2025 ChemE Cube Competition
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This session is being recorded.

Introductions

- Who/What is RAPID?
  - Ignasi Palou-Rivera, Executive Director & CTO, RAPID
  - Keith Joseph, Director EWD, RAPID
  - Mahir Alam, RAPID
- Prasanna Joshi, Vice President of Low Carbon Solutions Technology, ExxonMobil
- Jun Shi, ExxonMobil
- Jason McMullan, ExxonMobil
- Jesse McManus, ExxonMobil
- Greg Ogden, University of Arizona, ChemE Cube Safety Coordinator

2025 Title Sponsor

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AIChE The Global Home of Chemical Engineers | DOING A WORLD OF GOOD

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Attendee Introductions: Poll Question #1

- Which statement best describes you?
  - I'm a student interested in starting a ChemE Cube team and not sure where to start.
  - I'm a student who is already part of a ChemE Cube team who plans to participate in this competition.
  - I'm a faculty member with students who could potentially be interested in starting a ChemE Cube team.
  - I'm a faculty member who is here to support an already-established ChemE Cube team.
  - I'm interested in sponsoring ChemE Cube.
  - I'm not a student or faculty member, just here to learn more.

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ChemE Cube Background

- Pilot 1.0: 2021 in Boston, MA
  (Theme: On-Demand Water Purification)
  – 5 teams (1st Place: University of Delaware)

- Pilot 2.0: 2022 in Phoenix, AZ
  (Theme: On-Demand Water Purification w/ Chemical Disinfectant)
  – 7 teams (1st Place: Carnegie Mellon University)

- 3rd Annual 2023 ChemE Cube Competition in Orlando, FL
  (Theme: Direct Air Capture [DAC])
  – 10 teams (1st Place: University of South Carolina)

- 4th Annual 2024 ChemE Cube Competition in San Diego, CA
  (Theme: Direct Air Capture [DAC] and Regeneration)
  – 18 teams (1st Place: Virginia Tech)

- 5th Annual 2025 ChemE Cube Competition in Boston, MA
  (Theme: Direct Air Capture [DAC] and Regeneration *NEW*)

Today's Webinar Will Cover

Competition Overview

- Format & Core Values
- Competition Rules
- Safety Program
- Overview of the Rubrics
  - The Ad
  - The Pitch
  - The Run
  - The Poster
- Awards

2025 Problem Statement (DAC)

- Industrial relevance of DAC
- Review of technical criteria

Next Steps & FAQs

- Key Competition Dates
- How to Get Started
- Team Eligibility
- Etc.

Q&A

Submit all questions through the Q&A function in Zoom, we will save all questions for the end.

Full Competition Materials Available at www2.aiche.org/chemecube2025

How does ChemE Cube work?

COMPETITION OVERVIEW

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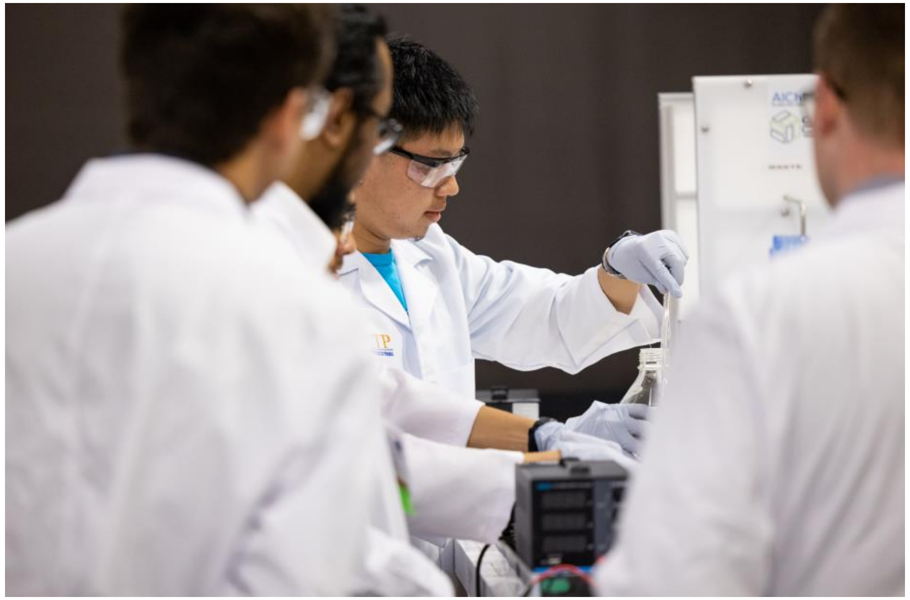
ChemE Cube Core Values

- Teamwork
- Creativity & Innovation
- Sustainable Development
- Diversity & Inclusion
- AIChE's Code of Conduct and Code of Ethics



Full Competition Materials Available at www2.aiche.org/chemecube2025

ChemE Cube Competition Format

- Virtual Qualifying Presentation
  - Present your team's ChemE Cube design and value proposition to a panel of judges
  - Sign up for time slot by March 31st
  - Presentations take place April 14-25

- For Teams who Qualify: Onsite Competition
  - **Run:** Bring your physical cube and operate it in real-time against your competitors
  - **Pitch:** Come prepared to pitch your cube as a product and seek investments from a panel of mock investors
  - **Poster:** Defend your cube's design and technical accomplishments to a set of judges
  - **Ad:** Develop an engaging Ad to sell your product (due in advance of competition)
  - **Date:** November 2-3, 2025 in Boston, MA as part of the AIChE Annual Student Conference

ChemE Cube Competition Rules

Where to Start

- Competition Objectives
- Code of Conduct
- Team Eligibility & Number of Students per Team
- Virtual Qualification Process
- In-Person Competition Format
- Scoring Overview (see rubrics for details)
- Safety Program Overview (see safety program for details)
- The Ad Format Requirements
- The Poster Format Requirements
- The Cube Requirements (System Design, Size, Capital Cost, see Problem Statement for Technical Criteria)
- Forfeiting
- Funding

ChemE Cube Safety Program

- Safety Review Process
  - Safety in Design: Consider safety in preparing for VQP
  - Safety in Build: Complete required safety training at your organization/lab (faculty advisors to oversee).
  - Safety in Operation: Onsite safety procedures (including inspection)
- Compliance Audit
  - Preliminary (during VQP)
  - Online (1 month prior): Teams submit an Engineering Documentation Package (EDP) and Regeneration Questionnaire
  - Onsite : Teams bring a physical copy of their EDP, EDP reviewer feedback and management of Change (MOC) forms.
- Competition Safety Rules Onsite
- What to do if there is a safety incident

ChemE Cube™ Competition 2025

Problem Statement: Modular Direct Air Capture

Business Objective

The carbon cycle is nature's way of recycling carbon atoms from the atmosphere to the terrestrial organisms, ocean, land, and then back into the atmosphere. With the introduction of human carbon emissions, there has been a net positive increase of carbon dioxide in the air. Carbon dioxide emissions are the largest greenhouse gas (GHG) emissions globally, accounting for 76% of all GHG emissions annually[1] and reaching 34.8 billion tons in 2020.[2]

The rising CO_2 emissions leads to increasing global temperatures, rise in ocean acidification, and disruption of ecosystems. The effects of climate change can directly and indirectly impact human health. In order to take into account this global issue, the 2015 Paris Climate Change Agreement was enacted in order to combat the rise of global CO_2 emissions. Its goal is to limit global warming to preferably 1.5°C.[3]

There are different ways to reduce the amount of CO_2 emitted. Conserving energy, efficient energy use, switching fuel type, and changes in use of land and land management practices help reduce the amount of CO_2 emitted. Carbon capture and storage (CCS) can be used to capture CO_2 at the point where it is emitted to keep it from entering the atmosphere. However, even after employing all of these approaches, many external technology assessments[4] suggest that additional steps will be needed to meet stated climate goals. This includes the deployment of direct air capture technologies, where CO_2 in the air is removed and sequestered.[5] This is what your design will aim to achieve.

You are tasked with creating a modular direct-air capture mini-plant with both adsorption and regeneration that can fit inside a cube that is 1-foot in length, width, and height. Your mini plant must capture CO_2 from surrounding atmospheric air. It is also important that your cube design is efficient so that the CO_2 emissions that come from the energy (used to power the mini plant) is low. You will have a maximum budget of $2,500 for your first-of-a-kind prototype. Your design should be marketable as a modular CO_2 capture device. Ultimately, it should create an impact by demonstrating technological breakthroughs, be able to address a market, and finally, benefit humanity.

[1] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
[2] https://ourworldindata.org/co2-emissions
[3] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[4] https://www.iea.org/reports/net-zero-by-2050
[5] An updated roadmap to Net Zero Emissions by 2050 – World Energy Outlook 2022 – Analysis - IEA

Version 1.0 (January 2025) Questions? Contact chemecube@aiche.org

ChemE Cube Scoring

- Virtual Qualifying Presentation: 180 Total Points
  - Cube Design & Safety Considerations: 120 Points
  - Value Proposition: 60 Points

- On-Site Competition: 1,000 Total Points
  - Run: 600 Points (250 Per Run + 100 Bonus Points)
  - Pitch: 200 Points
  - Poster: 100 Points
  - Ad: 100 Points

- Tip: The judges will be responding to the rubrics for all scoring. Make sure you address each criteria.

Note: The scoring of The Run is currently under progress.

ChemE Cube Virtual Qualifying Presentation

- **Goal**: Your team's goal is to sell your design to the judges and convince them that you deserve a spot at the in-person competition. Scored on a variety of criteria (see rubric).

- **Format**: Each team gets a 30-minute time slot.
  - 20 minutes for presentation
  - 10 minutes for Q&A from virtual judges
  - Takes place over Zoom April 14-25 (sign up by March 31)

- **Tip #1**: in the real world, before you're able to build your design, you need to sell your design's novel qualities and its value to an organization. It is also important for your design to operate safely and reliably.

- **Tip #2**: The sooner you sign up for a time slot, the more options you have.

Poll Question #2

- How should your team begin the application process for ChemE Cube in order to enter the competition?
  - Email ChemECube@aiche.org
  - Sign up for the AIChE Annual Student Conference
  - Sign up for a Virtual Qualifying Presentation anytime before the competition on November 2nd
  - Sign up for a Virtual Qualifying Presentation by March 31

Poll Question #2

- How should your team begin the application process for ChemE Cube in order to enter the competition?
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  - Sign up for a Virtual Qualifying Presentation anytime before the competition on November 2nd
  - Sign up for a Virtual Qualifying Presentation by March 31

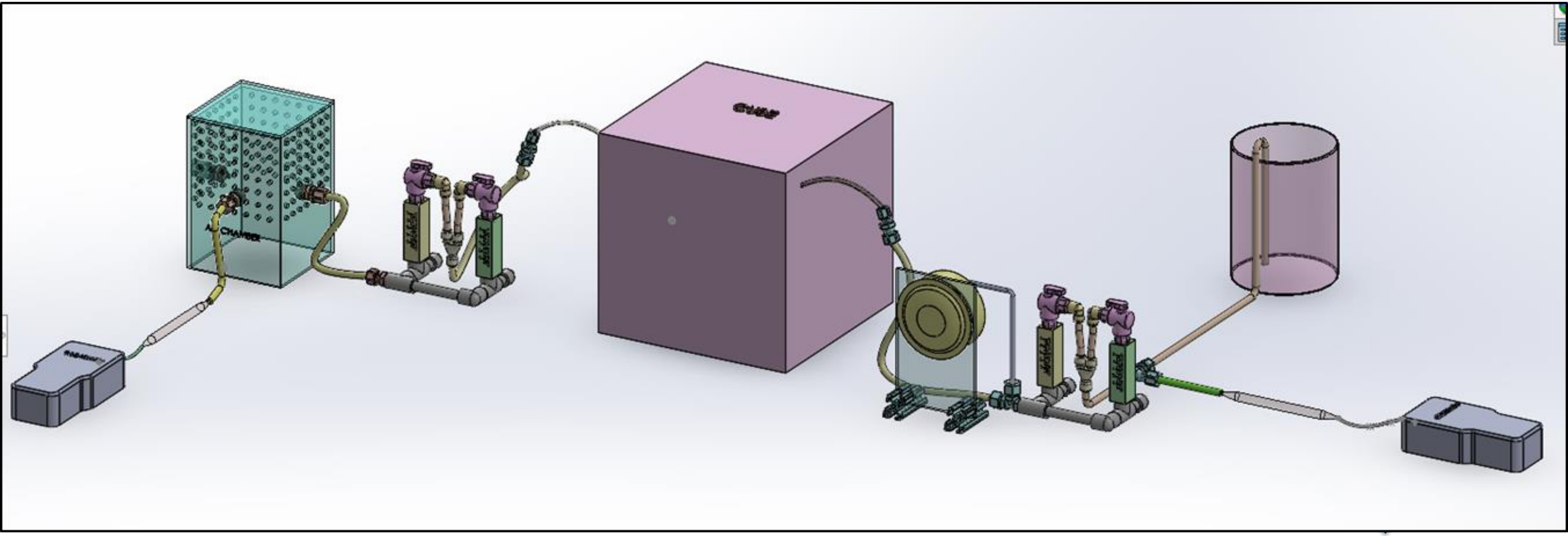
Onsite: The Run

- **Goal**: In the arena, operate your cube and meet as much of the technical criteria as you can in the allotted time.

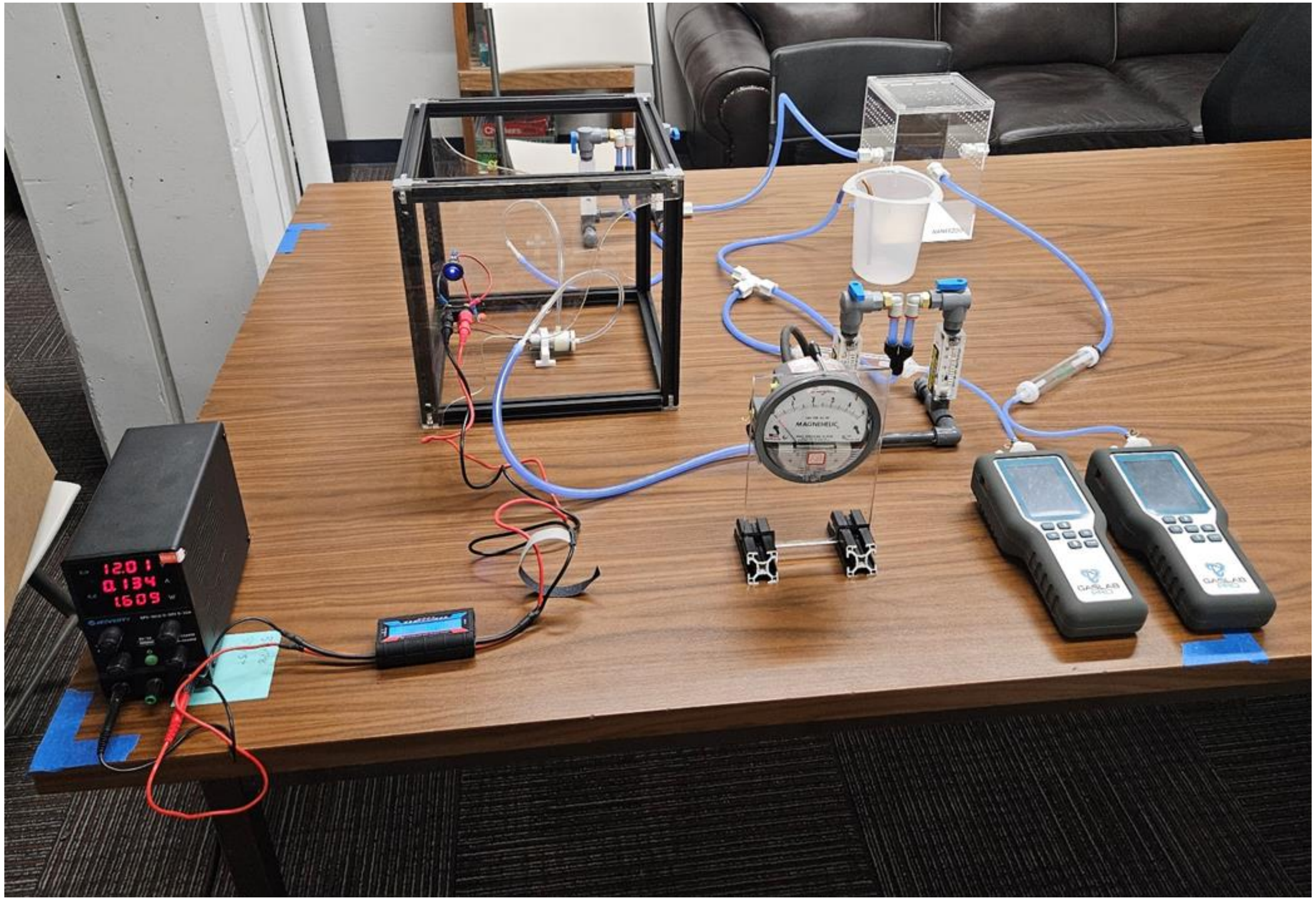
- **Format**: Each team will compete two runs. Each run lasts for 15 minutes.
  - The first 5 minutes will be setup/startup of the cube.
  - The next 10 minutes, the cube will run autonomously.
  - Final 5 minutes will be the shutdown of the cube.

- A “pit” area will be provided to teams for tinkering and competition prep.

Duel Setup



Duel Setup



Onsite: The Ad

- **Goal**: A fun, creative ~1-minute-long video advertising your product, should convey:
  - Innovative elements of cube
  - Impact and potential of the cube/technology
  - Quality visuals
  - An engaging message

- **Format**: 1-minute .mp4 file, see Rules Document for requirements, due 2 weeks before competition, will play for crowd onsite during transitions.

- **Tips**:
  - Imagine your video appearing in the middle of a YouTube video
  - See: The Ad Rubric for Scoring

Onsite: The Pitch

- **Goal**: To seek investors to invest in your product/cube
- **Format**: 10-minute pitch presentation on stage + 10-minute Q&A
  - A projector & screen are provided
- **Fun Fact**: During Q&A: Judges can call on any member of the team to answer a question
- You are pitching yourself as a newly formed startup with little to no capital to a group of angel investors.
  - Similarly to how a start-up would do this process in real life

Onsite: The Poster

- **Goal**: Dive into the technical details around your cube and describe your cube's:
  - Unique and innovative features
  - Design description, drawings, and testing results
  - A breakdown the total capital equipment costs (including manufacturing costs)
  - A visual demonstrating your business case for modular numbering-up of the process

- **Format**: The poster session will not be held in the pit area this year. Rather it will be either held on November 2nd or in a separate area away from the pit on November 3rd.

Onsite: Awards

- **First Place Award:** $1000 USD, Trophy, and Individual Medals (Determined by Scoring)
- **Second Place Award:** $500 USD, Trophy, and Individual Medals (Determined by Scoring)
- **Third Place Award:** $250 USD, Trophy, and Individual Medals (Determined by Scoring)
- **Outside-the-Cube Award:** Most Innovative and Original Cube Design (Judged by Poster Judges)
- **Entrepreneur Award:** Most Mock Investment Dollars Received (Determined by Pitch Judges)
- **RAPID Award:** Best Implementation of Modular Chemical Process Intensification (MCPI) Concepts (Determined by Poster Judges)

What does our cube need to do?

2025 PROBLEM STATEMENT
DIRECT AIR CAPTURE

Direct Air Capture (DAC)

Negative Emissions technologies - including DAC - are critical to meet net zero goals (IPCC AR6 and IEA Net Zero)

- ~400 MTA - 1GTA estimated need for DAC by 2050
- <10kta of DAC capacity today

Key components of DAC technologies

Materials

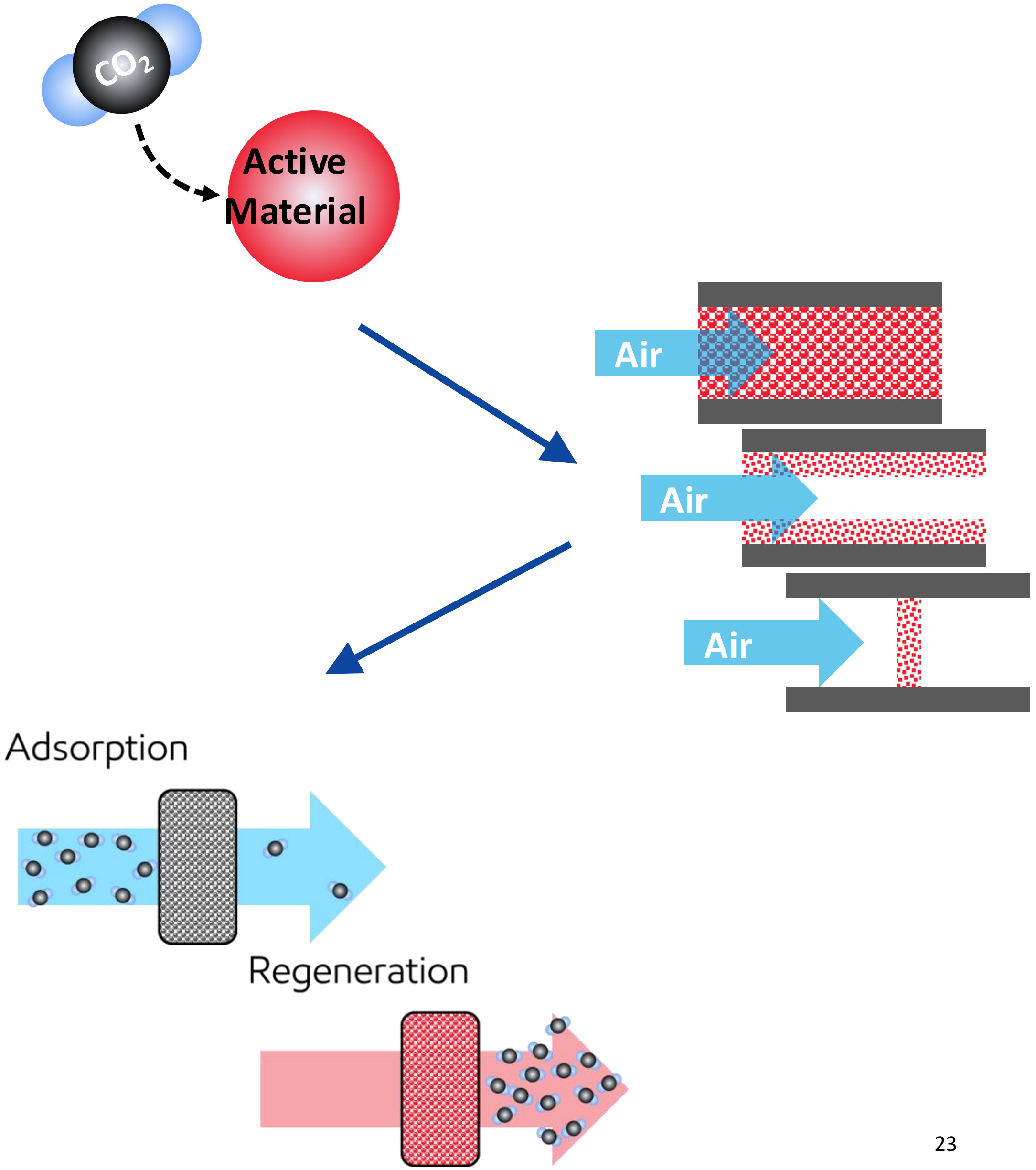
- High CO_2 affinity at lower concentrations (400ppm)
- High selectivity over water and Oxygen

Contactor/Equipment

- Low cost and scalable
- Low energy requirement for desorption

Process

- Efficient process cycles needed to lower cost and footprint
- Robust new hardware designs are required for continuous operations



Direct Air Capture Background

- **Your task is to create a modular direct-air capture mini-plant** that:
  - Fits in a 1-foot cube.
  - Captures CO_2 in a 10-minute period.
  - Has a low cost-to-capture via the chosen regen method.
  - Energy efficient.
  - ***NEW*** Built with a budget of **$2,500.**
  - Marketable and have a positive impact on humanity.

1. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
2. https://ourworldindata.org/co2-emissions

New Returning Teams

- Teams that participated in the 2023 and 2024 competitions are not allowed to reuse a previous design and must display an appreciable change. This can be shown as:
  - Material size difference in the vessels containing the active material
  - Difference process flow configurations
  - Different sorbent
- We encourage teams to explore different avenues and experiment with different capture methods, however the use of a different capture method is not required.
- More information on showing the appreciable change in the Virtual Qualifying Presentation will be provided at a later date.

New Pricing of Materials

- Teams are required to use McMaster-Carr prices when listing the Capital Cost of their cube
  - You are allowed to buy from reputable sources (McMaster-Carr, Grainger, Home Depot/Lowes, Amazon)
  - Buying from eBay, AliExpress, Temu are NOT allowed
  - In your EDP, you must provide an invoice/receipt of item
- Any in-house fabricated part (3D printed, machined, etc.) has a $200 overcharge
  - Price of material will be determined based on the amount used.
- Chemicals will be priced as normal.

Regeneration Questionnaire

- Teams will choose their choice of method of regeneration via a questionnaire.
  - Team will research and choose the best regeneration method that works for their design
  - Each method has its own price and will be incorporated in the “Total Cost to Capture” criteria
  - Price of regen is calculated based on energy/heat, complexity, and amount of adsorbent in your system.
- List of possible regeneration methods are on the problem statement document.

CO_2 Wager

- Teams will wager the amount of CO_2 they think their cube will capture based on the current CO_2 concentration at the inlet.

- This allows teams to demonstrate their control of the DAC reactions in their cube.

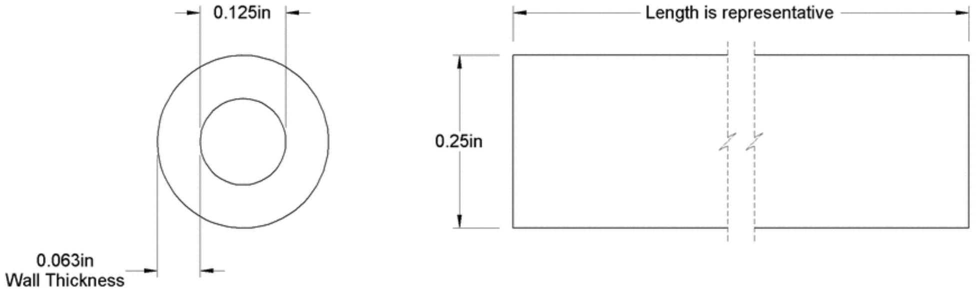
- Points are awarded based off how close you are to your wager.

Input Requirements

- Teams will need to pull air (via suction) from the air inlet ballast tank into their system. This is to prevent large fluctuations of CO_2 concentrations during the duel.
- Air will **NOT** be pumped into your system.
- Your flowrate must be in between 0.3 SCFH – 10 SCFH (0.15 L/min – 9.4 L/min)
  - Teams will choose their own inlet flowrate to hit the target concentration they wish to hit. This encourages teams to find the perfect balance when designing their cubes.

Output Requirements

- Your flowrate must be in between 0.3 SCFH – 10 SCFH (0.15 L/min – 9.4 L/min)
- It must be compatible with PVC tubing with ⅛ inch I.D. and ¼ inch O.D. (or have an adapter).



[Soft Masterkleer PVC Tubing for Air&Water, 1/8" ID, 1/4" OD | McMaster-Carr]

Energy Usage/Electricity Requirement

- Each team must include their required electrical current (not to exceed 10A) in their team's Engineering Design Package (EDP). Regulated 12 V DC power will be provided for the competition.
- **Your plant must use exactly 12 V.**
- Power will be provided from standard male banana jacks (socket) color coded red and back to indicate polarity.
- Cubes should provide suitably insulated, properly gauged leads terminated in standard female banana plugs to access the provided power.

How do I get started with ChemE Cube?

NEXT STEPS & FAQs

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March 31
Last day to sign up for Virtual Qualifying Presentations

April 14-25
Virtual Qualifying Presentations

May 2
Teams are notified if they qualify for the on-site competition

May 9
Teams must confirm participation at on-site competition

August 19
2024 Competition Prep Call

October 3
Deadline for Engineering Design Package

October 24
Deadline for The Ad

November 2-3
5th Annual ChemE Cube Competition

Full Competition Materials Available at www2.aiche.org/chemecube2025

How to Get Started

- Review all documents at www2.aiche.org/chemecube2025
- Form a team:
  - No limit to the number of students who may participate on a ChemE Cube team
  - Majors outside of chemical engineering are highly encouraged
- Start researching:
  - 1-hour RAPID webinar "Design, Application & Economics of Process Intensification"
  - 1-hour AIChE webinar "Carbon Capture, Transport and Sequestration"
- Sign up for a Virtual Qualifying Presentation Time Slot by March 31
- Begin designing your cube and preparing your virtual presentation

FAQ: Am I eligible to compete in ChemE Cube?

- Team must consist of undergraduate students
  - Tip: if your team leader graduates this spring, make sure you have a succession plan as they will not be able to compete in-person

- Open to ANY:
  - Universities (including non-US)
  - Majors

FAQ: Does our cube need to be built by April?

- No, your team will be judged only by the virtual design presentation in April.

- In fact, we do not want you to build your cube until your team qualifies in case your design reveals:
  - Unrealizable design
  - Potential reliability issues
  - Most importantly: potential safety issues

FAQ: Should my team be made up of all chemical engineers?

- In short: N-O!
- In your career you will need to depend on and collaborate with others from a variety of backgrounds, consider including team members from other majors:
  - Mechanical Engineers
  - Electrical Engineers
  - Accountancy Majors
  - Business Majors
  - Economic and Public Policy Majors
  - Graphic Design

FAQ: Who do I contact if I have more questions?

ChemECube@aiche.org

Additional FAQs

- For ongoing answers to questions you may have, visit https://www.aiche.org/rapid/education-workforce-development/cheme-cube-competition/faqs
  - Preparing for qualifications
  - Recently qualified
  - Preparing for the competition at Annual
  - Registering for the competition at Annual
  - Shipping
  - Competition Day

- Check back often as we will add questions as they come in from teams that are helpful to others!

What questions do you have today?

Q&A