BUILDINGS ENERGY EFFICIENCY CONSORTIUM

U.S. - CHINA CLEAN ENERGY RESEARCH CENTER (CERC-BEE)

Introduction to CERC-BEE

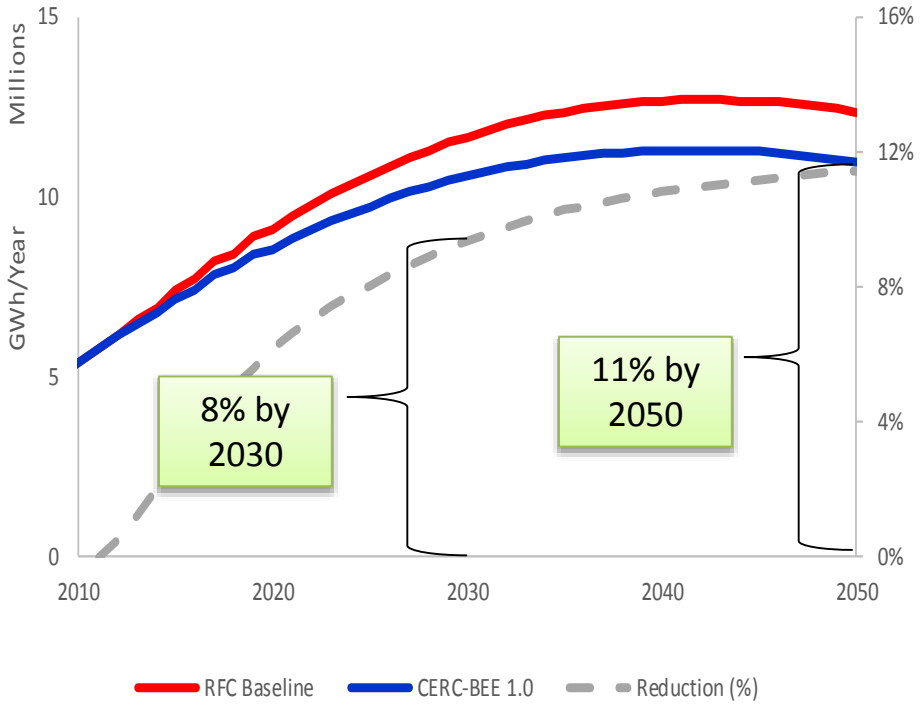
Presented by: Dr. Nan Zhou, Staff Scientist at
Lawrence Berkeley National Laboratory (LBNL) and
CERC BEE U.S. Director

March 2017

U.S.–China R&D Consortium with Real World Impact

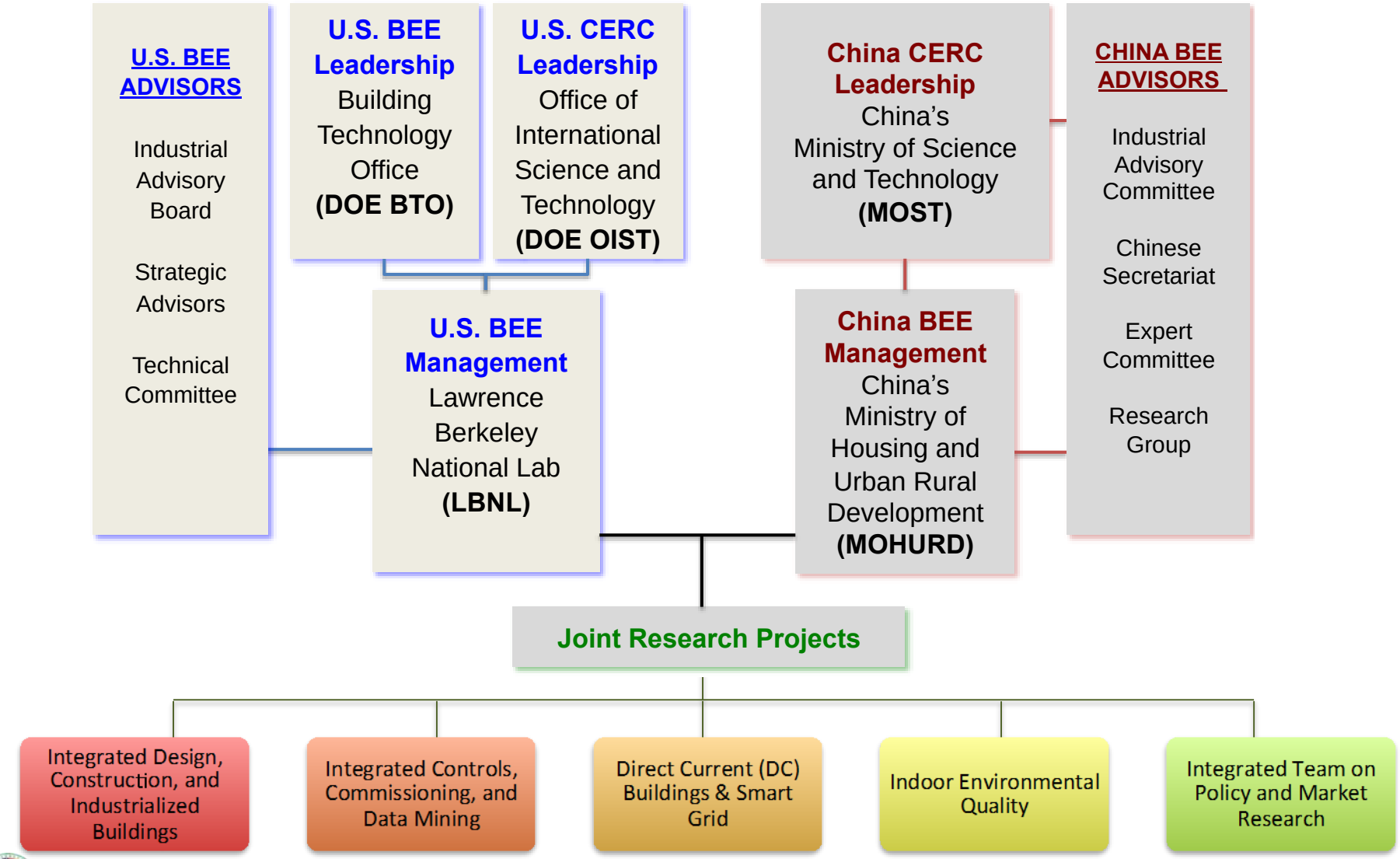
- Initiated at the presidential level in 2009 (CERC 1.0), renewed in 2014 (CERC 2.0).
- Vision: Achieve large scale adoption of very low energy buildings in the U.S. and China.
- CERC 1.0 (2010-2015): $50M+, five year program with shared investment from government and industry.

Annual Energy Savings of CERC-BEE 1.0 Technologies Against BAU*



- Nachtrieb et al. "CERC-BEE Impact Model." Unpublished report, last modified December 9, 2016.

CERC-BEE Organization Chart



U.S. CERC-BEE ORGANIZATION

U.S. LEADERSHIP
DOE OPI
Bob Marley
U.S. Director, CERC

U.S. LEADERSHIP
DOE BTO
Dave Nemtzow &
Karma Sawyer,
Technical Oversight

U.S. Advisors
Industrial Board
Clay Nesler
(Johnson Controls), *Chair*

Technical
Patrick Hughes
Adam Hinge
John Millhone
Carl Blumstein

Strategic
Bill Jackson
Tom McCawley
Brian Heimberg

LBNL
Nan Zhou
Director, CERC-BEE
Rick Diamond
Deputy Director, CERC-BEE
Carolyn Szum
Operations Manager
Yao Yuan
China Liaison

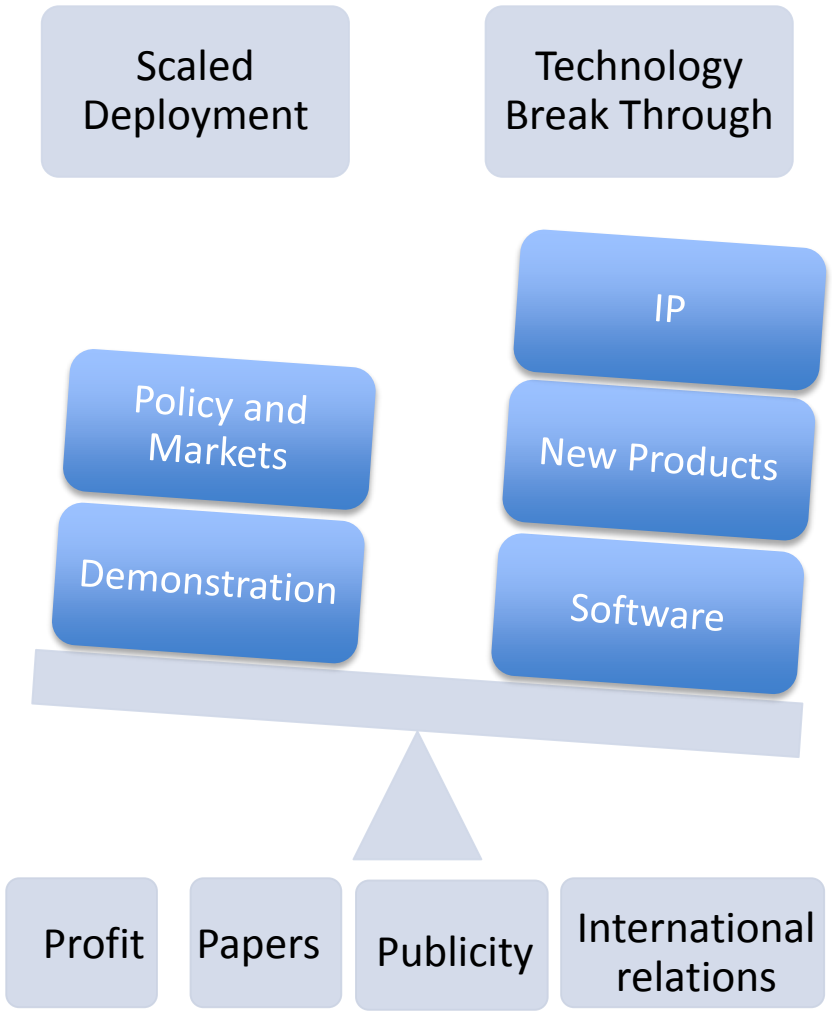
Research Groups

Industry

CERC-BEE Unique Criteria For Selection and Evaluation of Projects

6 Criteria:

1. Beneficial outcomes for U.S. and China;
2. Research emphasis on science, technology and innovation, with potential for intellectual property (IP), ideally joint IP;
3. Scalable impact on energy and emissions.
4. Potential path to commercialization of resulting knowledge or technology;
5. Evidence of business partners from both countries participating in each CERC project;
6. Evidence of "other-country" collaborators participating in each CERC project.



Impact and Approaches

100 million tons CO_2 reduction per year by 2025

Pioneering collaboration model with foundational IP protection

Accelerated technology development and deployment benefiting both countries

Development

Technology Innovation:

- New state-of-the art products
- Software
- Tools
- Guidebooks

Demonstration

Pilot Buildings:

- Demonstrating value of technologies
- Accelerating development
- Commercial impact

Deployment

Codes and Market:

- Industry commercialization
- Policies and standards
- Trainings
- Financing and service delivery models

>71 Research & Industry Partners

Supported by U.S. Department of Energy and China Ministry of Science Technology, with:

>13 U.S. & China Research Partners

MoHURD Center of Science & Technology of Construction

Tsinghua University

China Academy of Building Research

Chongqing University

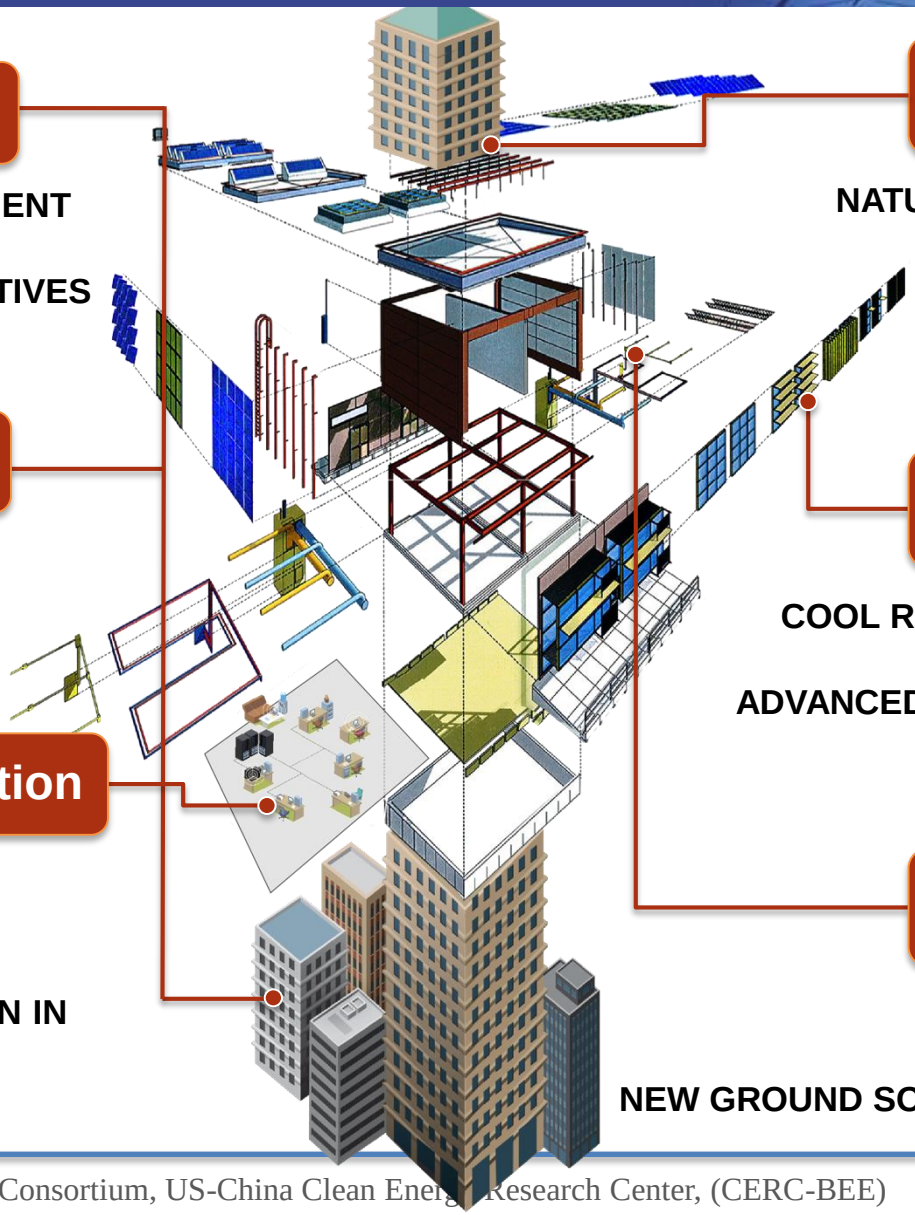
Tongji University

Tianjin University

China Society for Urban Studies

>59 U.S. & China Industry Partners including:

CERC-BEE 1.0
A Portfolio to Deliver Real World Impact



Policy, Market

DATA & ENERGY MANAGEMENT

POLICY ANALYSIS & INCENTIVES

Demonstrations

BUILDING TECHNOLOGY INTEGRATION

Renewables Integration

BUILDING TECHNOLOGY INTEGRATION

INTEGRATION & OPERATION IN REAL TIME

Design

NATURAL VENTILATION DESIGN

INTEGRATED DESIGN

OCCUPANT BEHAVIOR

Envelope

COOL ROOFS/SURFACE COATINGS

ADVANCED WINDOW TECHNOLOGIES

INSULATION

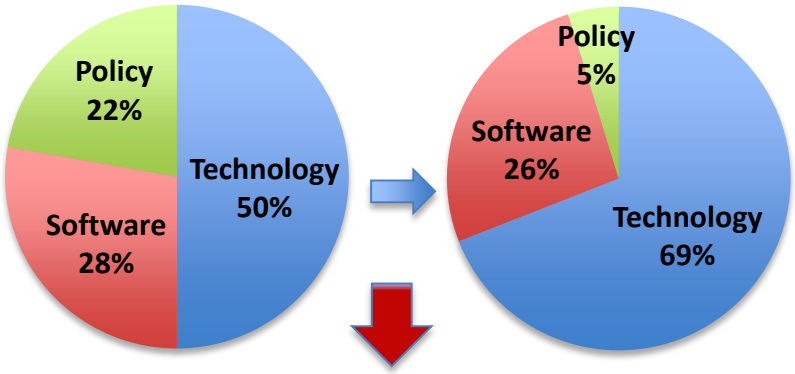
Equipment

LIGHTING CONTROLS

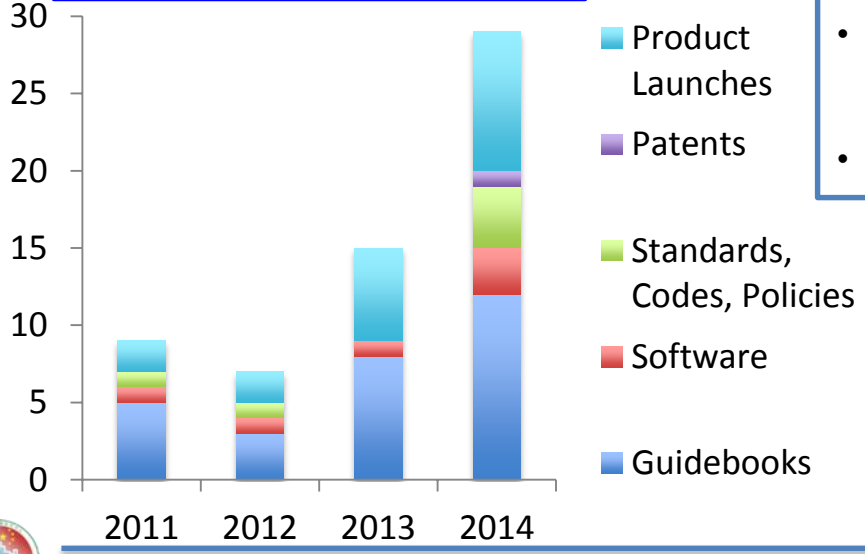
NEW GROUND SOURCE HEAT PUMP DESIGN

Rigorous and Dynamic Portfolio Management and Review Process Ensuring Technical Quality

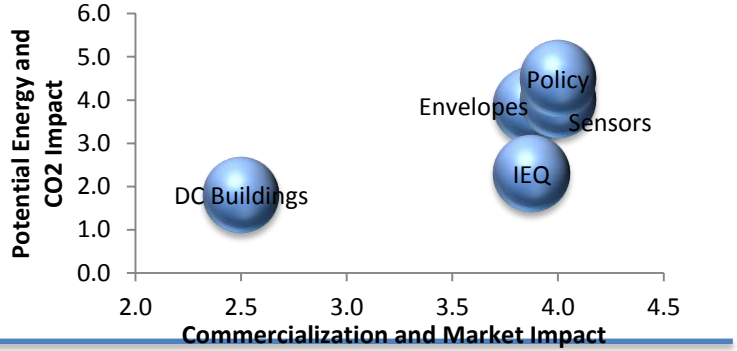
Investment shift in 2013



Outputs



- Annual Steering Committee Meeting by Secretory of DOE and China Minister of MoST
- Annual BTO Peer Review
- Annual U.S.-China Joint Review and Planning meeting
- Merit Review
- GAO audits
- Quarterly technical progress reports, by R&D project area, delivered to BTO. Includes key accomplishments/project milestones and budget status by R&D project area.
- Semi-annual webinars, by R&D project area to BTO. Includes key accomplishments/project milestones and budget status by R&D project area.
- Quarterly updates to the BTO AOP, describing progress against CERC-BEE program milestones/deliverables.
- Quarterly updates to IA's "Metrics/Indicators" report, which includes key R&D achievements (i.e., patents, publications, trainings) across the CERC-BEE program.
- Monthly BTO-IAB-CERC Management Check-In meetings.



List of Key Accomplishments

Products Launched

- 3M: daylight redirecting window launched
- ClimateMaster: Co-axial ground heat exchanger (GHX) and Trilogy integrated heat pump
- DOW: LIQUIDARMOR – RS and LIQUIDARMOR – CM

Patents & Invention Disclosures

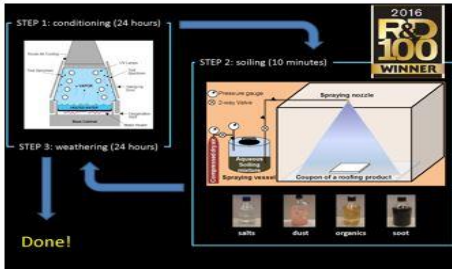
- DOW Air sealing - US 8,641,846 B2
- Smart Pumping Control for Hydraulic Distribution Systems
- Incorporation of SH powders in water based acrylic coatings

Standards, Codes, Policies

- ISO 15099 for standardized characterization of window and fenestration products
- China Building Energy Consumption Standard
- MOHURD national energy performance benchmarking and disclosure (EPB&PD) policy

Copyrights Software

- Enhancement to EnergyPlus, Behavior software module
- DER-CAM, webopt and operation DER-CAM
- Online Hotel Commercial building benchmarking tool for China



- LIQUIDARMOR, by DOW and ORNL, wins 2016 Gold Edison Award for Building Construction & Lighting Innovations and is selected as an 2015 R&D100 finalist.
- ClimateMaster's next-generation ground source heat pump system wins *R&D Magazine's* 2013 R&D 100 Award.
- LBNL wins 2016 R&D 100 Award for the Cool Roof Time Machine

Equipment & Envelope Innovation

Next Generation GSHP Systems

Low-cost, integrated, smart controls

- ClimateMaster, ORNL, CABR, Tongji U., Tianjin U., and ChongingU.
- Designed new GHX that uses **14%–30%** less drilling and energy.
- Developed first-of- its-kind R&D center and test bed for distributed GSHP systems at CABR.
- Developed a new analytic tool for cost monitoring and detecting faults in GSHP systems.
- Designed an innovative flow-demand-based control to **reduce pumping energy by 20%.**
- ClimateMaster launches Co-axial GHX and the Trilogy integrated heat pump, which wins R&D 100 Award.

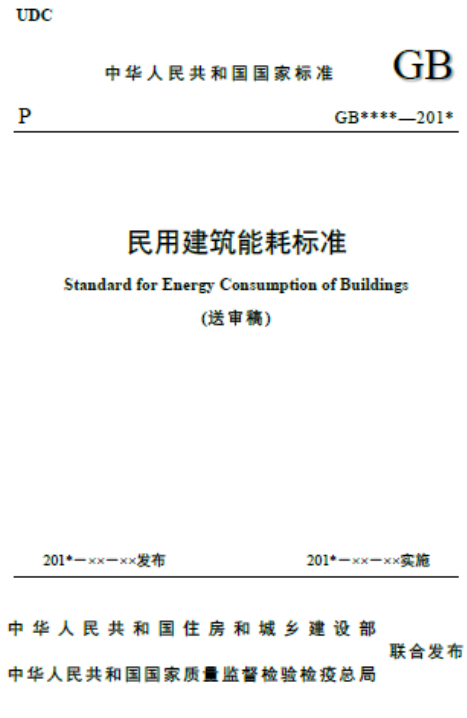
Liquid Flashing

Easy to Apply, Low-toxicity

- Dow, ORNL, and CABR created materials and testing procedures.
- **~10%** decrease in heating loads in commercial buildings in the U.S.
- Low cost and bridges gaps up to ¼” wide without supporting materials.
- Reduces installation time by **50 to 75%** when compared to tape.
- Selected as an R&D100 finalist in 2015 and won the 2016 Gold Edison Award for Building Construction & Lighting Innovations.

New Energy Conservation Standards & Tools

Residential Building Energy Consumption Standard GB/T 51161-2016


UDC

中华人民共和国国家标准 GB

P GB****—201*

民用建筑能耗标准

Standard for Energy Consumption of Buildings

(送审稿)

201*—××—××发布 201*—××—××实施

中华人民共和国住房和城乡建设部

联合发布

中华人民共和国国家质量监督检验检疫总局

- Planning Stage
- Plan Bidding
- Plan Design
- Drawing Design
- Equipment
- Bidding
- Construction Controlling
- Operation Management
- Diagnosis of Energy Saving

- The **first outcome-based standard**.
- Constraint value, advanced value for different climates.
- Guide the design, construction, and operation of the whole building.
- Focus on the usage patterns, O&M level of the buildings.
- **Implemented from Dec. 1st , 2016**.

Building Operational Energy Performance Benchmarking Tool

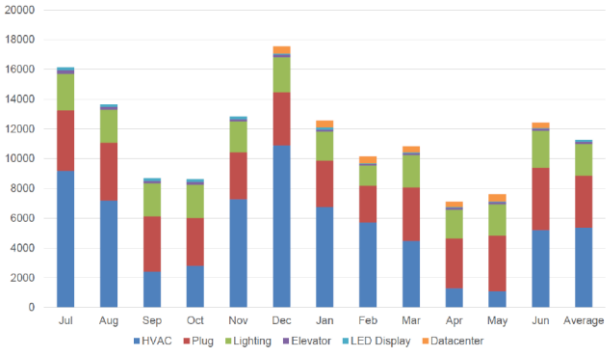
- Evaluates **whole-building, operational energy performance** relative to peers.
- **Normalizes** for factors such as climate, weather, size, and occupancy, and converts site to source energy for a more equitable comparison of performance.
- **Available on-line for offices, hotels, hospitals, and shopping malls** at http://115.29.110.113/.
- Incorporated into Chinese national *Code for Operation and Management of Central Air Conditioning System GB50365*.
- Incorporated into China's *Energy Performance Benchmarking & Public Disclosure (EPB&PD) in Large Public Buildings* pilot program.

CERC 1.0 Demonstration Projects Yield Meaningful Technological Progress

#1 Beijing, CABR Demo Building

- Office, cold climate zone, 4025m^2
- Energy Intensity 25 kWh/(m2.a) (37kWh/(m^2·a) total energy)
- 0 fossil fuel for space heating
- Uses 50% less energy for cooling
- Uses 75% less energy for lighting
- High actual indoor environment satisfaction level
- After adjustment, the efficiency of various systems is higher

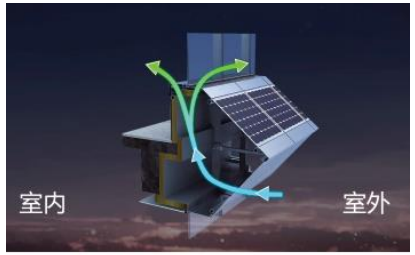
CABR Demo



Annual Energy Consumption Index Value

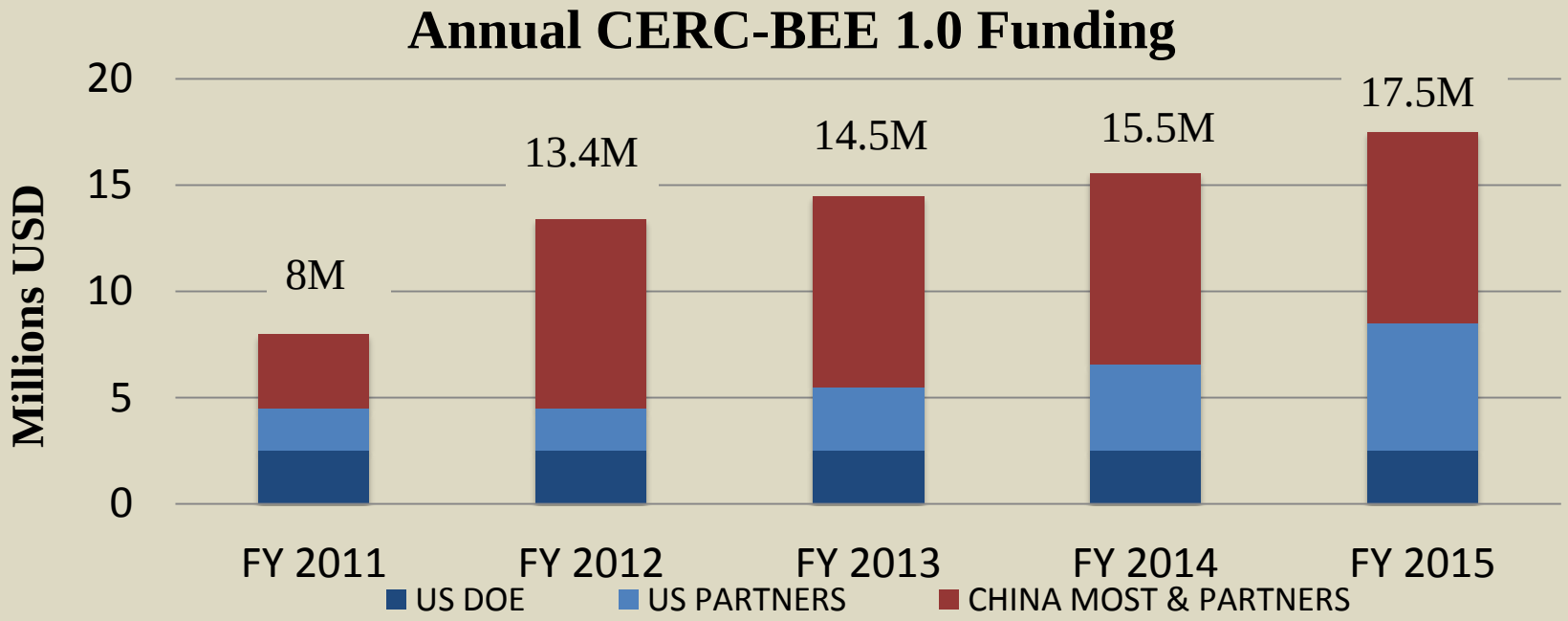
#2 Zhuhai, Xingye Demo Building

- Office Building, 23,500 m^2, Hot Summer and Warm Winter zone
- Annual Energy Intensity：52.4kWh/m^2·a
- Energy Saving Target：76.7%
- Renewable energy：172,863 kWh
- Percentage of Renewable energy：14.4%

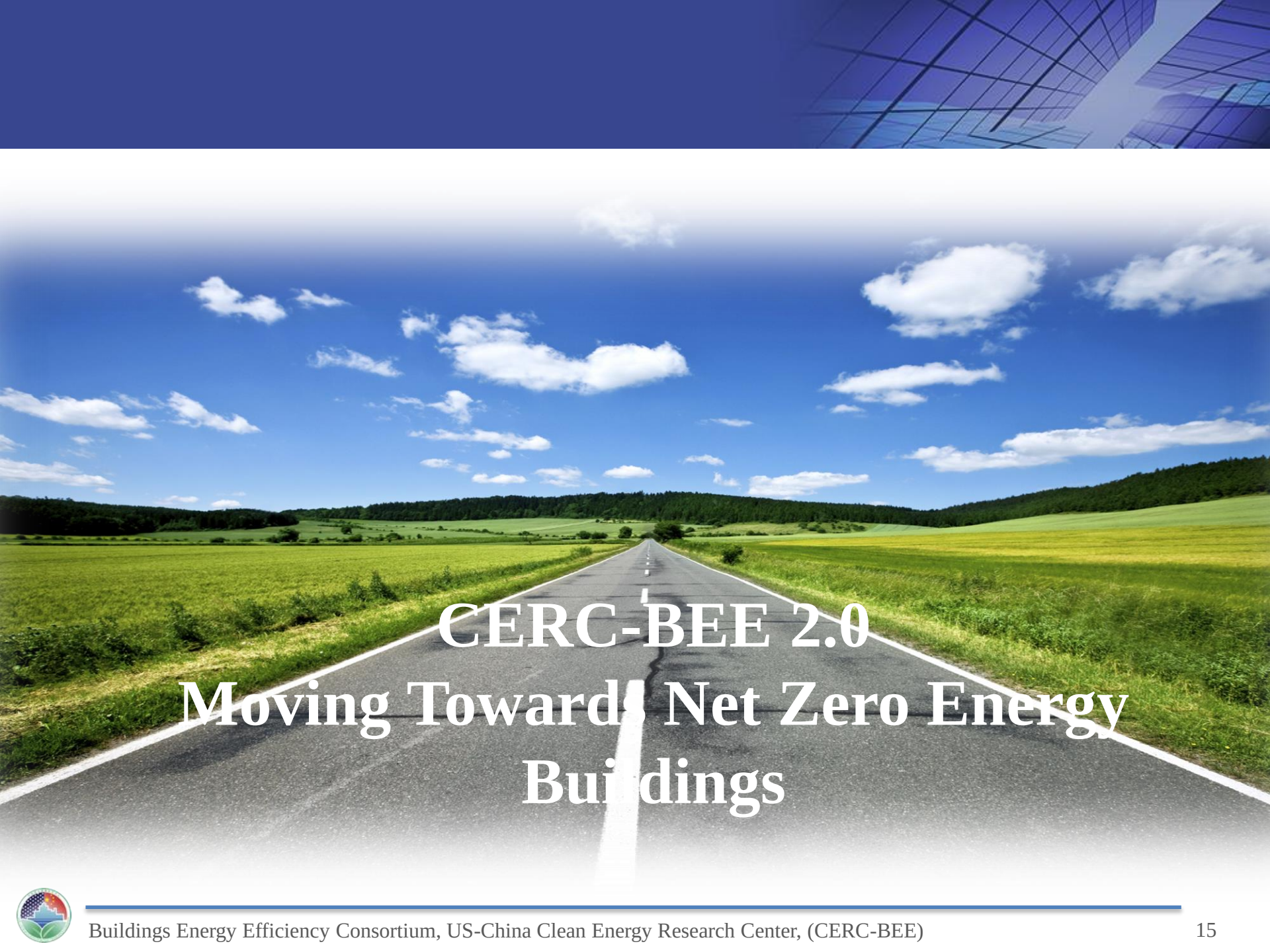


春秋过渡季节及夜晚

CERC-BEE Demonstrating Strong Industry Engagement and Leverage



- Industrial partners see value, demonstrated by +30% annual average growth rate for cash and in-kind contributions to date
- Projected 5-year total program funding of $69M vs. $50M planned (+38%)


CERC-BEE 2.0
Moving Towards Net Zero Energy Buildings

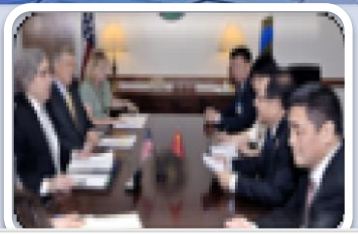
Program Prioritization to Focus on High Impact Projects

2011-2013 CERC1.0

- 35 projects, 50% joint
- Projects too scattered, disconnected
- Focusing on small incremental improvement in single component
- Producing reports and papers

2013-2015 CERC 1.2

- 14 projects, 100% joint
- Projects more focused and aggregated, but still disconnected
- Demo projects to test integration of technologies
- Shifting investment focusing on innovation
- Independent IP

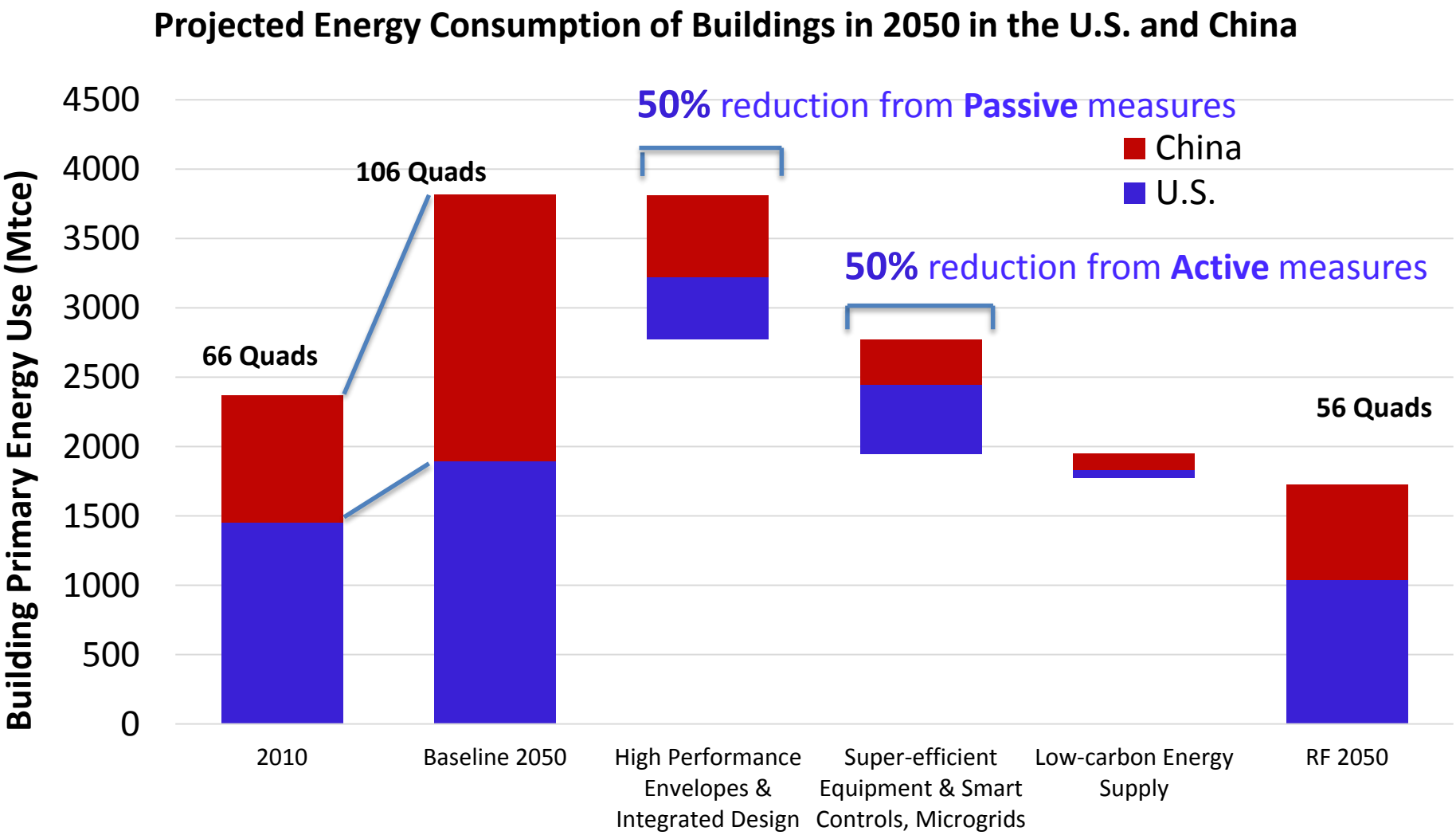


2016~ CERC 2.0

- 5 large projects, 100% joint
- Integrated technologies to deliver maximum system efficiency
- High impact technology breakthroughs and scalability
- Demo in U.S. and China, includes retrofit, district applications
- Aiming for joint IP
- Increased focus on commercialization

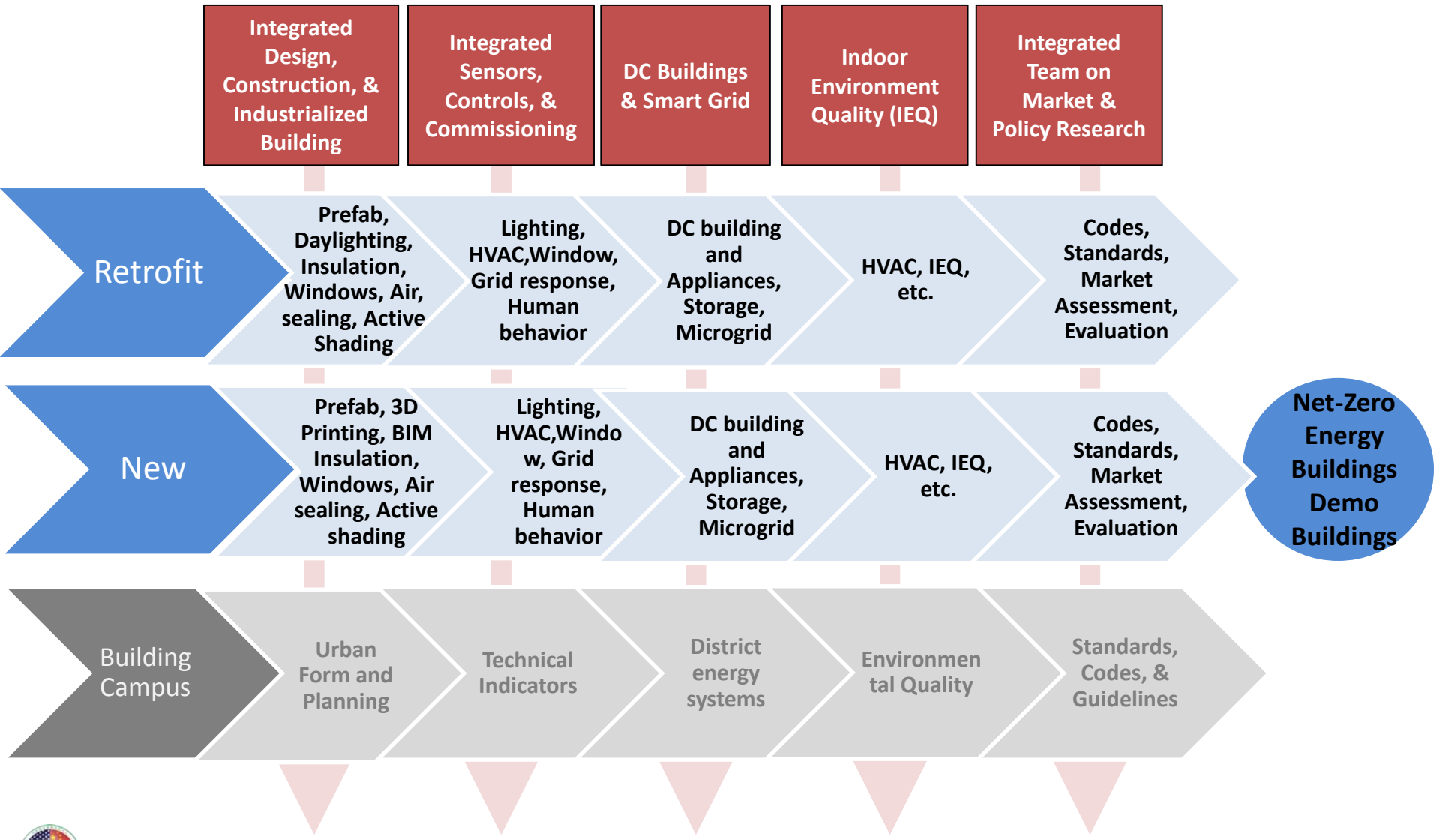
Transitioning from CERC-BEE 1.0 to 2.0 to achieve Net-Zero Energy Buildings

50% Reduction Potential in buildings in both U.S. and China



Note: U.S. numbers *based* on RMI Reinventing Fire, China numbers based on LBNL 2050 DREAM model

Pathways for Integrated Technology Development



Program1: Integrated Design, Construction, and Industrialized Building

Problem:

- Opaque walls account for ~14% of energy use in existing U.S. commercial buildings.
- Savings from energy-efficient building envelope technologies depend on quality of on-site workmanship, and on-site construction quality control is difficult.
- Owners are reluctant to retrofit because of scarcity of data on energy savings and payback period.

Approach:

- Develop licensable energy-efficient pre-cast concrete wall system packages.
- Provide construction industry with retrofit case studies on energy savings and payback periods.
- Test and evaluate performance of two envelope air sealing products that have faster installation times.

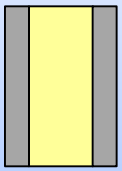
Impact:

- This project expects to save 0.74 Quads of energy annually by 2030.

Next Generation Precast Concrete Walls

New Design

1½" : 4" : 1½"



Concrete density = 100 pcf
Panel weight = 25 psf

- **50% lighter**
- **50% higher thermal performance**
- **Cost-neutral design**

Retrofit Case Studies

Before Retrofit

Rendering After Retrofit

Air Sealing Product Testing

Dow LIQUIDARMOR
Sprayable liquid flashing

3M 3015VP air and water barrier primer-less self-adhered membrane

Program 2: Integrated Sensors, Controls, and Commissioning

Problem:

- Building operation needs to become elastic, energy-optimized, grid-aware and occupancy-responsive to improve overall system efficiency.

Objective:

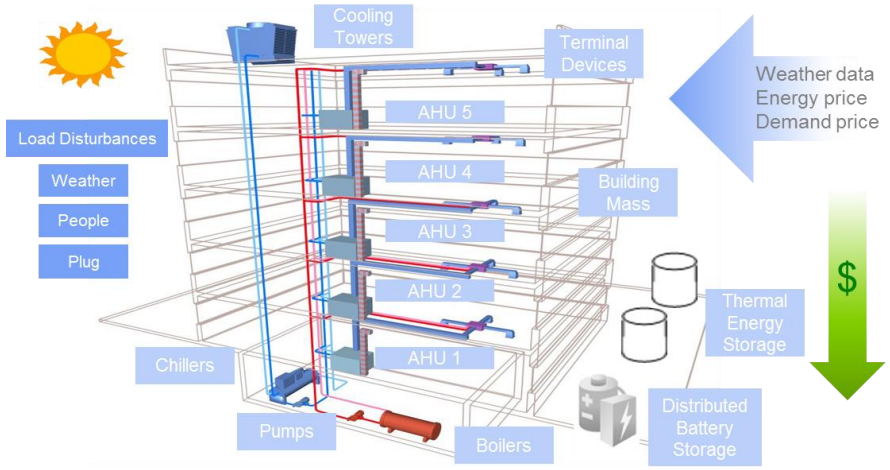
- Develop and demonstrate open-source, hierarchical occupancy-responsive model predictive control (MPC) framework at room, building, and campus levels.

Approach:

- Develop building and district energy systems that:
  - Optimize their operation across end-uses.
  - Learn about energy system dynamics and user preferences.
  - Inform building occupants and operator about how to reduce energy consumption.
- On-site demo within open infrastructure that allows industry and academia to test and integrate their technologies.

Impact:

- Transform the built environment to be zero-net energy and smart-grid ready. The annual energy savings potential by 2025 of the project is 2.9 Quads.



Framework for model predictive control (MPC) at building level

Johnson Controls Inc. (JCI) Asia-Pacific Headquarters (Shanghai China) – MPC open test-bed where industry and academia can develop and demonstrate their building control solutions.

Program 3: Direct Current (DC) Buildings and Smart Grid

Problem:

- Current hybrid buildings with on-site generation and/or storage require multiple energy conversions between AC and DC, increasing energy consumption by 10-20%.
- Many technologies for DC buildings already exist, but energy-savings potential is not well understood.

Objectives:

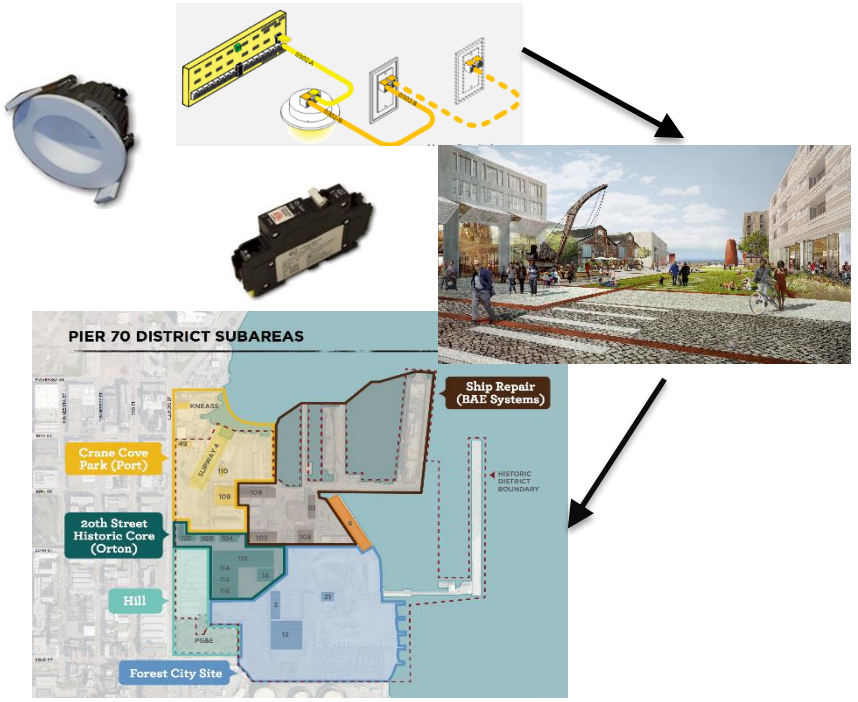
- Demonstrate the technical viability of direct DC distribution in buildings, and evaluate its potential energy saving and other non-energy costs and benefits.
- Enhance DC building benefits through communication and control features.

Approach:

- Review existing studies of building DC system and savings in comparison with AC.
- Provide research platform for testing, demonstration, and installation of all electric appliances of DC buildings.
- Verify energy-savings, efficiency, safety, reliability, and cost-benefit potential of DC buildings.
- Measure DC system in pilot projects and demo buildings and validate efficiency.
- Develop standard and control algorithm for DC system.

Energy Savings and CO_2 Impact

2025 Estimates	Total
Annual energy savings (quads)	0.7 – 3.8
CO_2 reductions (M tons)	128 – 719



Rendering and site plan for Forest City developers' major urban redevelopment project, currently under construction, which includes DC power distribution in many buildings.

Program 4: Indoor Environment Quality (IEQ)

Problem:

- Outdoor air ventilation for commercial buildings limits energy reduction opportunities and impacts indoor air quality because outdoor air must be thermally conditioned and the greatest amount of energy for conditioning is often needed during peak times.

Objective:

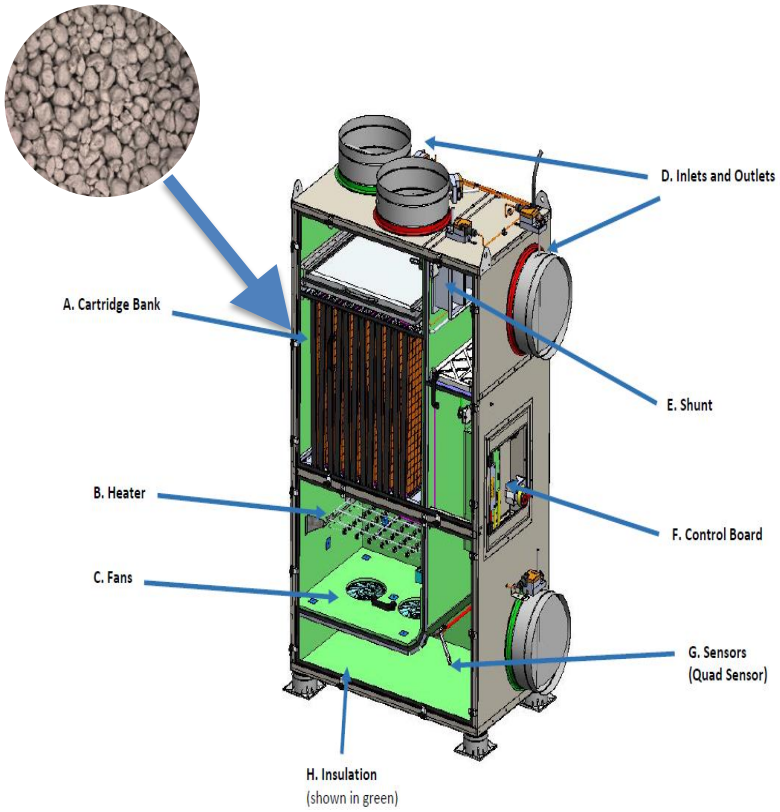
- Develop and demonstrate technologies that manipulate air supply for energy-efficient HVAC while providing excellent indoor environmental quality.

Approach:

- Develop metrics and test conditions for air cleaning materials.
- Develop and investigate advanced materials to remove CO_2, formaldehyde, VOCs.
- Integrate ventilation & air cleaning with sensor-based controls.
- Develop simulation tools to advance deployment of air cleaning technologies for energy savings.
- Integrate air quality module into Energy Plus.

Energy Savings and CO_2 Impact

2030 Estimates	Total
Energy savings (quads)	0.56
CO_2 reductions (tons)	68



BASF materials and Johnson Controls scrubber unit

Program 5: Markets & Policy Initiative

Goal:

- By 2025, expand the global market for building energy efficiency technologies by $60 billion annually.

Approach:

- **Building Codes**: Deliver new model codes and methodology to develop and enforce outcome-based codes.
- **Impact Modeling**: Develop and implement realistic models of technology adoption to predict effectiveness of R&D and technology innovation projects under CERC-BEE.
- **Data Transparency and Benchmarking**: Identify, pilot, and scale up new data transparency policies and an open-source audit tool that provides:
  - cost-effective financial analyses and energy conservation measure (ECM) identification;
  - accurate, comprehensive policy EM&V, and
  - greater standardization and automation of building EE policy implementation.
- **Financing:** Identify and pilot a suite of tools, policies, and financial products that allow capital markets to better assess the technical viability and creditworthiness of projects, thereby facilitating EE investment at scale.

New York City Changning District, Shanghai Collaboration on Codes and Data Transparency and Benchmarking Policy

Energy Savings and CO_2 Impact

2025 Estimates	Total
Energy savings (quads)	5.7
CO_2 reductions ($MtCO_2$)	540

CERC-BEE Research Teams

Integrated Design, Construction, and Industrialized Buildings

RESEARCHERS:

-US Lead: Patrick Hughes, [ORNL]

-US Co-Lead: Diana Hun, [ORNL]

-CH Lead: Guo Haishan [CSCEC*]

-CH POC: Liu Kang, [CSCTC*] & Yao Chunni [MOHURD*]

INDUSTRY:

-US Lead: Greg Bergtold, [DOW] – US Co-Lead: Bill Sikorski, [3M]

- CH Partners: Beijing Persagy Energy Saving Technology (Beijing)

Integrated Controls, Commissioning, and Data Mining

RESEARCHERS:

-US Lead: Mary Ann Piette, [LBNL]

-US Co-Lead: Tianzhen Hong [LBNL]

-CH Lead: Xu Wei, [CABR]

-CH POC: Zhang Shicong [CABR*] & Liu Haizhu/Zeng Di [MoHURD]

INDUSTRY:

-Lead: Clay Nesler, [Johnson Controls]

-Co-Lead: Murilo Bonhilha, [UTRC]

-Co-Lead: Bruce Rauhe, [Disney]

- CH Partners: Zhuhai Xingye Green Construction Technology Co., Ltd.

Direct Current (DC) Buildings & Smart Grid

RESEARCHERS:

-US Lead: Wei Feng, [LBNL]

-US Co-Lead: Bruce Nordman [LBNL]

-CH Lead: Wang Fulin [Tsinghua]

-CH POC: Wang Fulin [Tsinghua]

INDUSTRY:

-Lead: Paul Salvage [Nextek]

-Co-Lead: Ayhan Sarikaya [Saint-Gobain]

- CH Partners:

Zhuhai Xingye Green Construction Technology Co., Ltd.

Indoor Environmental Quality

RESEARCHERS:

-US Lead: Brett Singer, [LBNL]

-US Co-Lead: Hugo Destaillats, [LBNL]

-CH Lead: Zhang Yinping [Tsinghua]

-CH POC: Mo Jinhan [Tsinghua]

INDUSTRY:

-US Lead: lead: Ying Wu, [BASF]

-US Co-Lead: Murilo Bonhilha, [UTRC]

-CH Partners: China Merchants Shekou Industrial Zone Holdings Co. Ltd.

Integrated Team on Policy and Market Research

RESEARCHERS:

-US Lead: Nan Zhou, [LBNL]

-US Co-Lead: Carolyn Szum, [LBNL]

-CH Lead: Peng Chen [MOHURD]

-CH Co-Lead: Liu Shan [MOHURD]

INDUSTRY:

-US Lead: Rob Nachtrieb, [Lutron]

-US Co-Lead: Murilo Bonhilha, [UTRC]

- CH Partners: CSCEC*

U.S Industry Advisory Board Continue to Grow

IAB MEMBERS

- JCI
- 3M
- UTC
- Lutron
- DOW
- BASF
- Saint Gobain
- Sage
- Disney
- Lend Lease
- Climate Master
- C3 Energy

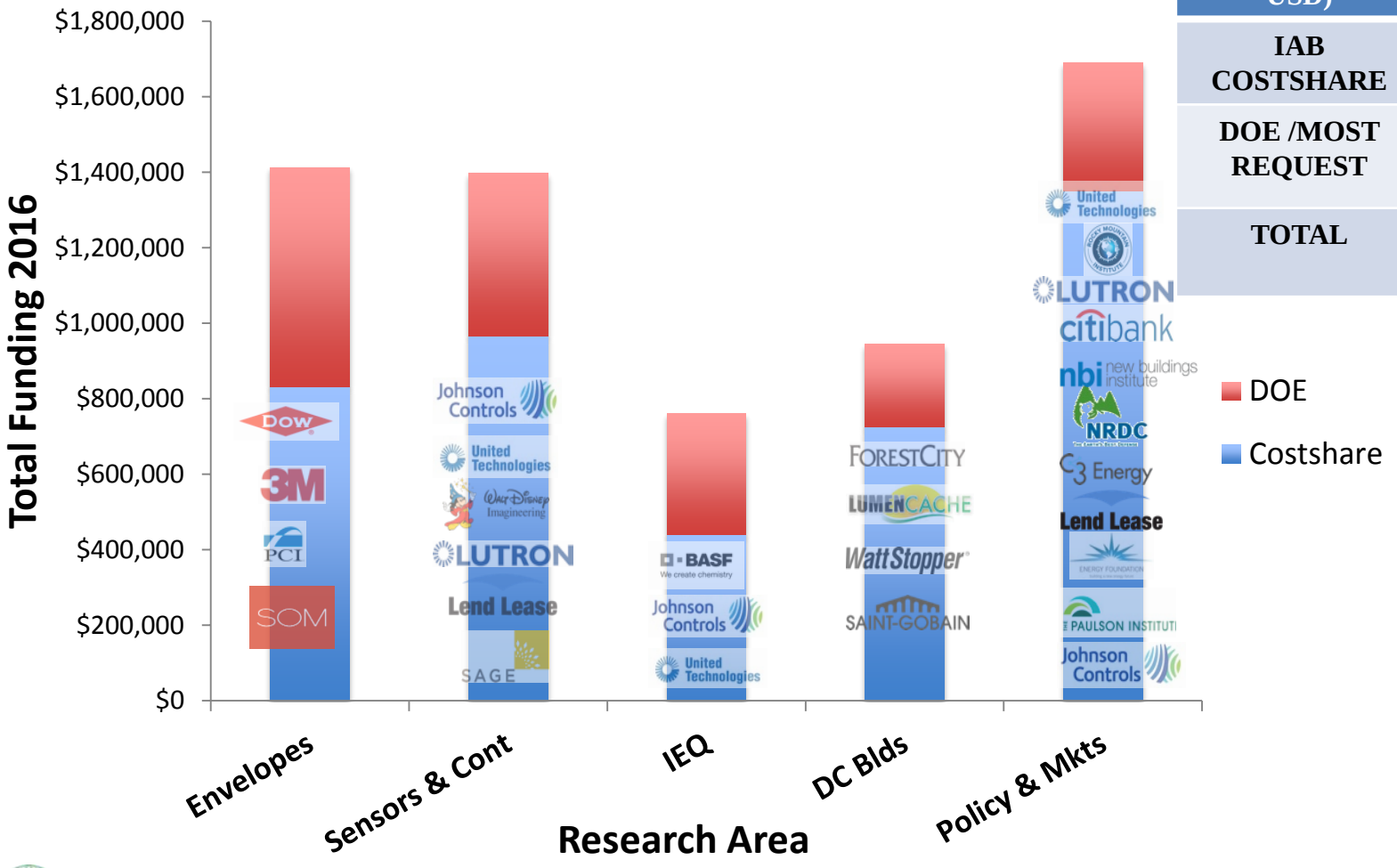
AFFILIATES

- Rocky Mountain Institute
- Forest City
- WattStopper
- Lumencache
- Citibank
- NRDC
- New Buildings Institute
- Paulson Institute

CERC-BEE Funding 2016

U.S China Combined

2016 (Million USD)	US	China	Total
IAB COSTSHARE	4.3	4.85	9.15
DOE /MOST REQUEST	2.5	2.5	5
TOTAL	6.8	7.35	14.15



Key Technical Progress to Date

Integrated Design, Construction, and Industrialized Building	• Developed prototypes for concrete mixes, clifting inserts, 3D printed molds, aiming for **50% lighter, 50% higher thermal performance, and cost-neutral** • New Air Sealing technologies
Integrated Sensors, Controls, and Commissioning	• An architecture for an occupant behavior (OB) module to exchange information between occupants and **MPC** at room and building levels • Room-Level MPC Demonstration preparation
Direct Current (DC) Buildings and Smart Grid	• **4~5%** efficiency gain identified compared with AC system (without considering advanced controls). Up to **8%** possible. • Identified demonstration projects to test the actual energy savings
Indoor Environment Quality (IEQ)	• Developed **Sorb300** at pilot scale that removes twice as much CO_2 at 1000 ppm, and developed test sequence. • Linked EnergyPlus with CONTAM to enable co-simulation of HVAC and air pollutants.
Markets & Policy Initiative	• Operating conditions can have an impact on outcome-based performance - **up to 12% savings** through modified O&M. • Quantified impact of CERC-BEE 1.0: 11% energy savings by 2050. • **1st U.S.-China Joint IPMP drafted for the open-source audit tool**

Demonstration of NZEB in China

- Construction of 5-8 "net-zero energy buildings" to promote technology application and engineering development in different climatic zones.
- Establishment of demonstration project program with participation from both China and U.S. to promote close cooperation between two parties.
- Implementation of all the technologies to be developed, highlighting the integrity and integration.






Demonstration project sites include: Beijing, Tianjin, Shanghai, Chengdu, Fuzhou, Shenzhen and others, to be completed before the end of 2018.

Demonstration VLEB in United States

- Heller Manus Architect's: five very low-energy building demonstration sites in California.
- Omaha's Dundee Theater: demonstrating Dow's STYROFOAM^{TM} Brand Spray Polyurethane foam.

350 Bush

505 Brannan

1510 Webster

181 Fremont

Menlo Gateway

Heller Manus Architect's Demonstration sites in California

CERC-BEE Outputs

Using CERC-BEE's established portfolio management process, joint project teams will deliver additional:

Patents, tools & software

Codes and policies

Award-winning products and licenses

Technology cost reductions

Integrated building energy solutions

New financing and business models

Demonstration of Net-Zero Energy Buildings

CERC-BEE 2.0 Preliminary Roadmaps and Outcomes Net-Zero Energy Buildings

- **Feasibility study and research for deployment**
- **New IP, product prototype**
- **Implementation of demonstration projects**

Zero

2020

- **Product commercialized and deployed at a scale**
- **Possible joint IP**
- **Huge energy and emission reduction in buildings**

2016

- **Joint Development of key Integrated EE technologies**
- **Joint design and development of demo projects in the U.S. and China**

BUILDINGS ENERGY EFFICIENCY CONSORTIUM

U.S. - CHINA CLEAN ENERGY RESEARCH CENTER (CERC-BEE)

For More Information:

http://cercbee.lbl.gov

Led by **MoHURD Center of Science and Technology of Construction** of China and **Lawrence Berkeley National Laboratory** of the United States with:

CERC-BEE 2.0 U.S. Management and Outreach Updates

3/3/2016 – CERC-BEE 2.0 IAB Planning Meeting in Washington, DC
3/4/2016 – **Merit Review of CERC-BEE 2.0 Proposals in Washington, DC**
6/1-2/2016 – CERC-BEE Booth at CEM7 Clean Energy Ministerial (CEM7) Solutions Showcase, San Francisco
6/7-8/2016 – U.S.-China Climate Leaders Summit, Beijing, China
7/1/2016 – CERC Steering Committee Meeting, Beijing, China
10/13/2016 – Seventh U.S.-China Energy Efficiency Forum
10/17-18/2016 – **CERC-BEE 1.0 Closeout/2.0 Kickoff Meeting Zhuhai, China**
10/20/2016 – CERC-BEE 2.0 "Barriers and Solutions" Workshop, Shanghai, China
11/1/2016 – CERC-BEE 2.0 Semi-Annual IAB Meeting, New York, NY
1/1/2017 – **U.S. CERC-BEE 2.0 Kicks off Year 2 Proposal Process**
2/2017 – **LBNL-MOHURD Meeting in Beijing to Align CERC-BEE 2.0 Year 2 Work Plans and Discuss Joint Activities**
3/2017 – U.S. CERC-BEE 2.0 Presents Work at the DOE BTO Peer Review

Potential CERC-BEE Collaboration Challenges and Mitigation Strategies

Potential Risk	Mitigation Strategy
Reduced Chinese Funding for Projects	▪ Monthly conference calls between U.S. and Chinese CERC-BEE management. ▪ Commitment from China for adequate funding for CERC-BEE projects.
Delayed Chinese Project Implementation	▪ Chinese Year-1 to Year-3 Work Plan will commence April 2017, in alignment with U.S. Year-2 Work Plan ▪ Chinese side will combine Year-1 and Year-2 activities into 2017 to catch up with U.S.
Shifts in Policy Priorities	▪ Strong U.S. industry support, delivering $4 of cost share for every $1 of DOE investment. ▪ Clear benefits for U.S. taxpayers, industry, infrastructure, and domestic and foreign policy.
Lack of Bilateral Collaboration on R&D	▪ Jointly-developed work plans requiring US and Chinese Researcher and Industry Partner signatures
Lack of Very-Low and Nearly Net-Zero Energy Building Building Demonstration Sites in China and U.S.	▪ Strict criteria for selection of U.S. and Chinese demonstration sites. ▪ Ongoing measurement and verification (M&V) of U.S. and Chinese demonstration site performance.

CERC-BEE Global Benefits

- Innovations in codes, policies, benchmarking and auditing tools, and financing mechanisms expand the global market for building EE, and deliver economic and environmental benefits.
  - Outcome-based codes (Sweden, Seattle, Tokyo, California Title 24 and 20).
  - Global investment in building EE must reach $3.8 trillion by 2035 (Rugova 2016).

- New construction globally leaning toward prefabrication (in particular China and Europe), and ageing buildings worldwide in need of cost-effective retrofit strategies.

- CERC-BEE provides a software and demonstration platform to test, evaluate, and scale MPC technologies globally.

- Health and productivity benefits of reducing air pollutants at workplaces provides much greater value than energy savings.
  - Growing awareness of economic benefits of good IAQ
  - Increase in healthy building ratings and certification programs.

- DC power has global benefits:
  - Global standard for DC voltage, connectors, communications (unlike AC).
  - Provides cost-effective technology path for developing country "energy access."
  - Inexpensive and efficient integration of local renewable generation and storage
  - Easy to control, good reliability and resiliency

CERC-BEE 2.0 Vision and Approach

Vision

Build on the foundation of knowledge, technologies, human capabilities, and relationships that accelerate and scale up the development and deployment of net zero energy buildings in the U.S. and China.