Scaling-up CO₂ Utilization:

Etosha Cave, Co-Founder | Cave@Opus-12.com
Prepared for Stanford Carbon Management Workshop
Transforming global CO$_2$ Emissions...

...into a multi-billion dollar opportunity

Prepared for Stanford Carbon Management Workshop
A platform technology that recycles CO$_2$ back into chemicals and fuels

**Inputs:** CO$_2$, Water, Electricity

**Electrochemical Reduction of CO$_2$**

**Outputs:** Products that drop into existing supply chains

- **1**
  - Inputs: CO$_2$, Water, Electricity

- **2**
  - Electrochemical Reduction of CO$_2$

- **3**
  - Outputs: Products that drop into existing supply chains
    - Fuels & Chemicals
    - O$_2$
We transform CO$_2$ into critical chemical products.
Industrial Photosynthesis
37,000 trees in a suitcase
Founded at Stanford and Lawrence Berkeley National Lab in 2016

Founding team

Dr. Kendra Kuhl  
CTO  
PhD in Chemistry, Stanford, Post doc, SLAC  
Research: Transition metal catalyzed CO₂ electroreduction, reactor design

Nicholas Flanders  
CEO  
MS E-I PER, Stanford  
Work Experience: COO/CFO Levo, McKinsey CleanTech practice

Dr. Etosha Cave  
COO  
PhD in Mechanical Eng, Stanford  
Research: Modified gold catalysts for CO₂ electroreduction, reactor design

“25 People Shaping the Next 50 Years”
Overall Reaction:

\[ \text{CO}_2 + \text{H}_2\text{O} + \text{Energy} \rightarrow \text{C}_x\text{H}_y\text{O}_z + \text{O}_2 \]

Split into electrochemical half reactions:

**Water Oxidation (Anode)**

\[
2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4(\text{H}^+ + \text{e}^-)
\]

**CO\textsubscript{2} Reduction (Cathode)**

\[
\text{CO}_2 + m(\text{H}^+ + \text{e}^-) \rightarrow \text{C}_x\text{H}_y\text{O}_z + n\text{H}_2\text{O}
\]

**Determines minimum energy required for ECO2R to various products**

Burning hydrocarbons releases energy and carbon dioxide

To convert carbon dioxide into chemicals and fuels, must add energy back into the system

**Fuels & Chemicals**
The project began as we explored the fundamentals of CO$_2$ conversion electrochemistry.
ECO2R can turn CO$_2$ into higher-value molecules in a single, low-temperature catalytic reaction.

The transformation occurs as charges are transferred at the catalyst surface.

Illustration: CO$_2$ to methane (CH$_4$)

$$\text{CO}_2 + 8\text{H}^+ \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$$

Steps (one charge transfer ($\text{H}^+/\text{e}^-$) per step):

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8

**CO$_2$ (from flue gas)**

**Current (from power source)**

**H$^+$ protons (from H$_2$O oxidation at the anode)**

**Catalyst surface**

[Diagram showing steps of the reaction]

[CO$_2$] → CO + [H$_2$O] → O + [CH$_4$] → [H$_2$O]

Andrew A. Peterson, Frank Abild-Pedersen, Felix Studt, Jan Rossmeisl and Jens K. Nørskov

 Known Scale-up Pathway
Integration into existing electrolyzer designs

We partner with electrolyzer producers to build CO₂ conversion systems

Prepared for Stanford Carbon Management Workshop
Future of Carbon Tech

It's not every day that Bill Gates visits our lab. Fortunately for us, it's captured in his newly released documentary Inside Bill's Brain on Netflix (see part 3 on #climate)! In his words: "You might be one of the first applications that fits that niche." #carbontech #climatesolutions #CO2