Building Energy
Smart Technologies
Research Center

Building Energy Smart Technologies (BEST) Center

Fall 2024 Industry Advisory Board Meeting
October 28, 2024

Welcome from the Leadership Team

Thank you for attending the sixth industry advisory board (IAB) meeting since the establishment of the Building Energy Smart Technologies (BEST) Center. We hope you enjoy the discussions with colleagues and presentations from our research project teams. The morning session will start with a welcome and keynote from Dr. Mike Birnkrant, Carrier Chief Architect and i3 Labs Leader. We will then spend an hour and a half networking and brainstorming research topics for next year's proposal process. Please see instructions for the brainstorming session in this agenda after the meeting information page. After lunch, FY24-25 research projects will be presented by faculty and students, and we will wrap up in closed session with our IAB.

The primary goal of the BEST Center is to foster collaborations between various stakeholders to develop innovative energy efficient and intelligent technologies for buildings, communities, and urban centers. The BEST Center has two university sites, the University of Colorado Boulder (CU) and the City College of New York (CCNY), and University at Albany is a collaborative site, leveraging the diverse academic capabilities of these institutions to benefit our industry partners.

Our IAB members and affiliates represent two utilities, two window manufacturers, one manufacturer of thermal systems and appliances, one building control and distribution systems manufacturer, one municipality, and six engineering consulting companies. In the coming year, we hope to expand the involvement of industry partners to support the building industry's expectations for improved sustainability, resiliency, and intelligence. With our industry partners' support, the BEST Center will continue to be a platform for the building industry to guide universities in educating and training a skilled and diverse workforce to address employment needs for years to come.

We thank all the people who made this event possible, and thanks to all our industry partners, faculty, students, and guests for attending!

Best,
Moncef Krarti, BEST Center Executive Director
Nicholas Clements, BEST Center Manager
Ahmed Mohamed, BEST CCNY Site Director
John Zhai, BEST CU Boulder Site Director
Jorge Gonzalez-Cruz, BEST UAlbany Collaborator Site Director

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October 28, 2024
CU Boulder: SEEC S372A/B
CCNY: Steinman Hall ST-124
Remote: https://cuboulder.zoom.us/j/6356894174

Agenda	
8–9 MT (10-11 ET)	**Registration and Breakfast**
9-9:30 MT (11-11:30 ET)	**Welcome and Keynote** Dr. Michael Birnkrant, Chief Architect, Carrier *Transforming Today for a Better Tomorrow*
9:30-11 MT (11:30-1 ET)	**FY25-26 Research Topic Brainstorming Session**
11-12 MT (1-2 ET)	**Lunch**
12-1:40 MT (2-3:40 ET)	**FY24-25 Project Presentations**
12–12:20 MT (2-2:20 ET)	BEST24-05: *Performance Evaluation and Grid Impacts of Intelligent Field Devices and Next-Generation Heat Pumps with an Application to Adaptive Reuse of Commercial Buildings*, Gregor Henze (CU)
12:20-12:40 MT (2:20-2:40 ET)	BEST24-04: *Design & Techno-Economic Assessment Tool for ASHP Systems for Cooling, Heating and Hot Water*, Prathap Ramamurthy (CCNY), Jorge Gonzalez-Cruz (U at Albany)
12:40-1:00 MT (2:40-3:00 ET)	BEST24-03: *Feasibility Evaluation of Net-Positive Window Systems*, Moncef Krarti, Michael McGehee (CU)
1-1:20 MT (3-3:20 ET)	BEST24-02: *Embodied Energy and Embodied Carbon Analysis of Residential & Commercial Building Envelopes*, Wil Srubar (CU)
1:20-1:40 MT (3:20-3:40 ET)	BEST24-01: *Enhancing Thermal Energy Harvesting and Storage using Monolithic Mesoporous Metamaterials (MMMs) and Phase Change Materials (PCMs)*, Ivan Smalyukh (CU)
1:40-2 MT (3:40-4 ET)	**Closing Remarks and Refreshments**
2-3 MT (4-5 ET)	**IAB Closed Meeting (*IAB Members and Affiliates Only*)**

University of Colorado Boulder

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PAE

Western Mechanical Solutions SUSTAINABLE HEATING COOLING

University of Colorado Boulder

NSF

The City College of New York

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Meeting Information

Registration

All attendees, including faculty, students, IAB members, and guests must register:

- **Registration Link** (Eventbrite)

Location

CU Boulder: SEEC S372A/B, **Google Maps Link**
CCNY: Steinman Hall ST-124, **Google Maps Link**
Remote Zoom Link: **https://cuboulder.zoom.us/j/6356894174**

Parking and Transit

CU Boulder:

- **CU Campus Map**
- Parking Information: Parking code and instructions will be provided to registered attendees via email. Please park in **Lot 550** next to the SEEC building.

CCNY:

- **CCNY Campus Map**
- **Transit Information and Directions**

Wireless Internet Access

CU Boulder

- Network: UCB Guest
- Once connected, confirm you agree with the terms and conditions and click "Connect"

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Research Topic Brainstorming Event

Schedule:

- **9:30–10:00 MT (11:30-12:00 ET):** Research topic brainstorming with colleagues in your meeting location (Boulder, New York, Remote)
- **10:00-10:15 MT (12:00-12:15 ET):** Clustering/summarizing research topics in each meeting location
- **10:15-10:45 MT (12:15-12:45 ET):** Sharing and discussing research topics from each location with all attendees
- **10:45-11:00 MT (12:45-1:00 ET):** Synthesis and next steps

Session Instructions (all):

- **Brainstorming:** In your meeting room there will be post-its and sharpies or whiteboard markers available at a station for each research theme of the center. See the next page for summaries of each research theme. For 30-minutes, add as many ideas as you want regarding research needs from your industry/field. ***There are no wrong or bad ideas at this stage!*** Spend a few minutes to discuss your ideas with others at each station. This is your chance to network and identify alignment in research interests between you and your colleagues.
- **Clustering and Summarizing:** Spend a few minutes working with others to group ideas and identify commonalities for a research theme of interest to you. Based on the groupings, prepare a summary of the research topics. Share these ideas with the moderator for your location. If a station doesn't have anyone working on it, take the initiative to help summarize the ideas there. Take a picture of your collage of ideas!
- **Sharing and Synthesis:** The moderator from each location will have 15 minutes to share their summary and moderate open discussion with the other locations. We will wrap up by identifying research topics with strong support from the industry advisory board and begin discussing how these topics align with faculty research interests and capabilities.

Remote Attendee-Specific Instructions:

- **Brainstorming:** A digital whiteboard will be shared via Zoom with all remote attendees. Please review the instructions on the whiteboard for additional details, but in short there are "piles" of post-its in each research theme box. Click and drag a post-it from the pile to an empty part of the associated box and begin typing to edit the post-it. If you see an idea you agree with, click on the post-it and add a "thumbs up" emoji. Summaries of the research center themes are included at the top of the whiteboard for reference.
- **Clustering and Sharing:** Click and drag post-its with commonalities into clusters for a research theme of interest to you, then use the "Research Idea Summary" box to summarize the ideas from each cluster. The remote moderator (Nick) will then present the topics in the "Research Idea Summary" box to the other groups for discussion.

Group Moderators:

- CU Boulder: Moncef Krarti
- CCNY: Ahmed Mohamed
- Remote: Nick Clements

BEST Center Research Themes

Innovative Building Materials: Dynamically adaptive building shells and envelope systems adjust to changes in indoor and outdoor environments and effectively meet structural & efficiency requirements.

Advanced Energy Systems: Enhance the energy efficiency of various building systems and equipment to meet occupants' comfort and health needs and increase their productivity.

Integrated Energy Generation & Storage Systems: Integrated energy generation and storage systems include solar power generation integrated into building envelopes, combined heat and power systems, and thermo-electric generators.

Smart Buildings & Cities: Integrate energy efficiency technologies, advanced controls, and renewable energy resources to improve building and city design and operation.

Intelligent Grid Systems: Operate an increasing number of distributed energy resources to exchange energy optimally and efficiently between the electric grid and buildings.

Building Retrofit Applications: Improve energy efficiency and operation of existing buildings, including upgrades of the electrical, lighting, envelop, thermal systems, and controls in an existing building.

FY2024-2025 Research Project Executive Summaries

BEST24-05: Performance Evaluation and Grid Impacts of Intelligent Field Devices and Next-Generation Heat Pumps with an Application to Adaptive Reuse of Commercial Buildings

Research Team: Gregor Henze (CU Boulder)

The BEST Center is fundamentally about bringing together industry stakeholders that are committed to innovate the built environment in terms of sustainability, resilience, and intelligence. Some of the societal drivers for innovation include the housing affordability crisis, the need for adaptive reuse of underutilized commercial real estate, and harnessing the rapidly growing availability of data for enhanced building operations in what could be called the data-energy nexus.

Our IAB members (a) develop novel building systems and equipment, building materials and glazing systems, (b) provide power to an increasingly electrified built environment, (c) design effective solutions for new construction and retrofits that respond to the above societal drivers.

This project aspires to provide value for each of these three groups of IAB members by (a) evaluating the performance of novel building systems and equipment, e.g., intelligent field devices, (b) analyzing the impact of design choices and control strategies on electric distribution system operations, and (c) enhancing the ability of consulting engineers to evaluate design strategies involving a spectrum of smart and emerging technology options. Rather than creating yet another software tool, this work will integrate software industry standards and internationally supported software development efforts.

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BEST24-04: Design & Techno-Economic Assessment Tool for ASHP Systems for Cooling, Heating and Hot Water

Research Team: Prathap Ramamurthy (CCNY), Jorge Gonzalez-Cruz (U at Albany)

This project aims to begin the novel discovery process for building retrofitting strategies by leveraging the latest advancements in artificial intelligence (AI), machine learning (ML), coupled with EnergyPlus™ and the National Renewable Energy Laboratory's (NREL) REopt tool. With a focused goal of enhancing energy efficiency, ensuring economic viability, and promoting environmental sustainability, this project represents a significant step towards optimizing energy systems across various building types, including commercial, residential, and municipal structures.

At the core of this project is a commitment to achieving a path to substantial energy performance improvements. Forecasting a 30-40% increase in energy efficiency and a 20-30% reduction in peak energy demand, the project's targeted outcomes are ambitious but attainable. These efficiency gains and demand savings are underpinned by a sophisticated methodology that integrates predictive modeling with multi-objective optimization (MOO) techniques. The MOO framework, enriched by AI and ML algorithms, facilitates the identification of optimal retrofitting strategies that balance energy savings with economic and environmental considerations.

Central to the project's methodology is the use of the NREL REopt tool, a techno-economic decision support model that enables the comprehensive analysis of energy systems. REopt's capabilities are extended through the application of AI/ML algorithms, ensuring high-precision predictive modeling of retrofit measures. This integration allows for the evaluation of various energy conservation measures (ECMs) and the determination of their economic and environmental impacts. Through this approach, the project aims to deliver optimized retrofitting plans that demonstrate significant improvements in energy efficiency, carbon emissions reduction, and cost-effectiveness.

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BEST24-03: Feasibility Evaluation of Net-Positive Window Systems
Research Team: Moncef Krarti, Michael McGehee (CU Boulder)

Windows remain the building envelope elements with the weakest thermal performance with limited guidelines for manufacturers and building professionals on the best specifications suitable for a wide range of building types and climates. This project addresses this gap to provide clear recommendations and optical design specifications for both static and dynamic windows to achieve net zero energy performance for office buildings located in representative US climates. Specifically, the project will calculate the energy loss or gain based on U-values and solar heat gain coefficients for windows with many different combinations of insulating strategies (double pane, triple pane, vacuum insulating glass and aerogel) and dynamic tinting strategies (electrochromic, thermochromic, reversible metal electrodeposition.) It will show which windows could be net energy positive and enable the calculation of payback times, which will assist window companies, investors, and architects in deciding which window designs to prioritize. Based on the conducted sensitivity analyses, the project will attempt to provide general guidelines to select thermal/optical properties as well as control strategies and any additional integrated systems required for net positive energy windows when deployed in US office buildings.

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BEST24-02: Embodied Energy and Embodied Carbon Analysis of Residential & Commercial Building Envelopes
Research Team: Wil Srubar (CU Boulder)

The objectives of this project are (1) to define the first science-based benchmarks for *embodied energy* intensity (EEI) (MJ/m^2 or BTU/ft^2) and *embodied carbon* intensity (ECI) ($kgCO_2/m^2$ or $kgCO_2/ft^2$) for new residential and commercial building envelopes (*i.e.*, wall assemblies) in the US and (2) to develop and deploy an analytical tool that will give architects, engineers, and manufacturers an ability to quickly quantify the embodied energy and embodied carbon savings (or penalties) of new or alternative residential and commercial building envelopes compared to the established benchmarks.

This project will focus on embodied energy intensity (EEI) (MJ/m^2) and embodied carbon intensity (ECI, $kgCO_2/m^2$) benchmarking of *single-family residential building envelopes (i.e., wall assemblies)*. The project will be divided into five tasks. Task I will define typical single-family residential building envelopes. Task II will define material use intensities (MUIs, kg/m^2) of those assemblies using the US DOE single-family residential building prototype building model as the basis for analysis. Task III and IV will define the EEIs (MJ/m^2) and ECIs ($kgCO_2/m^2$) of typical single-family residential building envelopes, respectively. Task V will develop an analytical tool to compare the EEI and ECI of new or alternative single-family residential building envelope assemblies compared to the established EEI and ECI benchmarks.

The primary benefits to industry members are two-fold: (1) definition of science-based EEI and ECI benchmarks for single-family residential building envelopes in the US context will enable goal-setting in new building and retrofit projects and (2) a simple analytical tool will enable architects, engineers, and product manufacturers to quantify the potential savings (or penalties) in embodied energy and embodied carbon emissions of new residential and commercial building envelope assemblies compared to the established benchmarks.

BEST24-01: Enhancing Thermal Energy Harvesting and Storage using Monolithic Mesoporous Metamaterials (MMMs) and Phase Change Materials (PCMs)
Research Team: Ivan Smalyukh (CU Boulder)

Renewable energy sources offer promise, but their full potential is hindered by the lack of scalable, affordable, and sustainable energy storage systems. In the United States, buildings are major consumers of electricity, accounting for a staggering 74% of usage. This highlights the crucial role of energy storage within the building sector. While electrochemical batteries have seen advancements in storing electrical energy, concerns about their cost and materials question their suitability for buildings. As an alternative, thermal energy storage (TES) stands out for its affordability, durability, and ability to improve heating and cooling functions. Given that heating and cooling needs constitute over half of a building's energy demand, implementing on-site TES offers a sustainable and scalable complement to electrochemical storage, reducing reliance on traditional power grids and advancing energy independence and sustainability goals.
Solar heat can be easily harnessed during the daytime but is often needed during the night time. To achieve this, we combine transparent thermally insulating materials and phase change materials (PCMs) to allow for harnessing the solar heat energy when available and releasing when needed. PCMs, particularly in latent heat thermal storage systems, have gained attention for their ability to store passive solar and other heat gains within a specific temperature range. This results in decreased energy consumption, enhanced thermal comfort through the mitigation of temperature fluctuations, and reduced peak loads. Aerogels present further potential with their high optical transparency and exceptional insulation properties, facilitating heat retention within thermal energy storage systems. Despite challenges such as high costs and fragility, recent breakthroughs in our research group have addressed these issues by developing economically viable monolithic mesoporous metamaterials (MMMs) with exceptionally high insulation values (high R-value/inch), excellent transparency, and durability. These advancements position MMMs as optimal solutions for achieving enhanced thermal energy storage efficiency. This project is focused on maximizing solar energy utilization through MMMs, coupled with PCM to efficiently store thermal energy. The transparency of MMMs enables the absorption of solar radiation by PCM, creating a greenhouse effect, while their insulation properties minimize heat loss, elevating thermal storage efficiency to unprecedented levels. The system allows for efficient collection and storage of thermal energy during the day, which can be used at later times for various applications.