

ANTECY



“CO₂ the Uber Resource”
- Direct CO₂ Capture from Air for E-Fuels & more -

History: Personal

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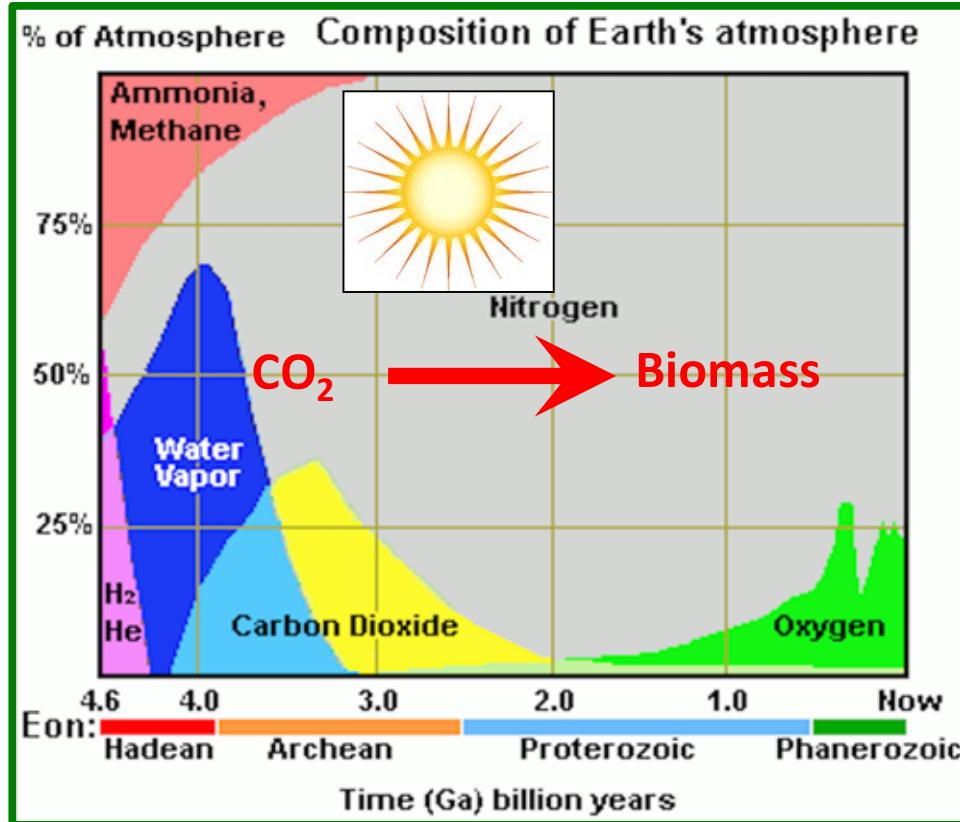
Paul O'Connor – Background

- Born in Curaçao, Netherlands Antilles
- **Chemical Technology at TU Eindhoven (1972-1977)**
- **SHELL:** Catalytic & Thermal Cracking (1977-1984)
 - The Hague (MFD), Refinery (Curaçao)
- **Akzo Nobel:**
 - FCC Catalyst testing & development (1984-2004)
 - Advanced materials & new fuels (2000-2004)
- **Albemarle:** New Business Development (2004-2005)
 - GTL, CTL, BTL...Renewables?
- **BIO^eCON:** 2nd Gen Biomass conversion (2006 – Now)
- **ANTECY:** “Solar” fuels & chemicals (2010 – Now)



History: CO₂ = Back to the Future

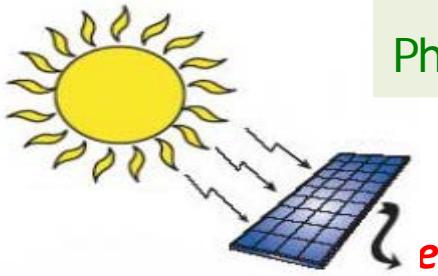
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CO₂ the “Uber” building block

$\text{CO}_2 + \text{H}_2 (\text{e})$: High Density E-Fuels!

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Photons → Electrons → Molecules (Gas → Liquid)



Lithium Ion
Battery
~ 30 liters

Hydrogen
@ 150 bar
~ 20 liters

Hydrogen
@ 720 bar
~ 6 liters



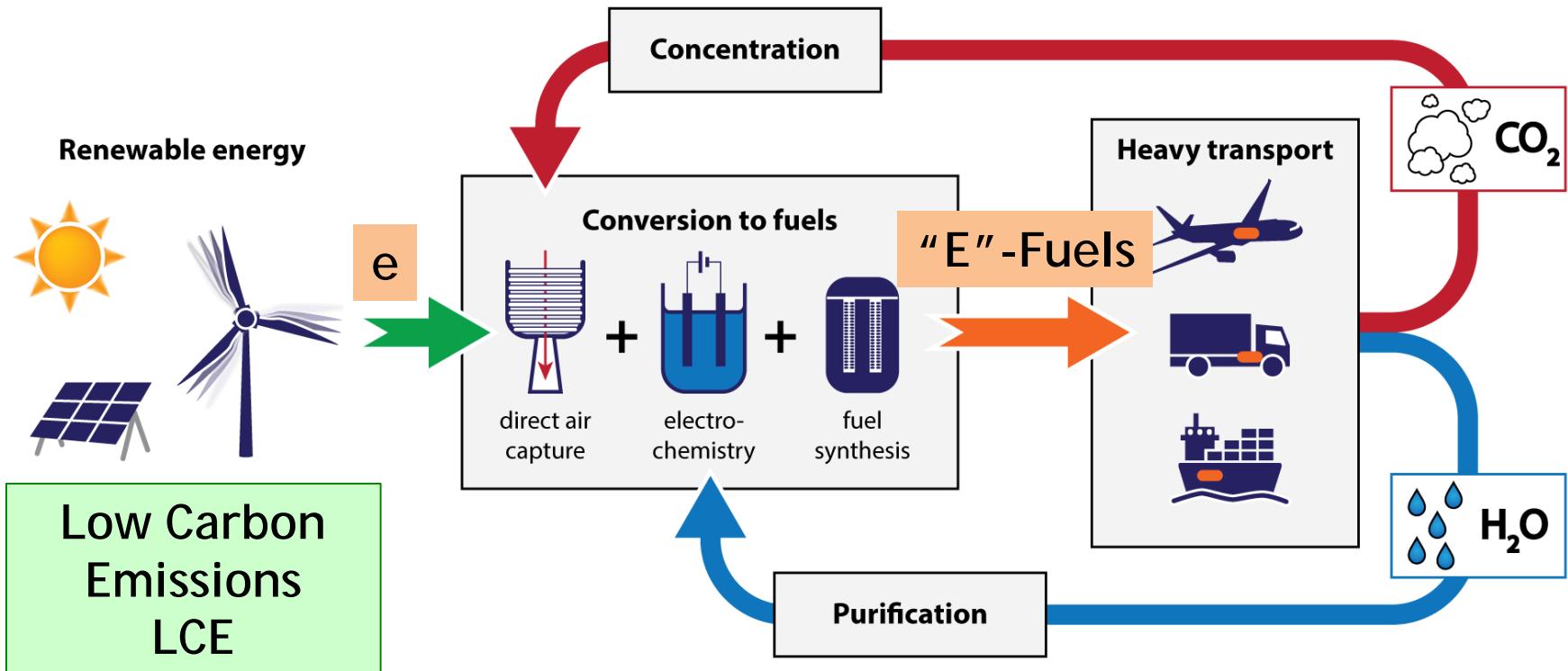
Methanol
~ 2 liters

Gasoline
1 liter

Volume @ constant energy content

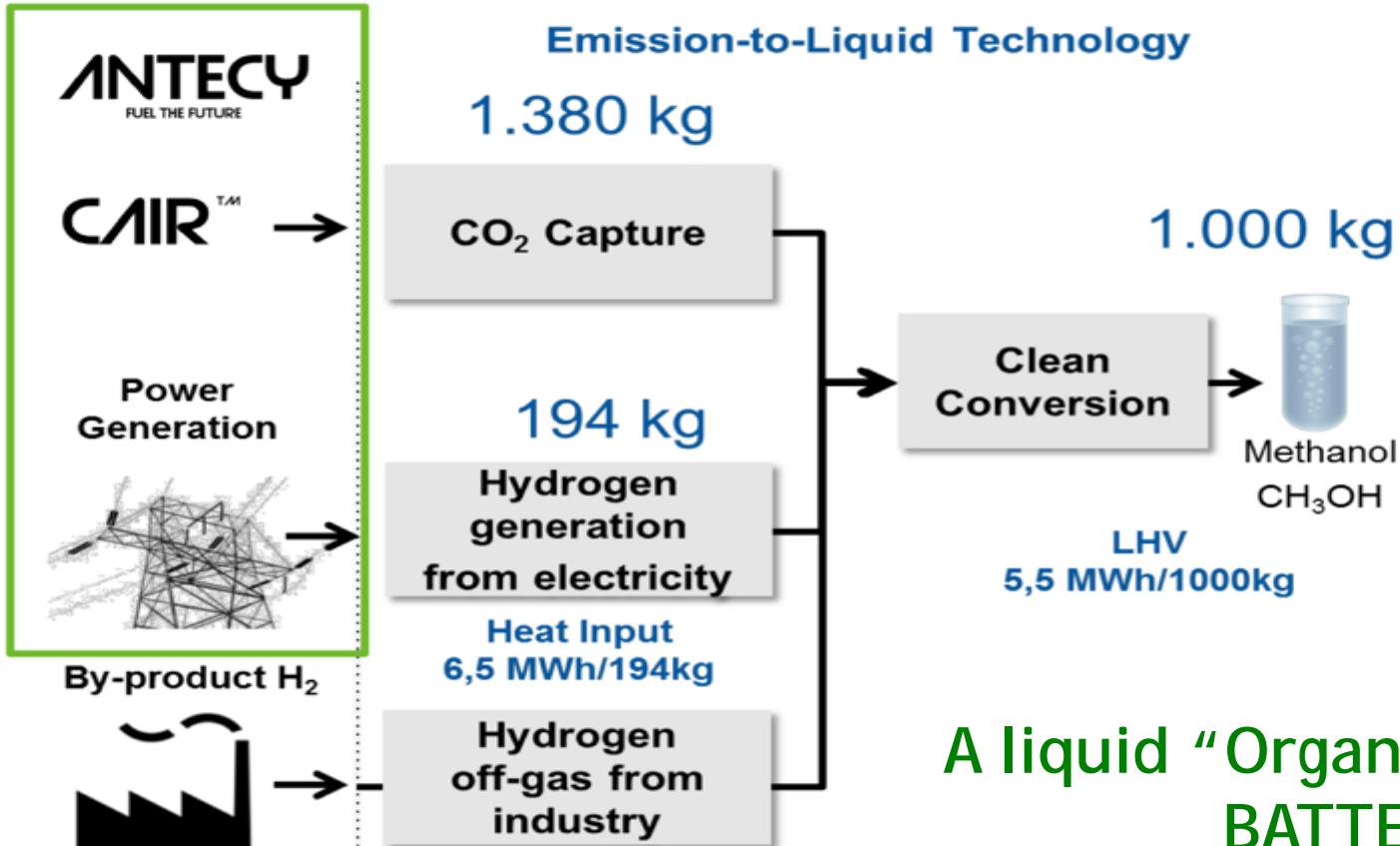
E-Fuels: Enabling Energy Transition

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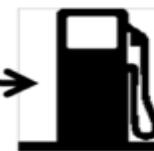
CO₂: As energy (e → H₂) carrier

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Markets

Liquid fuels



Raw materials

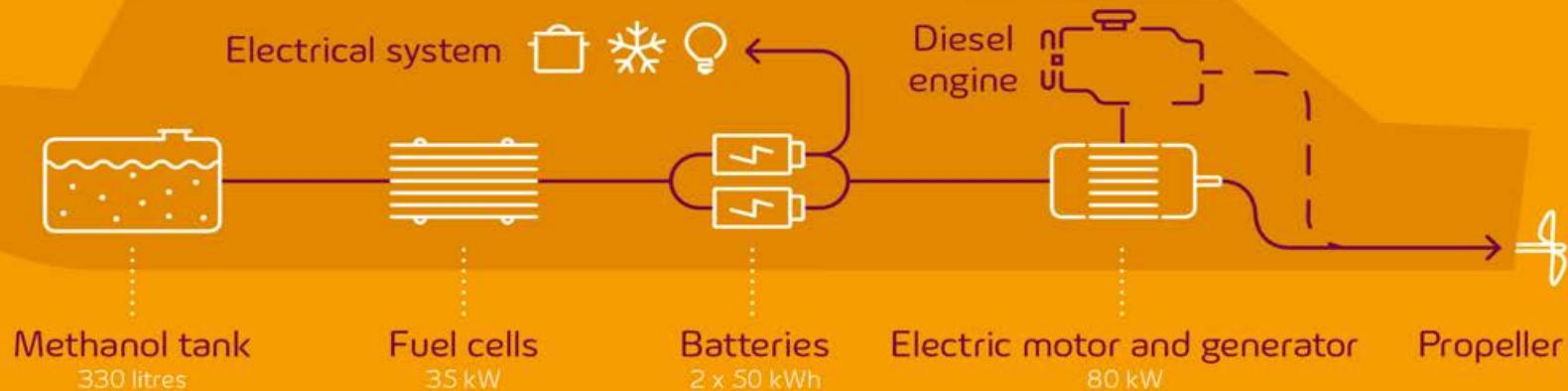


A liquid “Organic” recyclable BATTERY....

The Future is here!

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MS innogy



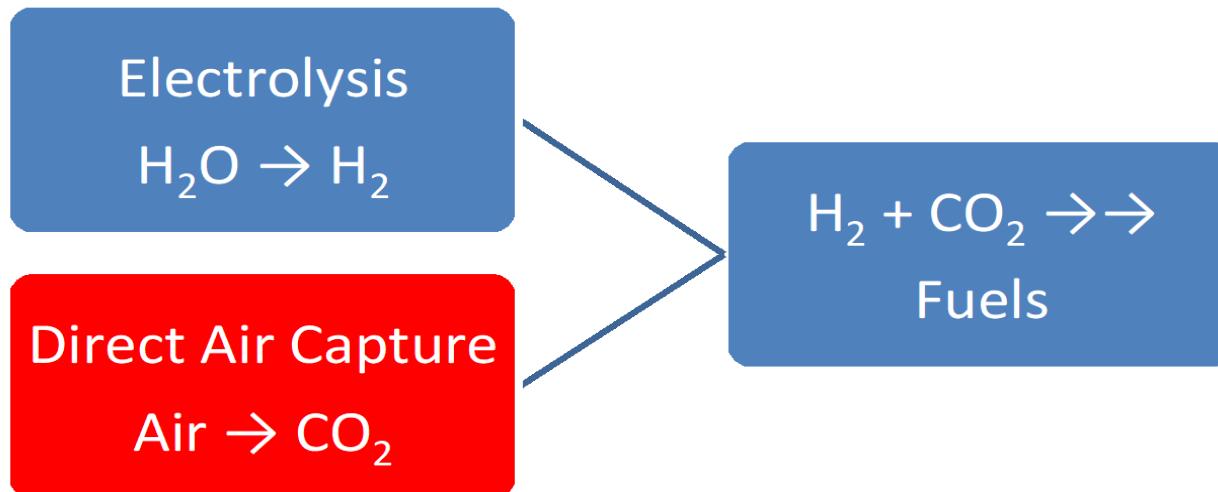
Ruud Koornstra : “So the future battery of my TESLA will be methanol!”

Key technology still missing?

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What is still missing?

Direct Air Capture of Carbon/ CO₂ from Air



Carbon (CO₂) point sources are limited!

CO₂ Capturing + Concentration!

Power to Liquids/Gas requires “pure” CO₂ (O₂ free)

<u>Source</u>	<u>CO₂</u>	<u>Concentration</u>
Bio gas	up to 20%	5x
Flue gas	±10%	10x
Open Air	± 0,04%	2500x

- Advantage: Clean

CO₂ from Air Challenge!

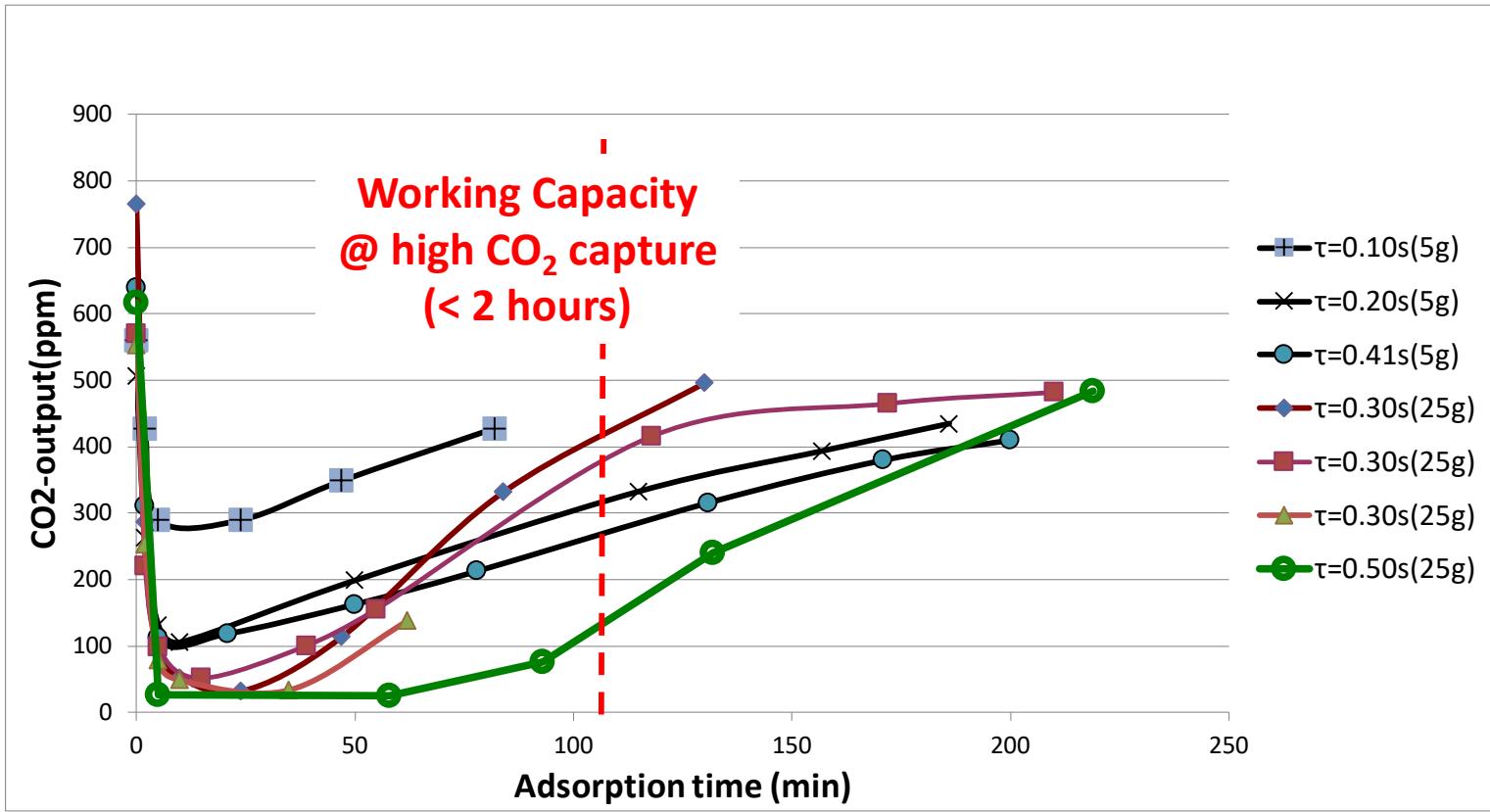
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Pick 400 “special” people (CO₂) out of crowd of a million in seconds!



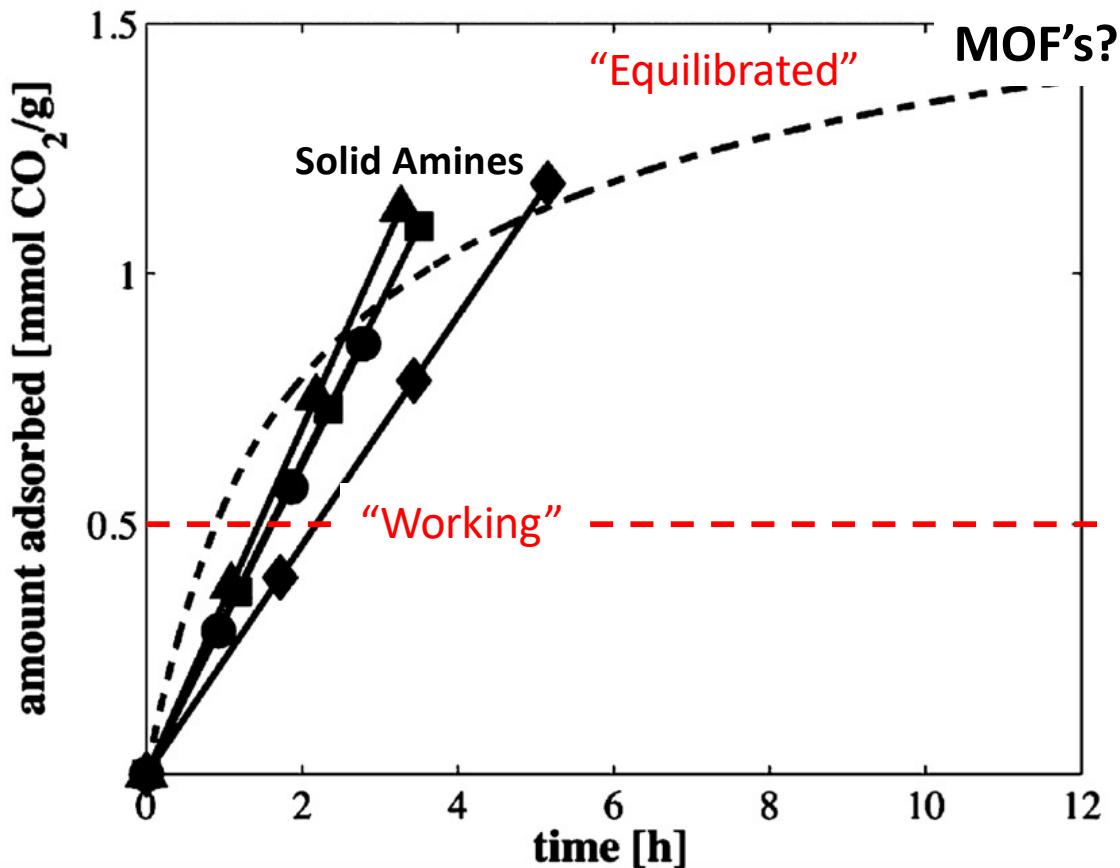
Adsorption Kinetics: Fast & Deep

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Sorbent Development: Capacity?

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Capacity:
Direct Air Capture

mmol CO₂ /g
g CO₂ /kg
g CO₂ /m³

Equilibrated

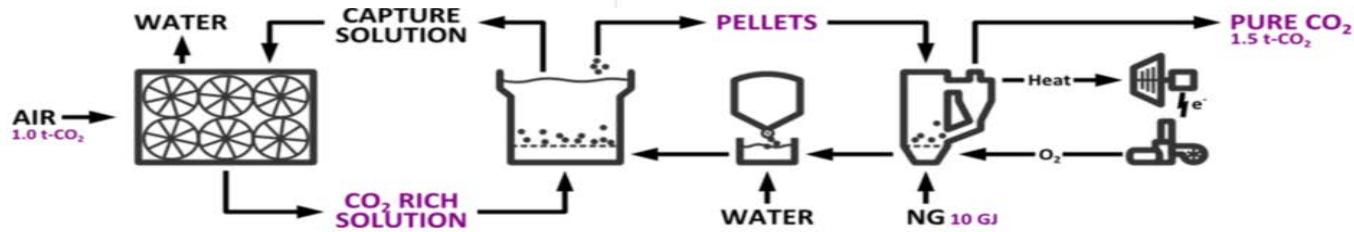
Working Capacity
@ high CO₂ capture
(< 1 hour)

Competitive Technologies

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Global
Thermostat



CE's Air Capture Process

Amine
Based

Non-
Amine

L: Liquid Adsorbent

S: Solid Adsorbent

**Amine G-L
Technology
State-of-the-Art**

AMINES G-S
Toxicity issues
Stability (lifetime)
Corrosion etc.

G-L
Slow mass transfer
→ Longer time/cycles
High Sorbent Volumes

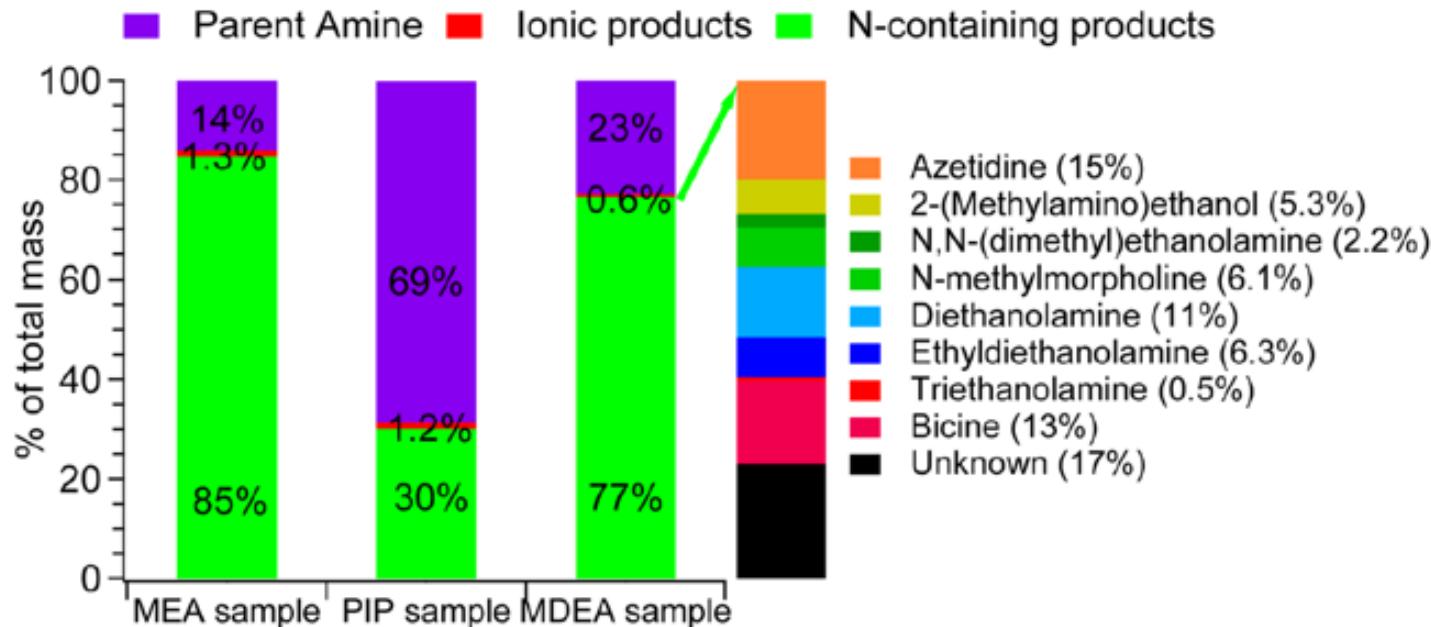


Decomposition/Desorption temperature



- CaCO_3 $T > 800^\circ\text{C}$
- Al-Mg-CO_3 $T > 400-600^\circ\text{C}$
- K-Al-Mg-CO_3 $T > 200-450^\circ\text{C}$
- Zn-CO_3 $T > 150-400^\circ\text{C}$
- **KHCO_3** **$T > 50-80^\circ\text{C}$** **$(\text{K}_2\text{CO}_3 \cdot 1.5\text{H}_2\text{O})$**
- Liquid Amines $T > 120-150^\circ\text{C}$

Why Non-Amine?



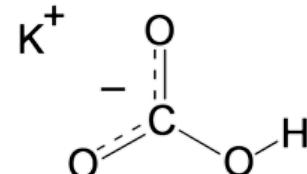
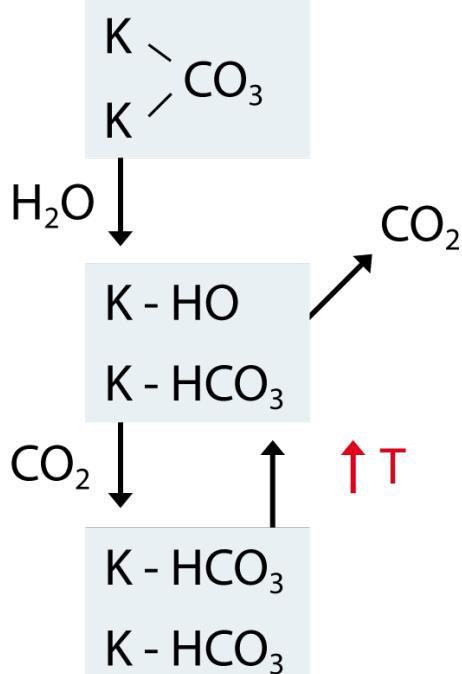
Average compositions of the degradation samples of MEA, PIP, and MDEA.

Stability Amines: Temperature , O₂ concentration

- Degradation: Loss of sorbent capacity ,Higher cost
- Degradation products can be toxic / carcinogenic
- Emission issues in waste water, air, CO₂?
- Solid grafted amines (complex MF)
- Much higher production costs vs. Carbon/KHCO₃

CAir: 1st generation Sorbent

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R&D Program funded:



Europese Unie



Europees Fonds voor Regionale Ontwikkeling



Main goal: Higher Sorbent Capacity

Target to double CO₂ captured per weight of sorbent

Faster kinetics & mass transfer

→ 50% Reduced energy consumption
OPEX

→ 50% Reduced adsorber/desorber size
CAPEX

Surprising Conclusions?

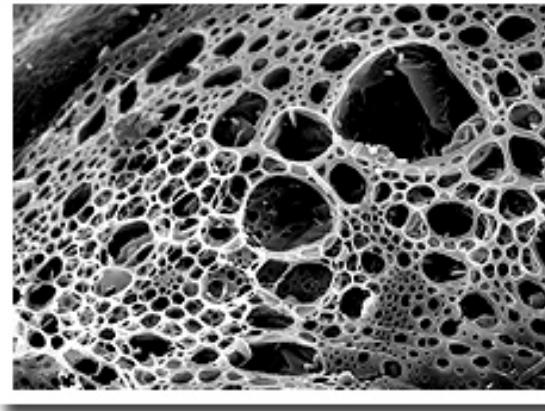
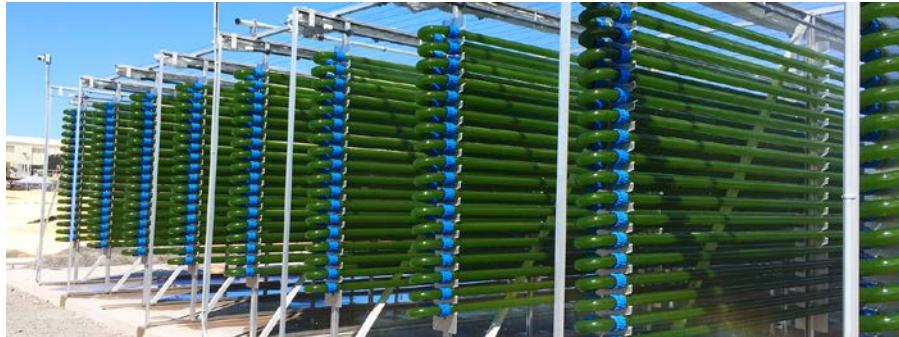
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- Future = E-Fuels (+ FC) > Hydrogen or batteries
 - EF-ICE and/or EF-FC Cars
- Future is already here: Low cost of Electricity
 - Norway, ME, E-Intermittency, Islands,..
- Preferred CO₂ source is Air and not Flue Gas
 - FG-CO2 is not (much) cheaper
 - FG-CO2 needs to be cleaned (Costs)
 - FG-CO2 is only available at certain locations (Points)
 - FG-CO2 is unreliable (suppliers?)
- Cost effective CO2 from Air is NOT impossible
 - ANTECY has the technology to do it!

CO₂ for non-Fuel applications

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Enclosed Agriculture Systems!

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900 ton/year CO₂ plant
± 300 ton CO₂ /ha per year

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Ready for take-off!