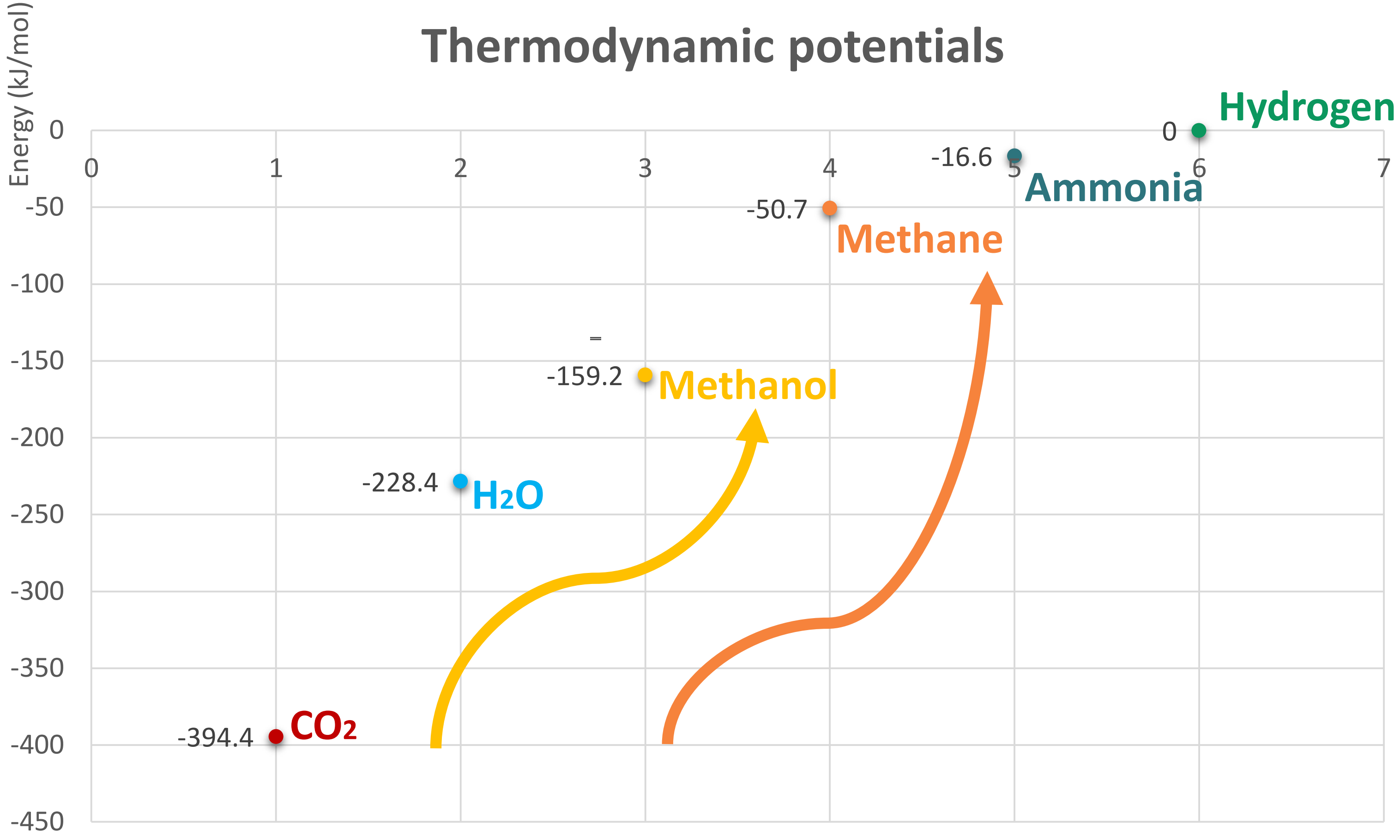
The emerging markets for **CO_2 use will only be able to address a small proportion** of the emissions that will need to be abated to meet climate targets.



The inputs

Types of CCU

Carbon dioxide is a molecule of low thermodynamic potential.



"/…/ it is known that the activation of C-O bonds in CO_2 molecules is hindered by its nature from a thermodynamic and kinetic standpoint. The high chemical/electrochemical stability of 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).

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Chemicals and Fuels

1. Relevant ongoing legislative process – the Renewable Energy Directive

2. Headlines, research and support from member states such as Germany

The entrepreneurs turning carbon dioxide into fuels

The race is on to prove that CO2 can be taken from the air and recycled into profitable, carbon neutral fuels. But cost and investment obstacles remain

Bosch: synthetic fuels can make combustion engines CO2-neutral

By JAMES HENDERSON • Aug 23, 2017, 6:34AM

Taking the leap in June 2015, the three founded Opus 12 which aims to develop a device to capture carbon emissions from its source, and to create valuable products in the process – i.e. clean-burning fuels and chemicals.

BUSINESS

Can clean synthetic diesel fuels succeed?

Some German industry officials have lately been touting 'e-fuels,' synthetic liquid fuels that can be burned in diesel engines, as an alternative to an all-electric automotive future. Is this workable - or mere PR?

The Guardian International edition

ENERGY DIGITAL

Forbes

DW

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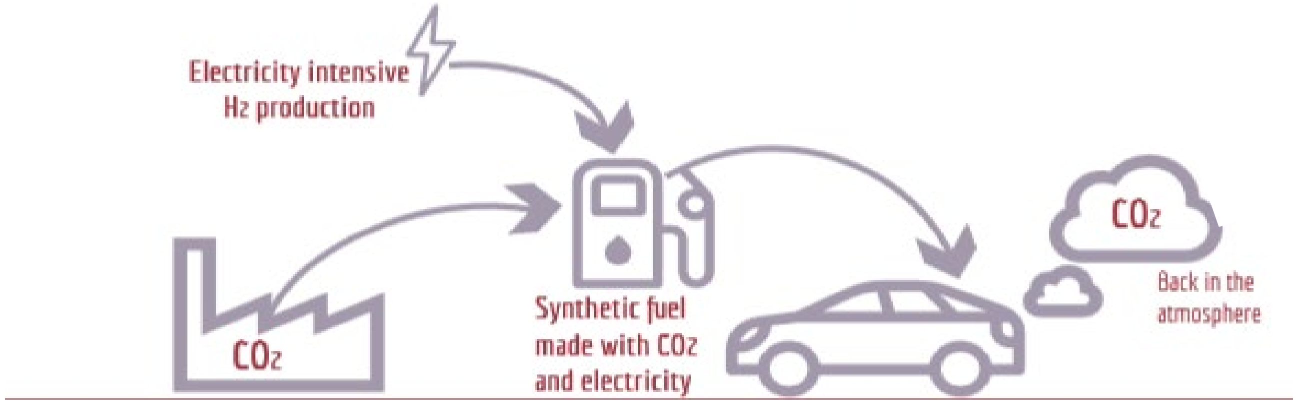
Chemicals and Fuels

1. Relevant EU legislation – the Renewable Energy Directive, Alternative fuels directive, Clean Vehicles Directive
2. Headlines, research and support from member states such as Germany

CO2 re-use technology	Uptake potential (Mt/y)	Research&Industrial engagement	TRLs
Methanol production	> 300	+ + +	4-6
(Carbonate) Mineralisation	> 300	+ + +	3-6
Polymerisation	5 < demand < 30	+ + +	8-9
Formic acid	> 300	+ + +	2-4
Urea	5 < demand < 30	+ + +	9
Enhanced coal bed methane recovery	30< demand < 300	+ - -	6
Enhanced geothermal systems	5 < demand < 30	+ + -	4
Algae cultivation	> 300	+ - -	3-5
Concrete curing	30< demand < 300	+ + -	4-6
Bauxite residue treatment	5 < demand < 30	+ + -	4-5
Fuels engineered micro-organism	>300	+ + -	2-4
CO2 injection to methanol synthesis	1<demand<5	+ - -	2-4

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



"Methane production from syngas goes back to **more than 100 years** of research and process development."
(Ronsch et al. 2016)

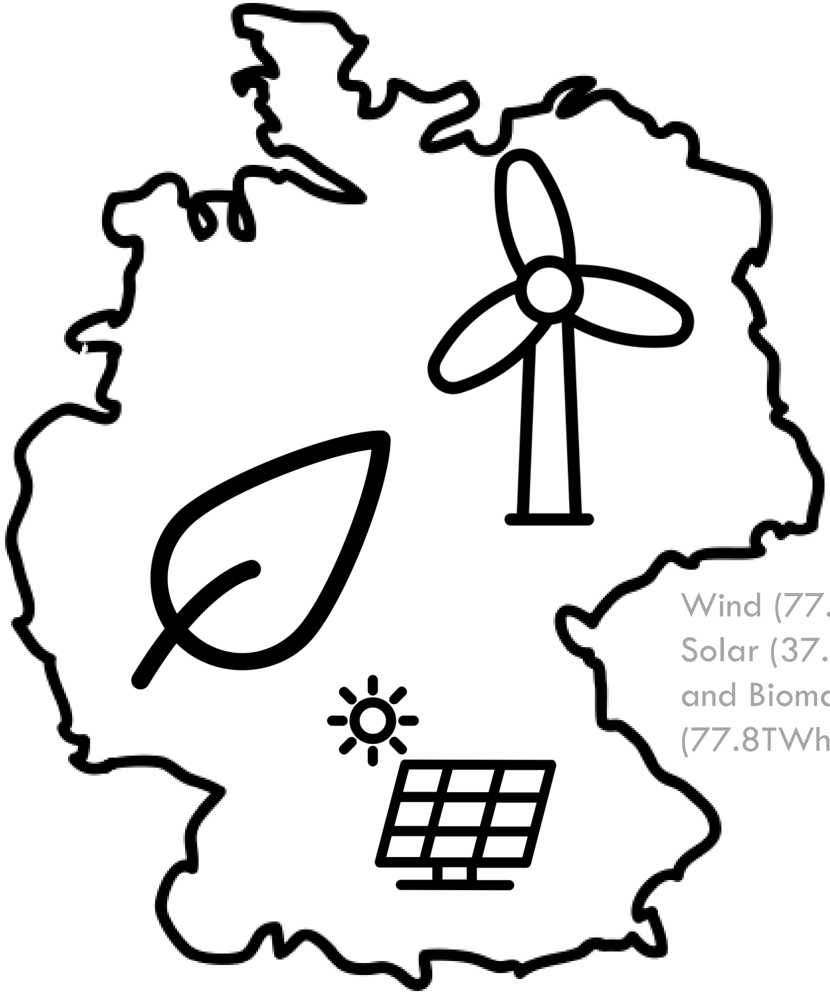
Source: Bocin-Dumitriu et al. 2013, Joint Research Centre

Scale – Renewable electricity input

The amount of CO_2 that can be converted to chemicals and materials is relatively small compared to the amount of anthropogenic CO_2 emitted from fossil fuel combustion. (Song et al. 2012)

A simple assessment shows using CCU fuels to reach the target of 3% fuel mixing of EU road transport would require

164 TWh*.



Wind (77.8 TWh), Solar (37.5 TWh) and Biomass (77.8TWh).

EU road transport 3305 TWh x 3% = 99 TWh of Power to liquid fuel. @ 60% conversion efficiency input electricity requirement = 164 TWh
Energy use in road transport in 2014 was 289.8 (Mtoe) = 3,370 TWh, (European Union, 2016). Excluding heavy duty vehicles (HDVs) (-30% = 2660 TWh) for direct comparison with Eurelectric 100% EV electricity requirement estimates (Muncrief, 2015). At 60% P2X conversion efficiency, 3,940 TWh of electricity would be required for 100% P2X EU car fleet. 7 100% electrified fleet will add 802 TWh or a 24.3% increase in total electricity demand. (Eurelectric 2015)

Scale – Emissions reductions

The low conversion efficiency of CCU paired with insufficient low carbon electricity can act as a multiplier of emissions intensity:

With current German grid electricity, the production results in fuel GHG emissions of >330 gCO_2/ MJ.
(German Federal ministry for the environment, nature conservation, building and nuclear safety, 2018)
This is
3.5 times more CO2 intensive then fossil diesel (94,1 gCO2/ MJ)

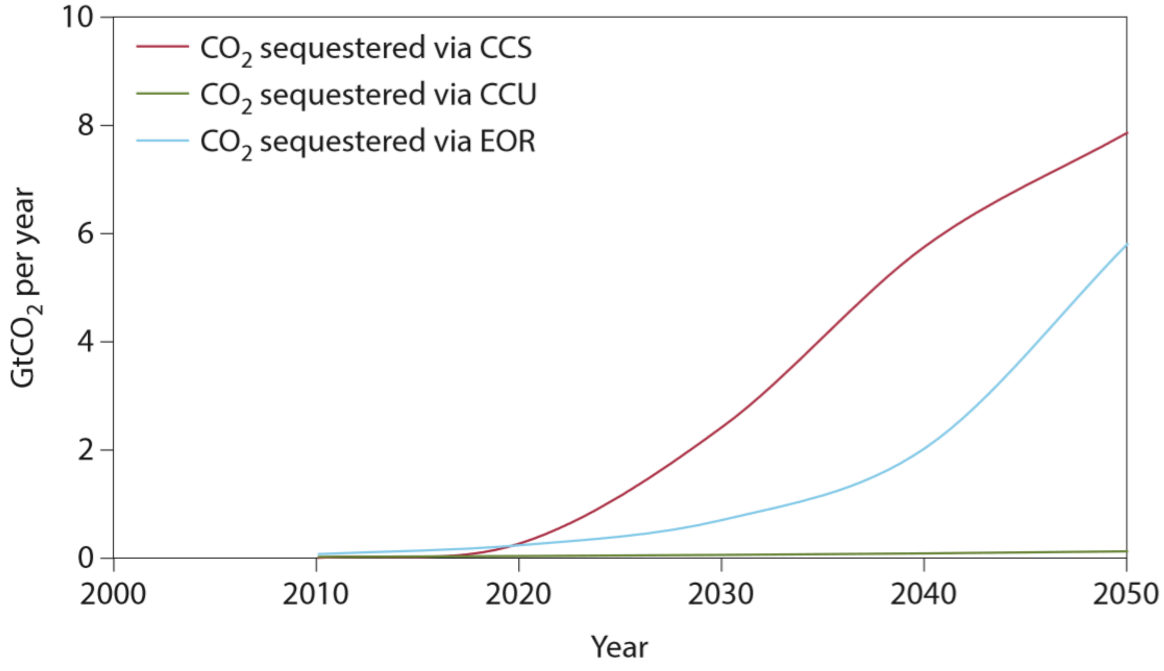
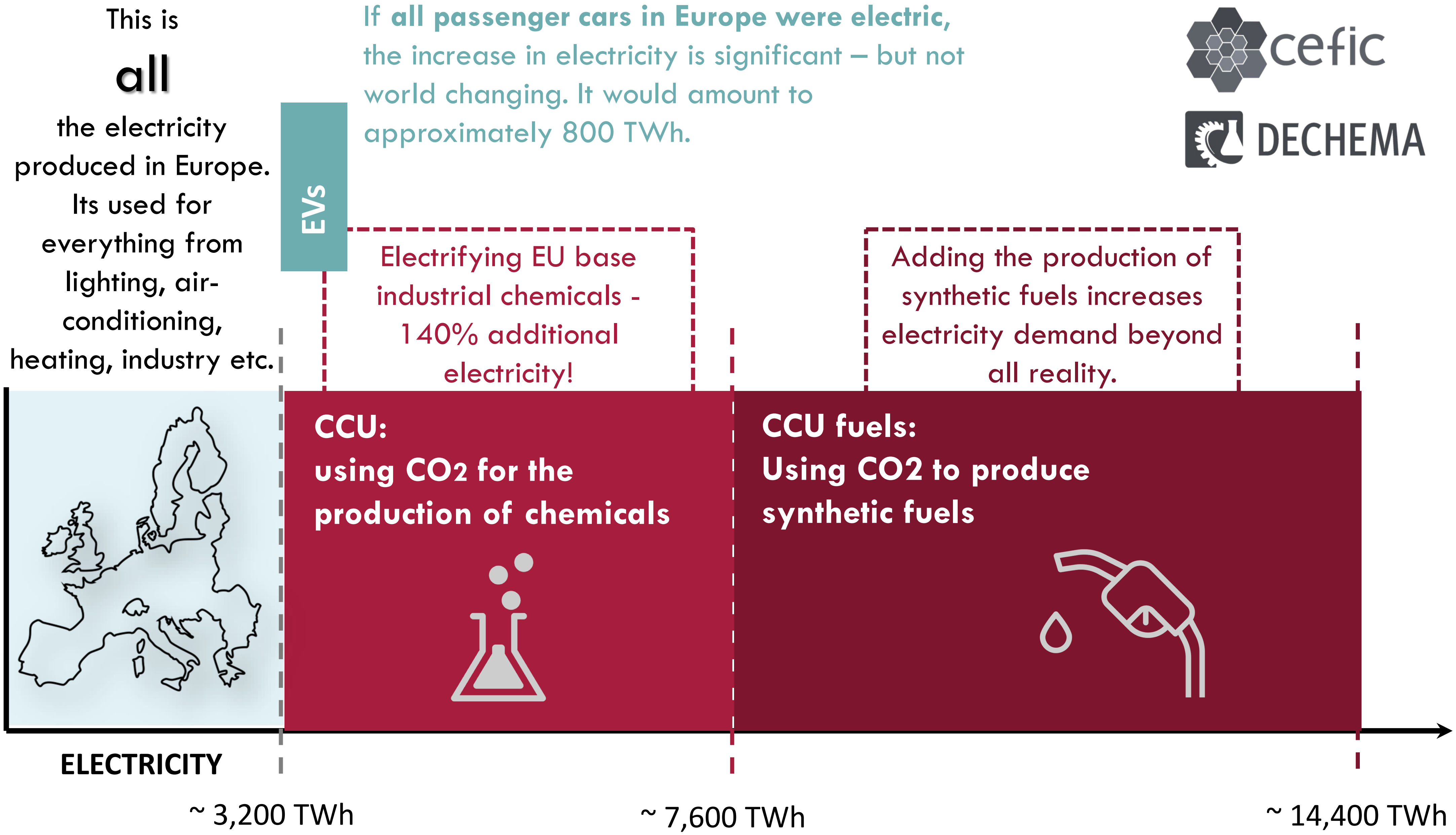


Figure 4 | CCS versus CCU—a perspective for the period 2010 to 2050.

Source: Mac Dowell et al., 2018

* EU road transport 3305 TWh x 3% = 99 TWh of Power to liquid fuel.
@ 60% conversion efficiency input electricity requirement = 164 TWh



Source: Bazzanella and Ausfelder Low carbon energy and feedstock for the European chemical industry [Report]. - Frankfurt : DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V., 2017.

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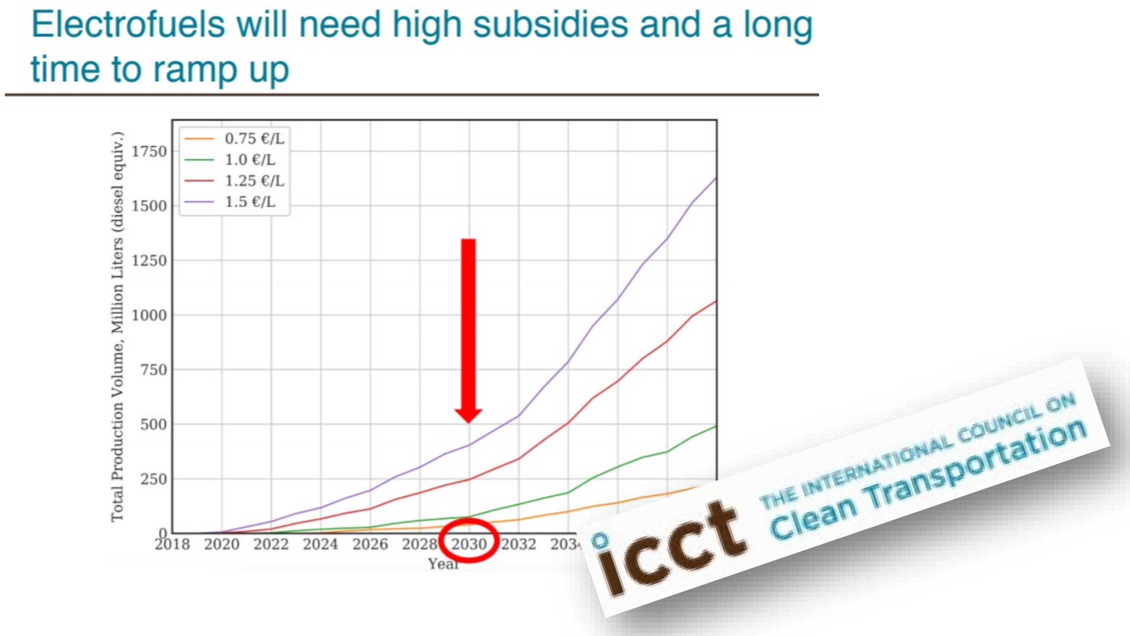
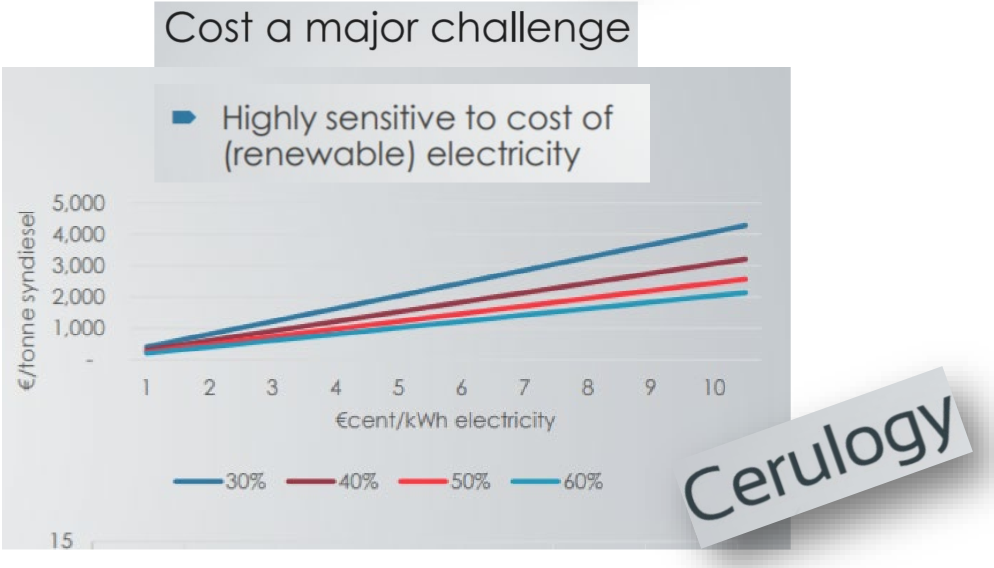
At what cost?

- Consultant reports on the commercial viability of CCU fuels rely on periods of oversupply and low wholesale prices in the electricity market.

- In addition, commercial operations of CCU fuels are expected to have high utilisation to recover sunk investment costs, estimates 5,000 to 6,000 operating hours a year are required for positive business case.

- The production of the CCU fuels is linked to the CO_2 producers operation





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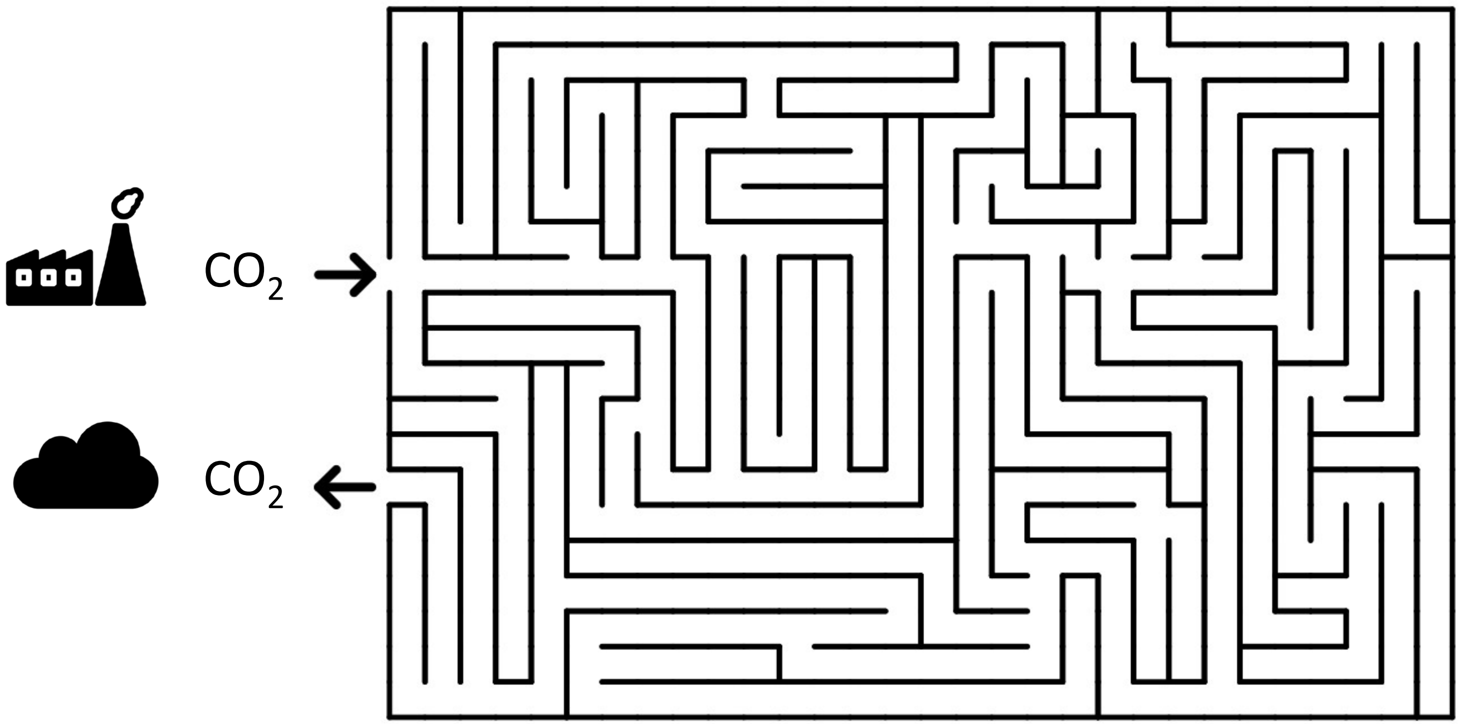
Accounting for emissions reductions in the current EU legislation

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 CCS, 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 CO_2 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 CO_2-to-fuel conversion step but the production of required carbon-free electricity at very low cost.

Abanades, Carlos J., Edward S. Rubin, Marco Mazzotti and Howard J. Herzog. 2017. On the climate change mitigation potential of CO2 conversion to fuels. Energy Environ. Sci. 10: 2491-2499.

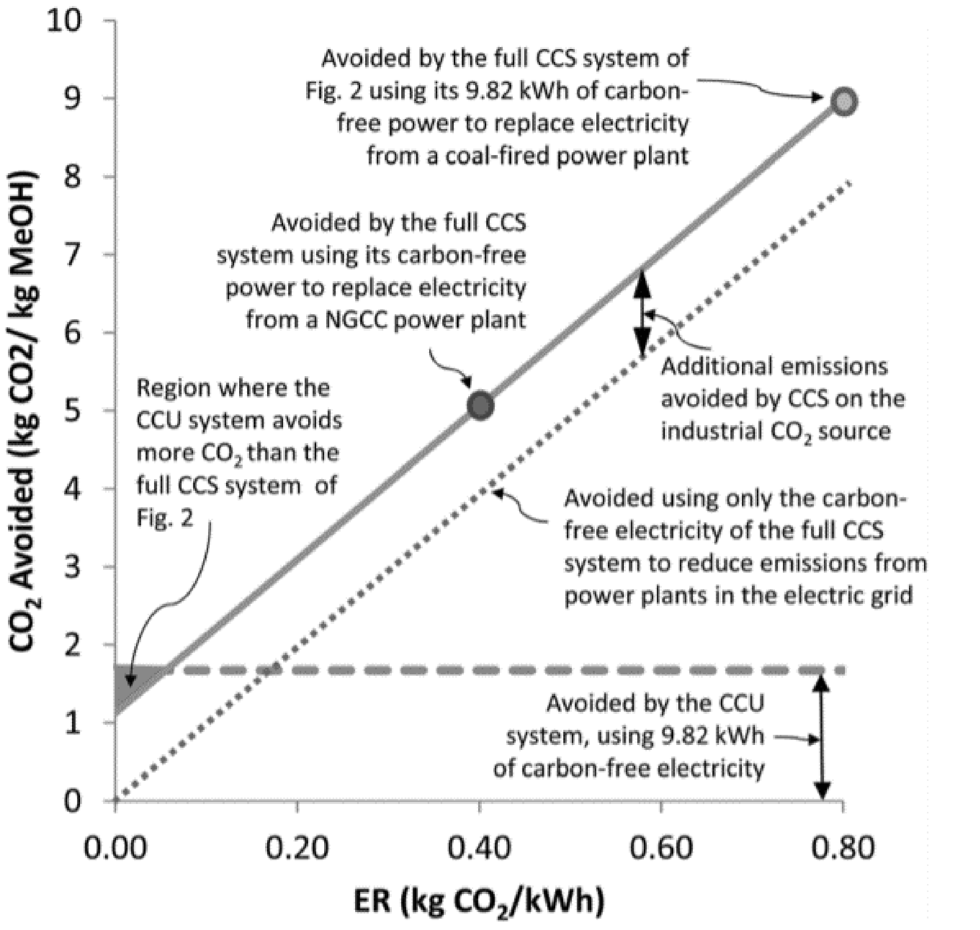


Fig. 3 Total CO_2 avoided per kg of MeOH product as a function of the emission rate, ER (kg CO_2 per kW h) of the power grid elements replaced by the 9.82 kW h of carbon-free electricity available in the full CCS system in Fig. 2.

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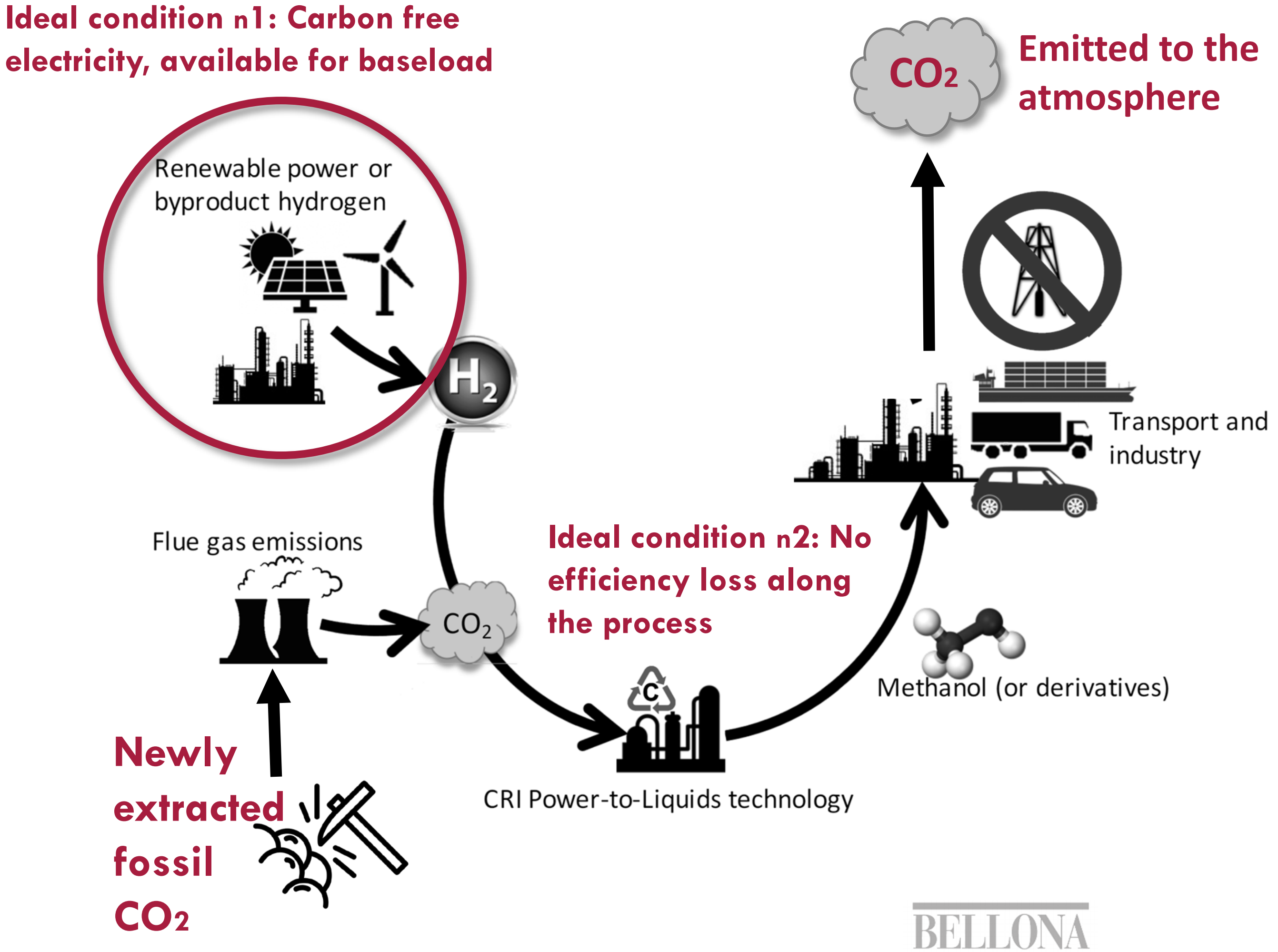
The life cycle of the product

The key to accounting for emissions reductions

1 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).



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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, referring to Peres-Fortes et al. 2016

> If you can use the industrial carbon dioxide, the only CO_2 emissions attached to it are the purification, compression and transport – because otherwise it would be released to the atmosphere.

Classifying CO_2 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

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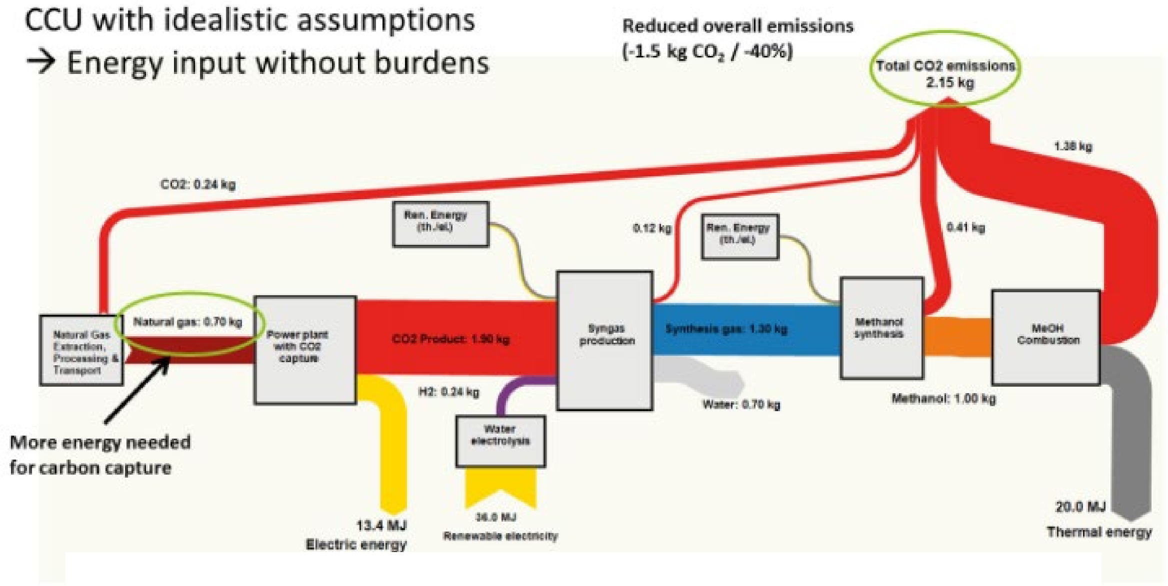
Counting the CO_2

- From 1 January 2018 greenhouse gas emission saving vs petroleum alternatives shall be at least 60 % for biofuels and bioliquids produced in installations in which production started on or after 1 January 2017 (70% by 2021).

- Counting the CO_2 in and CO_2 out, CCU fuels with industrial CO_2 source does not come close even to the 60% minimum target for biofuels

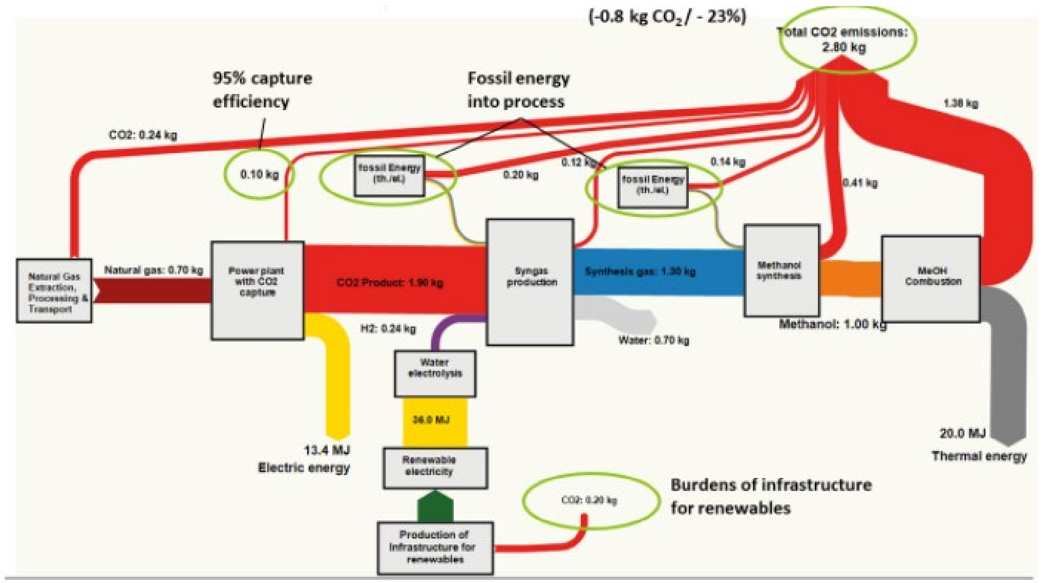


Ideal:

CO_2

reduction of **40%**

Methodology matters



Realistic:

CO_2

reduction of **25%**

Source: Nils Rittenmeier and Thomas Froehlich, IFEU 2017

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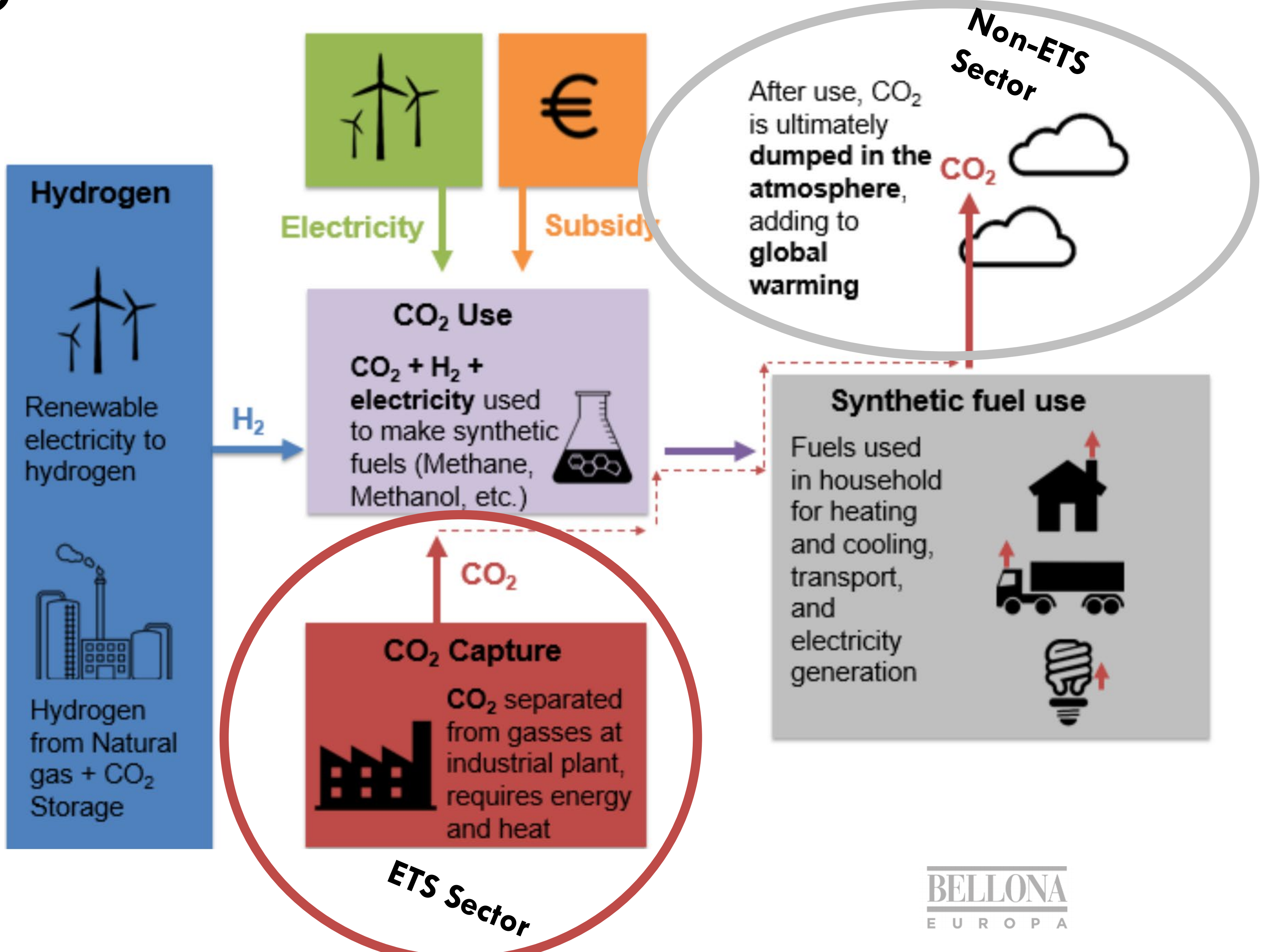
Double counting CO2 reductions

- CCU can link emissions from one sector to another
- CO_2 captured 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?



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How to avoid buyers remorse?

A full life cycle assessment is needed. The calculation of the climate footprint of these products must account for:

1. **The source of CO_2** (e.g. fossil CO_2 coming from industry)
2. **The resources and inputs** (e.g. the electricity used for the production of H_2)
3. **The final emissions at the end-of-life** stage of the product (e.g. final combustion of a fuel)

In addition to these elements vital to the GHG footprint, the knock on effects on other technologies should be considered. These products should not hinder the deployment of more efficient options.

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Zheng, Yun, Jianchen Wang, Bo Yu, Wenqiang Zhang, Jing Chen, Jinli Qiao and Jiujun Zhang. 2017. A review of high temperature co-electrolysis of H2O and CO2 to produce sustainable fuels using solid oxide electrolysis cells (SOECs): advanced materials and technology. Chemical Society Reviews 46: 1427-1463. DOI: 10.1039/C6CS00403B

J. Carlos Abanades, Edward S. Rubin, Marco Mazzotti and Howard J. Herzog. 2017. On the climate change mitigation potential of CO2 conversion to fuels. Energy Environ. Sci. 10: 2491—2499. DOI: 10.1039/c7ee02819

DENA. 2017. «E-FUELS» STUDY, the potential of electricity-based fuels for low-emissions transport in the EU. https://shop.dena.de/fileadmin/denashop/media/Downloads_Dateien/verkehr/9219_E-FUELS-STUDY_The_potential_of_electricity_based_fuels_for_low_emission_transport_in_the_EU.pdf

Renewable fuels of non-biological origin in transport decarbonisation, 2018, Federal ministry for the environment, nature conservation, building and nuclear safety. https://www.transportenvironment.org/sites/te/files/Renewable%20fuels%20of%20non-biological%20origin%20in%20transport%20decarbonisation%2C%20Thomas%20Weber_0.pdf

Mac Dowell, Niall, Paul S. Fennell, Nilay Shah & Geoffrey C. Maitland. 2017. The role of CO2 capture and utilization in mitigating climate change. Nature Climate Change volume 7, pages 243–249. doi:10.1038/nclimate3231.

Pérez-Fortes, Mar, Jan C.Schöneberger, Aikaterini Boulamanti, EvangelosTzimasa. 2016. Methanol synthesis using captured CO2 as raw material: Techno-economic and environmental assessment. Applied Energy 161: 718-732

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

von der Assen, Niklas, Johannes Jung and Andre Bardow. 2013. Life-cycle assessment of carbon dioxide capture and utilization: avoiding the pitfalls. Energy Environ. Science, 6: 2721–2734. DOI: 10.1039/c3ee41151f

When is CO_2 emitted counted as emitted?

SCHAEFER kalk

German Family owned calk manufacture

Precipitated Calcium Carbonate (PCC)

PCC is used in the Paper industry, healthcare, plastics

CO_2 used for the production of PCC is chemically bound in that stable product

Burning of limestone	$CaCO_3$	$\longrightarrow$	$CaO + CO_2$
Slacking of quicklime	$CaO + H_2O$	$\longrightarrow$	$Ca(OH)_2$
Precipitation	$Ca(OH)_2 + CO_2$	$\longrightarrow$	$CaCO_3 + H_2O$ (PCC)

In 2012 – Schaefer asked the German authorities, as this CO2 is not "emitted" may they be subtracted from ETS monitoring plan?

In 2017 ECJ = CCU CO_2 not emitted (in this case)

Press: "*ECJ acknowledges that CCU is not subject to emissions trading.*"; "*Bombshell in the ETS*"; "*ECJ rewards innovation in the ETS*"; SK's lawyers more cautious, refer only to the lime industry

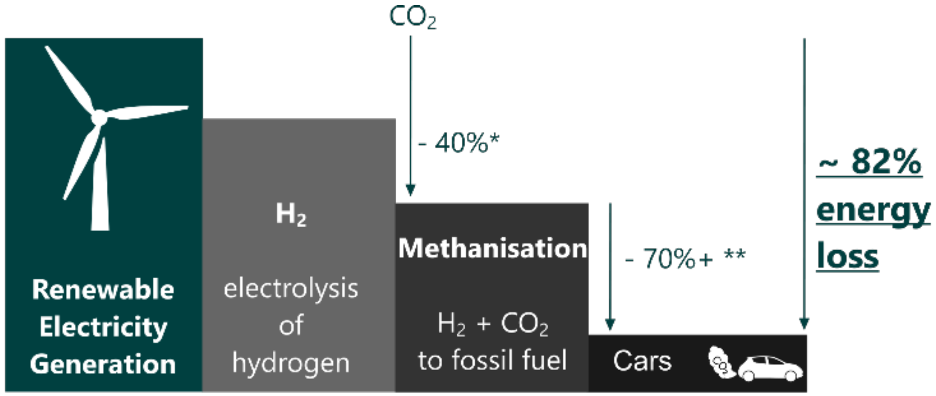
But: ECJ chose to invalidate provisions only for PCC; for all other examples CCU they stand – **despite the arguably transferable reasoning**

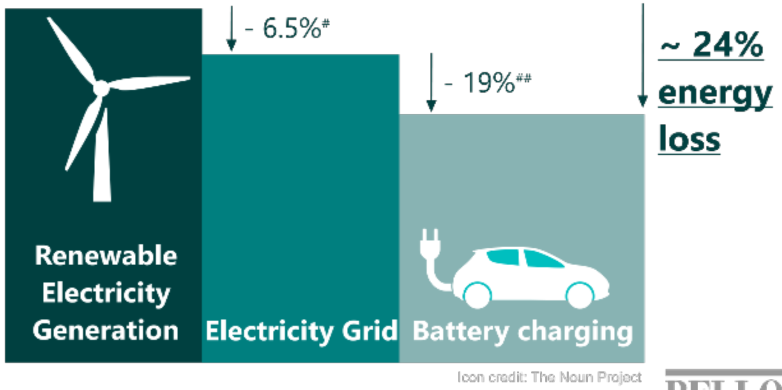
German emissions regulators will continue to apply rules in all other cases, **for the time being**

Art. 49(1), 2nd sentence and point 10(B) of Annex IV Monitoring Reg. "are invalid in so far as they systematically include […] CO_2 transferred to another installation for the production of [PCC] in the emissions of the lime combustion installation, **regardless of whether or not that CO_2 is released into the atmosphere**."

Do we have better ways to use renewable electricity for the same service?

- Electric vehicles (EVs) greatly outperform Internal Combustion Engine (ICE) cars using synthetic fossil fuels in the conversion of renewable electricity to kilometres.





- Synthetic fossil fuel manufacture with captured industrial CO_2 is ~60% efficient. (Stefansson 2015)
- ICE cars have an efficiency of 30%, but generally lower. Driving style and idling can reduce efficiency further. (EPA 2014)
- Electric power transmission and distribution losses in EU-28 (% of output) is 6.5% in 2014. (Worldbank 2017)
- EVs have an efficiency of 81%. (Samferdselsdepartementet 2017)