CIBS
ANNUAL REPORT
2022

CENTER FOR INTEGRATED BUILDING SYSTEMS

College of Engineering, Architecture and Technology

MESSAGE FROM THE DIRECTOR

Dear friends,

As I was compiling the information from 2022 for this report, I was struck with one overarching theme for 2022, **growth!** This is growth across all facets of the center, 1) research productivity, 2) student engagement, 3) synergistic activities, and 4) membership growth. As you review this report, I believe you will be struck with the same feeling.

In 2022 our research productivity increased by 2.3 times compared to the start of the center, and that resulted in huge growth in deliverables and scholarship. We produced 21 unique deliverables (models, codebases, and datasets) as well **25 pieces of scholarship** (publications, theses/dissertations). The impact of CIBS research is reinforced by large, transformative, affiliated grants like the two ground-source heat pump projects awarded this year to Jeff Spitler and an international team. These projects were based on CIBS-generated outcomes and highlight how impactful CIBS can be and what a difference we can make, together.

We also increased the student impact in 2022 by **supporting 86 students!** Frankly, I thought last year was outstanding and would be difficult to match, but our wonderful faculty kept engaged with students with increases across both research and broadening participation exposure. These are the students that will become the future of our industry and will make an immediate impact at our member companies.

This year also marked a return to normalcy, as we were able to travel in-person to several conferences to represent our work. These networking and sharing opportunities are critical to maintain excitement and engagement in the work outside of the laboratory and I'm so happy to be able to share this with the students.

Of course, this growth is made possible by our fabulous industrial partners. We welcomed several new faces this year, for 2023, including Trane Technologies, Ingersoll Rand, and Climate Control Group. The growth of our industrial partners is reflective of the great work our faculty and students have done so far to create value for our membership. I'm quite optimistic that this will lead to even bigger things in 2023.

All this growth makes me so optimistic about the future and excited for value we are generating for our members and community. I look forward to visiting with you all this year.

Go Pokes!

Craig R. Bradshaw

Director, Center for Integrated Building Systems
Carol M. Leonard Fellow | Associate Professor

CIBS PRODUCTIVITY - 2022

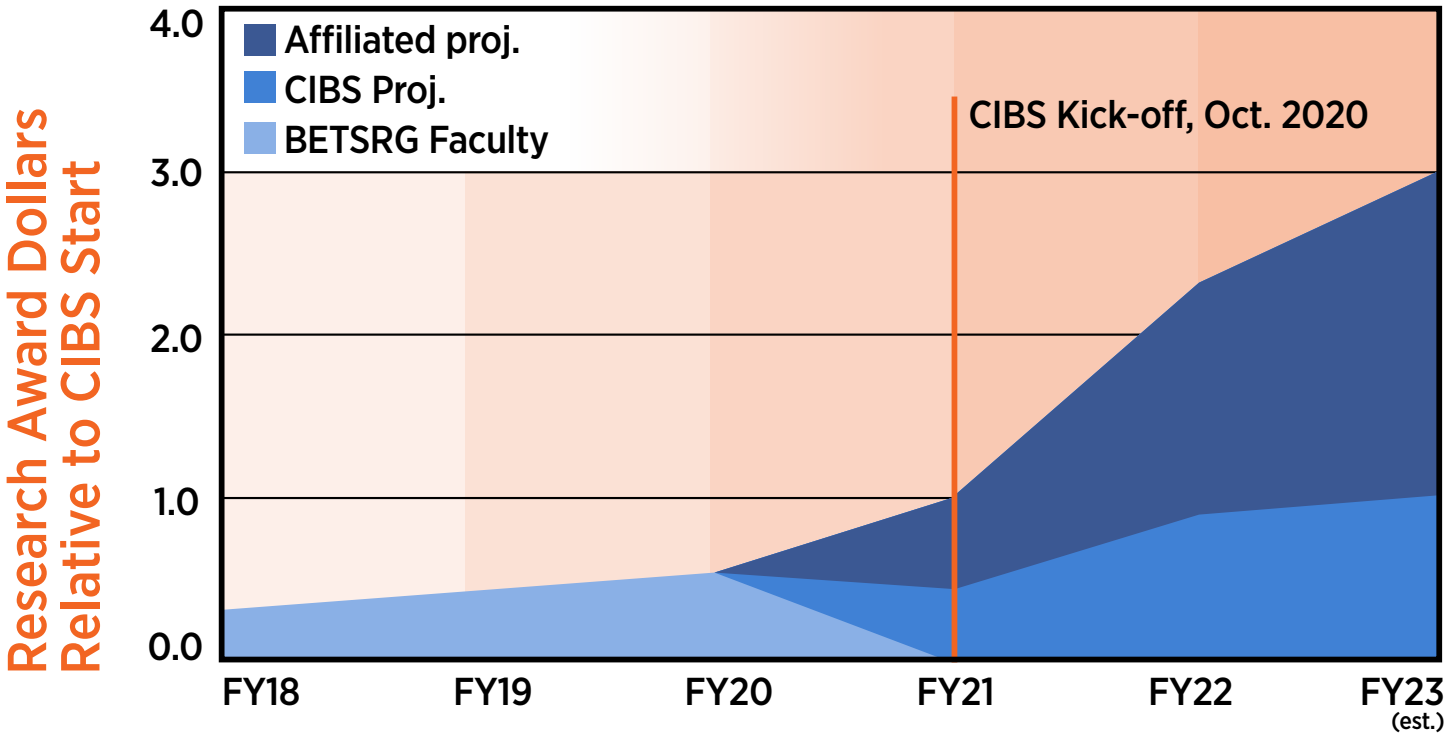
Figure 1: CIBS Spring 2022 Meeting in Stillwater, OK.

The center started its second year kicking off our seven (7) research projects across several research thrusts led by four (4) faculty from across the college. The meetings between the faculty, students, and industry partners at our bi-annual meetings and in between have become more frequent and engaging. This year it was very apparent that CIBS is starting to make a big impact on OSU and the community through both research productivity and student engagement.

One indication of this impact is the amount of funding the faculty associated with CIBS have been able to raise. This is a metric that encapsulates both the interest in the faculty and interest from external entities (CIBS Industry partners, federal/state agencies, etc.) on the work we are doing. The more exiting and impactful the work, the more research dollars you may expect.

The figure shows the research funding secured by the CIBS faculty before and after CIBS kick-off over fiscal year, normalized based on funding levels when CIBS started. It shows that this year, we raised roughly 2.3 dollars per every dollar raised during the center's first year. For next year (2023), we have already raised 3 dollars per every dollar raised in year 1. This is nearly a 6x increase in support from pre-CIBS levels!

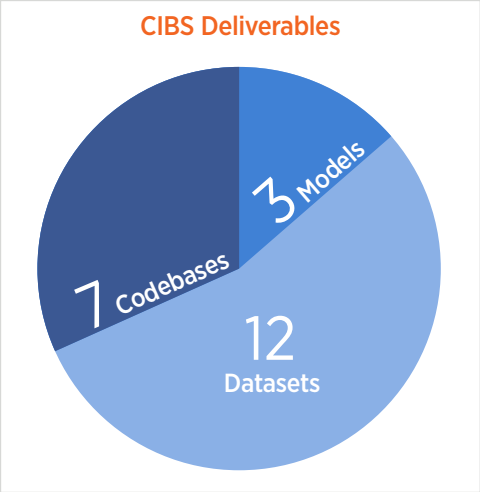
Funding Raised over Fiscal Year, Pre and Post-CIBS

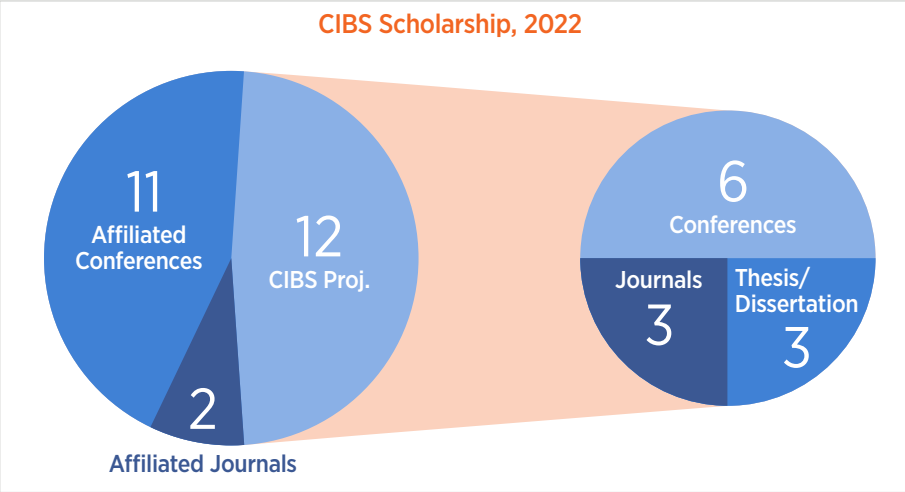


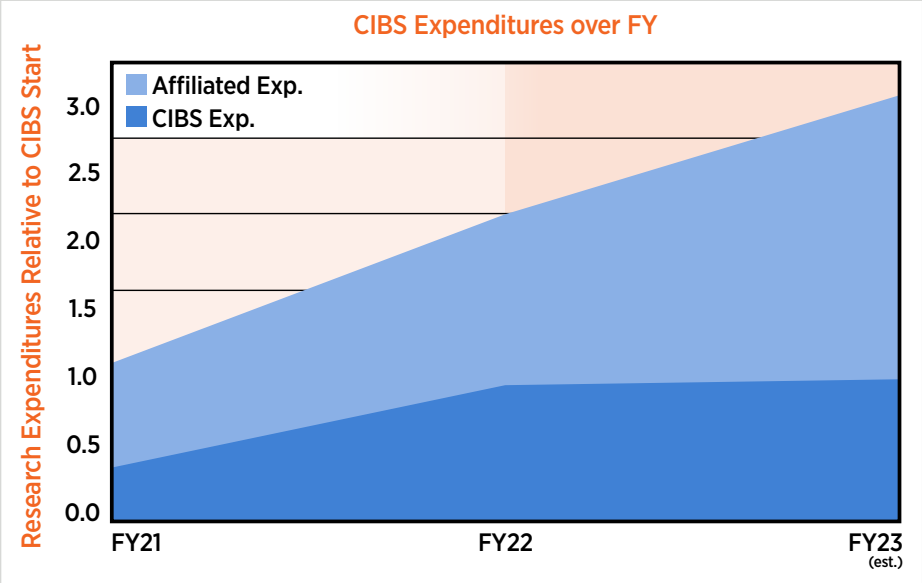
CIBS BY THE NUMBERS 2022

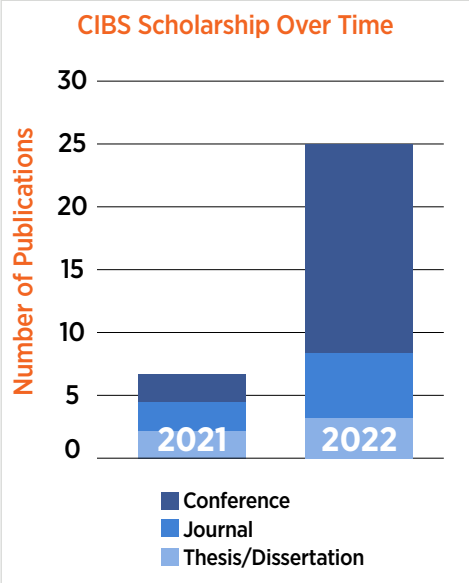
Research Productivity

We have seen incredible growth in our research productivity, no matter how it is measured. We delivered 3 models, 7 codebases, and 12 datasets, along with 25 publications, in 2022. CIBS expenditures (a lagging indicator of activity) have increased 2.7 times since the center began in 2020 and our **scholarship is up nearly 5 times**, compared to last year!





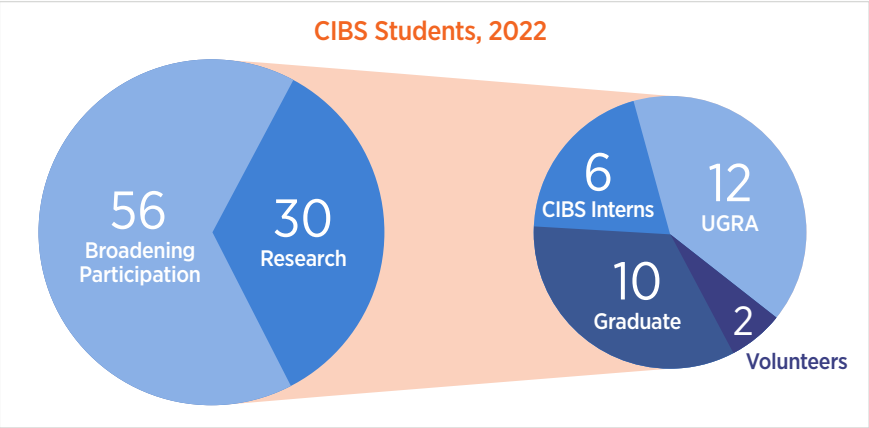


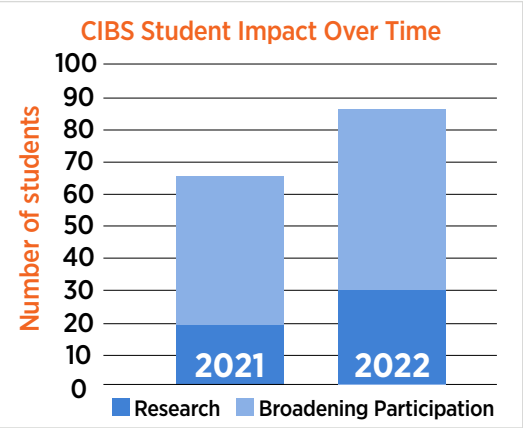


Student Engagement and Exposure

This year **CIBS impacted 86 students!** This included 30 directly related to research and another 56 through our Broadening Participation program. The growth is also exciting, with an additional 20 students impacted in 2022 compared to 2021.

STUDENT SUCCESS AND OTHER ACTIVITIES





2022 CIBS Graduate Student Graduations

Kalen Gabel, MS Thesis title: Quantitative analysis of positive-displacement compressor models tested in extrapolation scenarios. (Research Engineer at Rheem Mfg.)

2022 CIBS Intern Student Graduations

Caleb Bengs, PhD student at TAMU

Simon Delvin, MS student at Cambridge

Mahayla Mitchell, Boeing

Evan Nichols, Zeeco Inc.

Tien Nguyen

Capstone Projects Supported by CIBS

The center supported three (3) capstone projects in 2022, mentored by Drs. Christian Bach, Jeff Spitler and Aaron Alexander. They were:

- Furnace condensation experimental apparatus design (Spring 2022)
- Refrigeration cycle flow visualization (transparent refrigeration) (Fall 2022)
- Thermal Energy Storage (TES) tank design (Fall 2022)

Each of these projects supported one of our center research thrusts in 2022 and greatly increased the exposure to our field with students.

Figure 2: Transparent refrigeration team at design expo, Fall 2022

STUDENT SUCCESS AND OTHER ACTIVITIES

Return to In-Person in Las Vegas & West Lafayette

This year marked a return to in-person events for the center. The students and faculty were able to have a strong presence at both the ASHRAE winter meeting in Las Vegas as well as the Purdue Conferences in West Lafayette, IN.

Figure 3: CIBS representation at 2022 Purdue Conferences in West Lafayette, IN.

Figure 4: CIBS representation at 2022 ASHRAE Winter Conference in Las Vegas, NV.

The International Refrigeration and Compressor Course (IRCC)

The center also hosted a novel course, the International Refrigeration and Compressor Course (IRCC). This course is a novel collaboration between CIBS/OSU, Purdue University, and two German universities, the Technical University in Dresden, and Hochschule Karsruhe. This exciting course focuses on cultural exchange with topics specific to refrigeration and compressors that requires the students to spend time at a U.S. institution as well as German institutions. CIBS hosted the U.S. week of the course in 2022, read more about it at https://news.okstate.edu/articles/engineering-architecture-technology/2022/ceat_hosts_ircc_course_for_the_first_time.html

Figure 5: Photos of the 2022 IRCC students (left) and laboratory exercise (right) at OSU.

Two transformative Ground-Source Heat Pump (GSHP) grants awarded from the DOE and EU

Two projects were awarded this year, focused on district implementation of GSHP systems. Both grants are large-scale partnerships with government and university stakeholders that will increase proliferation of GSHP's by increasing development efficiency, using improved models and software. The OSU portions of both of these projects are led by Dr. Jeff Spitler. His project responsibilities are built off the foundation developed by his CIBS project on optimal borefield spacing. One grant is a multi-million euro investment by the European Union, through the Geothermica program. The second is funded by the DOE and valued at over $6M, read more about the DOE project here: https://news.okstate.edu/articles/communications/2022/osu_part_of_team_receiving_6_million_doe_investment.html

LOOKING FORWARD TO 2023

ASHRAE Podcast

Dr. Bradshaw was featured on the podcast HVAC Magicians to speak about the center and his background. This podcast is produced by the Central Oklahoma ASHRAE chapter. You can listen to this podcast on Spotify or other podcast source: https://open.spotify.com/episode/5HPYCh5fKs3NPWGBOZobcB?si=596b05bc6e41481f&nd=1

CIBS

1 **Electrification/ Decarbonization & Integration**

2 **Refrigerant Diversity & Future**

3 **Energy Efficiency & Thermal Management of Unique Building Applications**

At our April IAB meeting, the group sat down and planned our next phase of growth and landed a research strategy for 2023-2025 that included three (3) major thrusts, including 1) electrification/decarbonization & integration, 2) refrigerant diversity and future and 3) energy efficiency and thermal management of unique building applications. These thrusts will provide a roadmap for us to select projects.

The first research thrust, overlapped with the expertise at OSU, results in two major areas of research for 2023, a) heat pumps/components and b) thermal energy storage. The second thrust is omnipresent and finds itself as, at least, a secondary interest level in most of our eight (8), unique 2023 projects.

Project Title	Faculty PI	Project Title	Faculty PI
Development of a Vapor Injected and Refrigerant Flexible Semi-Empirical Compressor Model	Bradshaw 	Performance Evaluation of Refrigerants with High Temperature Glide-Measurements and Design Guidelines.	Bach 
Compressor Technology Evaluation for Heat Pumps using Low-GWP Working Fluids	Bradshaw 	Solar-powered ultra-low-GWP A3 heat pumps with DC compressors and TES	Spitler 
Additional Benefits of Secondary Loop Systems: Thermal Storage and Demand Response	Spitler 	Development of Reduced-order System Models for Next Generation Comfort Cooling Equipment	Bradshaw 
Physics-Based Charge Models for Low-GWP Refrigerants in Heat Pump Applications	Bach 	Enabling Thermal Energy Storage to Accomodate Oklahoma Wind Energy - TriCoil as Cost Effective Means for Residential System Integration	Bach 

Table 1: 2023 Project titles and faculty leader.

2023 Events

If you aren't a member, please contact Craig Bradshaw (**craig.bradshaw@okstate.edu**) to discuss membership so you don't miss out on our events for 2023.

April 12-13, 2023 – Project Update and Center Strategy Meeting – Stillwater, OK

October 4-5, 2023 – Project Update and Project Selection Meeting – Stillwater, OK

SPONSORS

CIBS Members for 2022

Double Full Member

AAON

Johnson Controls

Full Member

Ingersoll Rand

Rheem

Climate Control Group
NIBE GROUP MEMBER

Koura

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

TRANE TECHNOLOGIES

Small Business/ Consulting/ Contracting

HARRISON-ORR AIR CONDITIONING, LLC

TORAD

Non-Member Supporters of CIBS

ABB

Danfoss

HENRY TECHNOLOGIES

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