Arizona State University

Center for Negative Carbon Emissions

ASU Knowledge Enterprise
Arizona State University

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The Design School and School of Sustainability
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CNCE Mission

CNCE is working to advance carbon management technologies that can capture CO_2 directly from ambient air

CNCE considers the economic, political, social, and environmental ramifications that will arise with the availability of an affordable air capture technology. The center's long-term goal is to become the intellectual leader in this new field of sustainable energy infrastructure design, which is critical to achieving a carbon negative energy economy

CNCE - Capacities

CNCE is proud to host an interdisciplinary selection of research interests including:

- direct air capture of CO_2
- sorbent development
- CO_2 utilization
- systems design and analysis
- CO_2 storage
- business and finance
- educational outreach
- public policy

CNCE – Strengths

- **Outreach:** corporate & community engagement, DAC curriculum, IP research
- **DAC Characterization:** lab to bench to pilot, wind tunnel and thermal testing & analyses
- **Synthesis & Fabrication:** polymer-based sorbent synthesis, processing & scale up
- **Modeling:** process, economic, environmental, CFD, kinetic and transport modeling
- **DAC Integration:** sustainable materials, electrochemical, thermochemical, biological fuels, and energy storage

CNCE Partnerships

Universities

NAU

TEXAS
The University of Texas at Austin

BOSTON UNIVERSITY

COLUMBIA UNIVERSITY

COLORADO SCHOOL OF MINES

ARIZONA

Georgia Tech

Industry Partners

Meta

CARBON COLLECT

Governmental Partnerships – DOE Funded Projects

AUDACity: Utilizing sorbent to capture atmospheric CO_2 and delivering it to cyanobacterial pool to enhance growth

Mission DAC: Synthesizing novel chemistries and testing various form factors of sorbent materials for moisture swing carbon capture

SAPDAC: Developing a commercial-scale tree-farm while considering various geographic locations for energy optimization, techno-economic analysis, and life cycle analysis

Mechanical Tree (Carbon Collect Funding)

The MechanicalTree™ is a groundbreaking carbon dioxide direct air capture technology and a pioneering advancement to address climate change. This is the first MechanicalTree™ in the world and was installed by Carbon Collect at ASU to continue their sponsored research with the CNCE. Natural air flow driven by wind brings air in contact with a specialized material that removes the CO_2 without any need for fans or blowers. This passive capture makes the MechanicalTree™ unique by minimizing energy consumption. Once the material has become saturated with CO2 the tree collapses into its "trunk" where the collected CO2 is removed as concentrated gas for use or permanent storage.

Air Capture Integration in Data Centers (AC/DC), Meta funded

- Can we make existing industry infrastructure more sustainable by using direct air capture in applications with existing airflow or waste heat?
- The AC/DC project will capture CO2 using inorganic liquid sorbents in a hollow fiber membrane contactor located in the air supply of a data center. This sorbent will be regenerated with waste heat produced by the data center servers. Since the waste heat is only 10 degrees warmer than the input air, a 'ladder' regeneration system will rely on a series of small thermal swing vapor-liquid equilibriums to concentrate the CO2 to a high purity for sequestration or post-processing.

Klaus Lackner’s June 2010 Scientific American Article

It took Klaus 12 years to build an Operating Device

Recently, Klaus and I shared a doctorial student who was interested in BICC

BICC

Why BICC

- Buildings have 2.5-3 times the CO_2 concentration of ambient air, which will improve the efficacy
- For ventilation purposes, we are already moving considerable air in and out of buildings, thus it can take advantage of free fan energy. Post pandemic concerns may even increase building ventilation rates
- Globally there are millions of buildings that have HVAC systems, thus developing a BICC device for retrofitting can address scaling issues
- Most HVAC equipment is modular in their design, which will help in retrofitting and in cost reduction.
- Most HVAC equipment is on rooftops, and easy to access
- Globally the HVAC industry has a considerable infrastructure in place; thus the design, manufacturing and maintenance of a BICC can utilize this infrastructure

Recent Concepts for Building Integrated Carbon Capture

PLEA 2018 HONG KONG
Smart and Healthy within the 2-degree Limit

Building-integrated carbon capturing 2.0:
Moving a concept from R&D to a prototype

Harvey Bryan, Ph.D., Professor, Arizona State University
Fahad Ben Salamah, Ph.D. Candidate, Arizona State University

ABSTRACT: Building-integrated carbon capturing is a system that provides carbon dioxide (CO_2) capture and regeneration within buildings using a moisture-swing air capture technology developed by Dr. Klaus Lackner at Arizona State University's Centre for Negative Carbon Emissions. This paper serves as a continual ideation towards moving a concept from the research and development phase into prototype development to perform experimental evaluation of how such a project would perform in real-life scenarios. We intend to build on strengths and overcome past design weaknesses through cross-industry innovation to create a more robust mechanism that is capable of carbon capture and regeneration.
KEYWORDS: Carbon, Capture, Building-integrated, CO_2, Shade.

1. INTRODUCTION

Atmospheric carbon dioxide (CO_2) concentrations have been on the rise since the beginning of the Industrial Revolution due to various human activities involving the burning of oil, coal and gas, as well as deforestation. According to NASA, humans have increased CO_2 by a third since the Industrial Revolution, and CO_2, the heat-trapping greenhouse gas, is the long-living/key factor of climate change [1]. The United States of America is the second largest emitter, as it is responsible for almost 15% of global CO_2 emissions, and stabilizing the atmospheric CO_2 concentrations is becoming less and less possible, specifically after the current administration's intentions to withdraw from the Paris Climate Agreement [2] and its termination of the Clean Power Plan that the previous administration issued [3]. The central aim of the Paris Climate Agreement is to keep global temperature change below 2 degrees Celsius for this century [4]. Achieving this goal will require considerable effort toward a host of aggressive and innovative strategies to meet that challenge. To date, most strategies to combat climate change have focused on CO_2 mitigation. While this task is critically important, it is equally important to combat this challenge through the capture and reuse of CO_2.

2. BUILDING-INTEGRATED CARBON CAPTURING

This paper serves as a continuation of the paper we presented at PLEA 2017 titled "Building-Integrated Carbon Capturing," wherein we envisioned a form of biomimicry that models the natural process of photosynthesis, in which plants capture CO_2 and turn it into carbohydrates and oxygen. To summarize the last paper's goal, we proposed a building-integrated carbon capturing (BICC) device that treats building facades as giant artificial leaves, creating facades that are capable of self-shading and absorbing CO_2 from the air and turning it into useful carbon-based materials without harming the environment. BICC will capture CO_2 by adapting a carbon-capture technology called moisture swing air capture technology, which has been developed by Dr. Klaus Lackner at Arizona State University's Centre for Negative Carbon Emissions [5]. This technology uses thin fibres of sorbent material that can capture carbon dioxide when in a dry state and then release it when moisture is applied. Dr. Lackner and his team were able to translate their lab experiments into a "Carbon Carousel" device, which could be packaged in a single cargo shipping container for ease of transportation and would be capable of capturing one ton of CO_2 per day.

Figure 1: Carbon Carousel (Source: Kevin Hand, Courtesy of Columbia University, 2010).

The air filters embodied in the sorbent resin are placed on a moving conveyor for natural air exposure.

PLEA 2020 A CORUÑA
Planning Post Carbon Cities

Building-integrated Carbon Capturing 3.0:
Carbon Dioxide Removal and Utilization through Buildings' Mechanical Systems

Harvey Bryan, Ph.D., Professor, Arizona State University
Fahad Ben Salamah, Ph.D. Candidate, Arizona State University

ABSTRACT: Building-integrated carbon capturing (BICC) is a mechanism capable of absorbing carbon dioxide (CO2) from the air to be stored and then converted into useful carbon-based materials without negatively impacting the environment. We intend to build upon our previous work, in which we treated building façades as artificial leaves capable of providing shade to lower solar heat gain, while simultaneously capturing CO2 through the air filters attached to the building façades by attempting a different approach capable of capturing CO2 within buildings. In this newer version of BICC, we envision buildings as CO2 reservoirs or vacuums, into which mechanical systems introduce fresh air, and through human activities, the air within the building becomes enriched with CO2 before being exhausted back to the outer environment. The design of a carbon-capture mechanism will take advantage of the ventilation side of existing HVAC systems, through which we intend to capture CO2 from the exhaust-enriched CO2 air. We believe BICC is another small piece of the puzzle to combat the rise of atmospheric CO2 levels; just like planting a tree adds to the global carbon sink, BICC takes advantage of existing structures and equipment to provide another method to capture CO2.
KEYWORDS: Carbon, Capture, CO2, Building, Integration

1. INTRODUCTION

Carbon dioxide (CO2) concentration in the atmosphere has reached a record high and has been on the rise since the industrial revolution, due to human activities such as deforestation and the burning of oil, coal, and gas. CO2, due to its physical characteristics as a heat-trapping greenhouse gas, is considered a long-living and key factor contributing to climate change [1]. Stabilizing the level of emissions is becoming less and less possible; to combat climate change and meet the targets set out in the Paris Agreement on climate change, which are aimed at ensuring the global temperature increase is no more than 2°C for this century, a host of aggressive and innovative strategies must be enforced.
To date, most strategies have focused on carbon mitigation at national levels. Carbon mitigation involves reducing human emissions of greenhouse gases or increasing the capacity of the carbon sink. For buildings, carbon mitigation focuses on energy efficiency and the implementation of renewable energy. While carbon mitigation in buildings is crucial to lower emissions, it is not enough to offset carbon emissions from buildings. Even highly efficient buildings continue to use energy to meet operational needs, and on-site renewable energy implementation has a limitation on how much energy it can generate. Therefore, combating this challenge in the building industry through the capture and reuse of CO2 is of equal importance to lowering emissions through carbon mitigation.

This paper serves as a continual ideation toward developing an appropriate and applicable building-integrated carbon-capture (BICC) mechanism that can capture CO2 from buildings. We intend to build upon our previous BICC work, an envisioned form of biomimicry that models nature's process of photosynthesis, in which plants capture CO2 and turn it into carbohydrates and oxygen. BICC intends to absorb CO2 from the air and turn it into useful carbon-based materials without harming the environment. The first generation of BICC was intended to create shade and carbon capture from the atmosphere, where the mechanism was designed to be placed on building facades to cast shade to lower heat gain while capturing CO2.

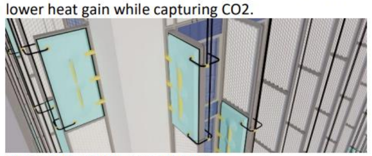
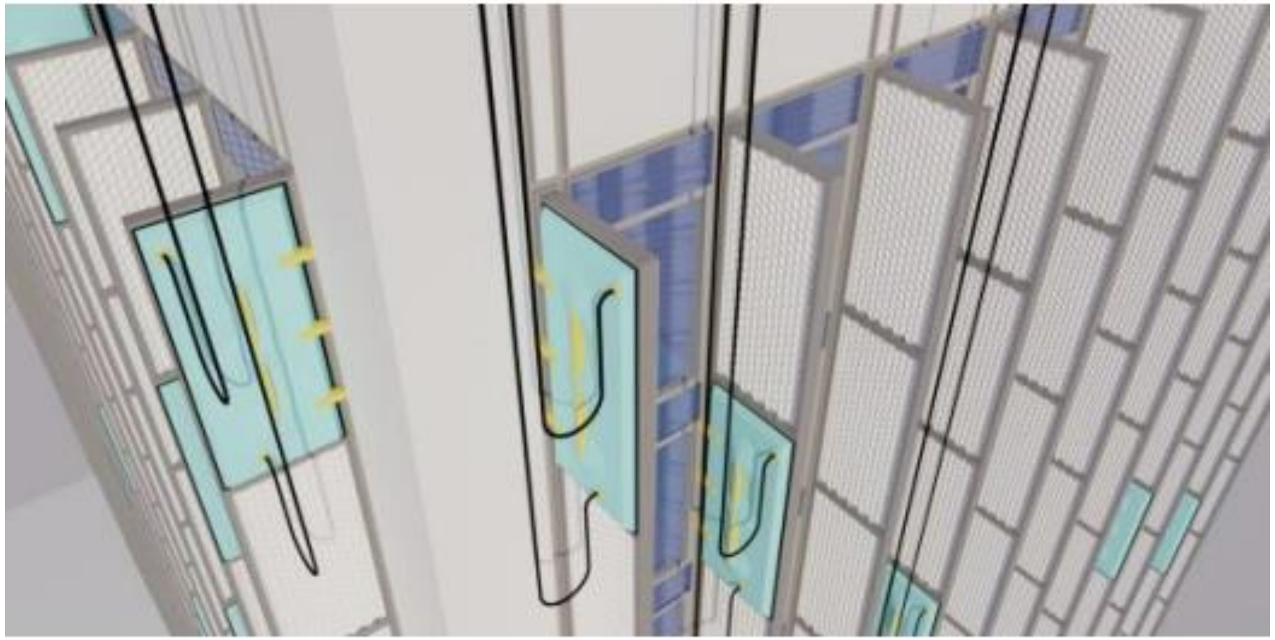


Figure 1: The first version of BICC.

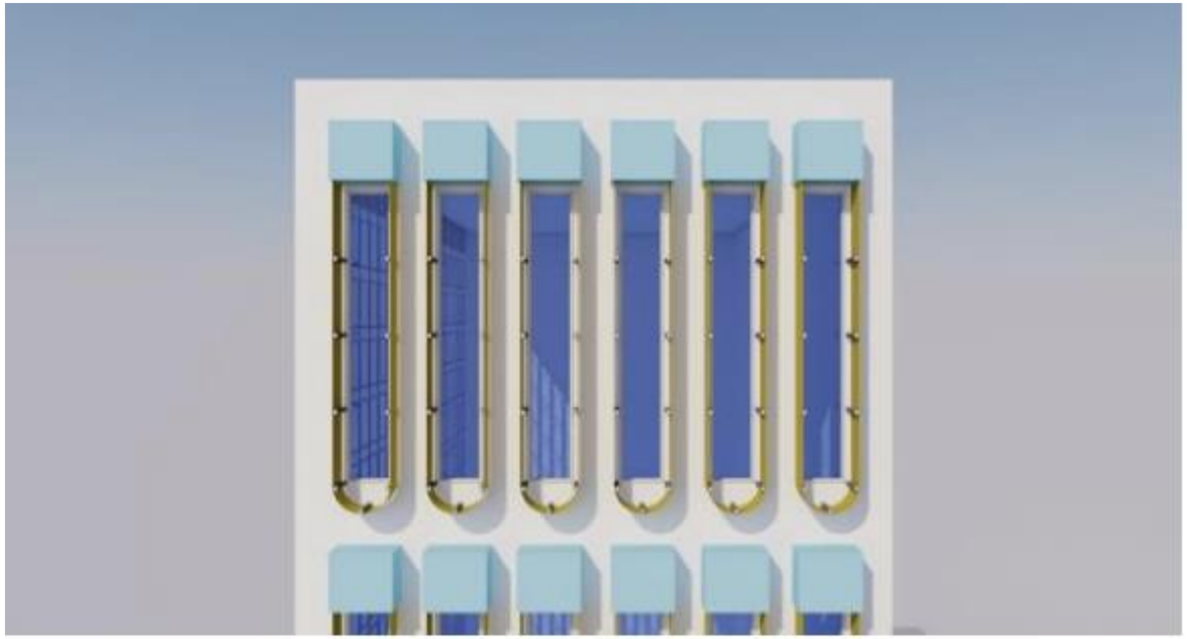
The second generation, which is the topic of this paper, focuses on the capture of CO2 from buildings, where it can be implemented within buildings' heating, ventilation, and air conditioning (HVAC)

Recent Concepts for Building Integrated Carbon Capture

Exterior Fabric Membrane Ideas



Movable cleaning chambers along horizonal fabric

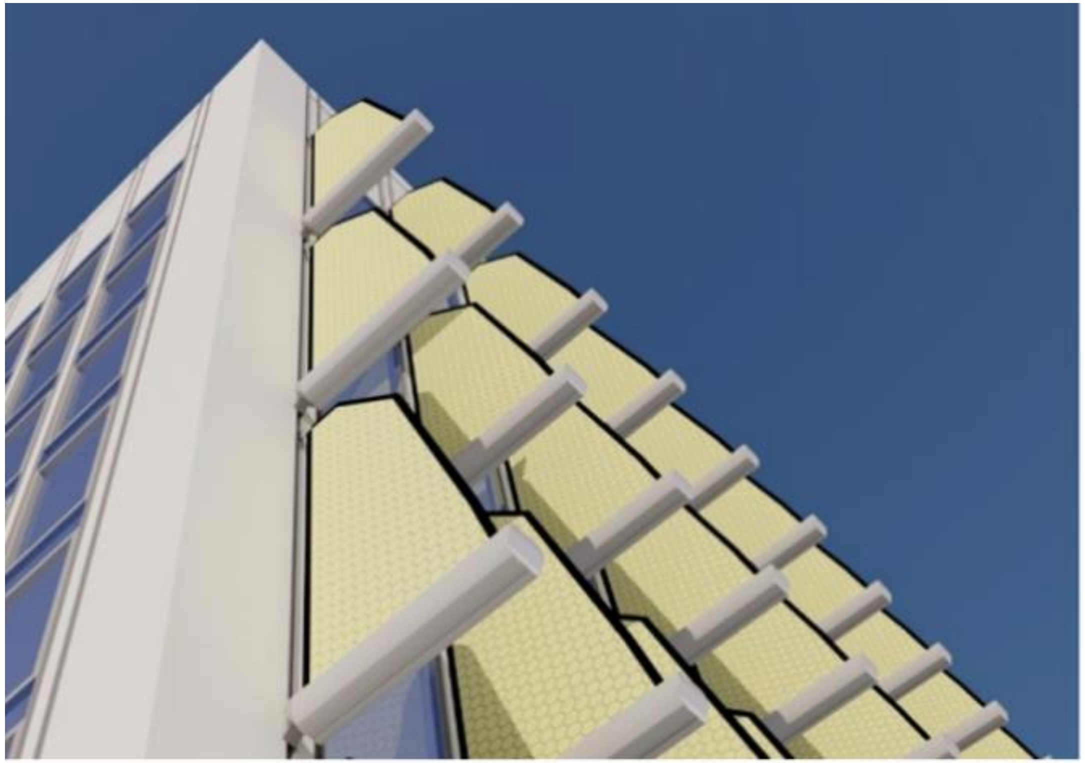


Stationary cleaning chambers with movable fabric

Recent Concepts for Building Integrated Carbon Capture

Exterior Fabric Membrane Ideas

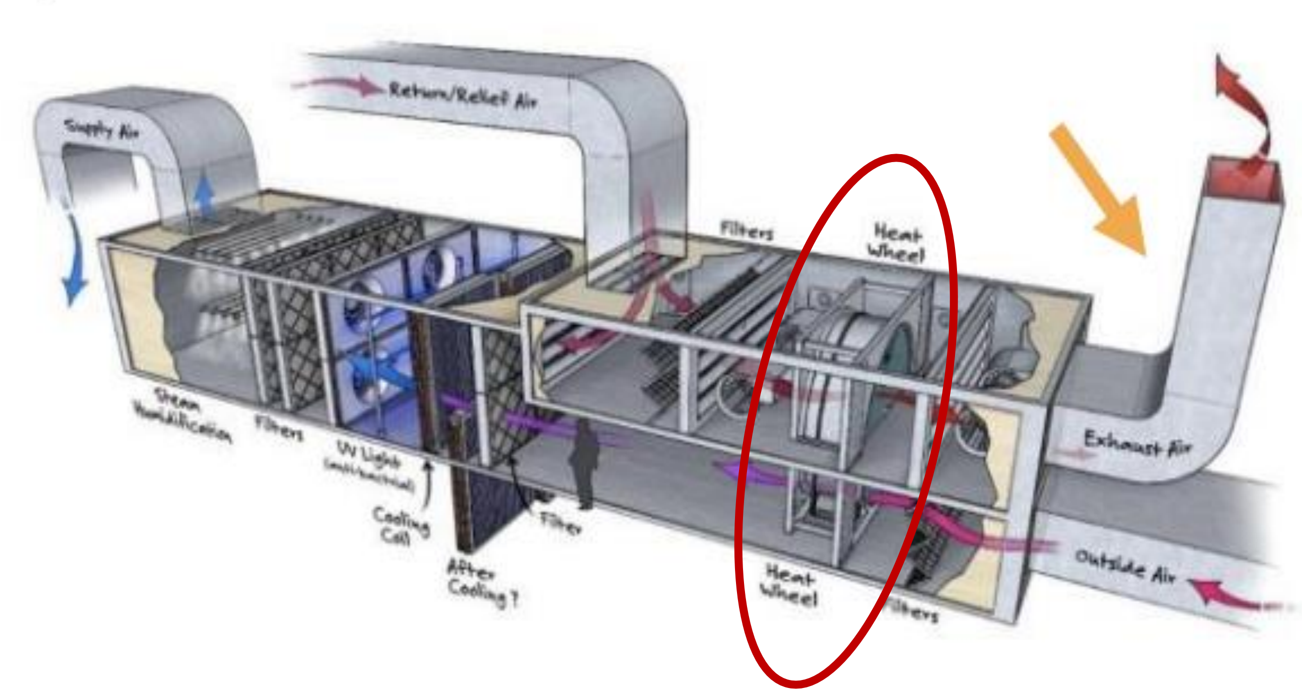
In-Boom Furling System

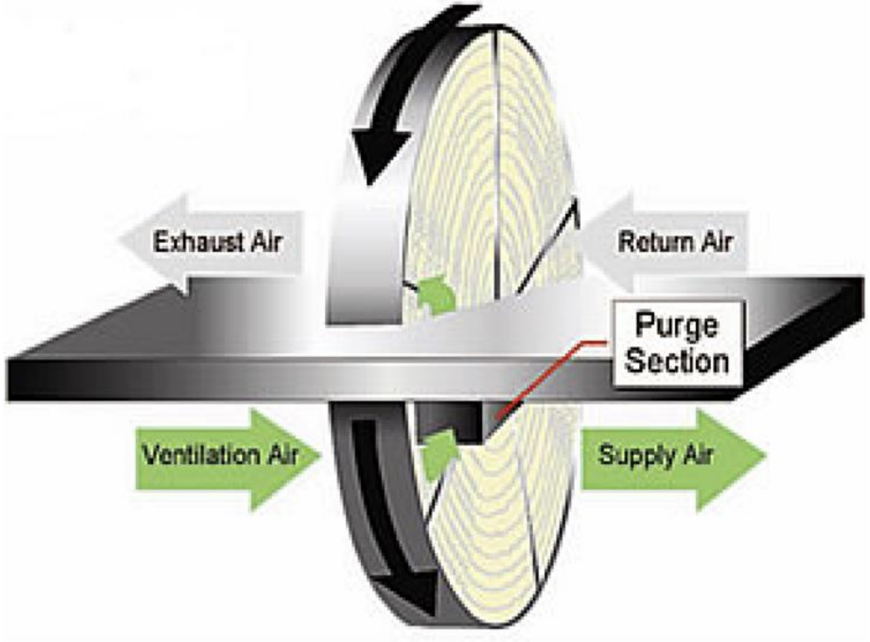


CarbonSail on a building

Recent Concepts for Building Integrated Carbon Capture

Mechanical System Ideas

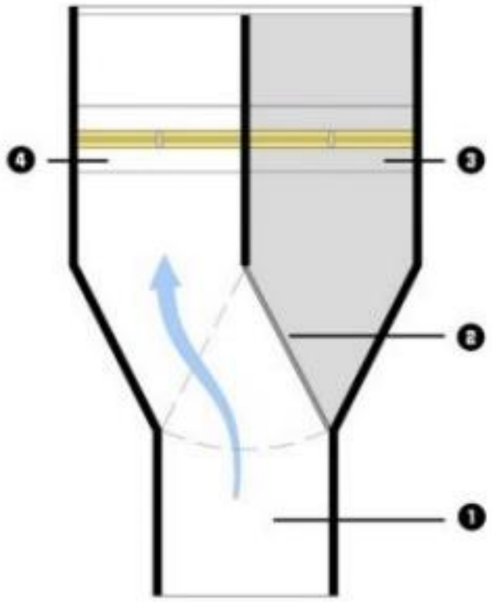


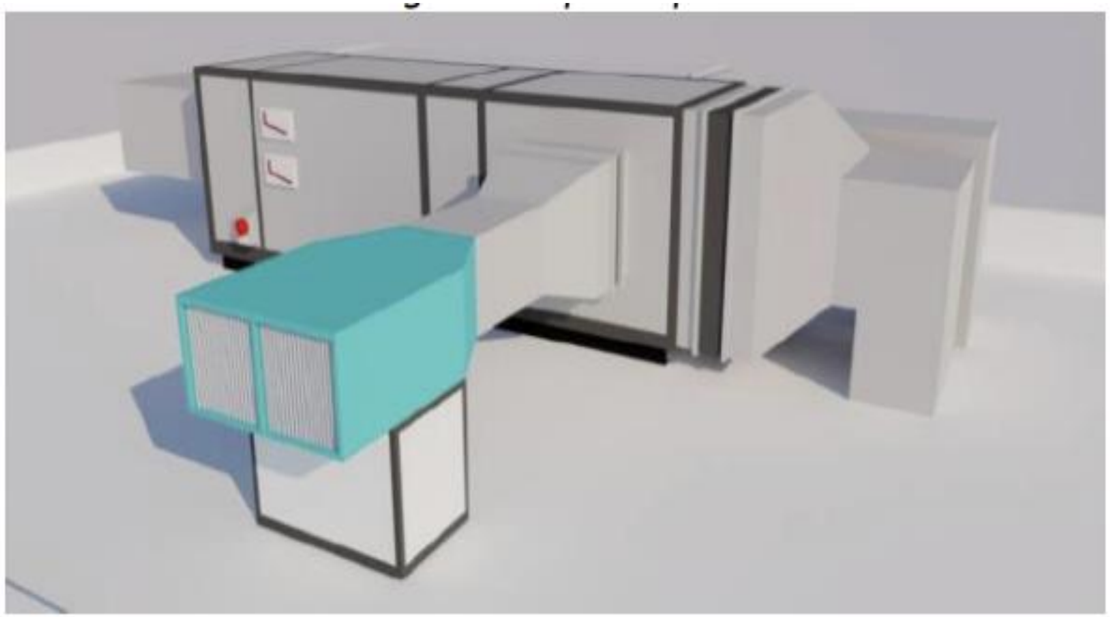


DAC using equipment concepts similar to heat recovery and enthalpy wheels

Recent Concepts for Building Integrated Carbon Capture

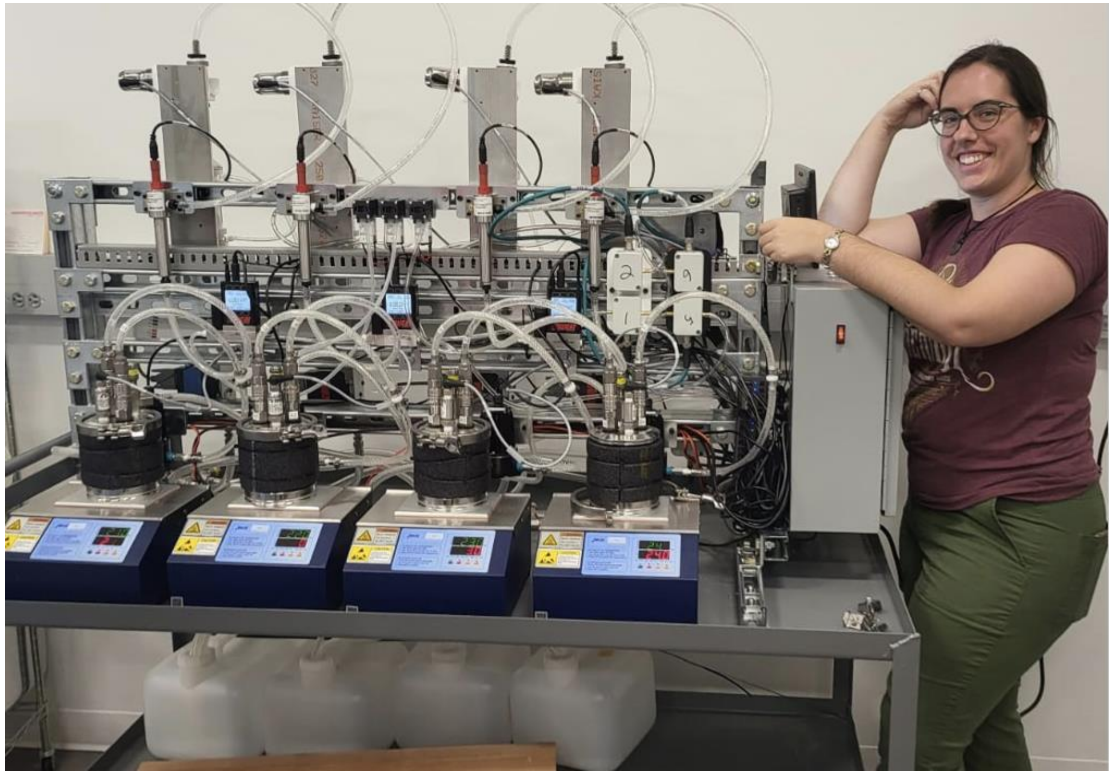
Mechanical System Ideas





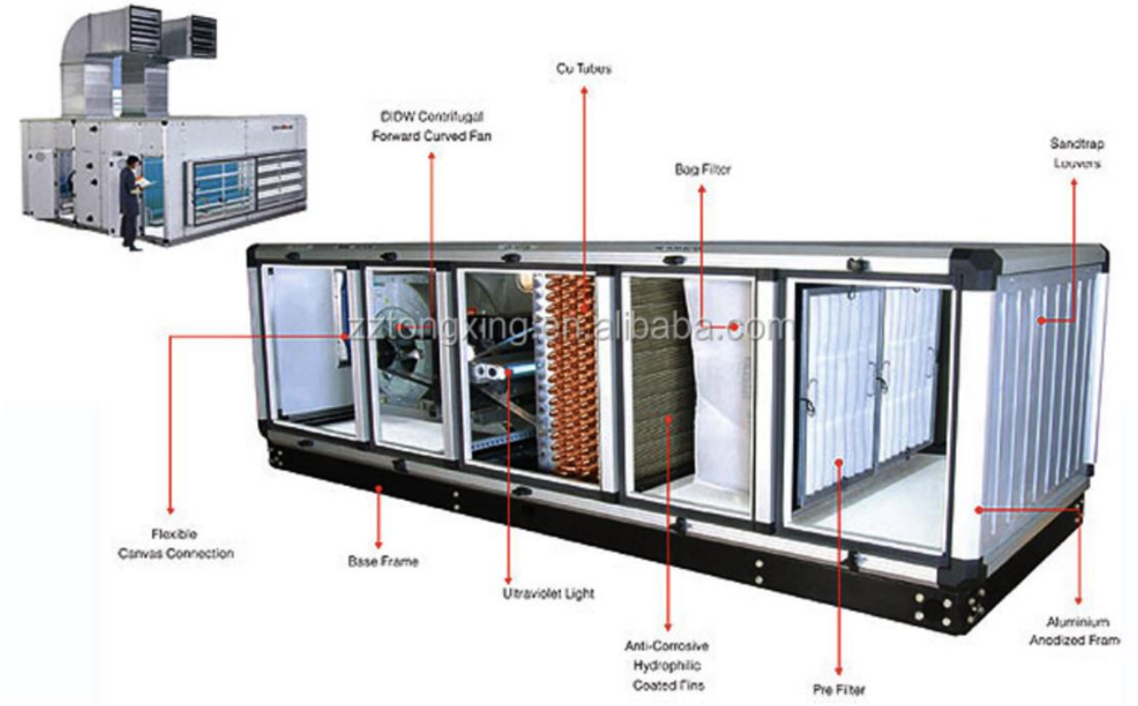
DAC using split path ductwork

What’s next for Building Integrated Carbon Capture?

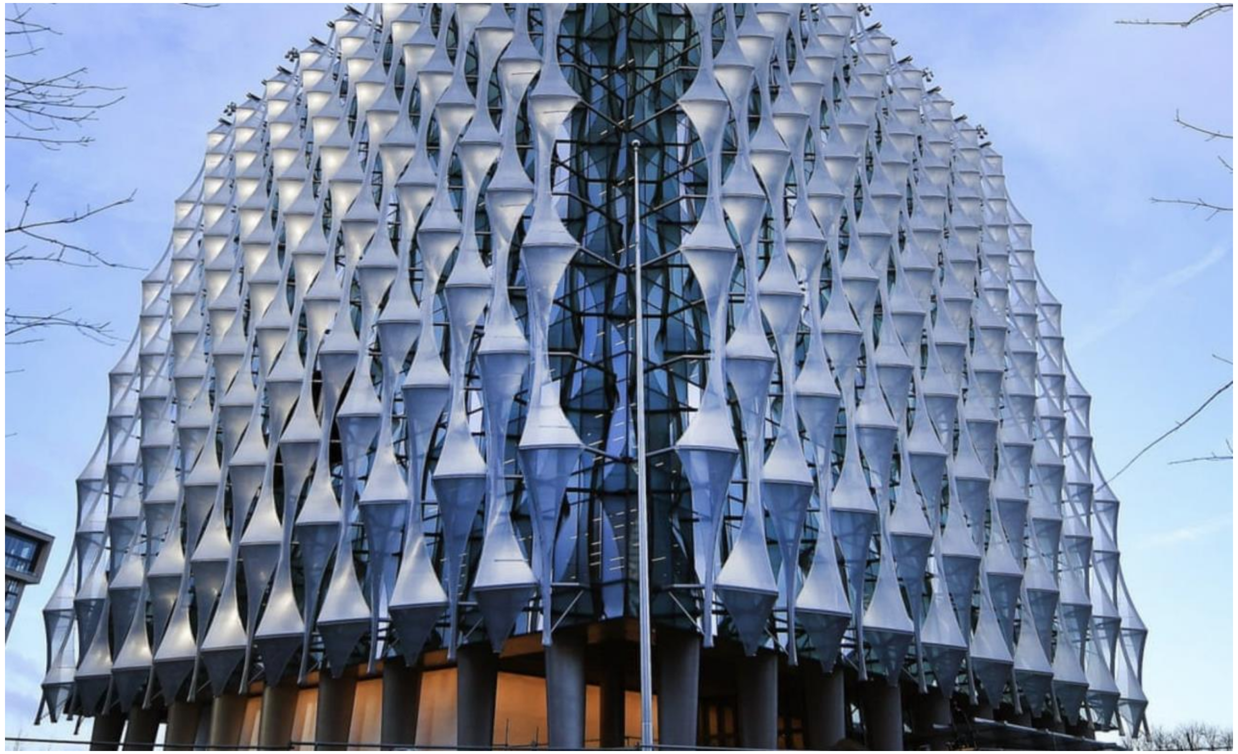


If the AC/DC project funded by META is successful it will be a real game changer. Utilizing liquid sorbent in a hollow fiber membrane will allow for distributed collection and centralized processing of the liquid. Liquid transport of the sorbent will also allow for the recovery of waste heat from building. Such features should lead to solutions that are more economical.

What’s next for Building Integrated Carbon Capture?



The DAC device could be another insert within the HVAC system



Bring back the exterior fabric idea with fewer moving parts – U.S. Embassy, London

Thank You

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Center for Negative Carbon Emissions
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