Climate effects of various CCU and CCS measures

Ana Serdoner
Policy & Project Advisor
Bellona Europa

ana@bellona.org
+32487798419

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Source: Thinkstock

Agenda

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The CCU and CCS comparison

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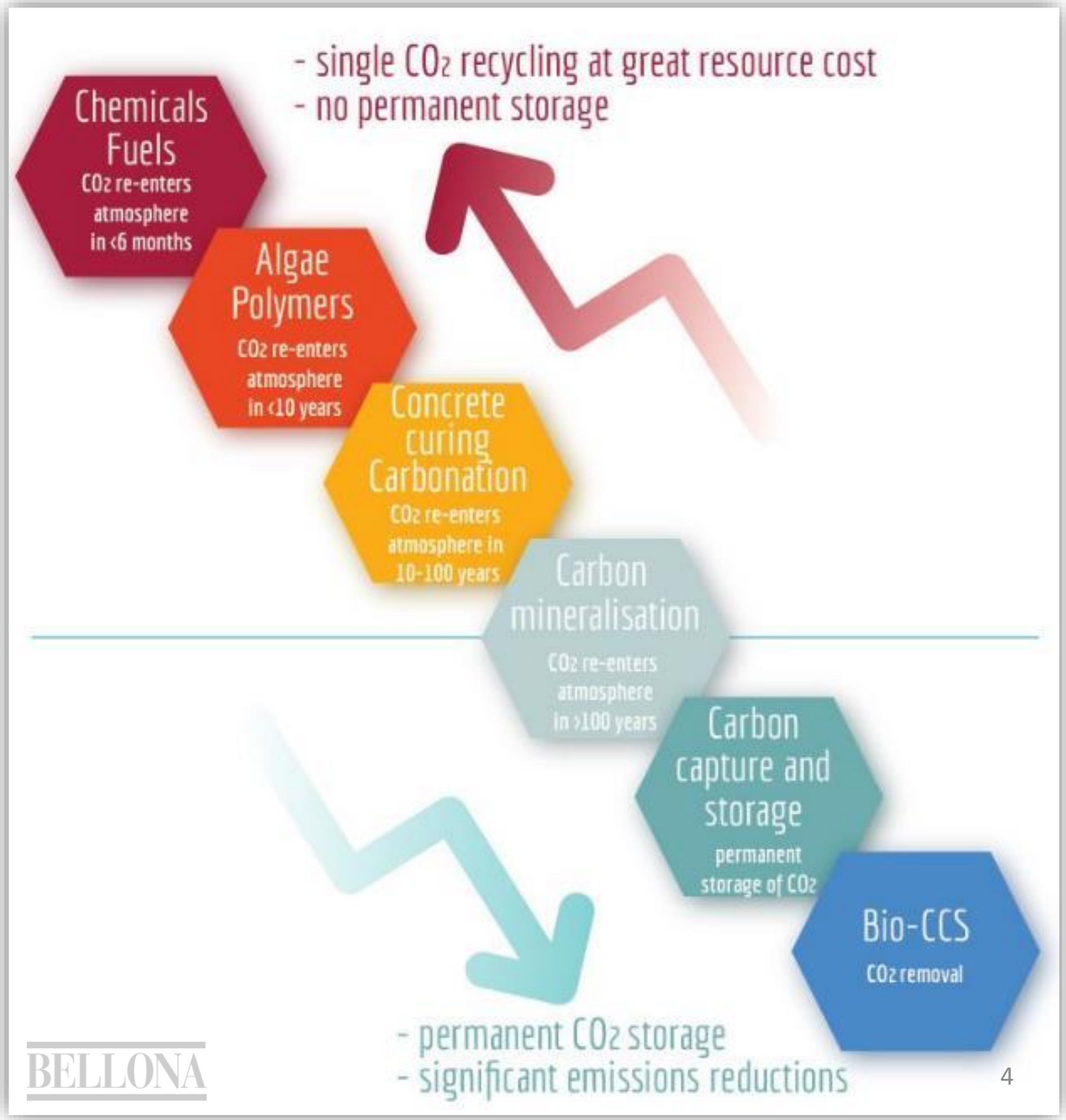
Storage potentials and energy use

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 CO2.
> **Medium term storage:** 10 to 100 years before release of utilised CO2.
> **Long term or permanent storage:** CO2 prevented from entering the atmosphere for a century or more.



Converting H_2 into products: Carbon capture and use

Types of CCU

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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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Chemicals and Fuels

1. Relevant legislation - the Renewable Energy Directive

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

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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 CO_2 reuse shortlisted technologies showing the CO_2 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

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CO_2 is a minor input in CCU – Energy and Resources Dominate

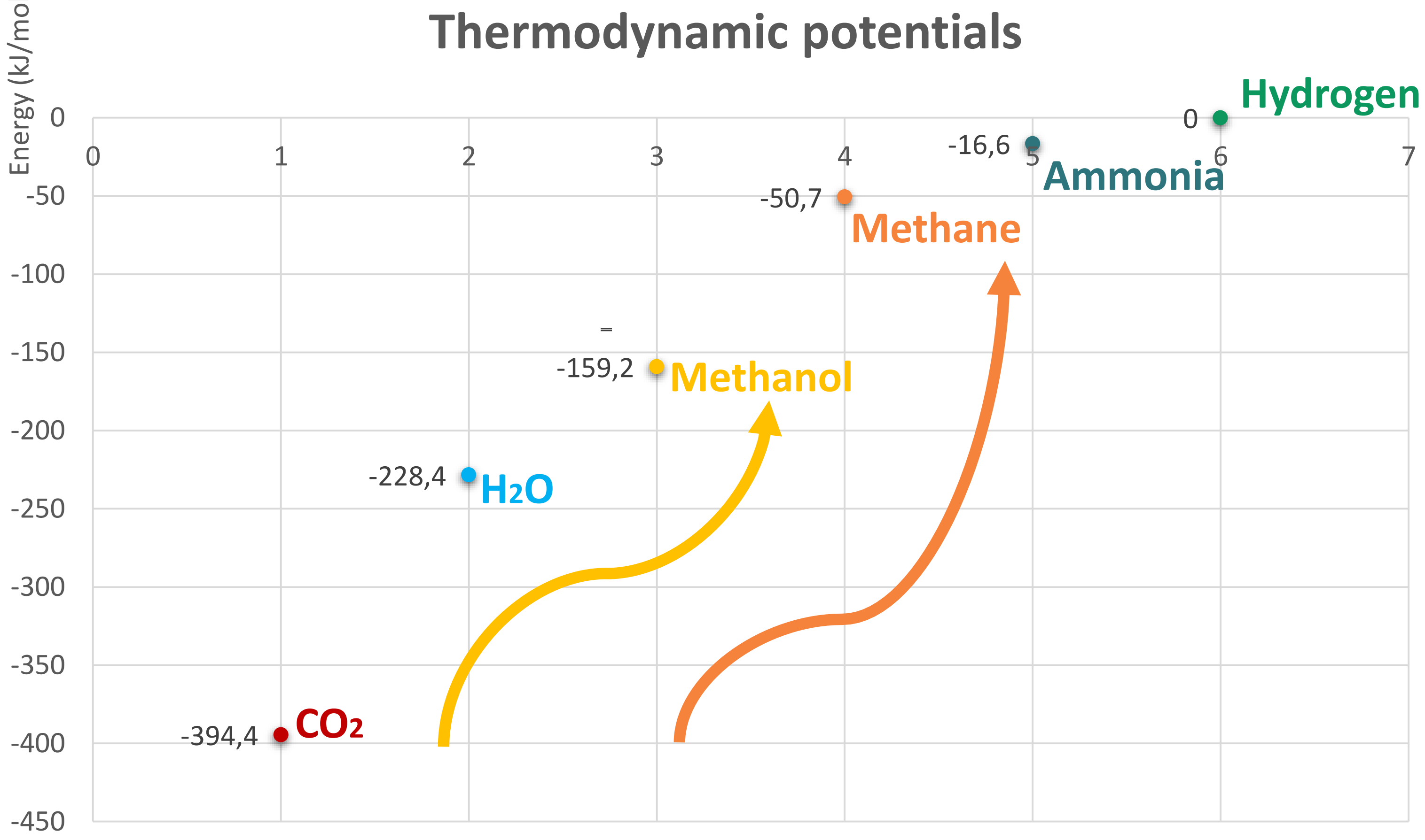
CCU Fuels / CCU chemicals – A high energy reactant such as H_2 is the major resource requirement.
e.g. for CCU with electrolytic H_2 and under favourable assumptions, the use of 1 tonne of CO_2 in the formation of methanol requires some 6.5 MWh of zero carbon electricity. Manufacturing diesel fuel would double the electricity requirement.

The amount of 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)

Source: Breyer (2017) Synthetic Methanol and Dimethyl Ether Production based on Hybrid PV-Wind Power Plants

Resource requirements

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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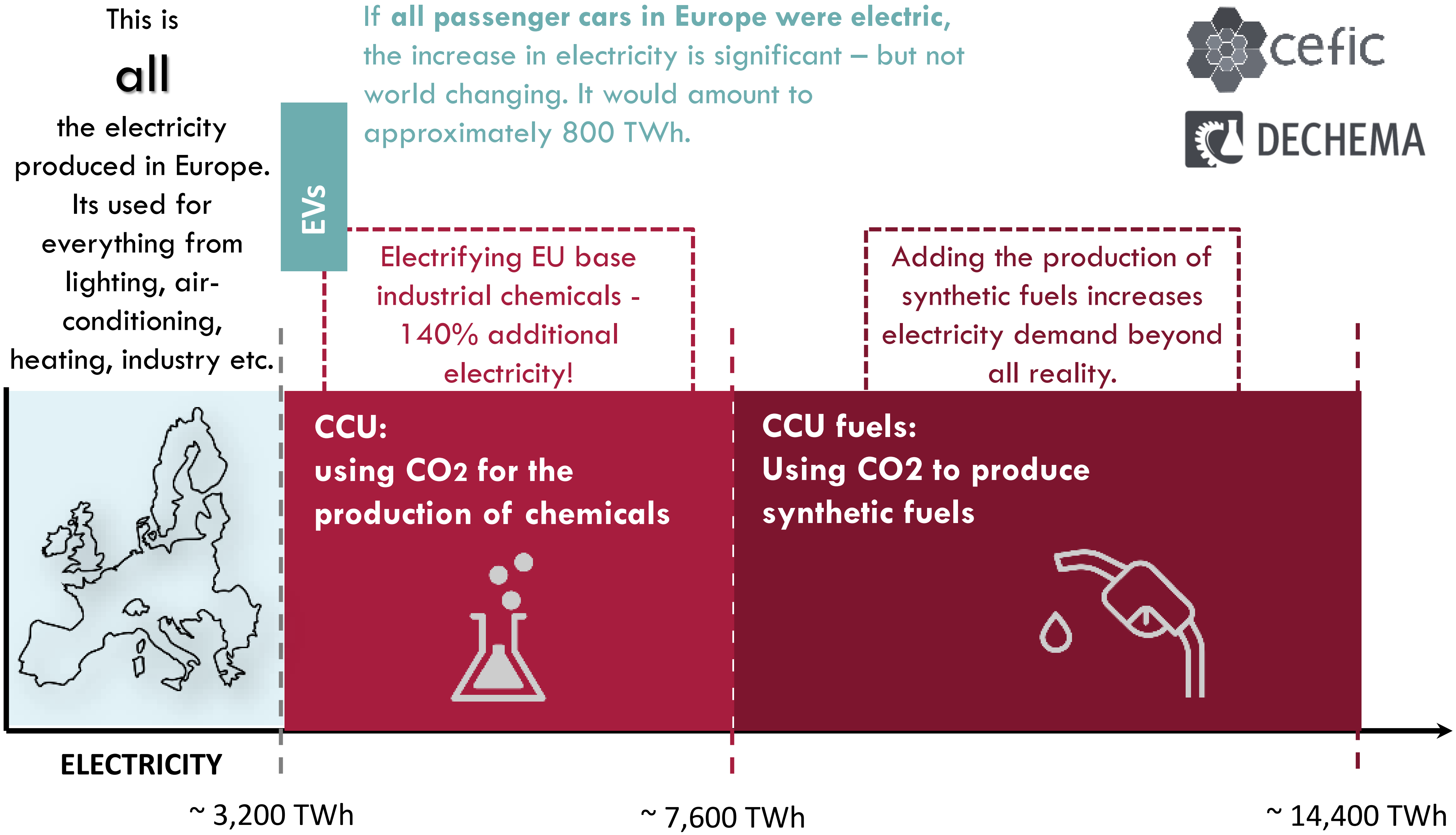
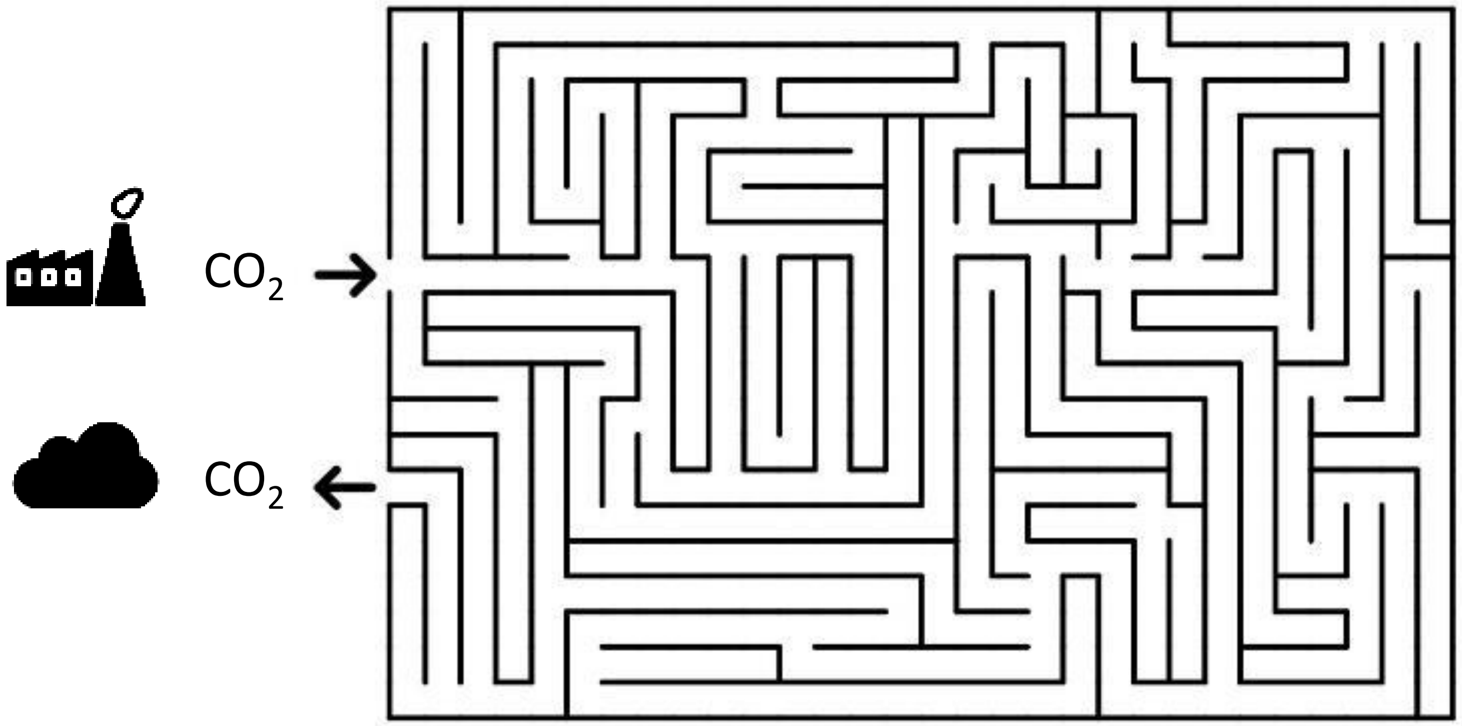


Source: Bazzanella and Ausfelder Low carbon energy and feedstock for the European chemical industry [Report]. - Frankfurt : DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V., 2017.

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 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.

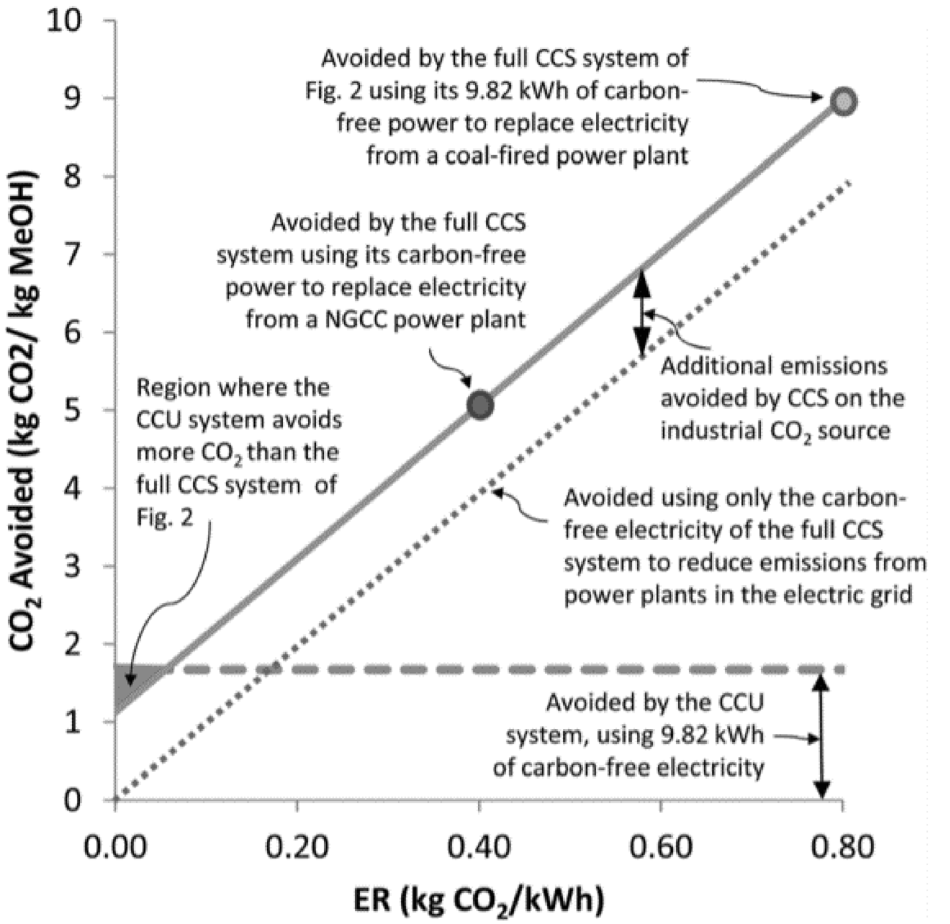


Fig. 3 Total CO_2 avoided per kg of MeOH product as a function of the emission rate, ER (kg CO_2 per kW h) of the power grid elements replaced by the 9.82 kW h of carbon-free electricity available in the full CCS system in Fig. 2.

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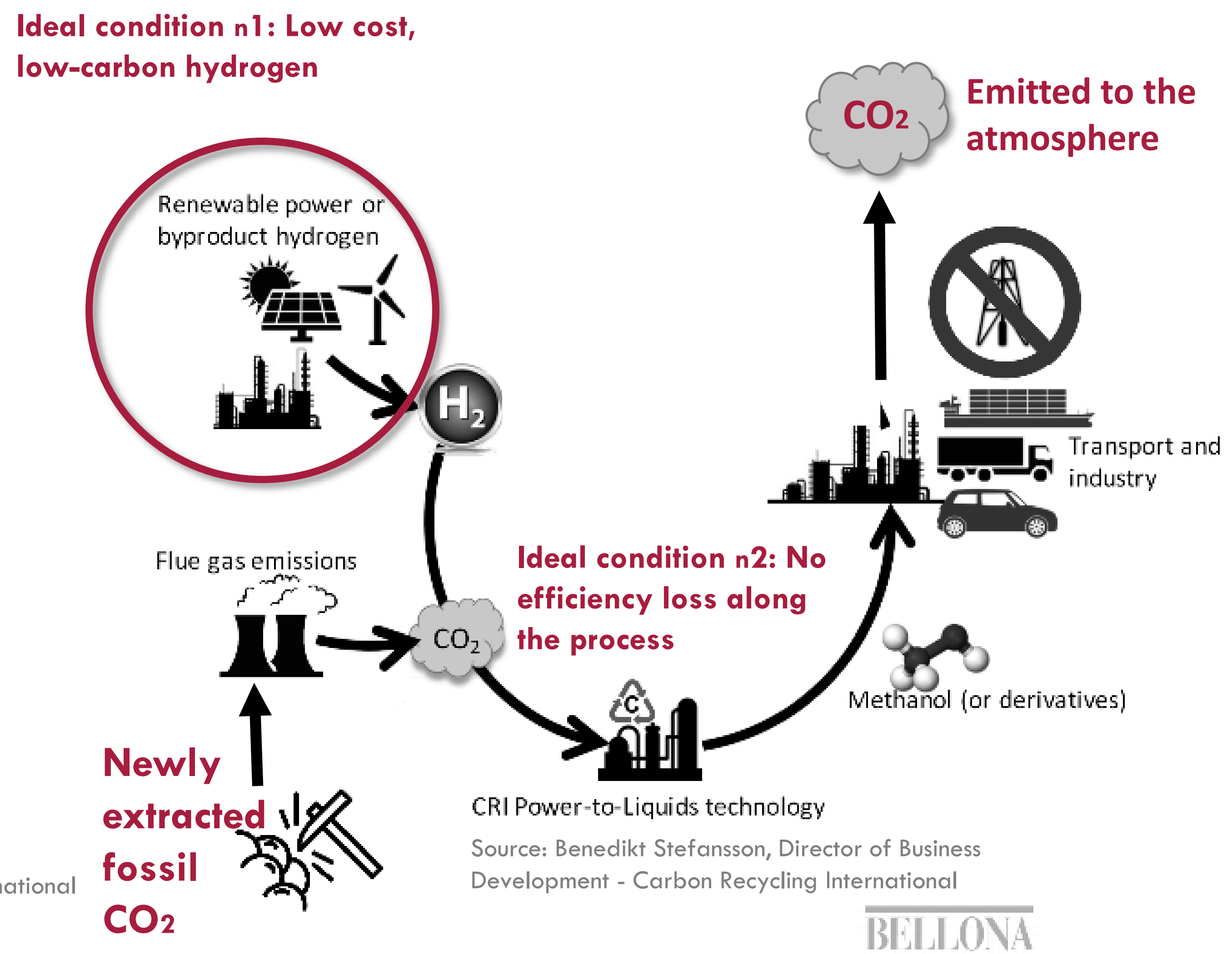
The life cycle of the product

The key to accounting for emissions reductions

Re-use of the CO_2 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

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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 (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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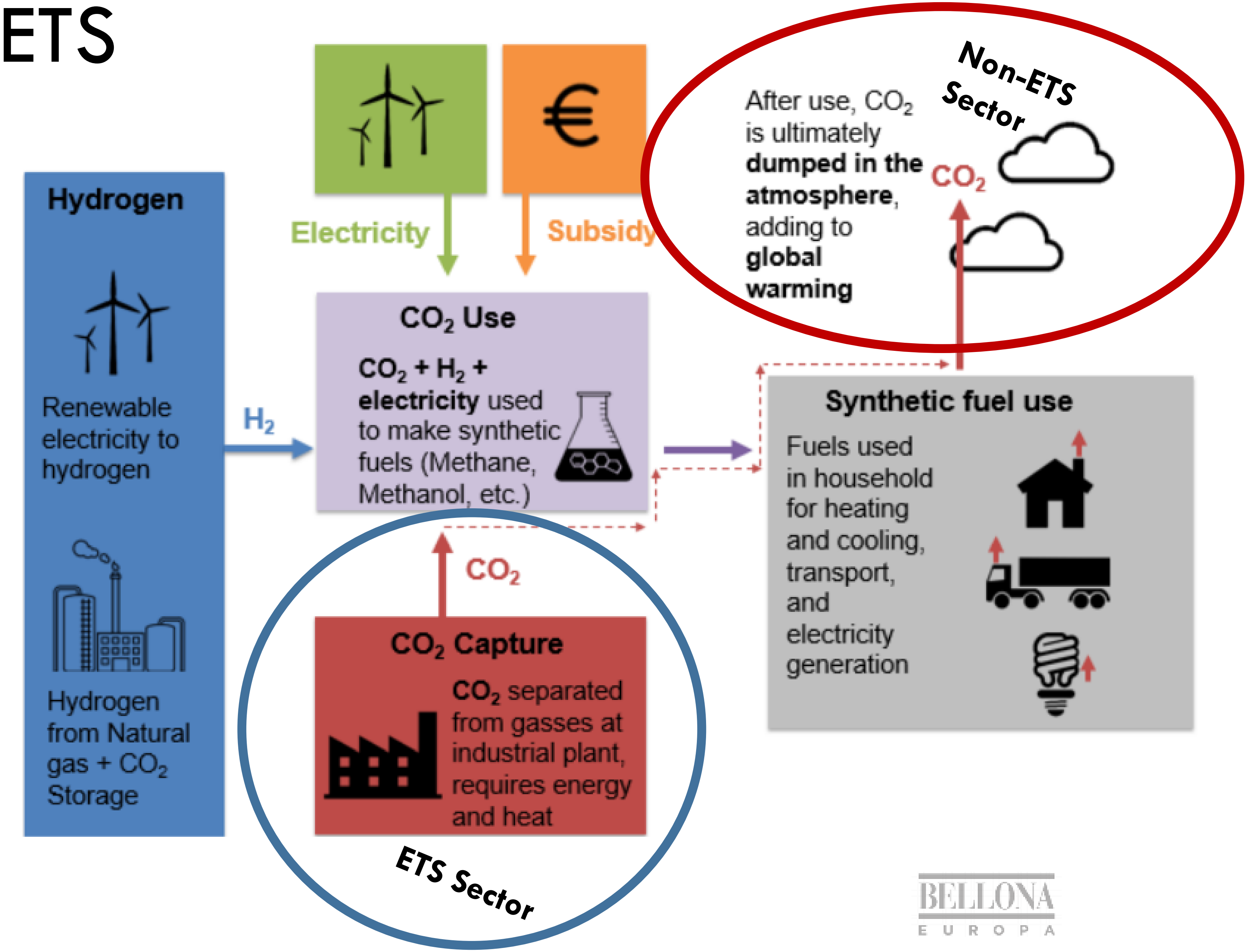
Counting the CO_2

- If the overall CO_2 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 (CO_2 supplier & CO_2 user) to be decarbonised. Any CO_2 reduction must be split or given to one party.
- Thus CO_2 recycle (CCU Fuels) can not reduce emissions from industry & transport simultaneously

Emissions reduction accounted to **CO_2 Supplier**		**Emissions reduction split** evenly between CO_2 supplier and fuel producer		**Emissions reduction** accounted to **Fuel Producer**	
CO_2 supplier	Fuel/Chem producer	CO_2 supplier	Fuel/Chem producer	CO_2 supplier	Fuel/Chem producer
~50% CO_2 reduction	Zero CO_2 reduction	CO_2 avoided shared. Both see a reduction of ~35%		Zero CO_2 reduction	~50% CO_2 reduction
CO_2 emissions abetment at CO_2 supplier.	Full carbon fuel made with renewable electricity	Small CO_2 reduction	Small CO_2 reduction	No abatment of emissions from where CO_2 is captured	Low carbon fuel made with renewable electricity –
CO2 emission now distributed in transport fleet	No rationale for fuel as not compatible with CO_2 reduction performance of REDII	Low CO_2 abetment – CO_2 scattered, not possible to reduce emissions further	Not sufficient abetment to reach reduction performance of REDII	Emitter must surrender EUA. CO_2 emissions now scattered, no abetment potential	CO_2 emissions from fuel still accounted at industrial source.

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

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

- **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.**''

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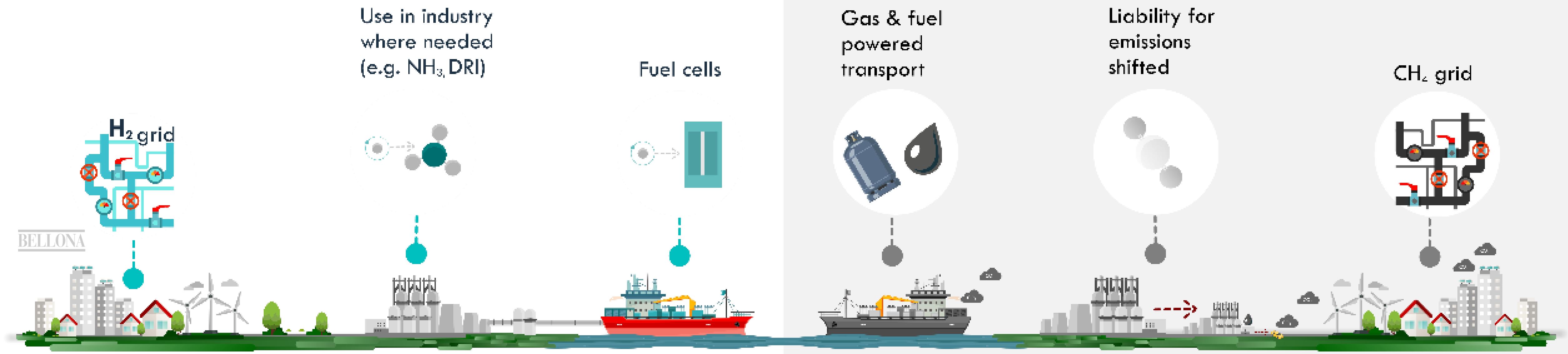
Creating a clean market instead of supplying the fossil one

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!

ana@bellona.org
+32487798419

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