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Electrochemical carbon dioxide reduction as an alternative source of fuels and chemicals

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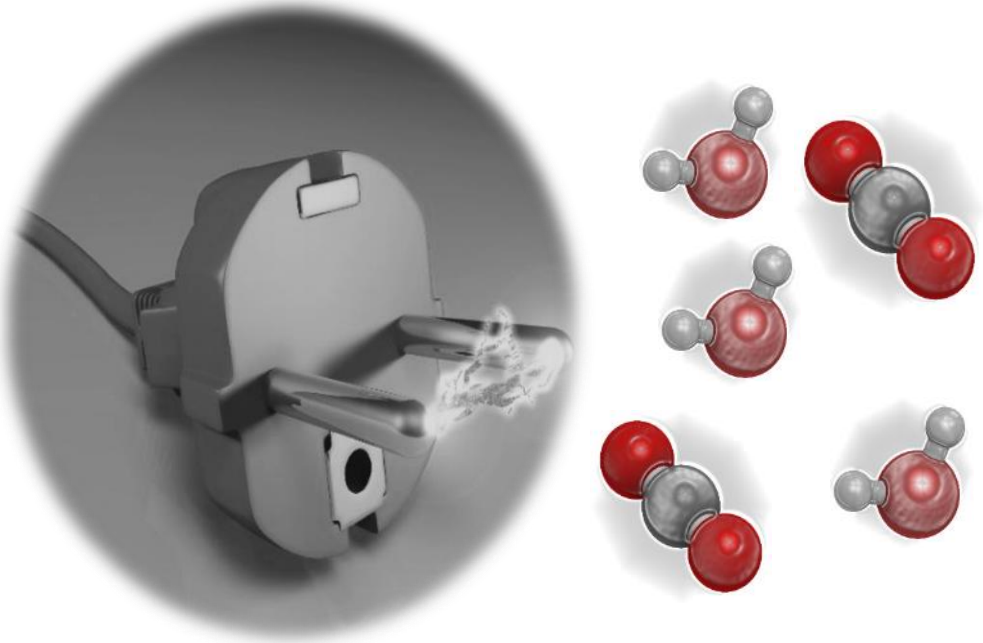
Recommended Citation

[1] K.P. Kuhl, E.R. Cave, D.N. Abram, T.F. Jaramillo, New insights into the electrochemical reduction of carbon dioxide on metallic copper surfaces, Energy Env. Sci., 5 (2012) 7050-7059. [2] K.P. Kuhl, T. Hatsukade, E.R. Cave, D.N. Abram, J. Kibsgaard, T.F. Jaramillo, Electrocatalytic Conversion of Carbon Dioxide to Methane and Methanol on Transition Metal Surfaces, Journal of the American Chemical Society, 136 (2014) 14107-14113. [3] F.S. Roberts, K.P. Kuhl, A. Nilsson, High Selectivity for Ethylene from Carbon Dioxide Reduction over Copper Nanocube Electrocatalysts, Angewandte Chemie International Edition, 54 (2015) 5179-5182.

Electrochemical carbon dioxide reduction as an alternative source of fuels and chemicals



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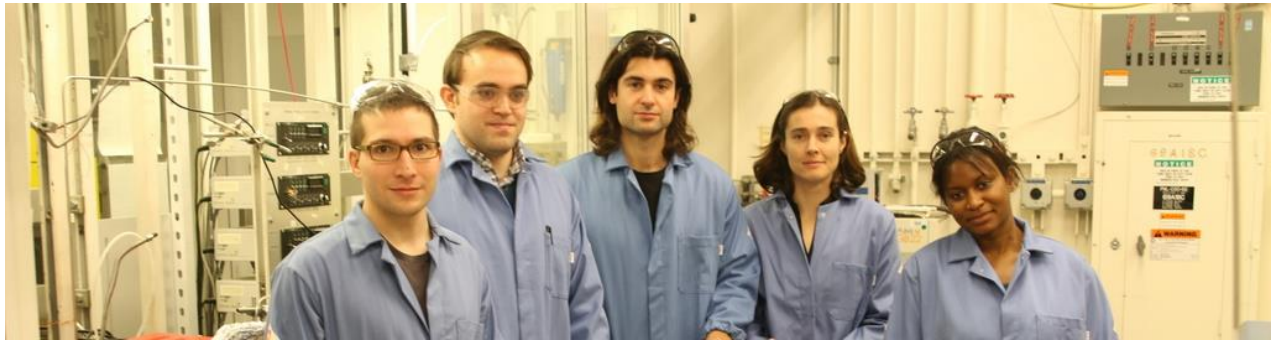
Team: uniquely positioned to bring this product to market

Team: 20 years of ECO2R research, previous startups



Nicholas Flanders, CEO
MBA/MS E-IPER, Stanford
Work Experience: COO/CFO Levo ($20M+), McKinsey CleanTech practice

Dr. Kendra Kuhl, CTO
PhD in Chemistry, Stanford, Post doc, SLAC
Research: Transition metal catalyzed CO_2 electroreduction.

Dr. Etosha Cave, CSO
PhD in Mechanical Eng, Stanford
Research: Nanostructured gold catalysts for CO_2 electroreduction.

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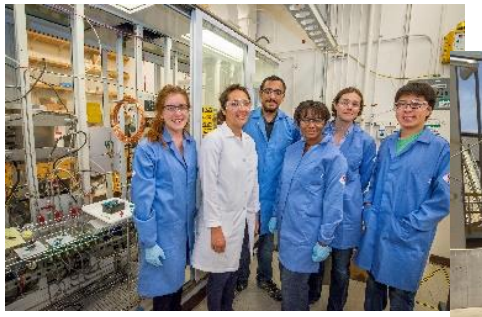
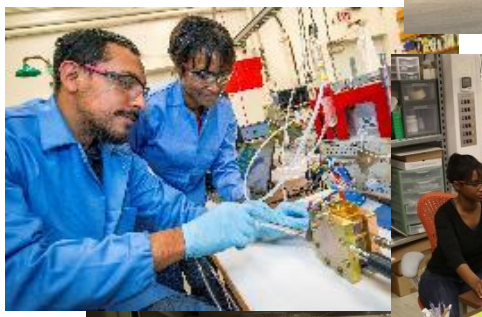
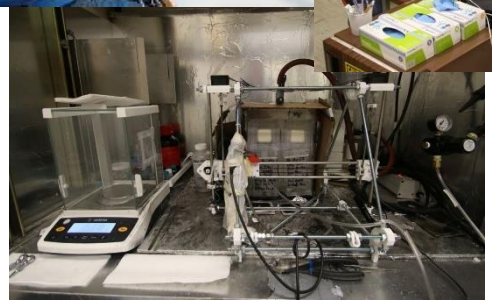
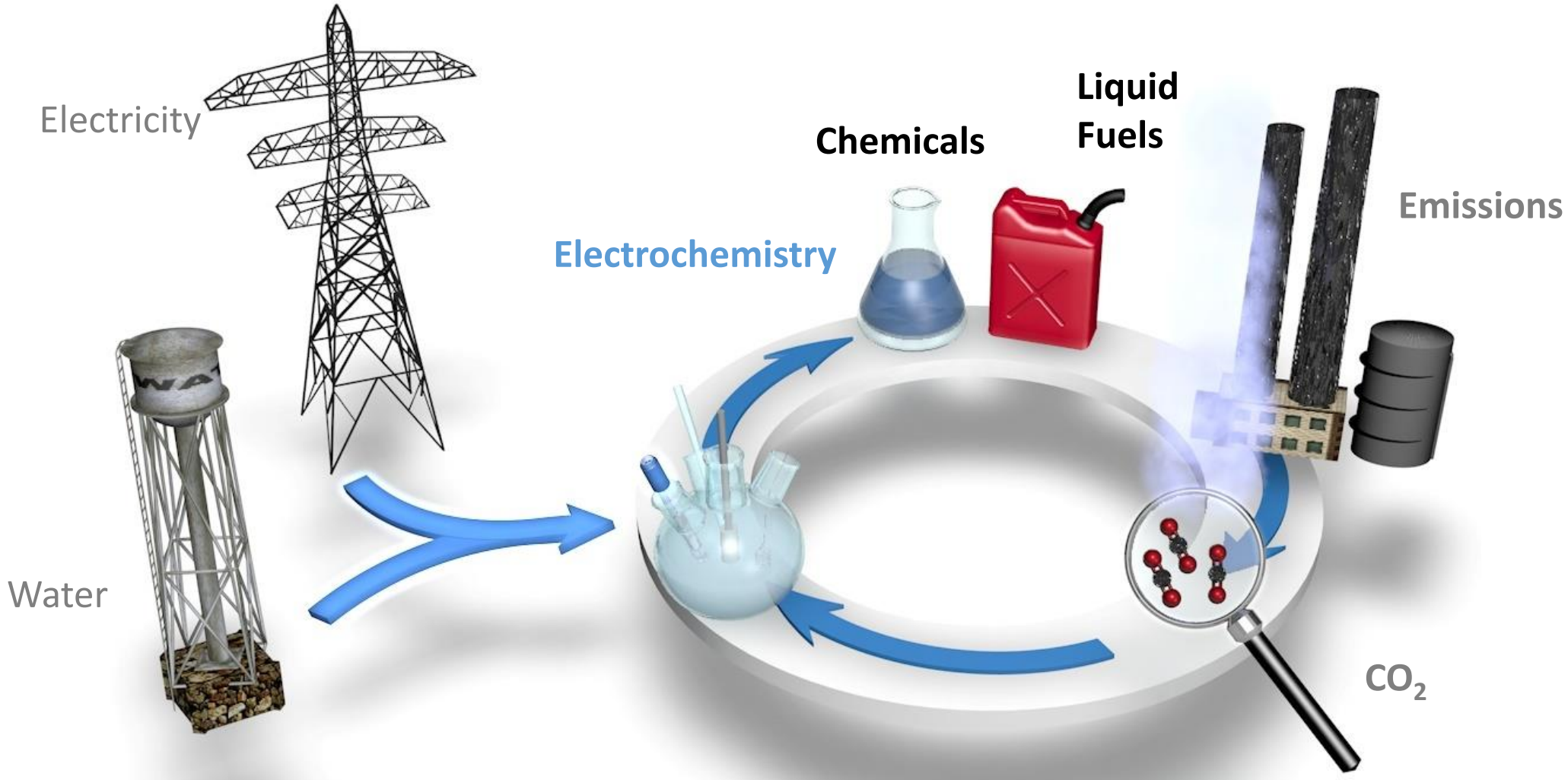






Recycle CO_2 into cost-competitive fuels and chemicals



Conservation of Energy

Burning hydrocarbons releases energy and carbon dioxide

Carbon-based compounds are good fuels because they are high in energy

Inefficiencies reduce the amount of energy harvested from the theoretical value & increase the amount of energy that must be added back in

CO_2

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

ECO2R can also be thought of as "reverse combustion"

Overall Reaction:

$$CO_2 + H_2O + \text{Energy} \rightarrow C_xH_yO_z + O_2$$

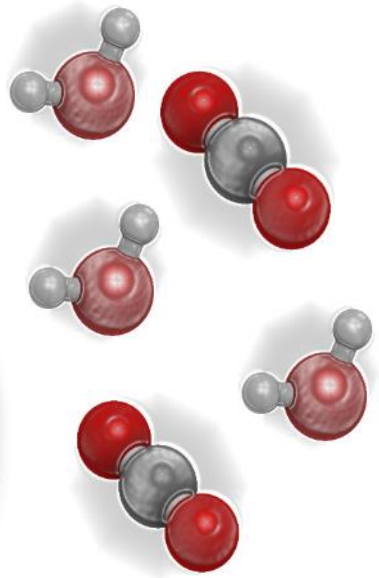
Split into electrochemical half reactions:

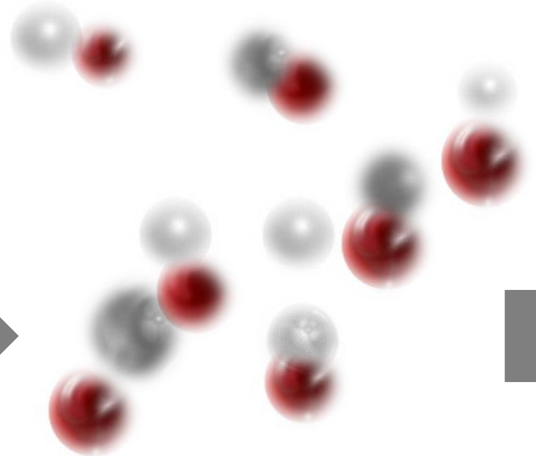
Water Oxidation (Anode)	**E°**
$2H_2O \rightarrow O_2 + 4(H^+ + e^-)$	1.23 V
CO_2 Reduction (Cathode)	
$CO_2 + m(H^+ + e^-) \rightarrow C_xH_yO_z + nH_2O$	~0 V

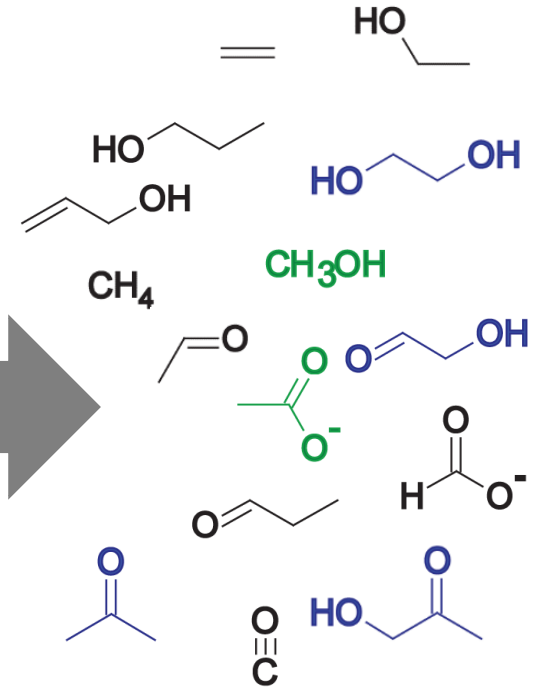
Determines minimum energy required for ECO2R to various products

↑
Fuels & Chemicals

Electrocatalytic process



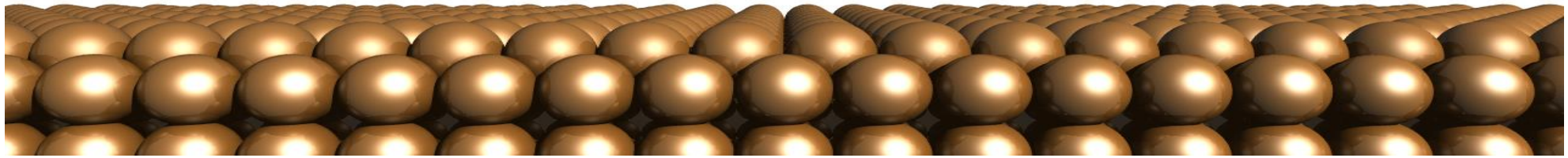




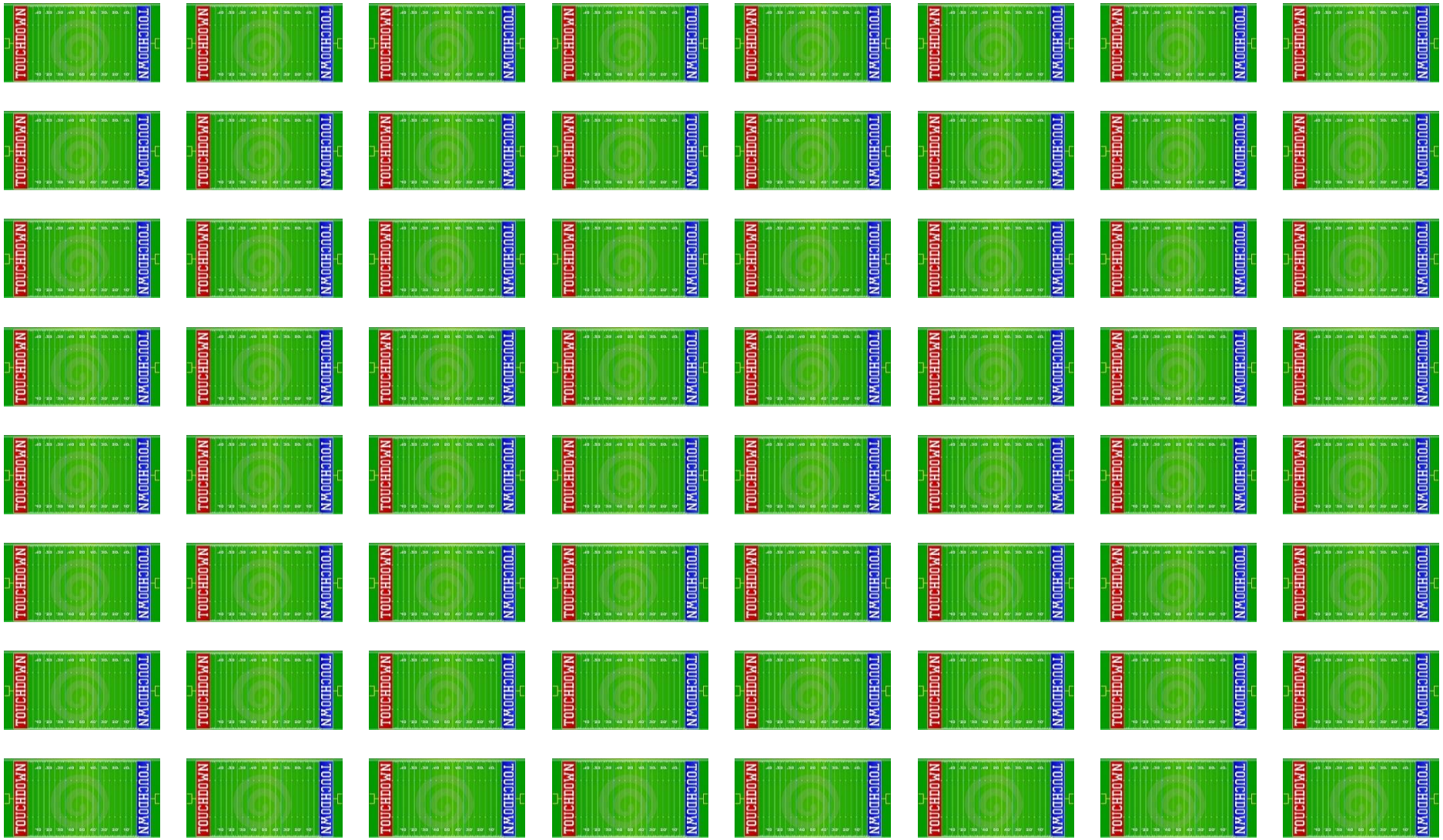
carbon dioxide + water

16 compounds

Kuhl, Cave, Jaramillo, et al. ***Energy Environ. Sci.***, 2012, **5**, 7050-7059



Our CO_2 conversion performance: like 64 football fields of dense forest…



…37,000 trees… **in a suitcase-sized reactor**

Our efforts are focused on improving four key technical performance metrics that impact overall system economics

The metrics that matter for cost-effective ECO2R:

1. **Product selectivity**

   The percent of the electrical current through the system that goes to producing the desired product.

2. **Voltage efficiency**

   The thermodynamic minimum voltage divided by the actual voltage.

3. **Current density**

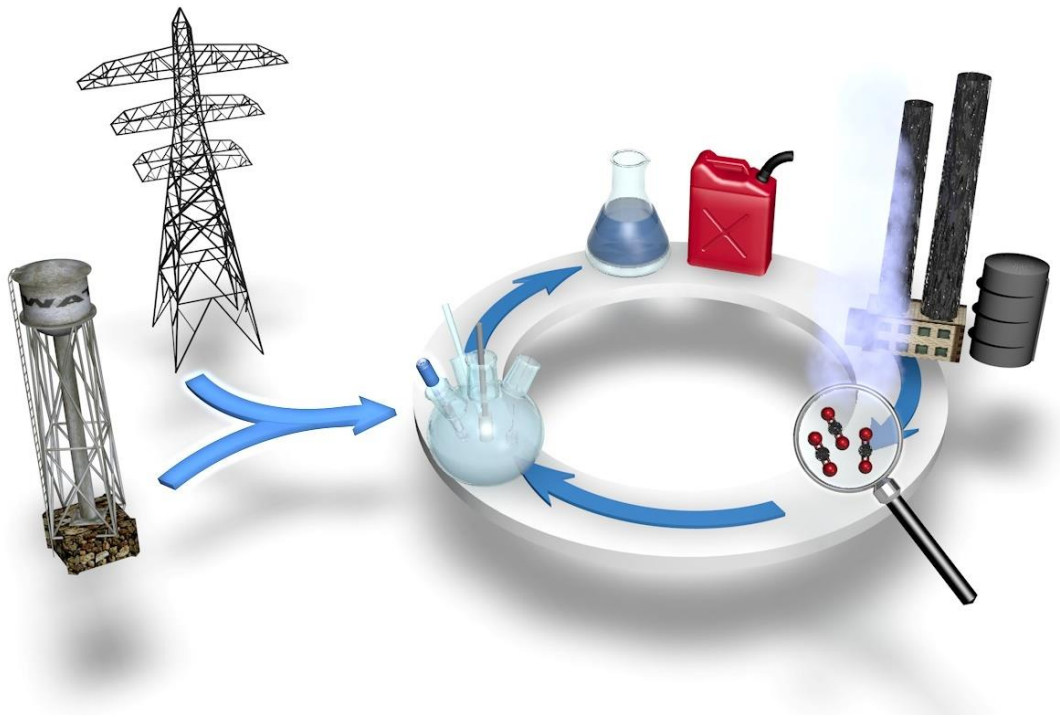
   The amount of current (proportional to the amount of product made) per electrode area

4. **Lifetime**

   How long the electrochemical reactor runs without a loss in energy efficiency or current density.

Electrochemical CO_2 Conversion

- A promising approach to recycle emissions
- Alternative source of carbon-based compounds
- Cost competitive in many situations



Thank you for your attention

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