Capturing CO$_2$ from Air

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Founder and Director

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Air

Climeworks
CO$_2$ capture plant

Pure CO$_2$

CO$_2$-free air
Climeworks Products

**Demonstrator**
- 2 ton CO$_2$ per year
- Online since 12/2012
- >99% CO$_2$ purity*
- **One unit sold** (delivered Apr 2015)

**CO$_2$ Collector**
- 50 tons CO$_2$ per year
- Full scale module
- Online since 08/2014
- >99.9% CO$_2$ purity*
- **One unit sold** (delivery Q4 2015)

**CO$_2$ Capture Plants**
- 1000+ tons CO$_2$ per year
- Modular, turnkey, standalone
- **Sales contract closed** (CO$_2$ production starts Q1/2016)

* Analysis by Airborne Labs International, Inc., USA
Climeworks plant delivers concentrated CO\textsubscript{2} from atmospheric air

Renewable energy source for Climeworks and subsequent fuel synthesis plant

Fuel synthesis plant converts CO\textsubscript{2} and water to fuels → grid balancing & storage

CO\textsubscript{2}-neutral fuel (gas, diesel, kerosine) is used in existing energy infrastructure

Combustion of CO\textsubscript{2}-neutral fuels does not create net emissions since the CO\textsubscript{2} was captured before → closed carbon cycle

Vision: Closing the Carbon Cycle
Markets

**CO₂ Supply for Renewable Fuel Synthesis**

- Reduce fleet CO₂ emissions through renewable fuels
- Storage of fluctuating renewable energies

**CO₂ Enrichment in Greenhouses**

- Increases crop yield by 20-30% through CO₂ injection in greenhouse
- Market for Climeworks’ first 1’000 t/y plant

**Beverage Carbonation**

- Short-term: Substitute fossil fuel CO₂ generation in 2nd/3rd world countries
- Long-term: application worldwide
Industrial Fuel Synthesis Plants

**Audi PtG Plant in Werlde (DE), 2014**
- 1’000 t renewable methane per year since 2014
- CO$_2$-neutrale mobility for 1’500 Audi A3 g-tron
- CO$_2$-supply through Climeworks from Q4 2015

**Sunfire PtL Plant in Dresden (DE), 2014**
- Fischer-Tropsch-based fuel synthesis from ren. Electricity
- 2015: first barrel «liquid fuel from air»
- Collaboration sunfire, Audi, Climeworks
Climeworks Technology

1. Air is driven through system w/ ventilator and CO₂ is bound chemically to filter material w/o conditioning of air stream; duration: 2-4h
2. System is closed, pressure inside chamber reduced and system heated to 100°C; thereby pure gaseous CO₂ is released; duration: 1-2h
3. System is cooled to ambient temperature, CO₂ capture is re-started; duration: 0.5h

• Developed in collaboration with ETH Zürich and EMPA

• Commercial plants contain parallel modules for continuous CO₂ delivery
• 8 patent families pending
USPs

- Around 90% of total energy demand supplied by low-grade heat (solar/waste heat at ~100 °C)
- Location independent feed gas quality and supply security
  - CO₂ supply is the primary process
- Modular design minimizes the scale-up risk
- Minimal carbon footprint: only 2-3% side emissions (CO₂-eq)
  - (ETH Zurich, University Stuttgart)
Company

Spin-off of ETH Zurich

- Incorporated 2009
- 15 FTEs
- Raised equity: CHF 5.25m
- Grants, awards: CHF 2.5m

Management

**Jan Wurzbacher**, Co-Founder & Co-CEO
Dr. sc. ETH Zürich, Mech. Eng.
ETH Zurich/UNSW Sydney

**Christoph Gebald**, Co-Founder & Co-CEO
Dr. sc. ETH Zürich, Mech. Eng.
ETH Zurich/UC Berkeley

**Dominique Kronenberg**, COO
MSc ETH Mech. Eng.
ETH Zurich

Team

Finalist of Virgin Earth Challenge: $ 25m award by Sir Richard Branson and Al Gore

Partnership with carmaker AUDI in the mobility sector
Latest Developments: Infrastructure

Based in Zürich-Oerlikon since October 2014

- 350m² office rooms
- 500m² assembly/workshop area with option to expand
- Embedded in heavy-industry area (logistic services and metal processing on-site)

Assembly line currently under construction

- Annual output of 90-150 CO₂ Collectors in one-shift operation
Latest Developments: Beta Plant Design

Detail Engineering in Progress

• Mechanical construction completed
• Process design completed
• Component dimensioning and sourcing ongoing
• Control engineering ongoing

Supported by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE
Latest Developments: CO₂ Conditioning

Standard unit modules for CO₂ conditioning are currently being developed with industrial partners

- CO₂ low-pressure buffering
- CO₂ compression
- CO₂ purification and dehumidification
- CO₂ liquefaction
- CO₂ high-pressure storage
- CO₂ liquid storage
Latest Developments: CO₂ Purity

CO₂ product gas analysis by certified laboratory

- Raw gas already fulfills most of food and beverage (F&B) requirements
- CO₂ is suitable for most PtG/PtL processes without purification

<table>
<thead>
<tr>
<th>Component (excerpt of analysis)</th>
<th>Climeworks CO₂</th>
<th>F&amp;B requirements</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>&gt;99.9%</td>
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</tr>
<tr>
<td>Oxygen (incl. Argon)</td>
<td>28 ppm</td>
<td>&lt; 30 ppm</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>not detected</td>
<td>&lt; 2.5 ppm</td>
</tr>
<tr>
<td>Total non-methane hydrocarbons</td>
<td>3.9 ppm</td>
<td>&lt; 20 ppm</td>
</tr>
<tr>
<td>Aromatic hydrocarbons</td>
<td>61 ppb *</td>
<td>&lt; 20 ppb</td>
</tr>
<tr>
<td>Total sulfur content</td>
<td>0.012 ppm</td>
<td>&lt; 0.1 ppm</td>
</tr>
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* To be removed with advanced activated carbon filter
## CO₂ Capture Plant

### Climeworks CO₂ Capture Plant

- Modular design
- Turnkey solution
- Standalone operation (fully automated)

### Specifications

<table>
<thead>
<tr>
<th>Heat requirement:</th>
<th>1500 – 2000 kWh / t CO₂</th>
<th>~ 105 °C in / 95 °C return</th>
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<tbody>
<tr>
<td>Electricity requirement:</td>
<td>200 – 300 kWh / t CO₂</td>
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<tr>
<td>Area requirement:</td>
<td>330 t CO₂ per year per 40 ft container</td>
<td>Stacking of up to 5 containers</td>
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