Center for High Performance Buildings (CHPB)

A center dedicated to partnering with industry in the development, demonstration, evaluation, and deployment of new technologies and analysis tools for high performance buildings.

CHPB Vision and Mission

Vision: To be the leading university research program for high performance building technology development and assessment.

Mission: To partner with industry in the development, demonstration, evaluation, and deployment of new technologies and analysis tools for high performance buildings.

Center for High Performance Buildings at Purdue

2016 Company Members

1. Bristol Compressors International, Inc.
2. Danfoss
3. Duke Energy
4. Emerson Climate Technologies
5. Field Diagnostic Services, Inc.
6. Honeywell International Inc.
7. Johnson Controls, Inc.
8. Jones Lang Lasalle (JLL)
9. Kawneer Company, Inc.
10. Lennox International Inc.
11. Regal Beloit Corporation
12. Siemens AG
13. UTC Carrier Corporation
14. Whirlpool

2016 Research Projects

1. Development of Self-Tuned Indoor Environments
2. Investigation of Chemical Looping for High Efficiency Heat Pumping
3. Development of General Purpose Simulation Tools for Positive Displacement Compressors
4. Evaluating the Benefits across the U.S. of Variable-Speed Equipment for Packaged Rooftop Units (RTUs)
5. Optimizing Seasonal Cooling and Heating Performance of Unitary Heat Pumps using Variable Speed Compressors and Fans
6. A Sequential Approach for Achieving Separate Sensible and Latent Cooling

2016 Research Projects

7. High Performance, Multi-Functional Building Envelopes Integrated with Lighting and Thermal Systems operation
8. Assessment of Alternative Technologies for Sustainable Housing Developments
9. An Inverse Modeling Toolbox for Buildings
10. Further Development of Fast Fluid Dynamics for Indoor Air Quality and Thermal Comfort Study and Control
11. Development of a simulation model predicting efficiency gains for residential appliances utilizing thermal integration
12. National/Regional Assessments of Demand Response Potential in Small Commercial Buildings
13. Automation and Demonstration of an RTU Coordinator in Small/Medium-sized Commercial Buildings

Comparison to Existing University Centers

- University of Illinois: ACRC
  - Emphasis on heat transfer and components
  - Initiated through NSF I/UCRC program

- University of Maryland: CEEE
  - Emphasis on components and primary cooling equipment
  - Collection of consortia: alternative cooling technologies, advanced heat exchangers, electronics cooling, …

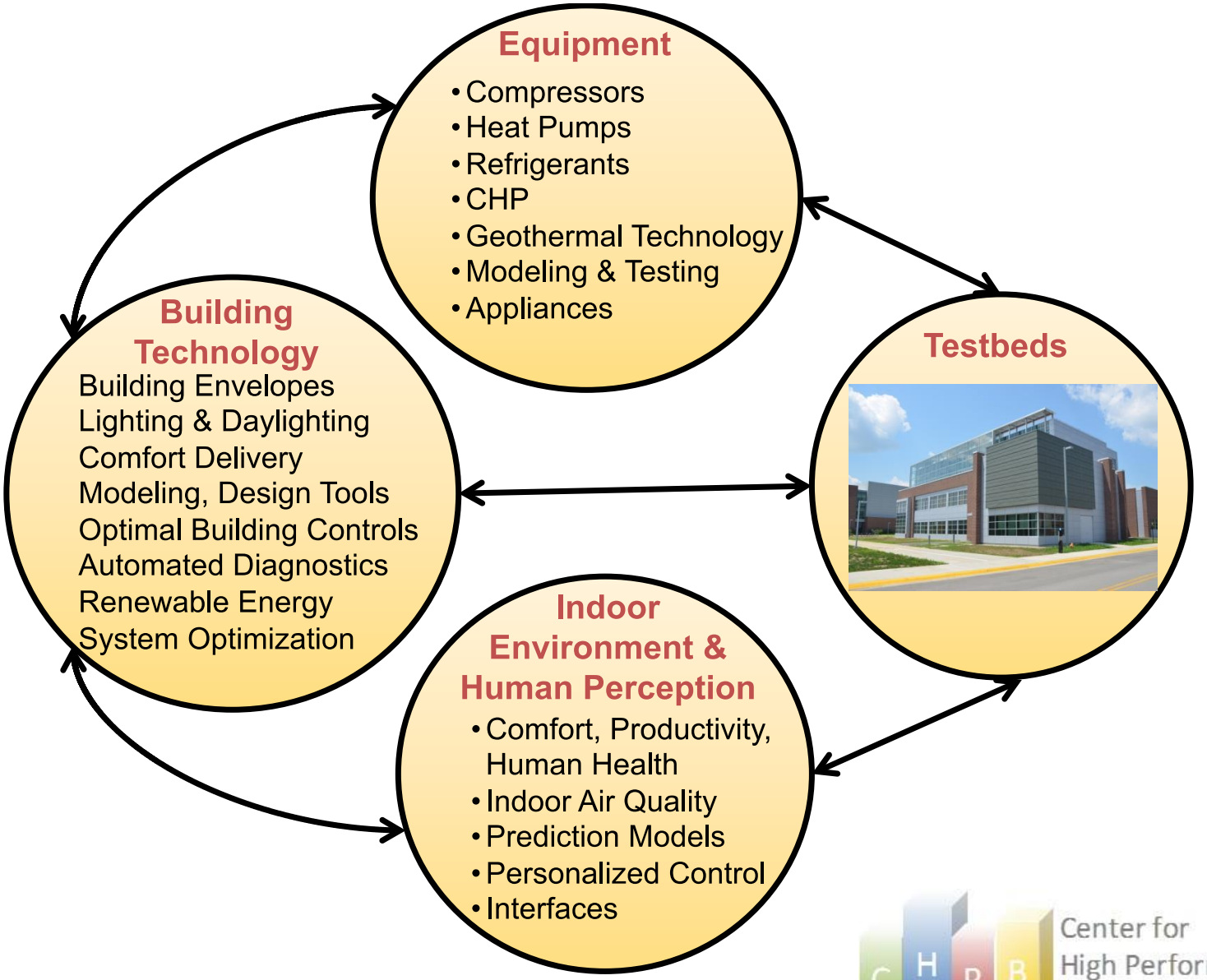
Comparison to Existing University Centers

- UC-Berkeley: CBE
  - Emphasis on occupant comfort and comfort delivery systems

- Purdue: CHPB
  - Expertise and facilities to study occupant comfort, comfort delivery, components, primary equipment, sub-systems, building envelopes, controls, automated diagnostics, integrated systems, ..
  - ***Integrated building systems and range of expertise/test beds are differentiators***

Center for High Performance Buildings at Purdue

Range of CHPB Research Activities



Center for High Performance Buildings at Purdue

CHPB Faculty

Professor	Primary Research Activities
Jim Braun	Modeling, analysis, and optimization with applications to: *Intelligent Controls, Automated Diagnostics, Component & System Improvements, Building Simulation Tools*
Stuart Bolton	Noise Control, Sound Absorbing Materials & Systems, Sound Propagation & Transmission, Source Characterization, & Sound Field Visualization & Simulation
Brandon Boor	Characterizing the dynamics of airborne particles (aerosols) in buildings and human exposure to indoor and urban air pollutants
Qingyan Chen	CFD for air flow in & around buildings with applications to: *Indoor Air Quality, Homeland Security, Energy Analysis*
George Chiu	Dynamic Systems and Control, Mechatronics, Embedded Systems and Real-Time Control

CHPB Faculty

Professor	Primary Research Activities
Patricia Davies	*Impacts of Noise on People*: Annoyance, Speech Interference, Sleep Disturbance; Sound Quality & Sound Perception. System Identification and Signal Processing.
Eckhard Groll	Experiments and modeling with applications to: *Alternative Refrigeration Technologies, Natural Refrigerants, Component & System Performance*
Travis Horton	*Ground-Coupled Heat Pumps, Building Energy Performance Analysis*
Jianghai Hu	Multi-agent systems; control of uncertain systems; *energy efficient building management*
Neera Jain	Dynamic modeling and optimal control; model predictive control; decentralized control with applications to; *distributed generation, variable refrigerant flow equipment, building systems*

Center for High Performance Buildings at Purdue

CHPB Faculty

Professor	Primary Research Activities
Panagiota Karava	*Mixed-Mode Buildings, Building-Integrated Solar Energy Systems, Buildings Systems Modeling and Identification, Model-Predictive Control, Human-Building Interactions*
Robert Proctor	Human Performance, Human Factors & Human-Computer Interaction, & Experimental Research Methods
Ming Qu	*Solar Systems, Intelligent Controls, Absorption Systems*
Thanos Tzempelikos	*Building Envelope, Lighting and Daylighting, Dynamic Facades, Thermal and Visual Comfort, Building Simulation*

Other Potential Collaborators

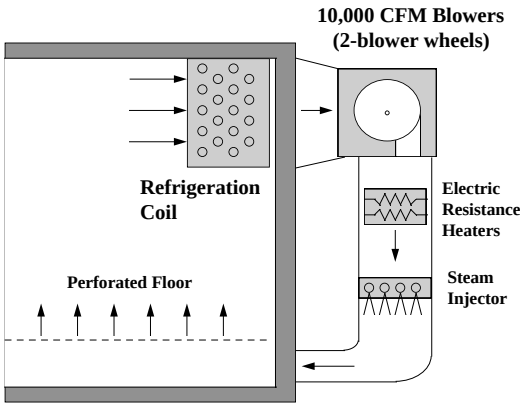
- Vijay Raghunathan (https://engineering.purdue.edu/~vr/)
  - Associate Professor Electrical and Computer Engineering
  - Leads Embedded Systems Lab
  - Hardware and software architectures for embedded systems, wireless sensors for the Internet of Things (IoT), and wearable and implantable electronics: emphasis on low power design, micro-scale energy harvesting, emerging memory technologies, and reliable/secure system design

- Jennifer Neville (https://www.cs.purdue.edu/homes/neville/)
  - Associate Professor and Miller Family Chair of Computer Science and Statistics
  - Design and implementation of machine learning and data mining techniques; discovery of, and adjustment for, statistical biases due to networks data characteristics; application to real-world tasks

Old Herrick Facilities

Two Large Environmental Chambers

- Testing of AC, HP and Refrig. Systems
- -20 C to + 50 C, < 5-ton equipment
- Steady-state and cyclic testing of existing, modified, or new equipment designs



90-ton Centrifugal Chiller

- Automated control of boundary conditions

Heat Exchanger Test Facility

- Testing of coiling coils, heating coils, evaporators, condensers
- Capable of controlled heat exchanger fouling

Compressor Test Facilities

- CO_2, R22, R410a Load Stands
- Compressor Calorimeter

Noise and Vibration Laboratory

- Noise source identification
- Sound quality facility

Center for
High Performance
Buildings at Purdue

Old Herrick Facilities

Indoor Environmental Chamber

Center for
High Performance
Buildings at Purdue

Architectural Engineering Facilities at Bowen

- Full-scale offices to study the impact of envelope systems and façade/lighting/thermal controls on energy use and indoor environment
- Testing facility for MPC strategies in buildings with mixed-mode cooling
- BIPV/T testing facility
- Concentrating solar collectors with absorption cooling

New Herrick Facilities

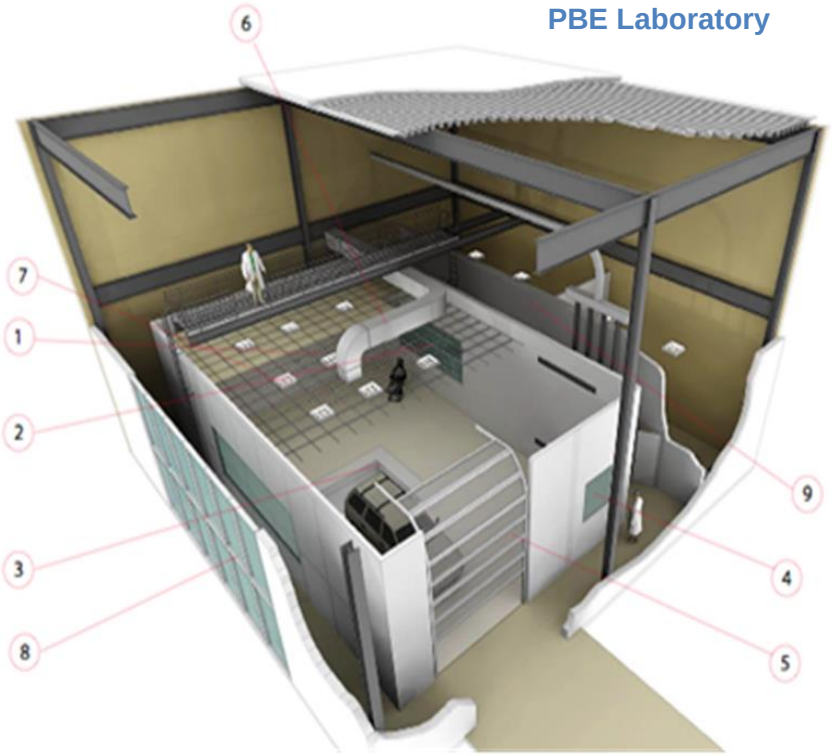
- **Perception-Based Engineering Laboratory:** study combined impacts of lighting, acoustics, air quality, temperature, humidity and air flow on occupant perceptions and performance
- **Psychrometric Rooms** – Two pairs of rooms with extended temperature and humidity ranges and capacity compared to existing rooms at Old Herrick
- **Geothermal Ground Loop:** Allows testing for model validation, control algorithms, equipment coupling, alternative bore designs, etc.
- **Indoor Air Quality Room** – Reproduces and expands capabilities compared to Old Herrick
- **Living Laboratories:** fully-instrumented occupied laboratory offices with reconfigurable facades, comfort delivery, primary equipment, and controls to allow testing for impacts of new building technologies on energy and occupant performance

New Herrick Facilities

Center for
High Performance
Buildings at Purdue

Perception-Based Engineering Lab

PBE Laboratory

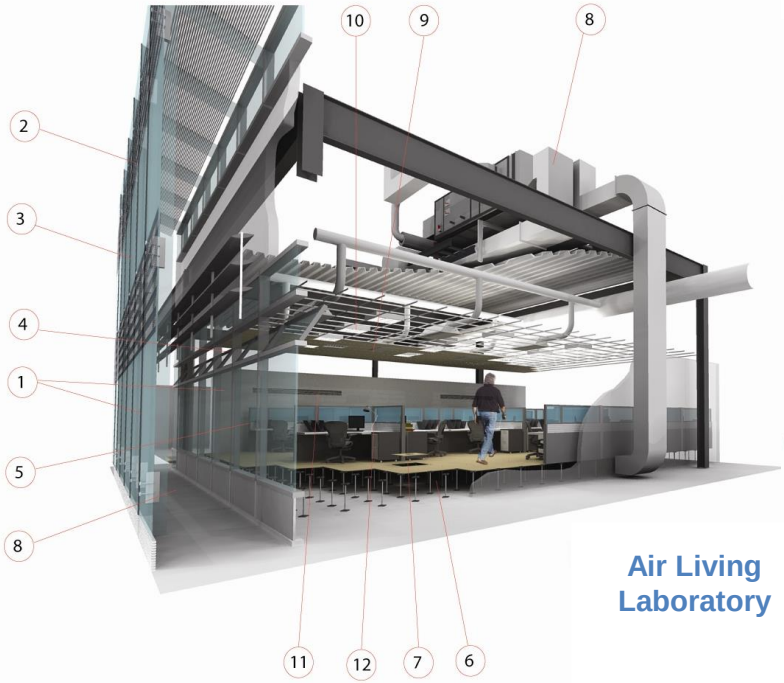


PBE Lab Control Room

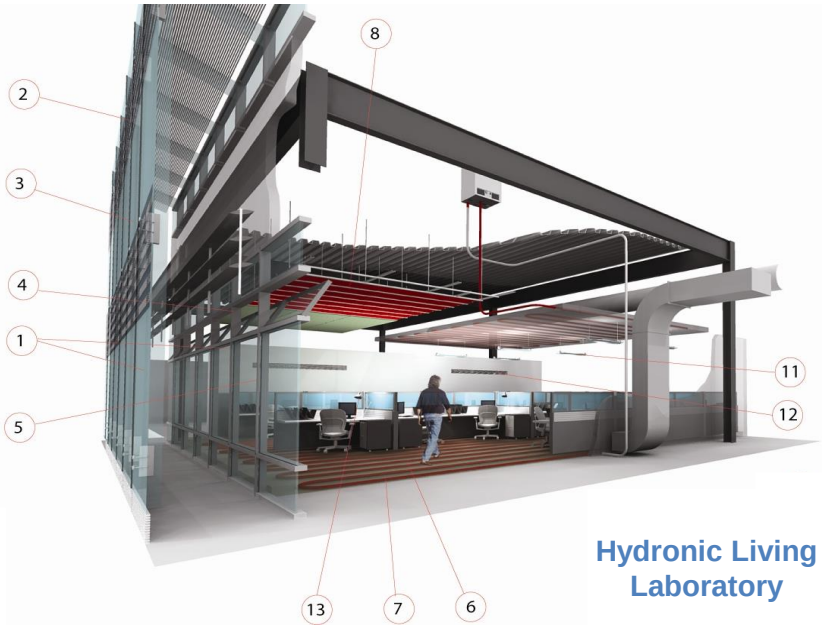
***PBE Lab Features**: 1. Accessible ceiling, 2. Observation panel, 3. 2-D shaker table, 4. Reconfigurable walls/room, 5. Overhead doors, 6. Reconfigurable overhead utilities, 7. Reconfigurable lighting, 8. South facing daylight exposure aligned with reconfigurable window/wall in lab, 9. Control room and subject reception area.*

Center for High Performance Buildings at Purdue

Living Laboratories



Air Living Laboratory



Hydronic Living Laboratory

Reconfigurable Features *with Opportunities for: 1. Double Skin Façade, 2. Integrated PV, 3. Advanced Glazing Materials, 4. Natural Ventilation, 5. Controllable Glazing: Visible Light Transmittance and Thermal Performance, 6. Underfloor Air Distribution (Air) or Radiant Floor Heating (Hydronic), 7. Personnel Ventilation Control (Air) or Integrated Thermal Mass (Hydronic), 8. Primary Air System with Broad Delivery Range (Air) or Radiant Ceiling Panels (Hydronic), 9. Overhead Air Distribution (Air) or Active and Passive Chilled Beams (Hydronic), 10. Overhead Light Fixtures (Air) or Displacement Ventilation (Hydronic), 11.Wall Light Fixtures (Air) or Overhead Light Fixtures (Hydronic), 12. Task Fixtures (Air) or Wall Light Fixtures (Hydronic), 13. Task Fixtures (Hydronic)*

Center for High Performance Buildings at Purdue

CHPB Management

- Focused on research activities that benefit CHPB members
- Actively involve CHPB member companies in planning and executing research projects
  - CHPB members identify research needs
  - CHPB members pledge their membership fees to research projects of their choosing
  - Project monitoring subcommittees formed from CHPB members that monitor and guide research activities

Types of CHPB Members Research

- Needs to be pre-competitive or have broad value across industry segments
  - **Generating better understanding of processes or new fundamental knowledge** → e.g., effect of indoor environment on occupant productivity
  - **General assessments of new/evolving technology** → demonstrations and/or broad evaluations across different regions to evaluate the business case for advanced retrofits, controls, diagnostics, etc.
  - **Development of general modeling approaches and/or software tools** → e.g., compressors, equipment, envelopes, building systems, etc.
  - **Tracking and assessing technology responses to new regulations or standards** → e.g., evaluating most cost effective approaches to meet future energy efficiency standards
  - **Development of improved standards** → e.g., methods for more effectively characterizing real HVAC equipment performance (part-load, economizers, acoustic, ..)
  - …..

CHPB Operating Procedures

CHPB Faculty Members

- Comprised of core CHPB researchers having offices and students located in HLAB

CHPB Industrial Steering Committee Members (ISC)

- Comprised of one designated representative from each of the CHPB company members
- Provide guidance to CHPB regarding research directions; allocation of CHPB resources for specific research projects; educational and technology transfer programs; changes in operating procedures and policies; and industrial/Intellectual property protection
- Meet twice a year in conjunction with CHPB bi-annual meetings
- ISC meetings are run by a chairperson who is selected by the CHPB director from the ISC members

CHPB Operating Procedures

CHPB Research Proposal Process

Pre-proposal Evaluation – Spring

- Faculty submit one-page concept papers with approximate budget one month prior to spring meeting
- Faculty provide 5-minute presentation of project concept at spring meeting
- ISC provides Go/No-Go recommendations for proposal development to CHPB Director
- Proposal feedback provided to faculty following spring meeting

CHPB Operating Procedures

CHPB Research Proposal Process

Proposal Evaluation – Fall

- Faculty submit 2 to 3 page proposals with budgets one month prior to fall meeting
- ISC selects funded projects in closed session at fall meeting

Proposal Planning – between Fall and Spring

- Research project brainstorming session held at fall meeting with faculty and CHPB industry members
- Individual CHPB industry members provide statement of research needs (1 to 2 paragraphs) within a month after fall meeting

CHPB Operating Procedures

Research Project Proposal Guidelines

- Proposals must include at least one CHPB faculty member: can bring in other expertise as needed
- Proposals are limited to 1 year: can lay out a vision for multiple years but a new project must be approved each year
- Budgets include small internal overhead (10-15%) to support CHPB infrastructure
- Typical 1-year budgets of $60-70K

Center for High Performance Buildings at Purdue

CHPB Operating Procedures

Research Project Selection Process – Fall Meeting

- Project proposal review comments made available to ISC members
- ISC meets in closed session to select projects using bidding process
  - ISC members use virtual money for bidding ($50K for larger, $30K for smaller companies)
  - ISC chairperson offers projects for bidding in no particular order
  - Individual companies bid a portion or all of their money for individual projects (companies can combine resources to fund a project)
  - Project is a “go” & removed from bidding when funding matches budget
  - Project that receives bids but is underfunded has another chance to be funded in the next round
  - Project that receives no bids is removed from the bidding
  - Project failing to get funded on 2nd try is removed from bidding
  - Process continues until there are no remaining projects for bid or there are insufficient funds for any of the remaining projects
  - Excess funding after the bidding process goes into the administrative fund for the CHPB

CHPB Operating Procedures

Research Project Reporting and Monitoring

- Project monitoring subcommittees (PMS) are formed during the fall meeting for each selected project and include one representative from each of the companies who were part of the final bids on that project
- PMS members select a PMS chair
- Projects are launched on January 1 of each year just following the fall meeting where they were selected
- Project lead sends short monthly written progress reports to PMS and also posts them under the project on a secure section of the CHPB website to provide access for all CHPB members
- Project lead organizes monthly or quarterly conference calls with PMS to provide updates on progress and plans
- Face-to-face project review meetings are held with PMS members at spring and fall meetings

CHPB Operating Procedures

Research Project Reporting and Monitoring

- Selected project presentations are given to entire CHPB members group in spring
- All projects present posters during a dedicated poster session at fall meetings
- Any theses and papers resulting from the project are posted under the project on a secure section of the CHPB website to provide access for all CHPB members

CHPB Operating Procedures

Spring Meetings of the CHPB

Joint Sessions (faculty and CHPB industry members)

- Selected presentations for on-going and related research projects
- 5-minute research project pre-proposal presentations by faculty for next year's projects

PMS Meetings

- Face-to-face meetings between PMS and project researchers

ISC Meetings

- Closed meeting to evaluate research project concept pre-proposals
- Meeting with director to provide guidance on CHPB management

CHPB Operating Procedures

Fall Meetings of the CHPB

Joint Sessions (faculty and CHPB industry members)

- Poster session for all current projects
- Selected presentations for on-going and related research projects
- Brainstorm research ideas for development of statement of needs

PMS Meetings

- Face-to-face meetings between PMS and project researchers

ISC Meetings

- Closed door meeting to choose research projects for coming year
- Meeting with director to provide guidance on CHPB management

CHPB Operating Procedures

CHPB Member Responsibilities

- Must confirm membership 60 days prior to beginning of new CHPB calendar year of membership (Jan – Dec)
- Can bring up to 3 representatives of their company to CHPB spring and fall meetings
- Must select one company representative to serve on ISC
- Must select one company representative to serve on PMS for all upcoming projects where they were part of the final bids
- Should participate in the development of research needs and provide feedback to CHPB faculty on research ideas and proposals
- Should provide guidance on CHPB management

IP Policy

- Purdue owns any IP coming out of member sponsored research
- CHPB will furnish members a disclosure of intellectual property developed by member research projects
- Each full member will have an option, within 60 days of receiving disclosure, to a exclusive/co-exclusive, royalty-bearing, paid-up license
- The paid-up license fee will be each members portion of all costs and fees for patent protection (for those members opting for the license)

Publication Policy

- PURDUE has the right to publish CHPB results in professional journals or at conferences
- Papers and presentations from CHPB projects provided to MEMBERS ninety (90) days prior to any submission.
- Members have thirty (30) days to review and identify (in writing) any proprietary information that should be removed

CHPB Members Program Timeline

Date	Description
Oct-Nov	Fall CHPB members meeting 1) establish research agenda for the 1st year of the CHPB 2) evaluate/improve processes for managing the CHPB projects and other initiatives going forward
Dec 31	1st half of membership fees due
Jan 1	Launch of CHPB research program
Mar 31	2nd half of membership fees due
Apr-May	Workshop for “new” interested companies
Apr-May	Spring CHPB members meeting 1) Project reviews 2) Present research concepts for following year

Center for High Performance Buildings at Purdue

Questions?