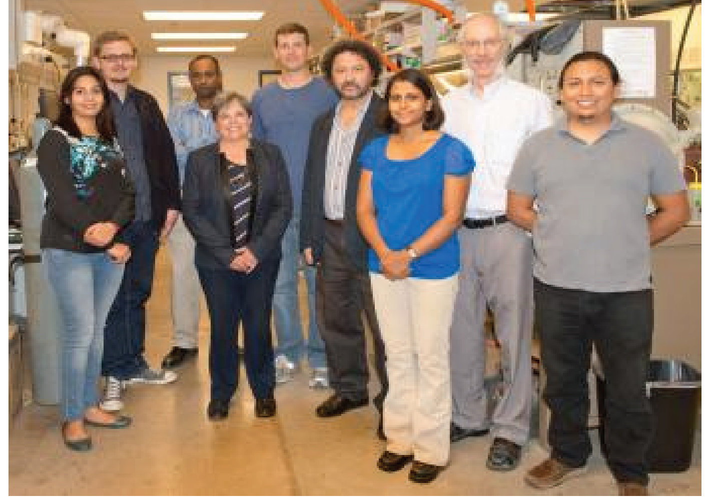
# The Center for Negative Carbon Emissions

Ira A. Fulton Schools of Engineering and Julie Ann Wrigley Global Institute of Sustainability at Arizona State University

In addressing excess atmospheric carbon dioxide to limit the most severe effects of climate change, it is no longer sufficient to solely focus on slowing down carbon dioxide emissions with improved energy efficiency and added renewable energy sources. While such decarbonization efforts should be accelerated, it is now urgent that we recapture carbon dioxide from the atmosphere and make the world's infrastructure not only carbon neutral, but also capable of reducing the total carbon circulating within the atmosphere, ocean, and biosphere systems. The Center for Negative Carbon Emissions (CNCE) is advancing carbon management technologies that can capture carbon dioxide directly from ambient air in an outdoor operating environment. Our aim is to demonstrate systems that over time increase in scope, complexity, reliability and efficiency while lowering the cost of carbon dioxide capture from air. We also consider the economic, political, social and environmental ramifications that will arise with the availability of an affordable air capture technology. It is our long-term goal to make the CNCE the intellectual leader in this new field of sustainable energy infrastructure design critical to achieving a carbon negative energy economy.

Dr. Klaus Lackner is the director of Center for Negative Carbon Emissions and professor at the School of Sustainable Engineering and the Built Environment of the Ira A. Fulton Schools of Engineering, Arizona State University.



*Three of the four co-PIs from the Electrochemical Capture project included above; Ellen Stechel, Vladimiro Mujica, and Dan Buttry.*

# Electrochemical Capture

School of Molecular Sciences and School for Engineering of Matter, Transport and Energy at Arizona State University

Changing the way the nation generates and consumes energy is at the heart of a multimillion dollar grant awarded to Arizona State University from the Department of Energy.

Under the award, the university will develop an efficient and cost-effective carbon capture technology using an innovative electrochemical technique to separate carbon dioxide from other emissions originating from power plants.

In what could be an economically enabling breakthrough in the drive to reduce carbon emissions, ASU researchers will explore the real possibility of reducing energy and cost requirements by more than half of commercially available approaches.

Led by Dan Buttry, professor and director of ASU's new School of Molecular Sciences in the College of Liberal Arts and Sciences, the grant is part of a special Department of Energy program designed to pursue high-risk, high-reward advances in alternative energy research.

***-ASU News: ASU grant aims to transform global energy landscape, 2014***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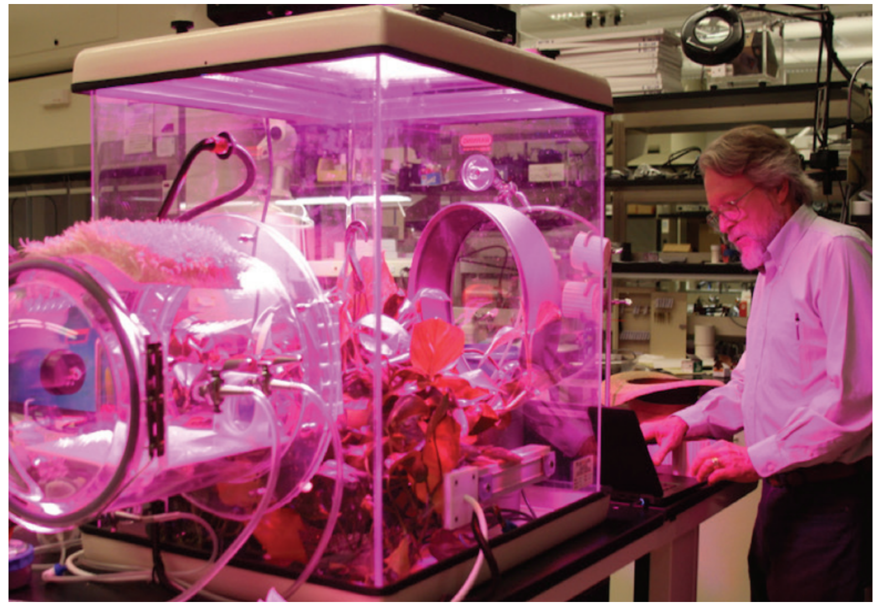
# Carbon Capture

# Center for Negative Carbon Emissions

### Why do we need negative carbon emissions?

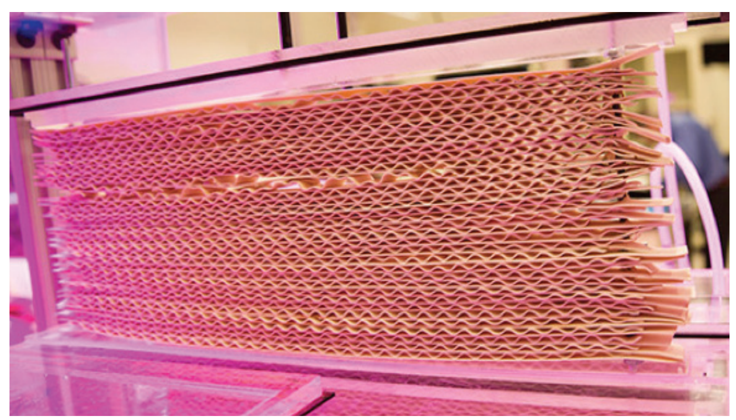
$CO_2$ is the largest and most persistent heat-trapping gas and excess man made $CO_2$ emissions can cause potentially catastrophic and irreversible damage to our earth systems. While natural forces will remove some of the $CO_2$ that is emitted to the atmosphere, a large fraction of today's emissions will linger for thousands of years. Therefore, avoiding the most severe effects of climate change requires not only the reduction of the rate of emissions through rapid decarbonization (ie. added renewable energy, end-to-end energy efficiencies, sustainable fuels, and point source carbon capture and storage), but the stabilization of all emissions below a dangerous threshold. The existence of negative carbon emissions permits stabilization through a carbon neutral balance for sources unable or unwilling to decarbonize and allow for a method to draw down $CO_2$ concentrations.



*In the laboratory, lead engineer and CNCE executive director Allen Wright monitors the carbon dioxide and atmospheric conditions to optimize plant growth and test the moisture swing sorption technology. Photo: Michelle Saldana, Biodesign Institute*

### How to Capture Carbon from the Air

There are several different methods to capture carbon dioxide that involve pressure, temperature, or humidity. We are developing and improving a material that operates on a humidity swing to capture and release carbon dioxide. It consists of a sorbent (anionic exchange resin), made of quaternary ammonium ion embedded in polystyrene, that absorbs (adsorbs) carbon dioxide when it is dry and releases it when wet, as a $CO_2$ – enriched stream of air of up to 5% or 50,000 parts per million.



*Sorbent developed at ASU's Center for Negative Carbon Emissions, designed to absorb and then release $CO_2$*

### What can be done with the Carbon dioxide once it is captured?

The humidity swing produces an enriched stream of $CO_2$. This can be concentrated further or can be used as is, based on the type of application. Ultimately, there are two ways of dealing with the $CO_2$ captured: recycling and disposal.

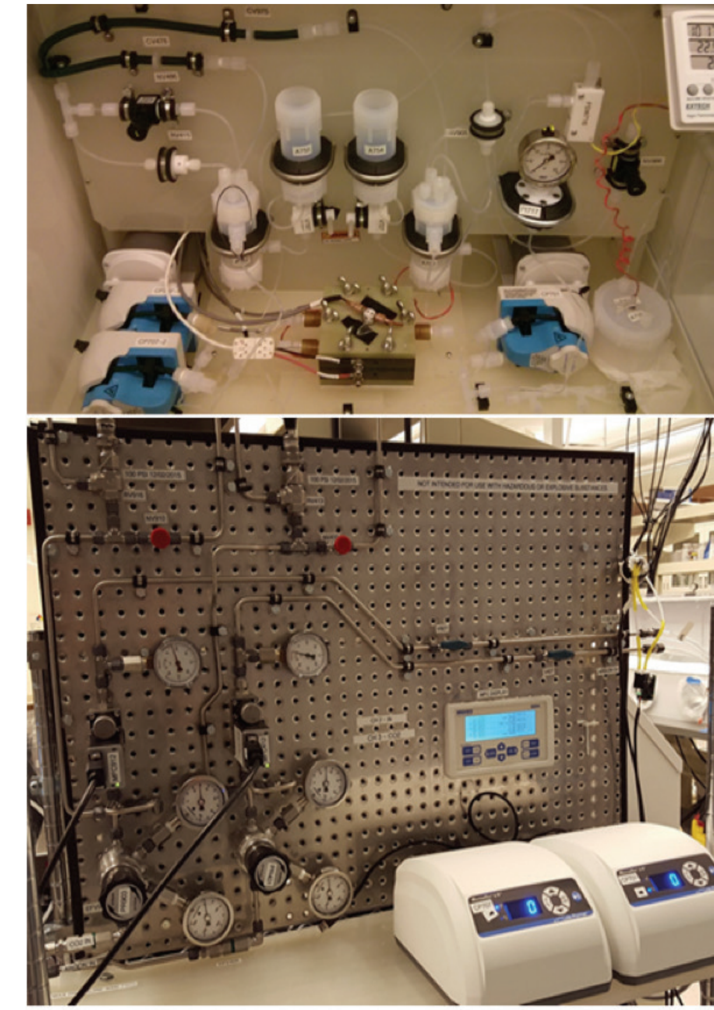
$CO_2$ Recycling uses the $CO_2$ that is removed from air, as a feed stock for a variety of processes that might require 1-99% concentration. At lower concentrations, $CO_2$ can be used to invigorate biomass growth for agriculture in greenhouses or bio-fuels. It also can be used to make materials like plastics. At higher concentrations it can be used to carbonate beverages, and enable enhanced oil recovery and synthesize renewable liquid hydrocarbons like methanol.

$CO_2$ Disposal assures the safe and permanent storage of $CO_2$ from air. Sequestration by mineralizing rocks and, ocean liming are some of the disposal methods of $CO_2$. Mineral sequestration involves converting $CO_2$ into carbonates using rocks like Olivine and Serpentine. Ocean Liming involves adding lime to salt water which reacts with $CO_2$ to form Calcium Carbonate.

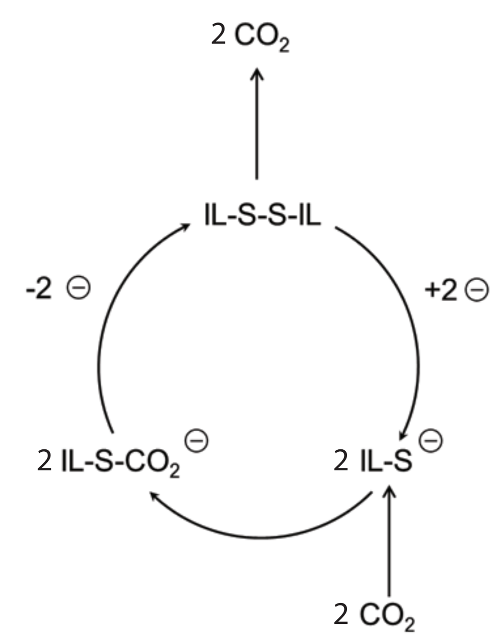
# Electrochemical Capture

Our team has developed a new electrochemical method for purification of carbon dioxide from mixed gas streams, such as flue gas. The method uses ionic liquids as the capture medium. This takes advantage of their extremely low volatility, enabling a method that does not require frequent renewal of the capture medium. The chemical capture step is based on strong interaction of sulfur-containing reagents with carbon dioxide. These reagents are less sensitive to oxygen than the amines used in the well-known monoethanolamine (MEA) process. The team has shown that the process has the potential for separating carbon dioxide from waste gas streams with energy costs less than half that of the MEA process. The team has implemented this electrochemical separation process in both membrane and flow cell formats, each offering a unique set of application characteristics.

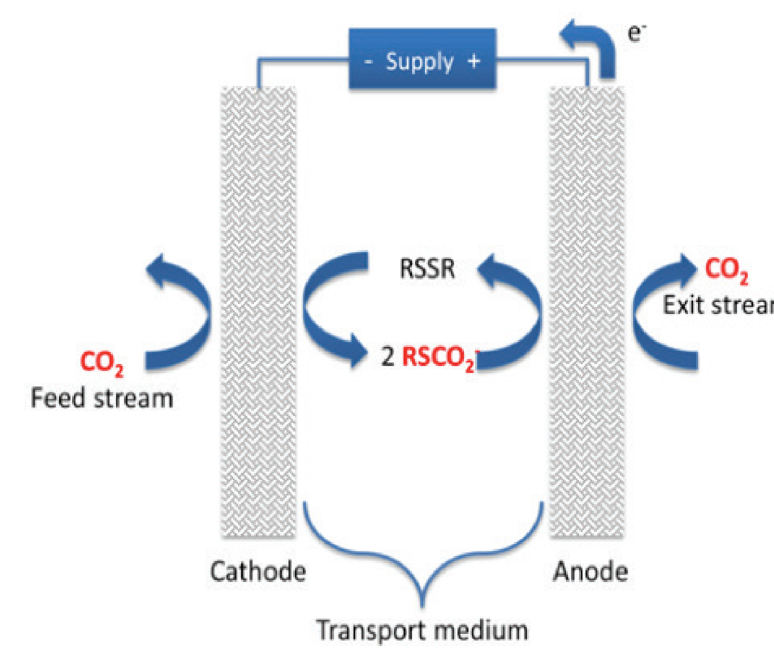
The team is comprised of three organizations and eight co-principle investigators from Arizona State University, University of Colorado and Proton OnSite. Each organization and investigator brings unique expertise to the effort, ranging from chemistry and electrochemistry to membrane synthesis and fabrication to cell design and fabrication, respectively. Our recent work includes development of new membrane formulation strategies and more stable electrolyte materials, as well as design and fabrication of a new flow cell design that enables faster capture rates.



*Upper: Flow cell system for $CO_2$ separation using ionic liquids.*
*Lower: Gas handling and controller functions for flow cell system.*




*Schematic of membrane-based separation of $CO_2$ using electrochemical generation of a thiocarbonate.*




*Reaction diagram for $CO_2$ separation using chemistry based on sulfur reagents.*