INSTITUT DE FRANCE – ACADEMIE DES SCIENCES

COMITE NATIONAL DE LA CHIMIE

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5èmes Rencontres académie-industrie du CNC

CO_2 déchet ou matière première :
Etat de l'art et perspectives

CO_2 comme source de matières premières à basse empreinte environnementale : la vision d'ARKEMA

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OUTLINE

→ **Context**

→ **Stakes**

Carbon Capture and Use (CCU) overview

CO2 chemical valorization overview

- **Technologies & Actors**
- **Economics and Environmental challenges**

→ **Case Study of CO_2 chemical valorization :**

- **MeOH**
- **Ethanol**
- **Polycarbonate (polyols)**

→ **Conclusions & Pespectives**

How to reduce Carbon Footprint ? A holistic approach !

SOURCING

PROCES

ENERGIES

CO_2 is not the problem : its source is !

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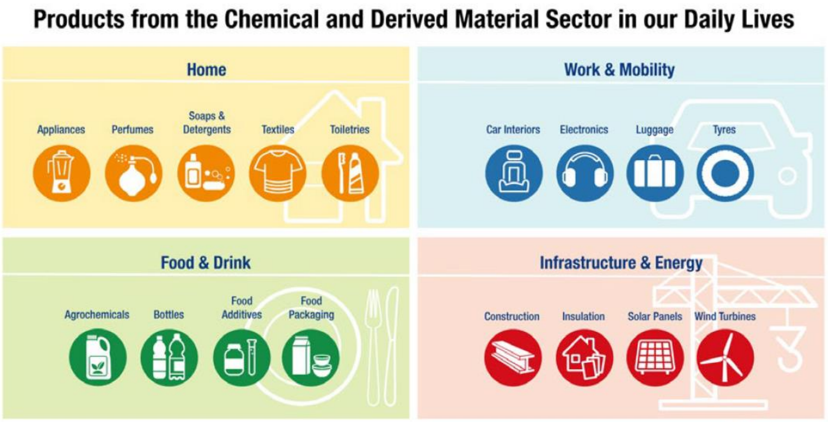
Focus on Carbon embedded in chemicals and derived materials*

* Nova Inst. scenario 2023

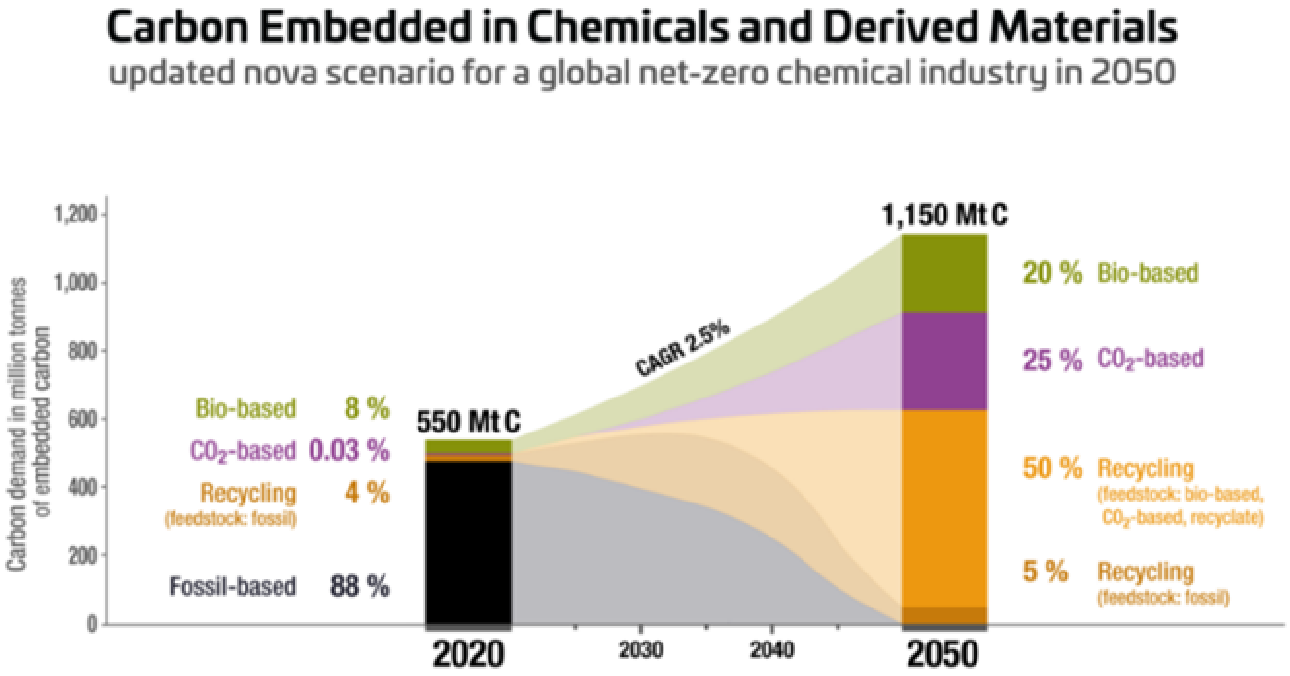
→ Carbon demand for fossil feed stock 2023

- **C embedded in chemicals and derived materials**
  - 550 Mt in 2020 (5% of global fossil C demand)
  - Fuels not included



→ Nova's scenario for 2050

- **100% increase of the C demand**
- **No more fossil**
- **CO2 based Target = 25 %**
- **Ambitious (300 MT !)**

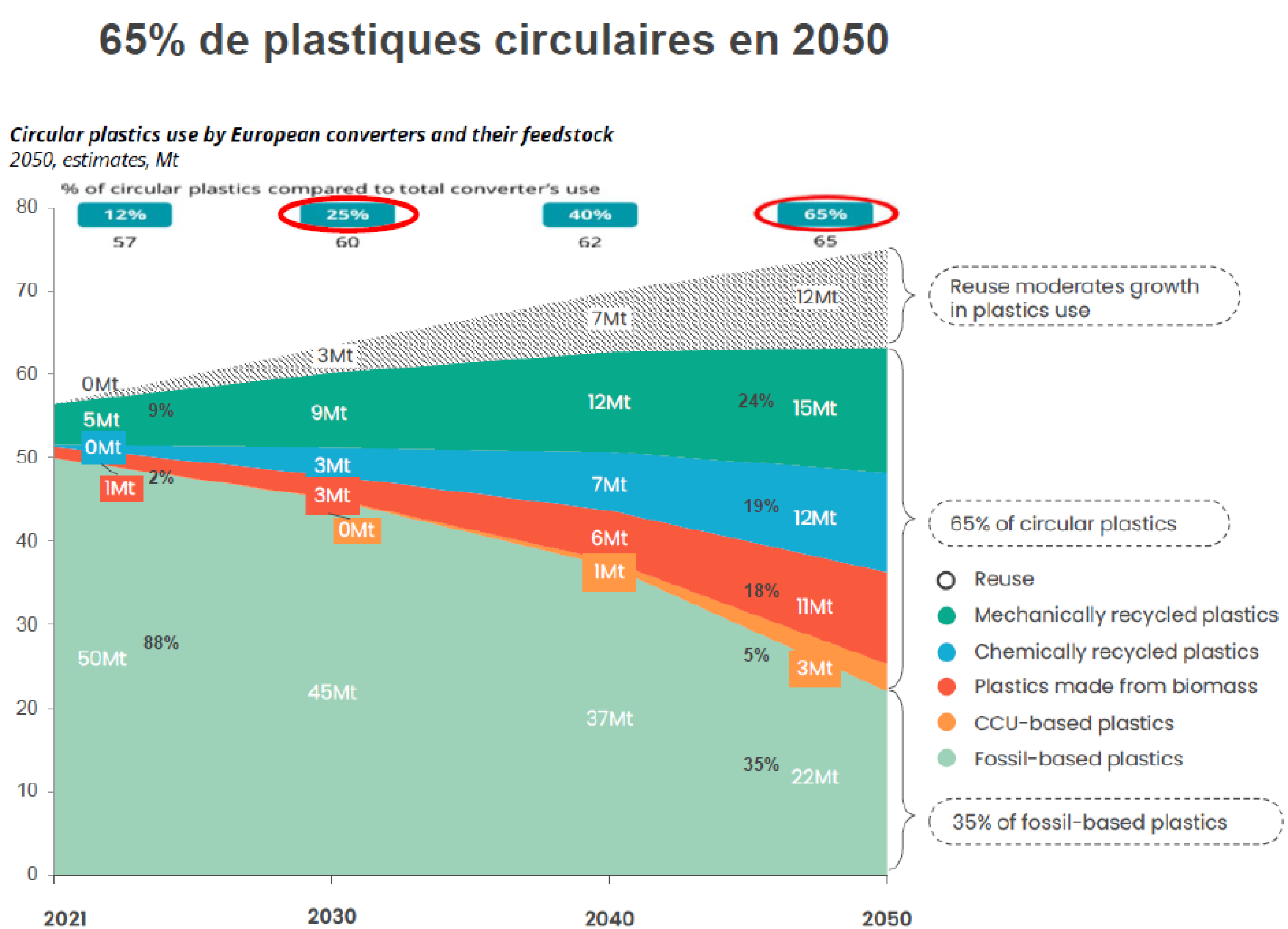


Less ambitious for others !!

Procédé =
conversion du CO_2 ou CO en méthanol
+ transformation du méthanol en Oléfines (éthylène, propylène)

1 t de plastique = 2,8 t de méthanol

65% de plastiques circulaires en 2050

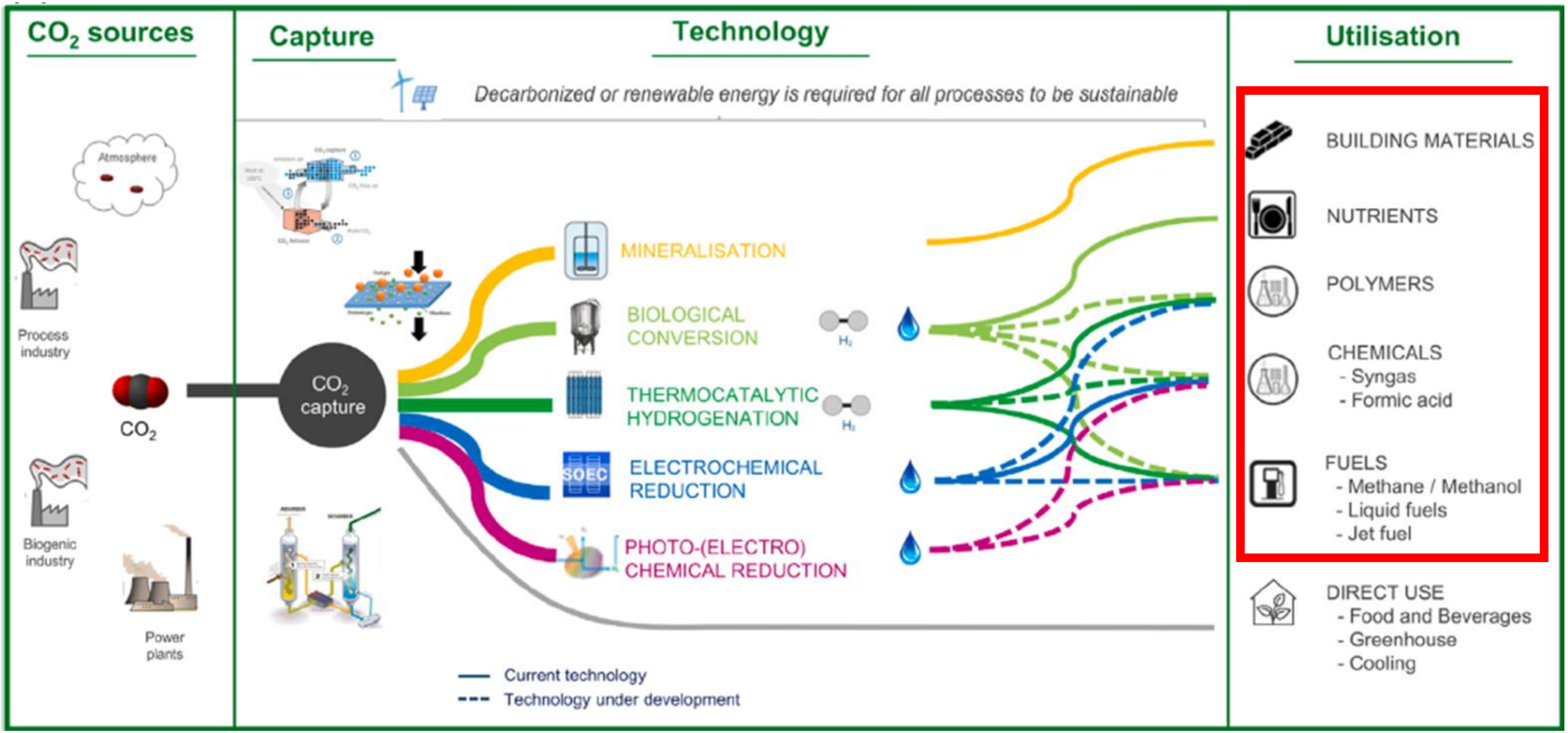


EU 27+3, en Mt, 2021-2050 (analyse Deloitte, 2023)

Key takeaways

- Through reuse, **12 Mt of plastics can be reduced by 2050**
- **Mechanical recycling** has the highest **technological maturity** and cost effectiveness, hence we project that it can steadily grow towards 2050
- **Chemical recycling** is expected to have its **breakthrough by 2030**, and grow exponentially from there towards 2050
- **Plastics made from biomass** will grow steadily until 2040 and will play a **key role** onwards
- While **plastics based on CCU and hydrogen** are poised to **grow towards 2050**, the limited maturity of the technologies and the high costs will not enable it to reach significant quantities

CCU in a nut shell



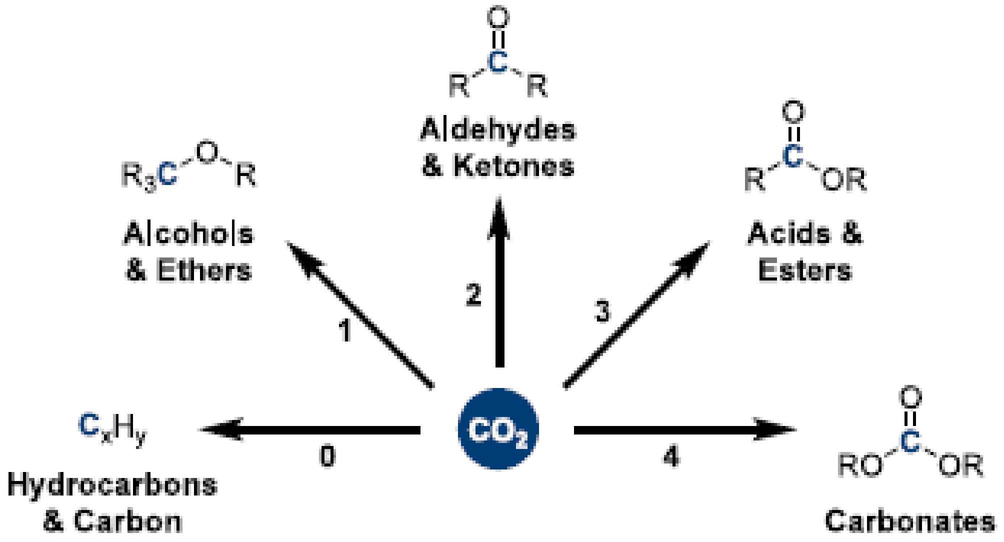
CO2 chemical valorization overview

→ Chemistry

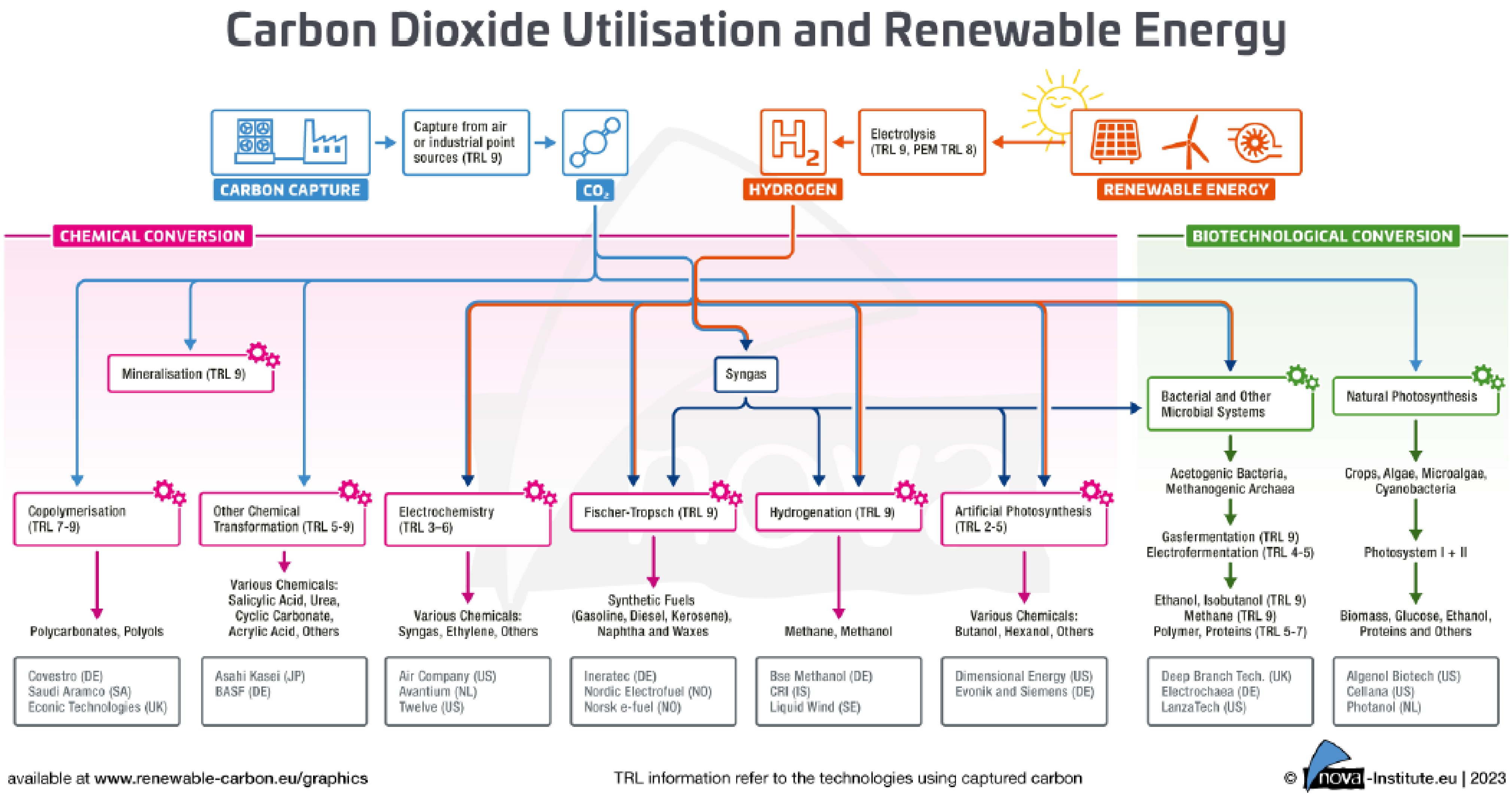
- **Challenge**
  - high thermodynamic stability of the CO2
- **New chemistry that requires**
  - significant energy input
  - Development of new efficient and selective catalysts
  - Development of new technologies

→ Main classes of products

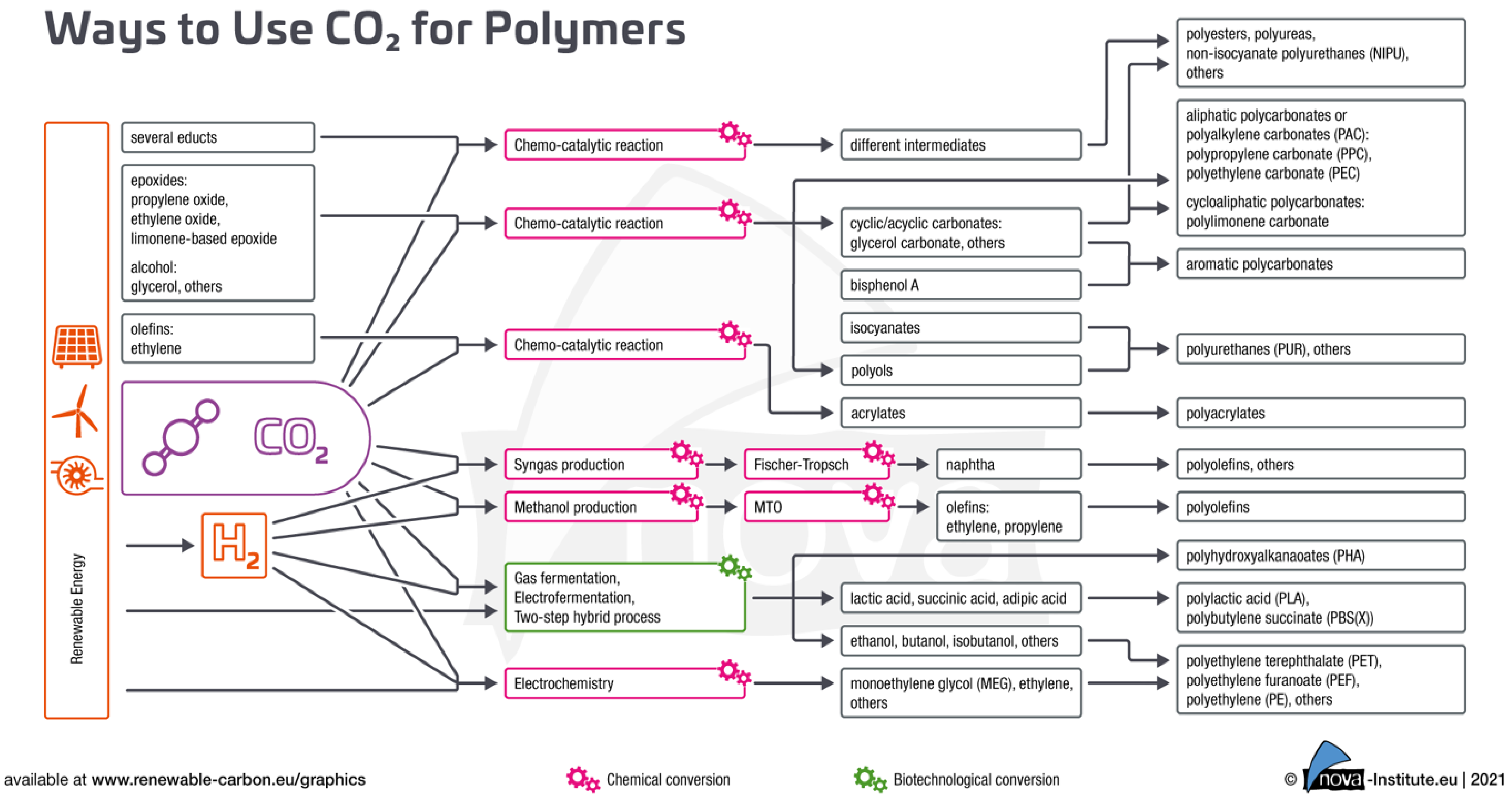
- **Depending on the “reduction level”**
- **Everything possible vs TRL**
- **Numerous academic work**



CO2 chemical valorization

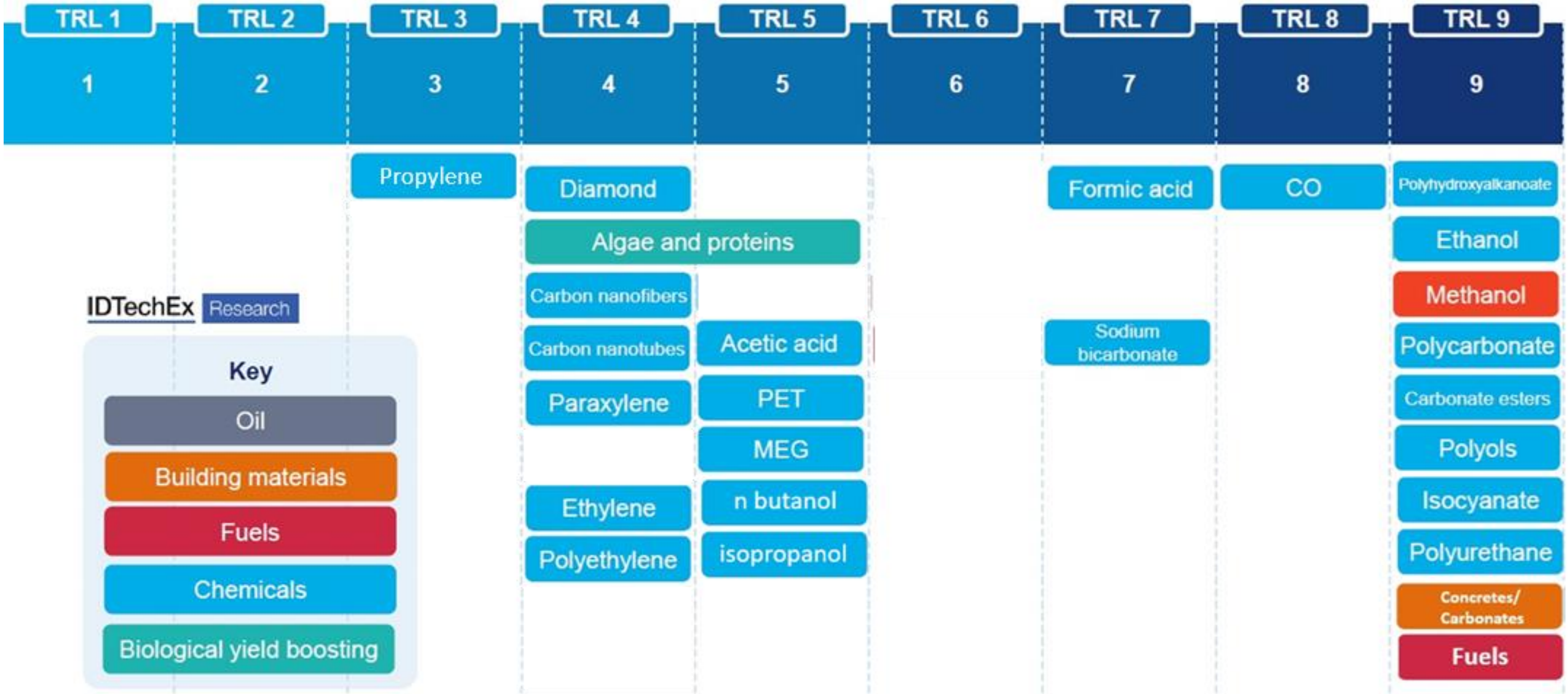


CO2 for polymers



CO2 chemical valorization overview - Drivers

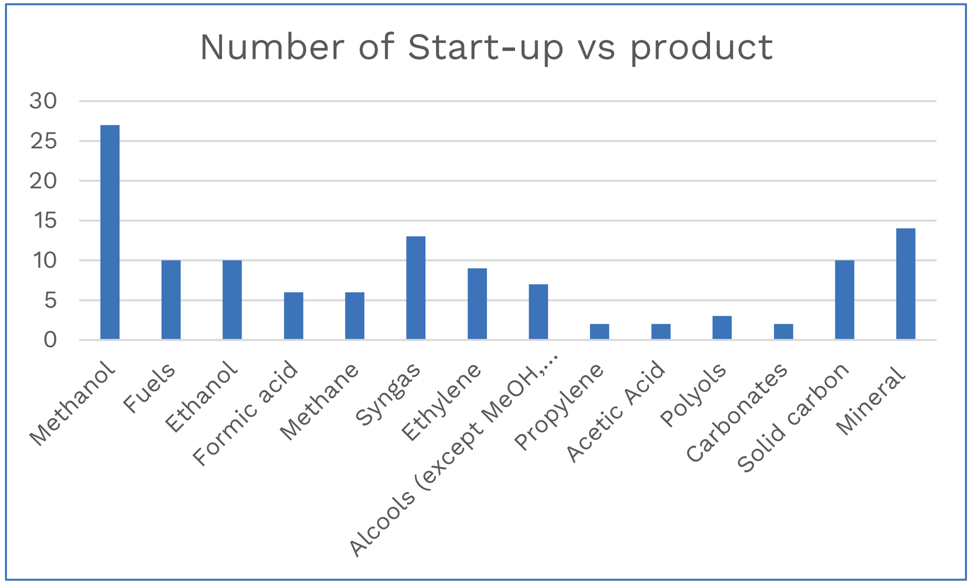
→ Examples of Technology Readiness Level (TRL) by product (best technology)

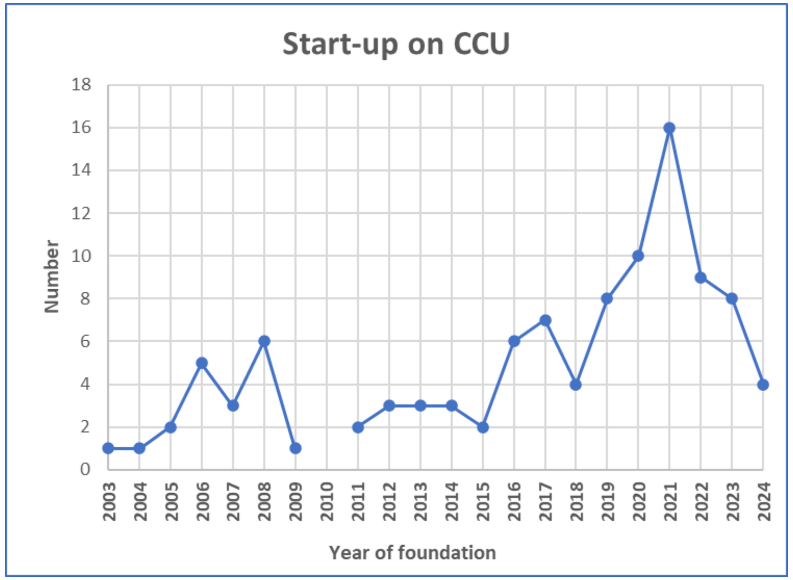


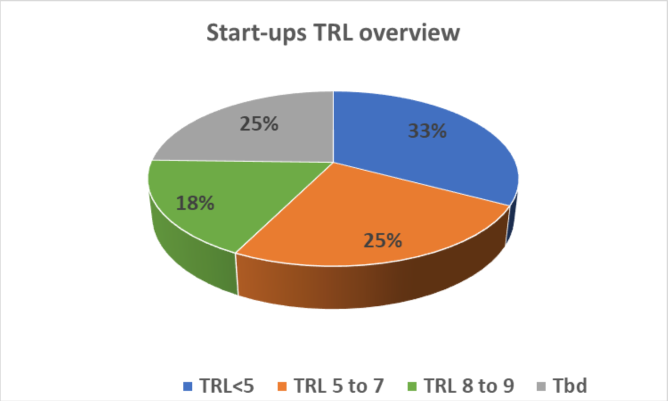
Renewable Carbon from CO2 capture : Players

→ Start-ups : non exhaustive

- **Around 120**







Renewable Carbon from CO2 capture : Players

→ Producers

- **Mainly for fuels**
- **Examples of producers :**
  - Celanese (MeOH 130kt/y)
  - Jiangsu Sailbot (MeOH 100kt/y)
  - Covestro (polyols 5kt/y)
  - LG Chem (Poly Ethylene Carbonate)
  - Perstorp Project Air (Methanol)
  - Total Energies e-CO2Met (Methanol)

→ Technology providers

- **Topsoe,**
- **CRI**
- **Johnson Matthey (importance of catalysts)**
- **Lanzatech**

CO2 chemical valorization overview - TRL

→ Technology Readiness Level

- **3 at industrial scale**

Process	TRL	Drivers
Thermochemical	3-9	MeOH, fuels, polyols…
Electrochemical	3-6	CO, syngas, formic acid
plasma	<6	CO
Biotechnology	3-9	Ethanol
Photocatalytic…	<3	
Mineralization	9	Carbonates, concretes

→ Players

- **Numerous start-ups >120**
- **larger companies mainly on chemical processes**
- **IP activity on CO2 as a raw material since 2009**
  - China positions itself as a leader
    - Highest number of commercial plants
    - Highest IP contributor by far today

CO2 chemical valorization overview : MSP and CFP

→ Minimum Selling Price

- **Highly depends on the :**
  - Technology
  - CO_2 source cost (capture and purification)
  - Energy costs (nature, location)
  - Available government incentives
- **Examples of available MSP ranges**

Product	MSP vs fossil
Methane	~ 2x
Methanol	~ 2-4x
Ethanol	~ 2-4x
Fuels	~ 6x
Treated Aggregates	< 1,5x
Cured Aggregates	~ 1,5x

→ Today, most customers are not ready to pay for premium

→ Carbon Foot Print (CFP)

- **Expected to be less but depends on the:**
  - Technology, CO_2 source, Energy mix
- **Can be up to -100% by 2050**
  - technology improvements and economies of scale
  - Fully decarbonized renewable energy, 2050

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CO2 chemical valorization detailed example : Methanol 1/3

→ Application

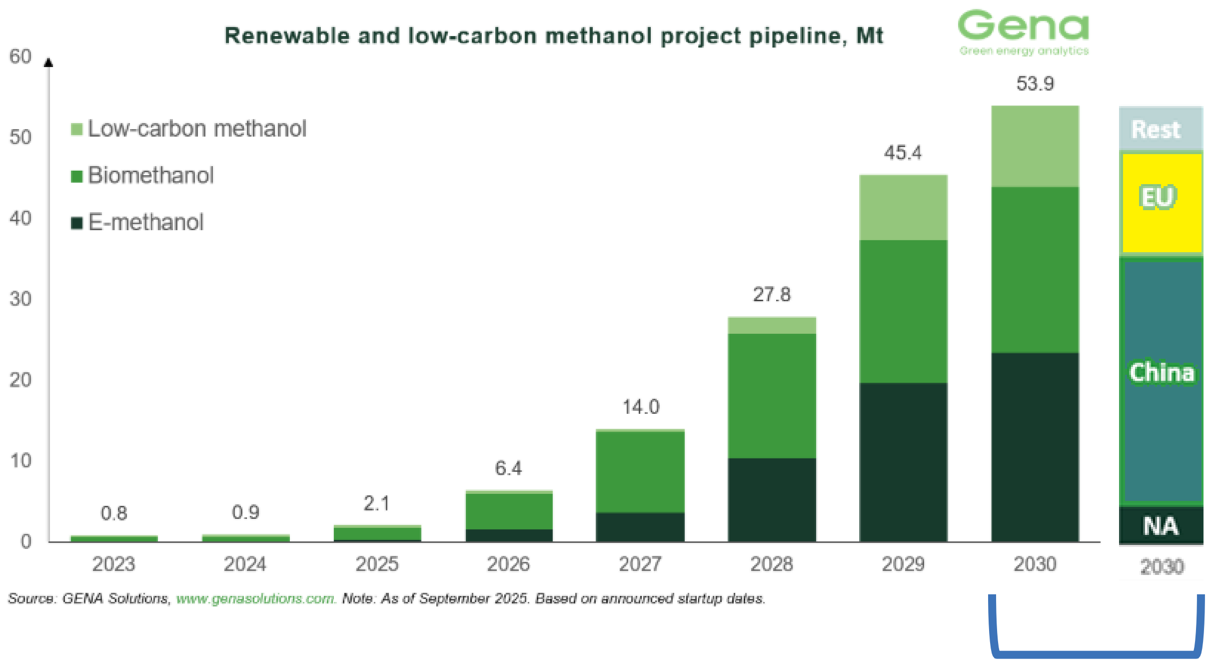
- **Fuels : maritime, aviation (e-SAF),**
- **Chemicals, building block for PP, PE, POM..**

→ CCU Grades

- **E-methanol : CO2/renewable H2**
- **Low C methanol: CO2/non renewable H2**

→ plants and projects by 2030

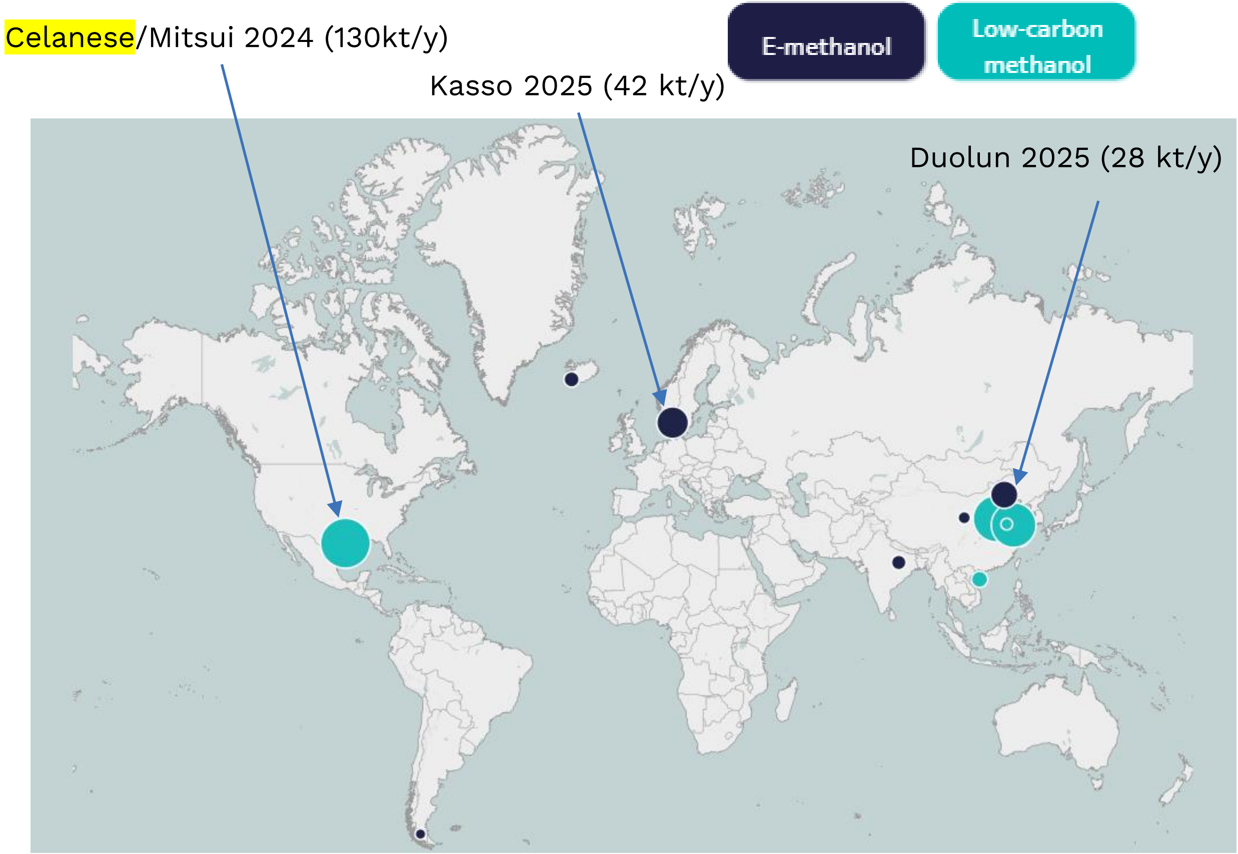
- **Today fossil capacity > 140Mt/y (fossil)**
- **2030 CCU grades : 47Mt**
- **265 for renewable and low-carbon methanol**
  - 50% on e-Methanol, > 50% in China,
- **Producers : Celanese, Mitsui, CRI, Jangsun Sailbot…**
- **licensors and catalyst providers**
  - Established : Haldor Topsoe , Air Liquide, JM, Axens
  - New : CRI, REintegrate, bse methanol



CO2 chemical valorization detailed example : Methanol 2/3

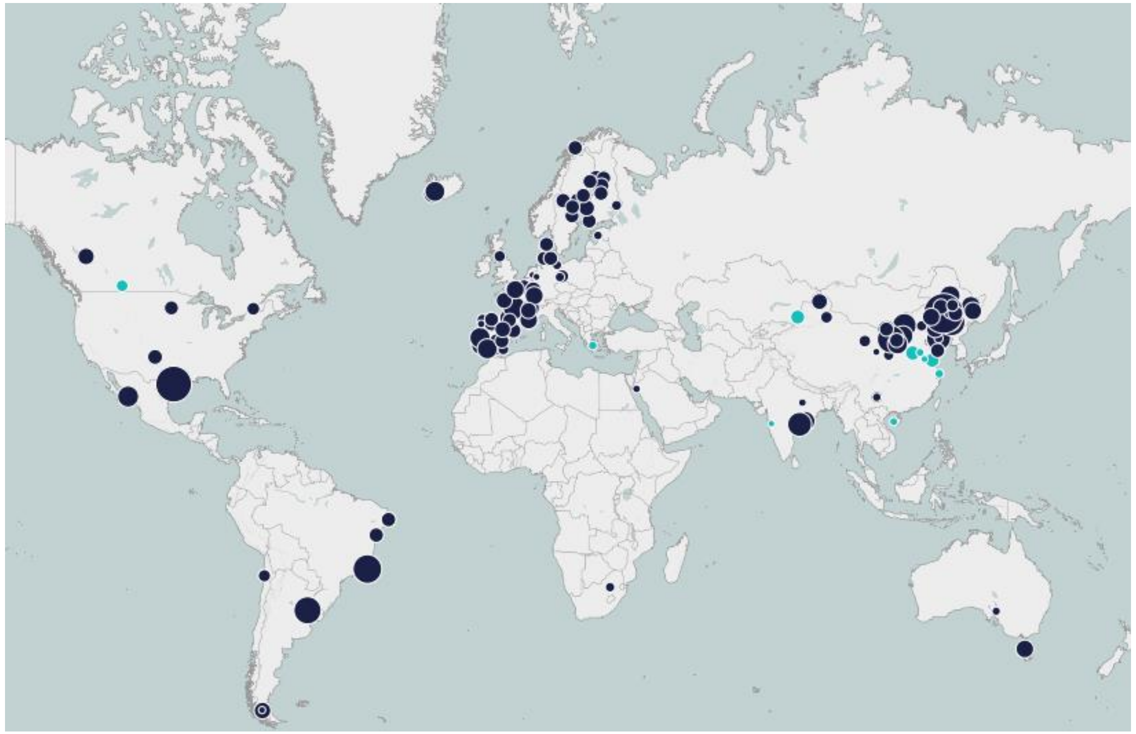
→ Plants operational in 2025

- **Mainly Low C projects**
- **370kt/y (GENA’s project)**



→ Plants feasibility, engineering, under construction and operational by 2030

- **Higher capacities announcements (total 21Mt/y capacity)**
  - China (1800kt/y) start planed 2028
  - USA (1400kt/y) start planed 2029



CO2 chemical valorization example : Ethanol

→ Applications

- **fuel additive (main driver)**
- **solvent**
- **starting reagent for chemistry, polymers**

→ Technologies

Process	TRL
Thermochemical	4
Electrochemical	3
Biotechnology	8 - 9
Others	<3

- **Lanzatech leading biotechnology provider**
  - Capacity >300kt/y vs existing plants,
- **few available data about Chinese producers**

→ Focus on Lanzatech

started

paused

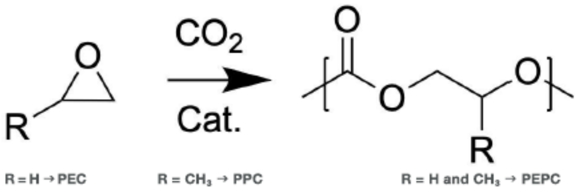
→ MSP Lanzatech

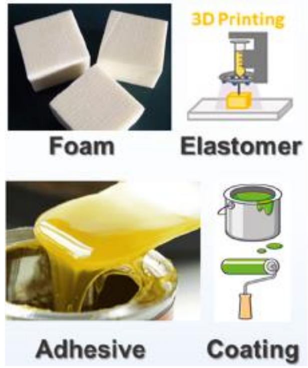
- **e-Ethanol ~ 1 to 2*bioethanol ~ 2 to 4*fossil**

CO_2 chemical valorization example : CO_2 based polymers

→ Direct synthesis : CO_2 copolymer

- **Aliphatic polycarbonates, PC based polyols for PU foams and CASE**
  - Chemical processes (TRL 9) – Procédé sans phosgène
  - Examples of polyols producers
    - Covestro/Cardyon®
    - Saudi Aramco/Converge® (ex Novomer)
    - Econic/Carnol™

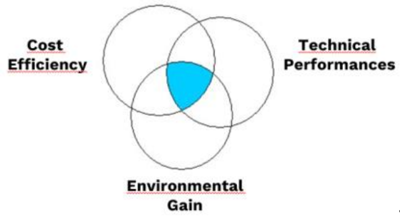




✅ Acteurs industriels clés

- **Asahi Kasei** : pionnier du procédé non-phosgène à base de CO_2 (commercialisation depuis 2002, >150 000 t/an). springer
- **CHIMEI + ITRI** : technologie « Fixed Carbon PC » (conversion CO_2 → dialkyl carbonate → diphényl carbonate → PC). chimeicorp
- **LG Chem** : pilote DRM (Dry Reforming of Methane) pour produire polycarbonates à partir de CO_2 capté. plasticstoday
- **Monument Chemical / Econic Technologies** : polycarbonate polyols pour polyuréthanes (Poly-CO_2®). econic-technologies
- **Chine (Hangzhou Puli)** : plus grande unité mondiale (300 000 t/an) de polycarbonate polyols à base de CO_2. chemanalyst

OUTLINE



Conclusions

→ CCU essential for 2050 Carbon neutral goals - strong contributor

- **PROs and CONs vs bio-based products**

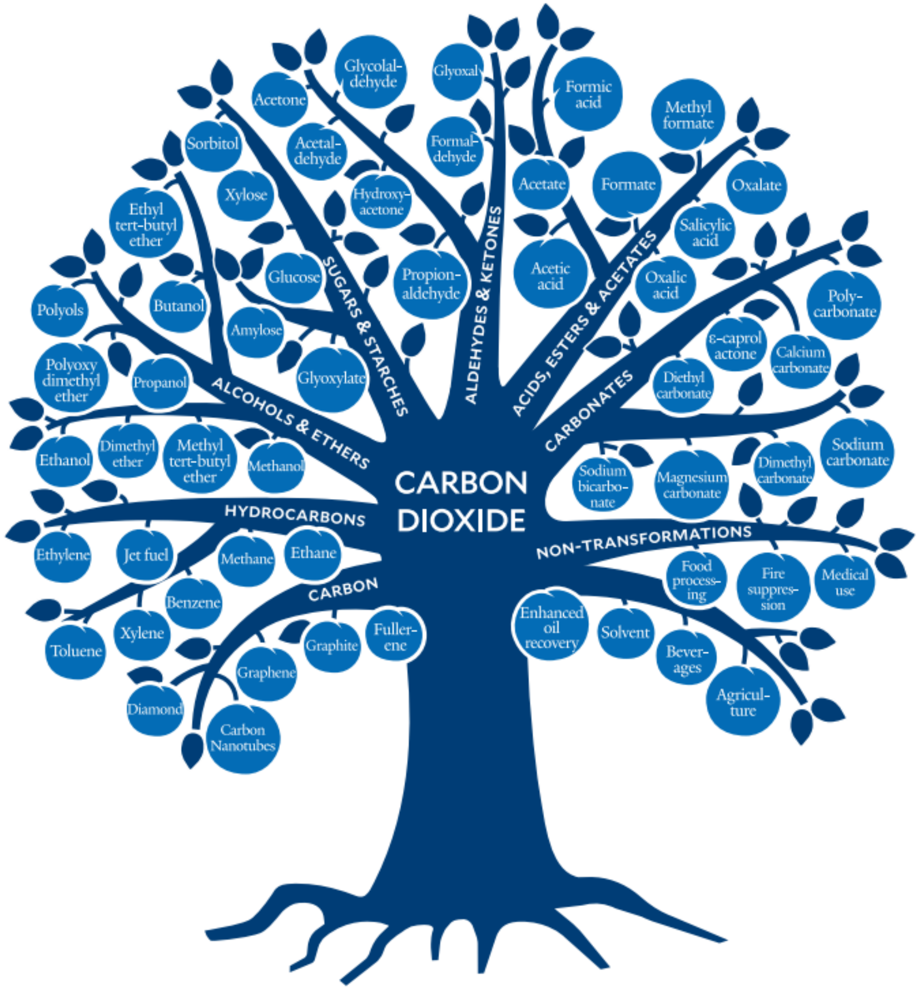
PROs	CONs
• Almost unlimited potential	• Competition on renewable energy (Food > Fuels > Chemicals)
• Low demand for land and water	• High CAPEX needed
• High TRL techno available	• High OPEX needed

→ Economics still far from market => Much too high premium prices

→ China CCU technology and market leader

→ Key Requirements for Successful Development

- **Enhance competitiveness and visibility**
  - Financial incentives (e.g., CO_2 tax).
  - Supportive regulatory and policy framework
- **Improve technology (catalysts etc.)**
- **Ensure the availability of renewable energy**
  - Allocation, infrastructure, energy storage
- **Ensure the access to renewable CO_2 sources**
  - Purification, transportation, storage



The Carbon tree
Compounds that have been made from CO2 from lab to commercial stage;
« The CO2 tree », H. LeClerc and al., ACS 2025