CLIMEWORKS

Capturing CO_2 from air

Regulatory and Financial Gaps Hindering Direct Air Capture

ERCST Roundtable, Brussels

Nov 21st, 2019

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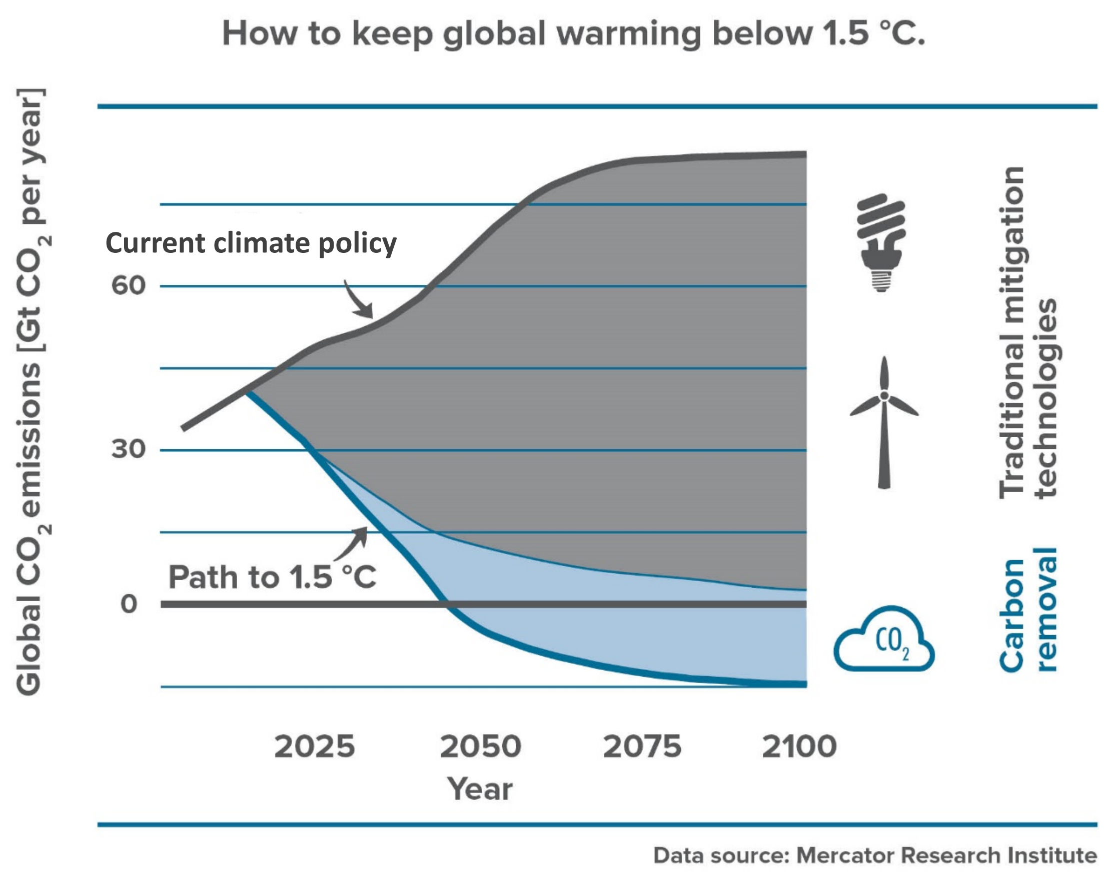
WHY DIRECT AIR CAPTURE OF CO_2

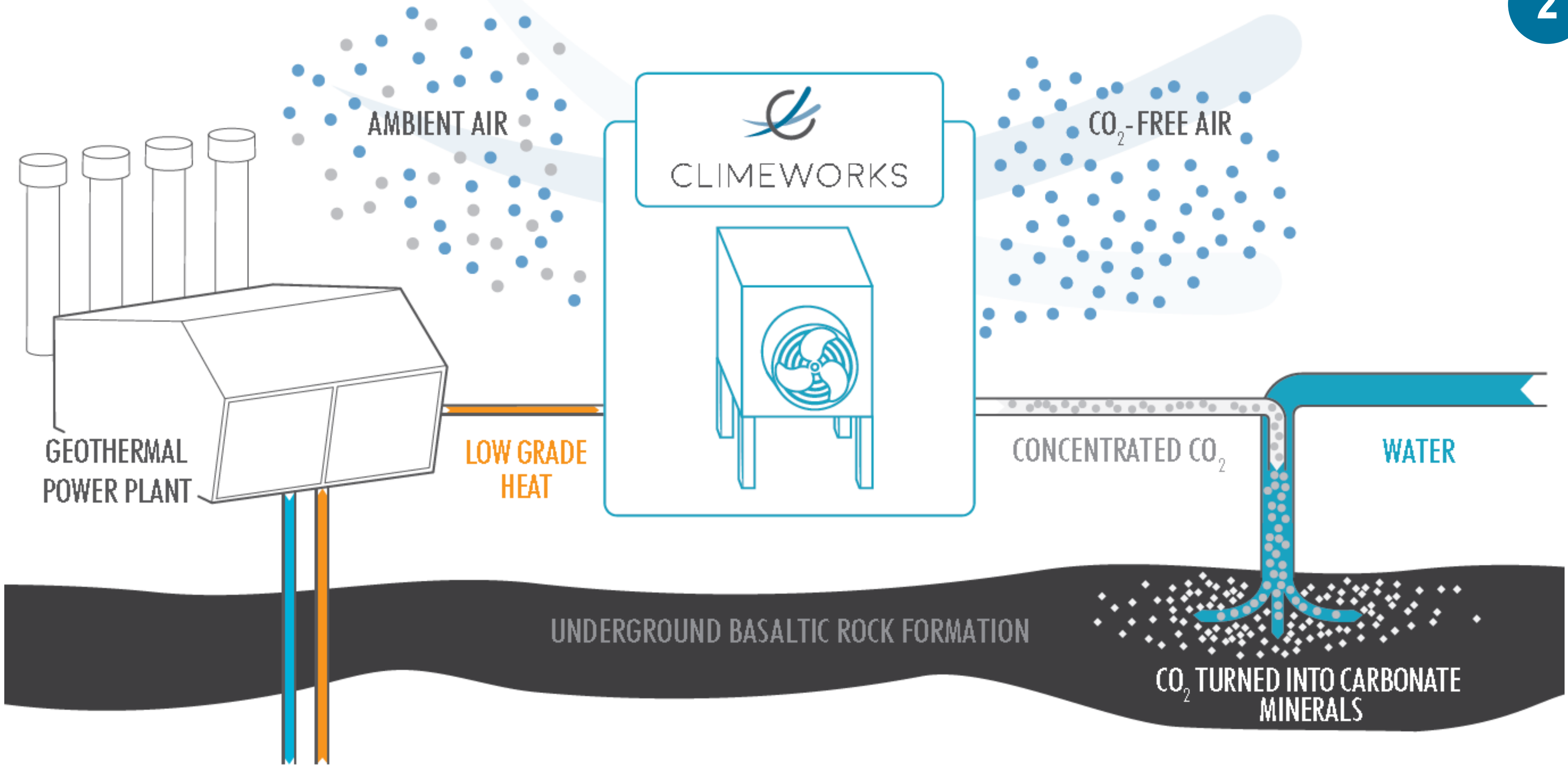
To make Paris large scale CDR is needed!

All IPCC mitigation scenarios compatible with the 1.5°C target - and 87% of 2°C – rely on the assumption of **large-scale atmospheric CO_2 removal**



PERMANENT ATMOSPHERIC CO_2-REMOVAL

1 CO_2 is captured directly from the air using renewable, e.g., geothermal energy



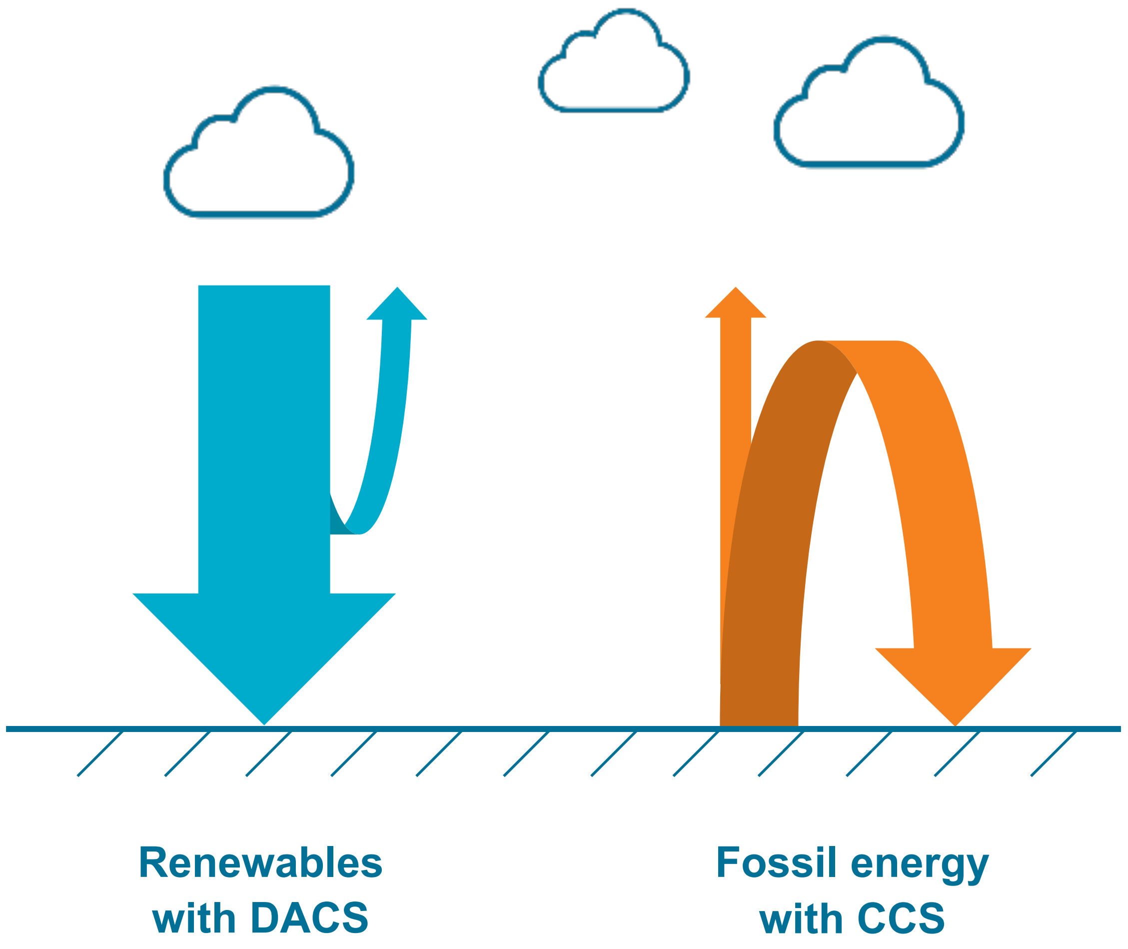
2 CO_2 is pumped underground at favorable CO_2 storage sites, e.g. Iceland.

3 CO_2 reacts with underground rock formations and is mineralized. Thereby CO_2 is bound permanently and safely, reducing the CO_2-content of the atmosphere.

COMPARISON: DACS VS. CCS

- **Direct Air Capture & Storage** (DACS): Captures and sequesters CO_2 directly from the atmosphere
- **Carbon Capture & Storage** (CCS): captures and sequesters fossil CO_2 from point sources
- **Only DACS** is **carbon negative**, while fossil CCS achieves carbon neutrality at best

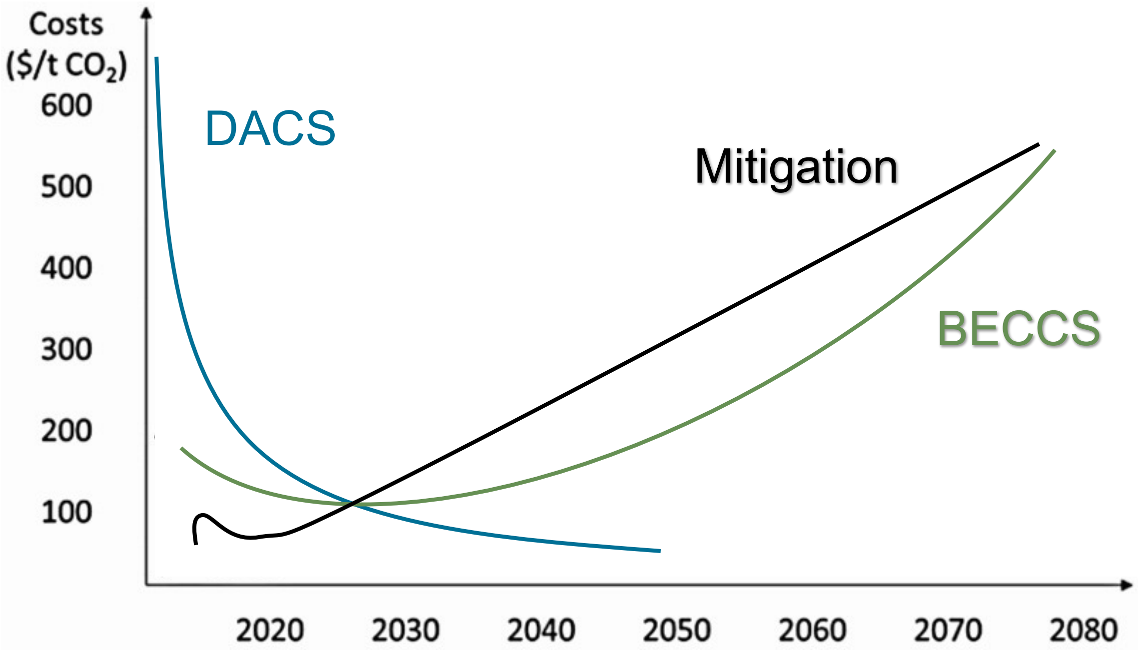
Schematic Carbon Flow



CO_2 REMOVAL APPROACHES – A COMPARISON

	AREA REQUIRED[1] to remove 8 Gt CO_2 per year	WATER REQUIRED[2] to remove 8 Gt CO_2 per year	EXPECTED COST at large scale	IMPACT ON ENVIRONMENT*
AFFORESTATION Large-scale tree plantations to increase carbon storage in biomass and soil.	6'400'000 km² (Europe = 10'500'000 km²)	740 km³ (Yearly global freshwater withdrawal 2010[2] = 4'000 km³)	5 - 50 USD / t CO_2[3]	BIODIVERSITY ALBEDO FOOD SECURITY
BECCS Bioenergy in combination with carbon capture and storage.	2'500'000 km²	480 km³	100 - 200 USD / t CO_2[3]	BIODIVERSITY ALBEDO FOOD SECURITY
ENHANCED WEATHERING Distribution of crushed silicate rocks on soil surfaces to absorb and bind CO_2 chemically.	220'000 km²	3 km³	50 - 200 USD / t CO_2[3]	RIVER/ OCEAN CHEMISTRY
DIRECT AIR CAPTURE Direct capture of CO_2 from ambient air through engineered chemical reactions.	15'800 km²**	none	<100 USD / t CO_2[4]	none

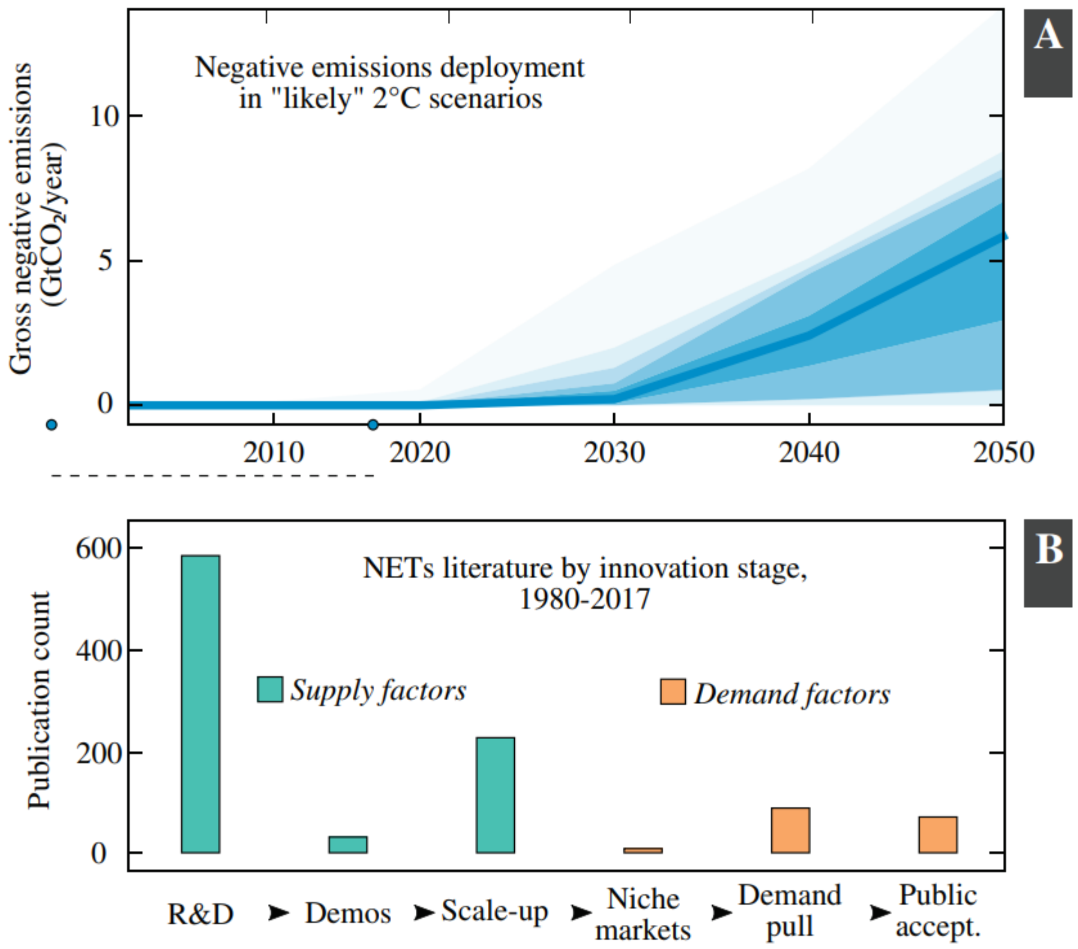
ECONOMICS OF MITIGATION, BECCS & DACS



Source: Reiner & Honegger 2018: Development of costs of BECCS, DACS and classical mitigation over time assuming strong political will to cover mitigation costs.
Note: Curves are indicative.

- **Cost of DACS is falling faster than science anticipated (blue curve)**
- Whilst costs of Mitigation and plant based CDR (BECCS) will be rising in the long run due to resource constraints (Land, Water)

CDR SCALE-UP REQUIREMENTS



Source: Nemet et al, Environmental Research Letters 13/6, 2018

- **Urgency** of scaling up NETs is largely **unappreciated**
- Annual NETs **growth rate of 58%** required from 2019 to remove **6 billion tons** by 2050
- **80% growth rate** per year needed, if delayed to 2025
- 100% from 2030…

Regulatory and Financial Gaps CDRTs

- **CDRTs are ready to scale**
- **Different regulatory frameworks for CCS and CDRTs needed** (fossil flue gas capture vs. atmopsheric capture)
- **Ramp up of CDRTs now to reach required scales** (and avoid sky-rocketing ETS prices)
- **PtX can be used to scale CDRTs** (Co2 needed as feedstock for e-fuels & materials)

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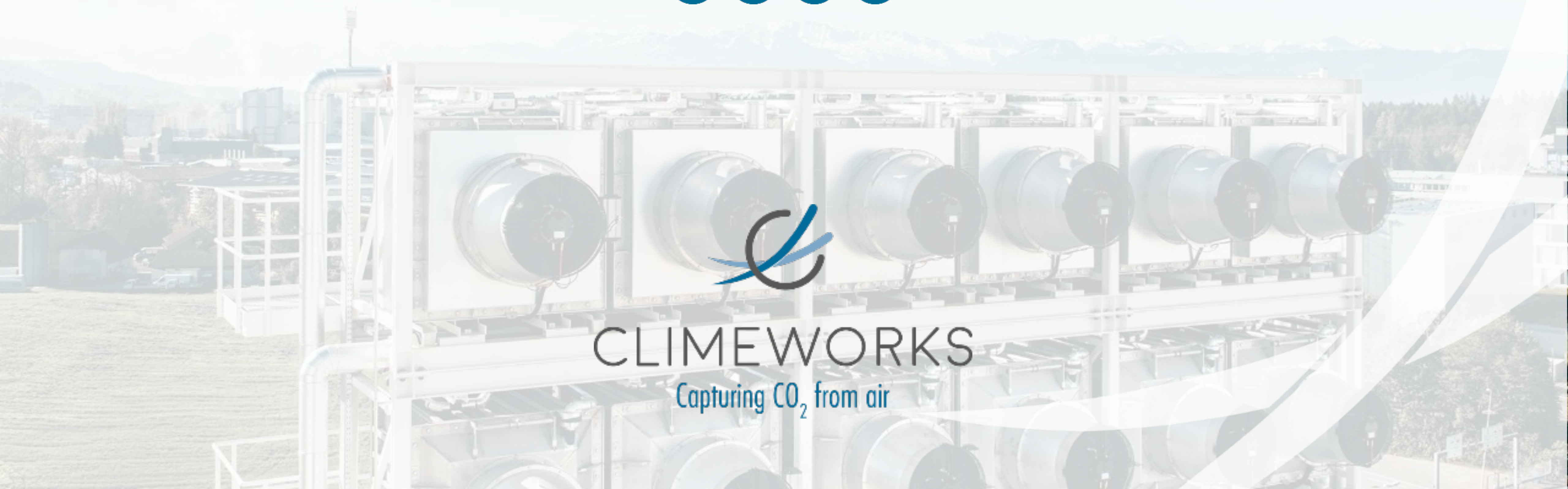

CLIMEWORKS

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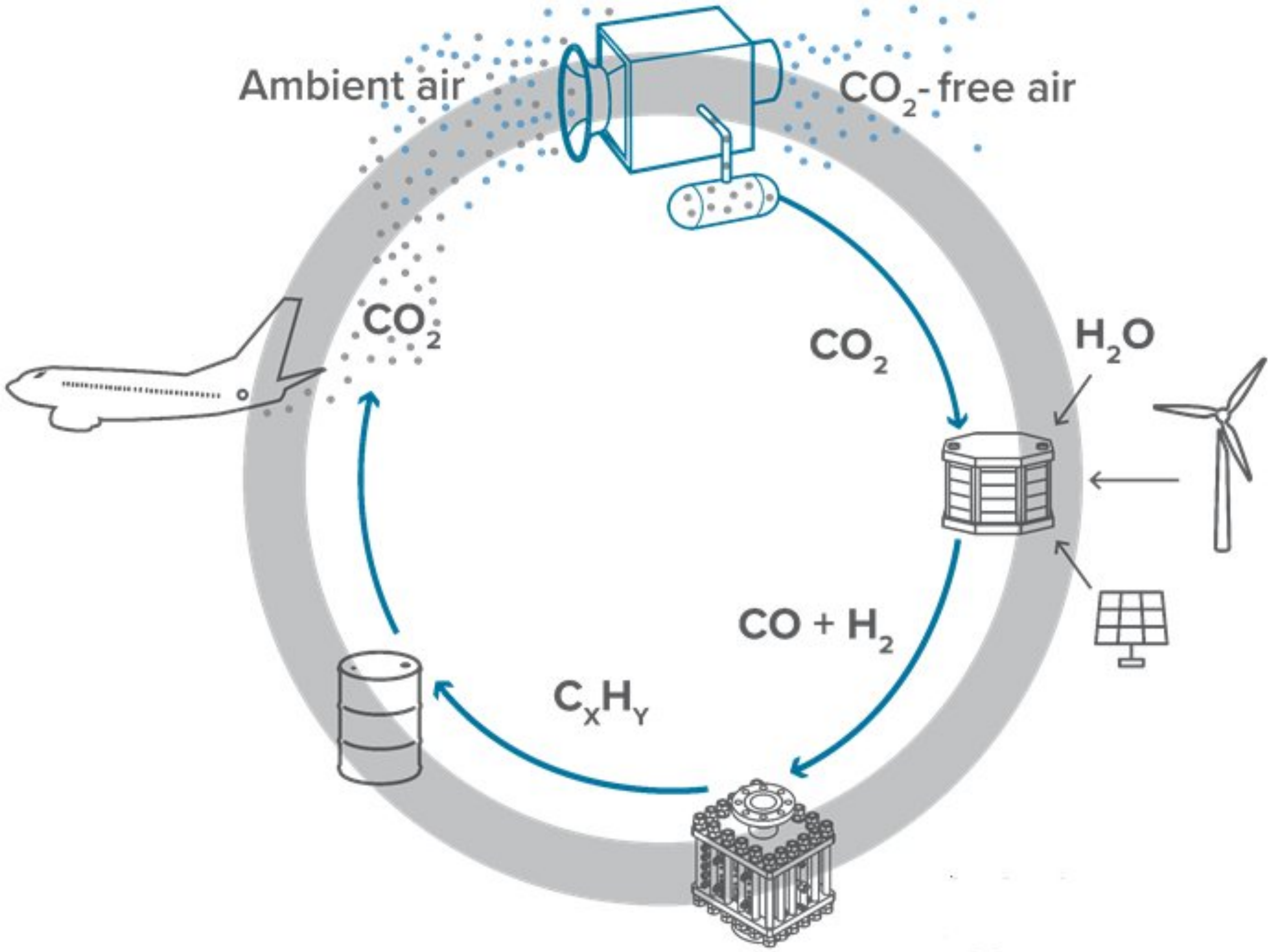
CLIMEWORKS - After 10 Years

- **World's first** company supplying atmospheric CO_2 to customers
- **16 DAC plants across Europe**
- **75** FTEs in Headquarters in **Zurich**, Switzerland with a subsidiary in **Cologne**, Germany
- **Modular** CO_2 capture plants. **Scale-up** via mass production of CO_2 collectors
- **Low-temperature heat** (renewable or waste) as main energy source (4/5th)
- **Minimal carbon footprint:** Current 90% net efficiency, mid-term target 95%
- **Cost:** Current 600CHF/ton, mid-term 100CHF/ton

E-FUELS FROM AIR: CLOSING THE CARBON CYCLE

- CO_2 is captured from atmosphere with **Direct Air Capture** (DAC).
- This allows for **carbon neutral E-fuel** production
- **DAC based E-Fuels** can be used **to scale CDRTs**



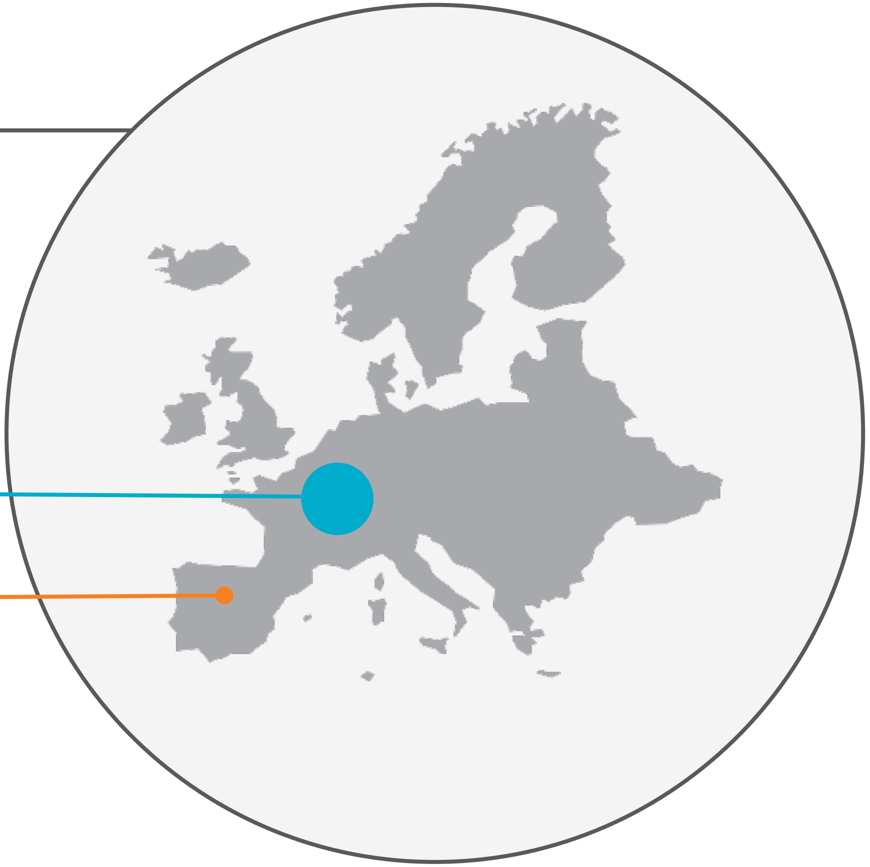
SCALEABILITY AND LAND REQUIREMENT

Surface area needed to meet the 2010 EU transportation energy demand (17,000 pJ/year)

Corn Biofuel
28’000’000 km^2
of arable land
(yield assumption 18 g/ac/y)

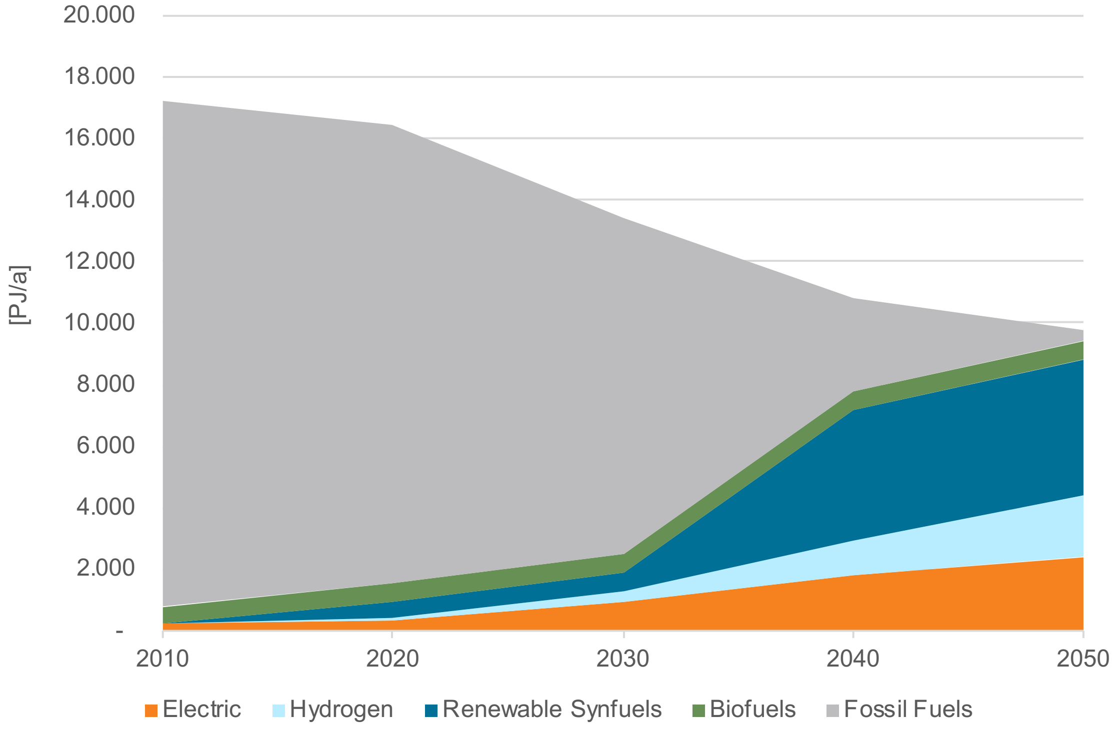
Algae Biofuel
200’000 km^2
of barren land
(yield assumption 2’500 g/ac/y)

Renewable Synfuels
14’200 km^2
of barren land
(assumption: 1’900kWh/m^2,
$\eta_{PV} = 25\%, \eta_{PtX} = 70\%$)



CO_2 WILL BE A SCARCE RESOURCE

EU Transportation sector final energy demand by fuel type
(eDrive scenario)



Source: DENA (2017) The Potential of electricity-based fuels for low emissions transport in the EU

EU CO_2 demand for synfuels vs. fossil fuels