CLIMEWORKS

Capturing $CO_2$ from air

# DACS & CARBFIX2 PILOT PROJECT

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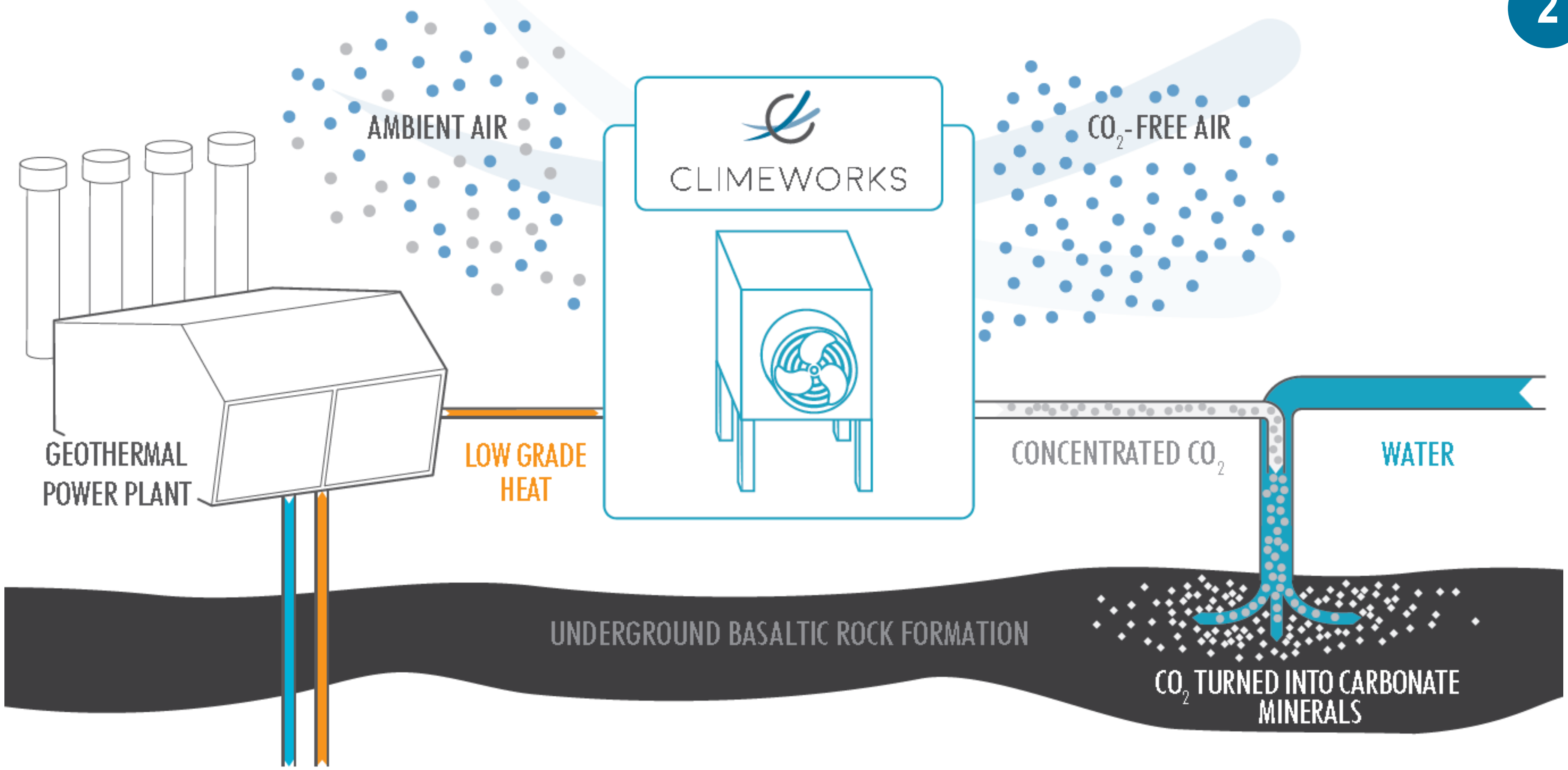
AIR
CLIMEWORKS
Capturing $CO_2$ from air
$CO_2$-FREE AIR
PURE $CO_2$
Also: $H_2O$

# WORLD'S FIRST COMMERCIAL DAC PLANT

- **World's first** company supplying atmospheric $CO_2$ to customers
- **14 plants across Europe (TRL8)**
- **65 FTEs**
- **Energy requirements:** 1/5th electricity, 4/5th low-temperature **heat at ~100C** (waste or renewables)
- **Minimal carbon footprint:** 90% net efficiency (mid term target 95%)
- Expected **cost $100/t** by 2028-30

# $CO_2$-REMOVAL VIA DIRECT AIR CAPTURE

**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.

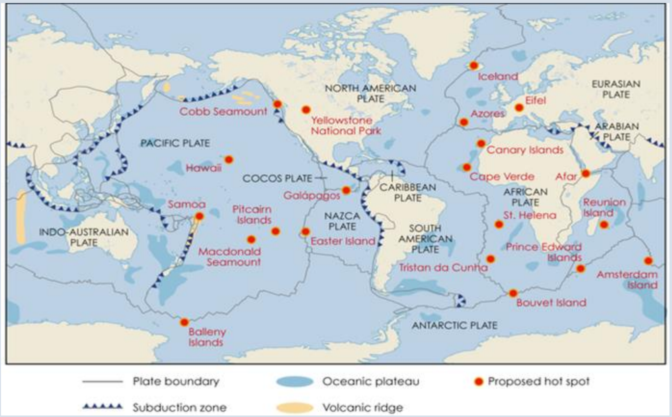
**3** $CO_2$ reacts with underground rock formations and is mineralized. Thereby $CO_2$ is bound permanently and safely, reducing the $CO_2$-content of the atmosphere.

# CARBON REMOVAL IN HELLISHEIDI ICELAND

# GEOLOGICAL $CO_2$ STORAGE POTENTIAL

- Climeworks follows a 2-step strategy for geological $CO_2$ storage:

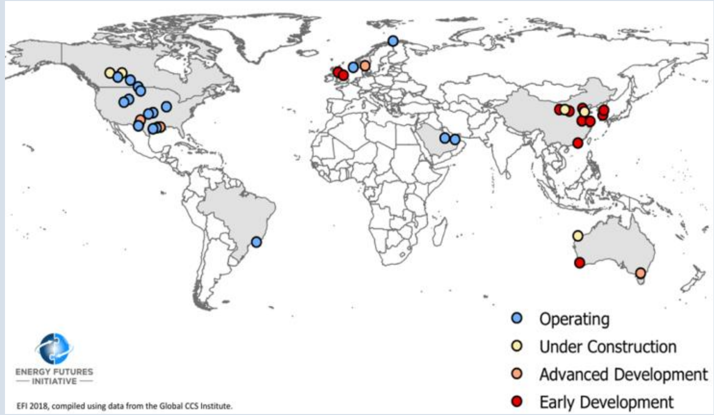
## Step 1: Underground mineralization of $CO_2$




Source: DePaolo, Donald und Manga, Michael. Deep origin of Hotspots - the Mantle Plume Model. s.l. : Science, 2003.

- **Explored global potential** at operational sites **>> 1’200 Gt**

## Step 2: Conventional geological $CO_2$ storage




Source: Energy Futures Initiative

- **Global estimate for conventional geological $CO_2$ storage** (e.g. depleted oil and gas fields, deep saline aquifer) potential currently lies at around **7’000 Gt**

# $CO_2$ 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<br>ALBEDO<br>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<br>ALBEDO<br>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 |

# CDR – Scale up needs to start now to reach pathways

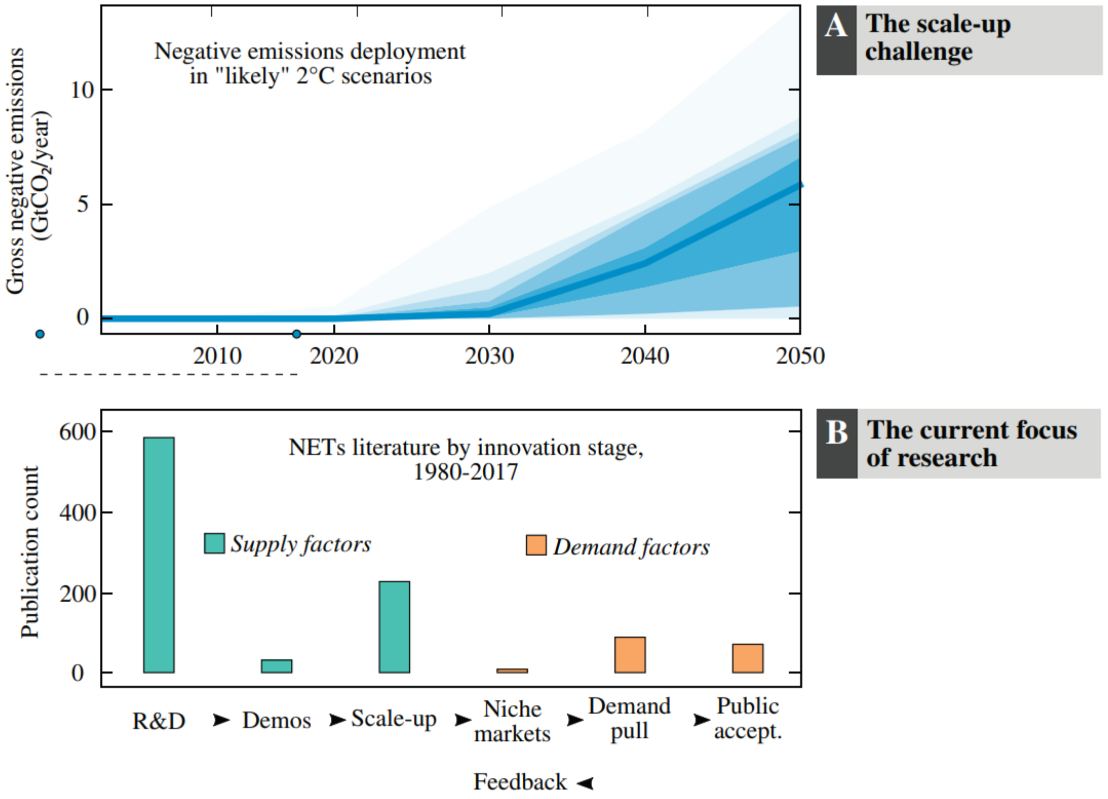
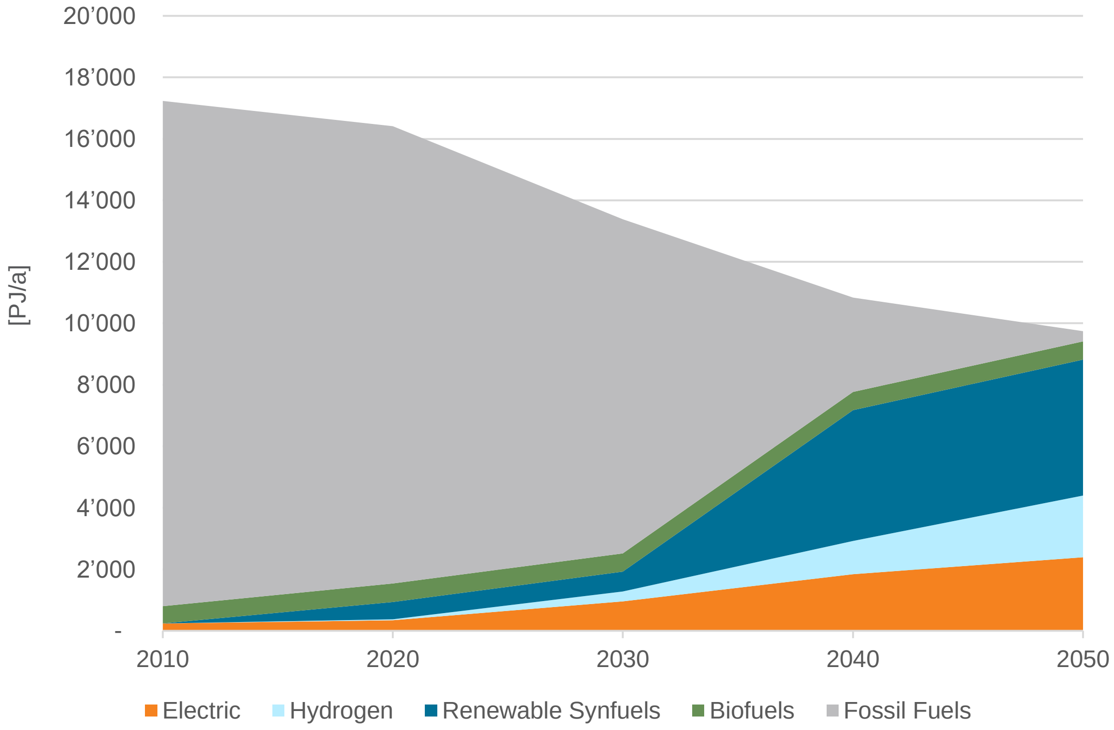



**Figure 6.** The growing need to scale up NETs from IAM results (A. upper) and the R&D-focused literature on NETs (B.lower). We see a dearth of work on the areas that will be crucial to the widespread deployment of NETs, notably in demonstration projects, niche markets, demand pull mechanisms, and public acceptance.

- **Urgency** to Scaling up NETs is largely **unappreciated**
- **Annual NETs growth rate required 2019 until 2050 to meet 6 Gigatonnes ~ 58%**
- **…80% per year, if delayed to 2025 …**
- **100% from 2030,…**

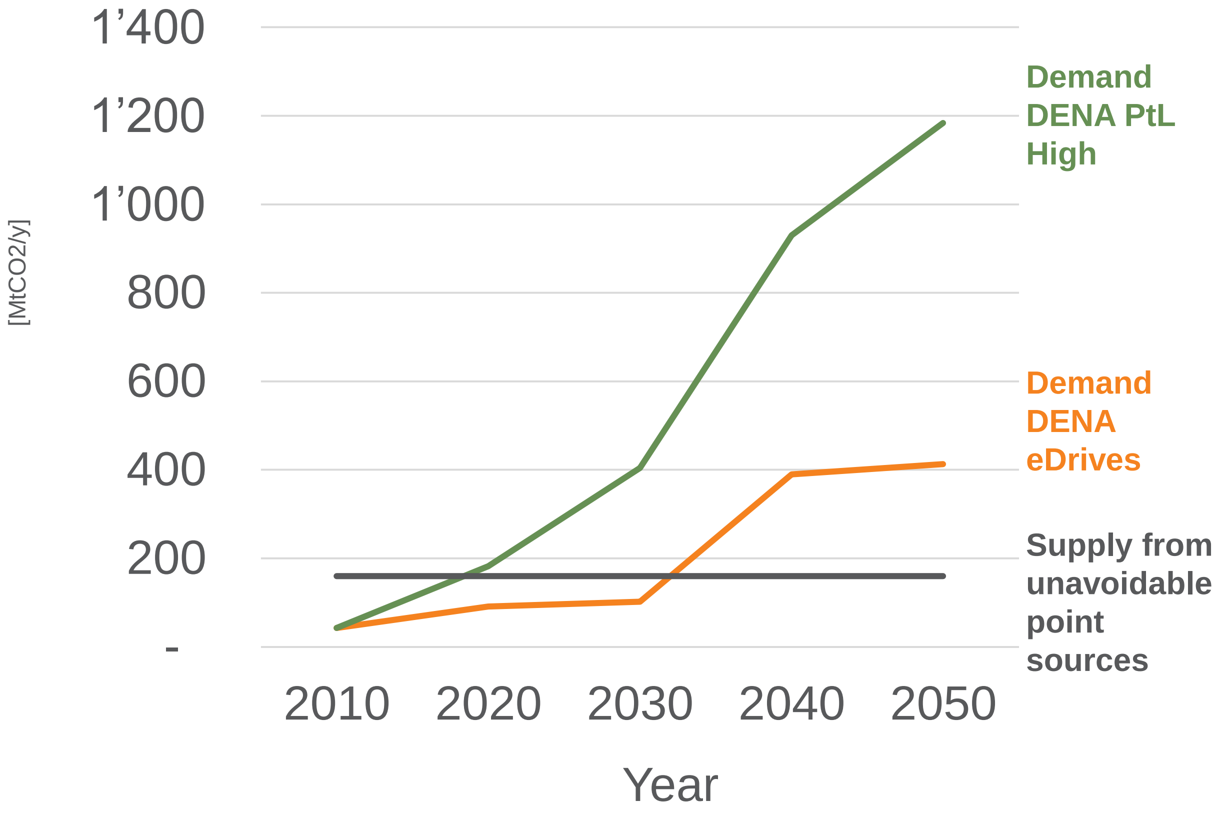
# $CO_2$ WILL BE A SCARCE RESOURCE

**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**



# $CO_2$-NEUTRAL FUELS VIA DIRECT AIR CAPTURE

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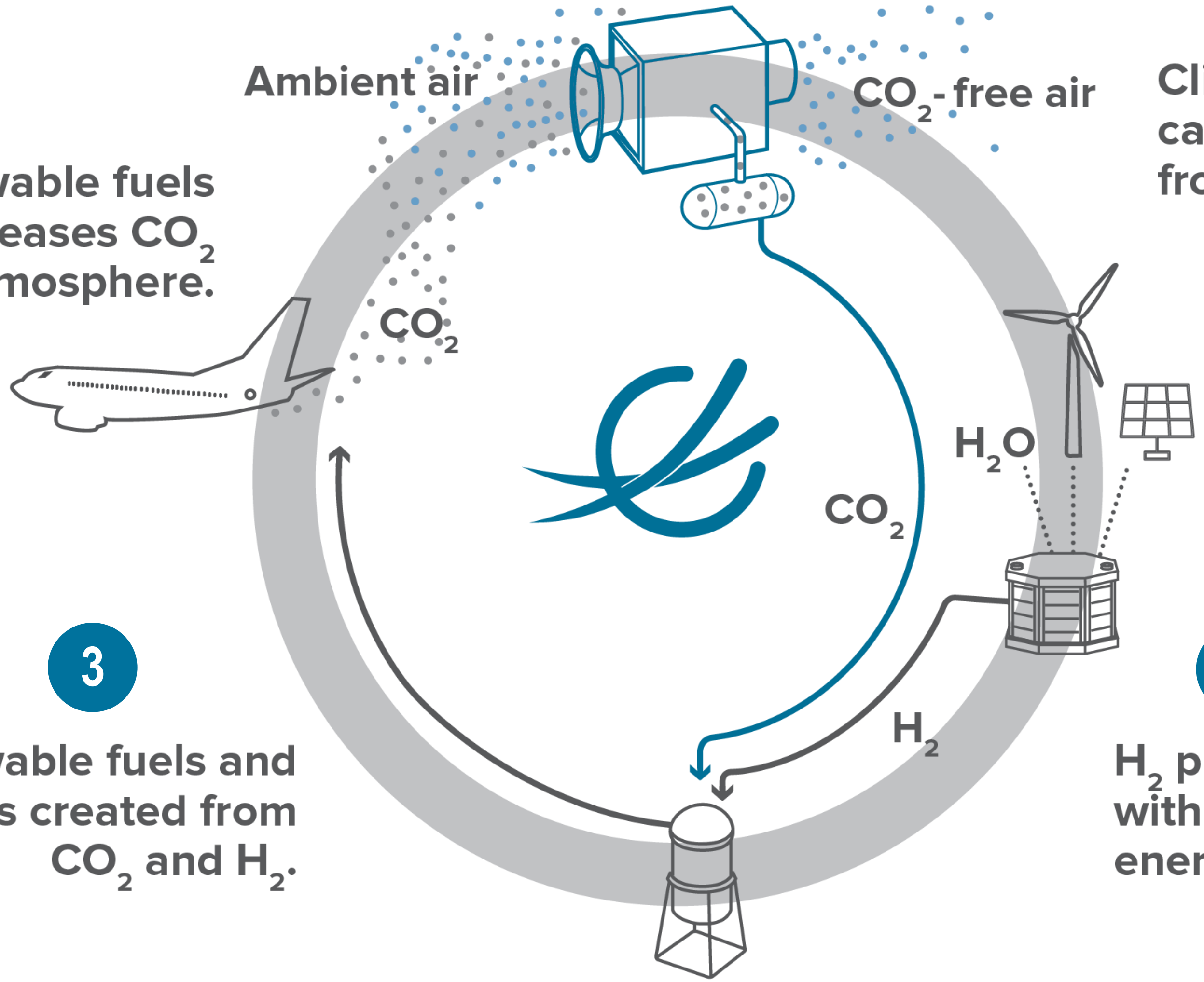
Application of renewable fuels and materials releases $CO_2$ back into the atmosphere.




1

Climeworks Plant captures pure $CO_2$ from air.

2

$H_2$ produced with renewable energy.

3

Renewable fuels and materials created from $CO_2$ and $H_2$.

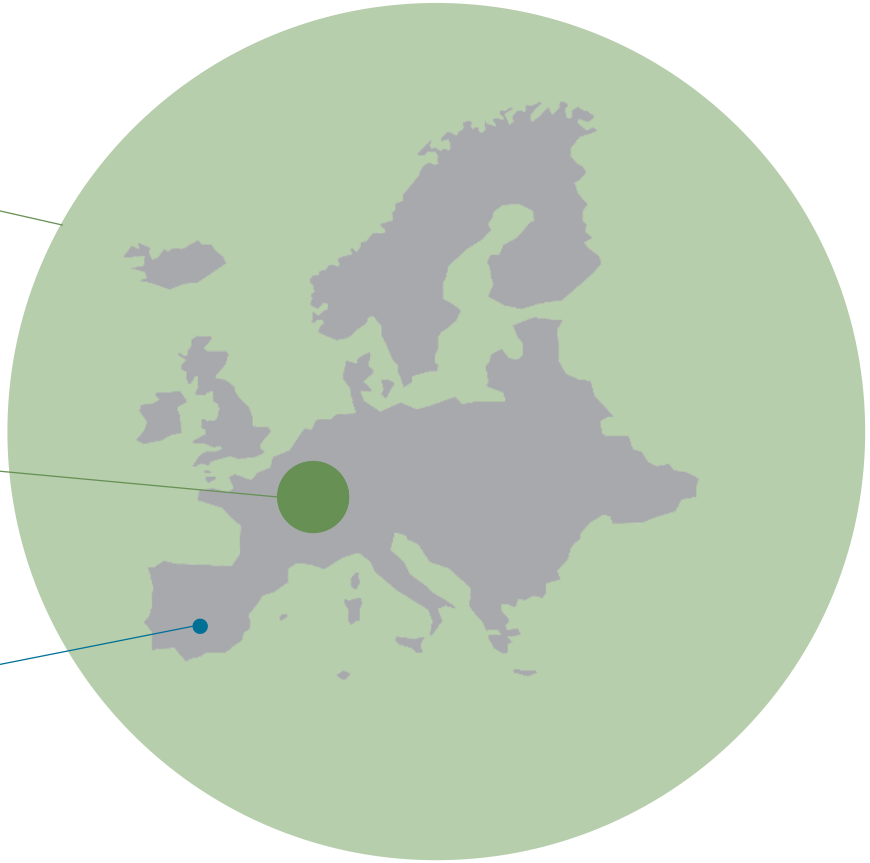
# SCALEABILITY AND LAND REQUIREMENT

**Surface area needed to cover 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
(assumptions: 1’900kWh/$m^2$, $\eta_{PV} = 25\%, \eta_{PtX} = 70\%$)



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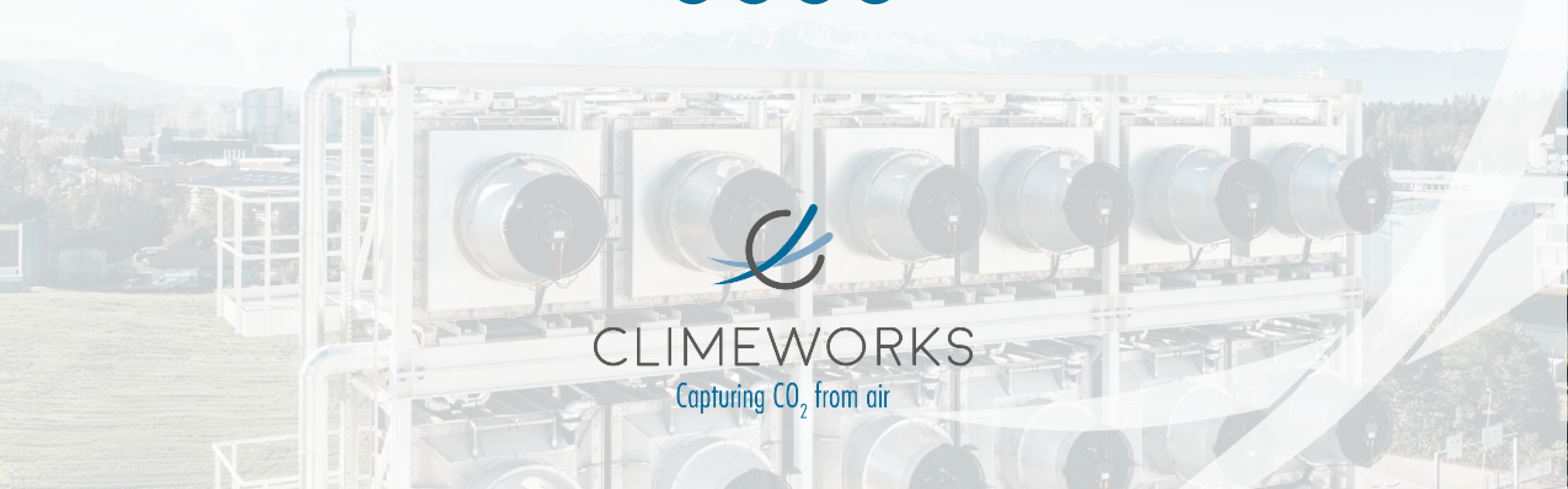

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