BUILDINGS ENERGY EFFICIENCY CONSORTIUM

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

CERC-BEE Steering Committee Meeting

June 1, Washington DC

Dr. Nan Zhou, Lawrence Berkeley National Laboratory of the United States

Professor Liang Junqiang, MoHURD Center of Science and Technology of Construction of China with:

>71 Research & Industry Partners

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

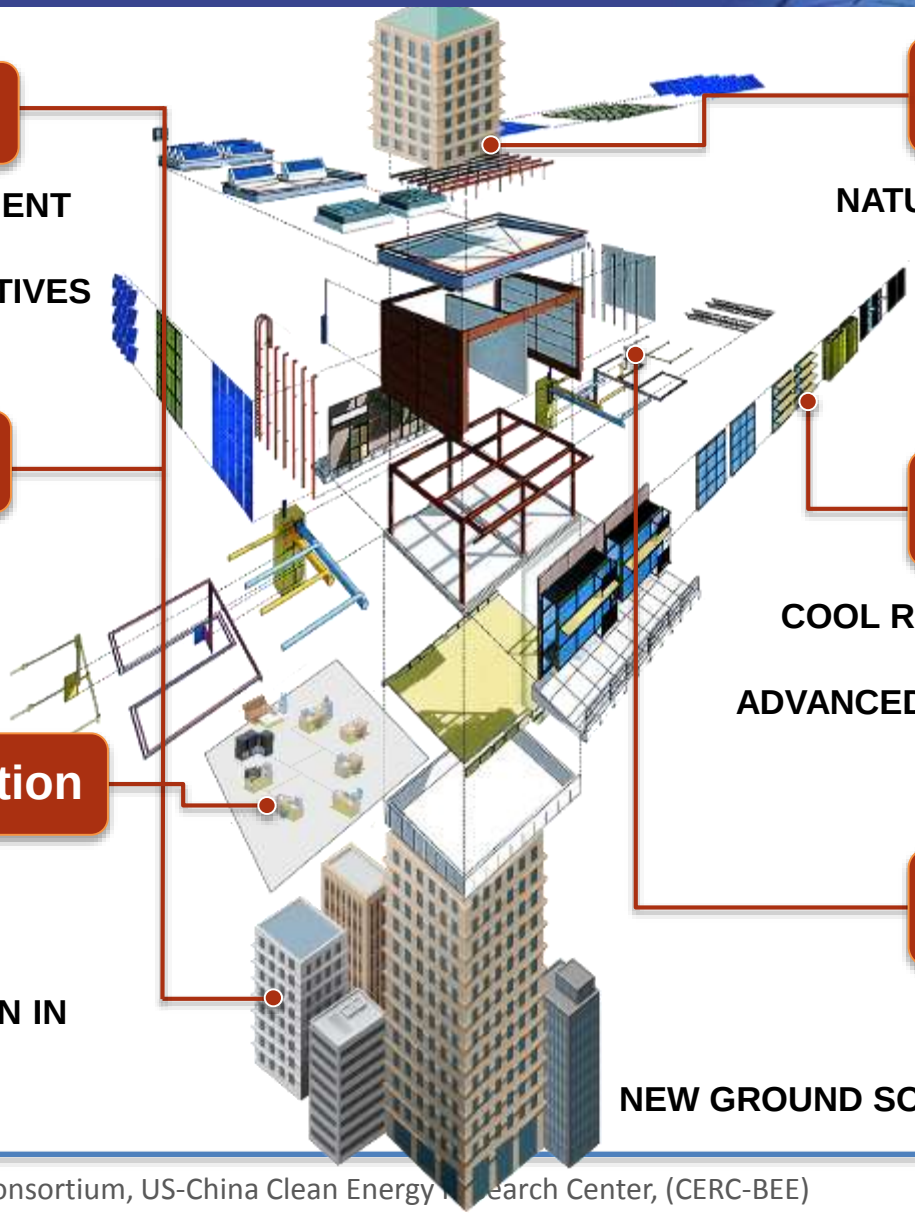
>13 U.S. & China Research Partners

- Berkeley Lab
- Oak Ridge National Laboratory
- NRDC
- ICF International
- MIT
- UC Davis University of California
- 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:

- Dow
- Saint-Gobain
- ClimateMaster
- 3M
- Lutron
- Lend Lease
- C3 Energy
- SageGlass
- United Technologies
- Energy Foundation
- Bentley
- Walt Disney Imagineering
- 興業太陽能 SINGYES SOLAR
- 中国建筑 China State Construction
- Johnson Controls
- NARI 国电南瑞科技股份有限公司 NARI Technology Development Co., Ltd.
- Pelsagy
- ENN 新奥
- 日新科技 RIXIN TECHNOLOGY

CERC-BEE
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

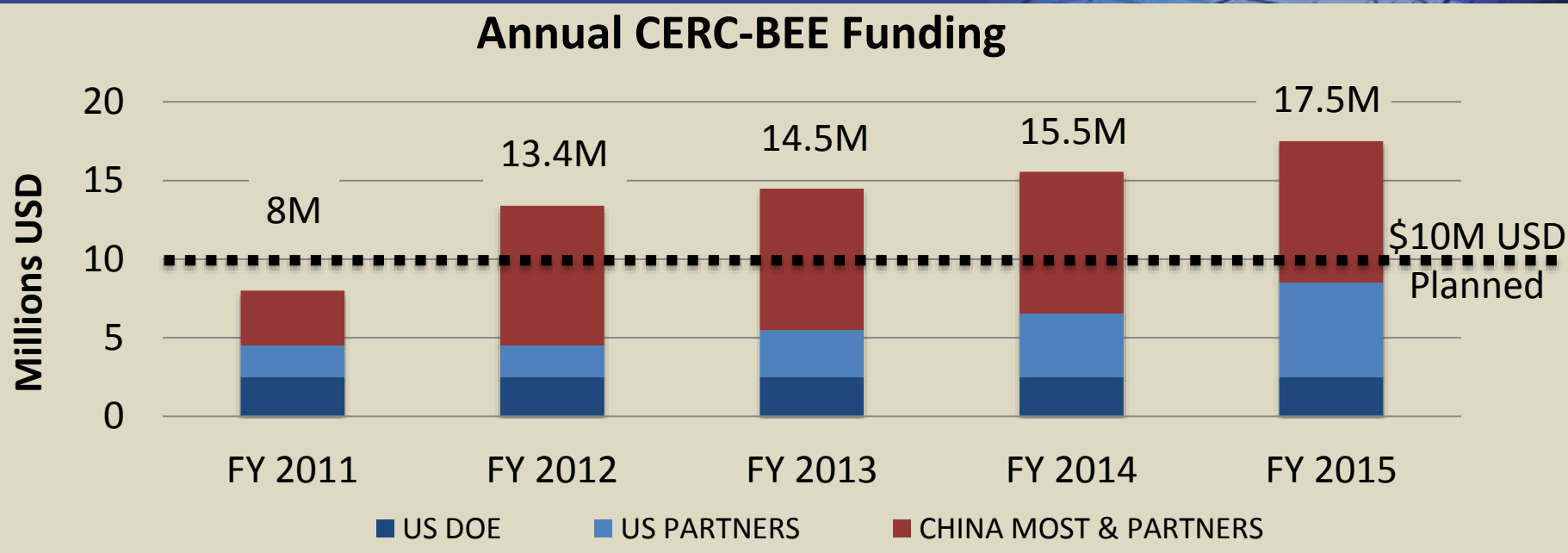
INSULATION

Equipment

LIGHTING CONTROLS

NEW GROUND SOURCE HEAT PUMP DESIGN

Industry engagement strongest ever

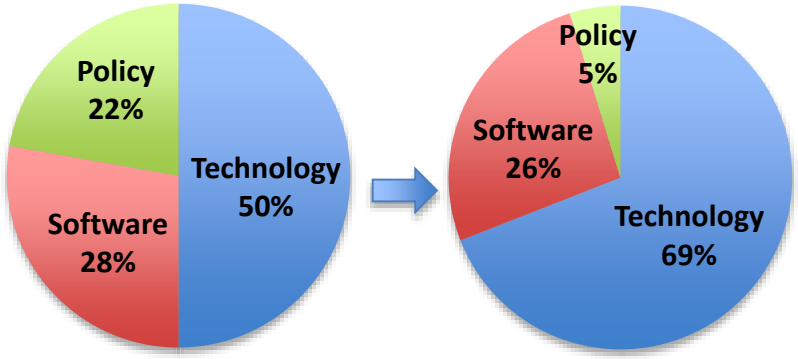


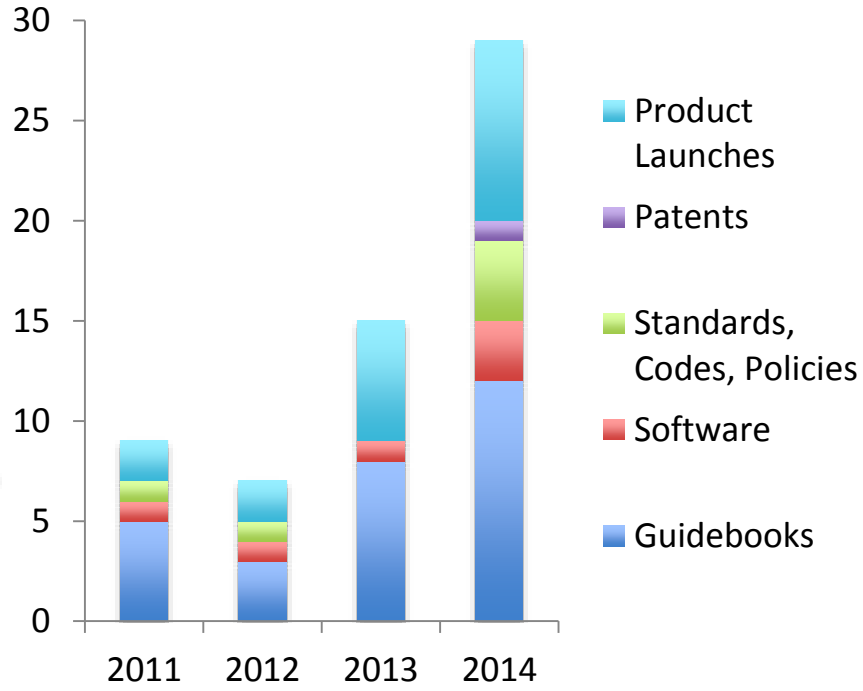
- New industrial partners in 2014 Q4: Walt Disney Imagineering, Lend Lease
- Anticipated industry partners in 2015 Q2: Johnson Controls, United Technologies
- Industrial partners see value, demonstrated by +30% annual average growth rate for cash and in-kind contributions to date
- Projected 5-year total program funding of $69M vs. $50M planned (+38%)

Significant Progress toward Targeted Outcomes focusing on Innovation Delivery

Dynamically Managed Portfolio

Technology investments up 138% from 2011 to 2014, plus qualitative shift in *type* of technology R&D





Investment

Outputs

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

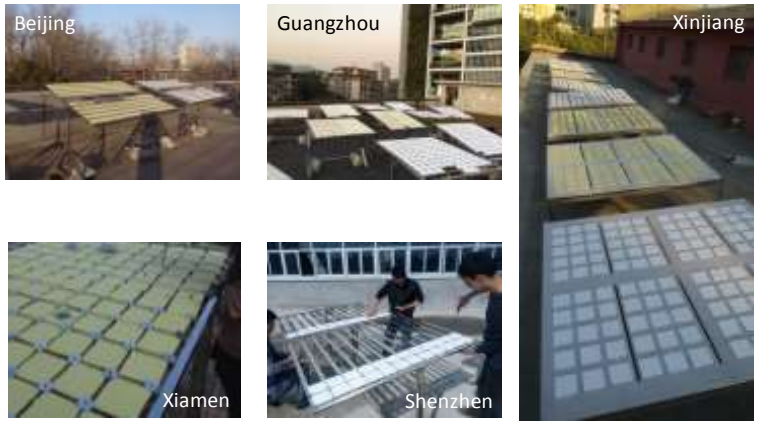
Copyrights Software

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

CERC 1.0 Highlights: Materials Innovation

Cool Roofs Surface Coatings

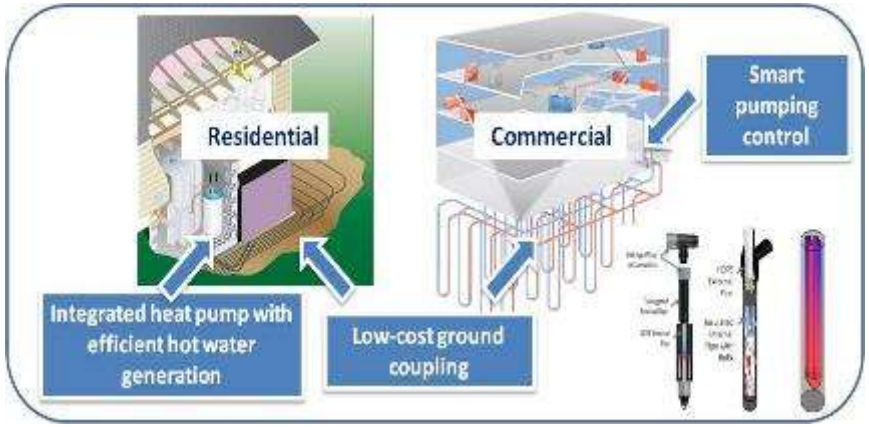
Cool Roof Time Machine headed to China



- Dow, ORNL, LBNL, GPABR, CU, IAP developing new materials and quantifying impacts
- RISN, LBNL, CTC, **7** Chinese BRIs testing U.S. and Chinese products in 9 Chinese cities
- LBNL's "Cool Roof Time Machine" (ASTM D7897-15) cuts prototype testing to **3 days** from 3 years
- **5-20%** reduction in annual cooling energy use on top floor of building in hot-summer climate
- **3B m^2** upgradeable by 2025 in the U.S. and China
- USD **$2.5M** awarded by CEC

New Generation GSHP Systems

Low cost, integrated, smart controls



- ClimateMaster, ORNL, CABR, and TU
- **20 to 30%** reduction in drilling depth
- Built a first-of-a-kind facility for R&D in advanced controls for GSHP systems
- Developing a wireless sensor based control to cut pumping power by **50%**
- Optimizing controls to improve hot water generation efficiency by at least **10%**

CERC 1.0 Highlights: Softwares and Standards

Building Energy Consumption Standard

- First **outcome based code** based on actual energy consumption
- Expected to be effective in August 2015
- Improve operation in exiting building
- Energy Saving potential for existing building up to **20%**
- Stimulate the retrofit market

Advanced Windows and Shading

Modeling Tools and Design

- Dynamic window, shading, and daylight-redirecting systems in US and China
- **20-30%** perimeter zone energy savings
- **63%** reduction in utility grid costs using window modeling tools
- Grid load profile of south-facing perimeter office flattened to nearly zero demand
- Reductions of ~**1 quad/year, 26 Mtons/year** CO_2 by 2025

Demonstration projects yield meaningful technological progress

#1 Beijing, China, CABR Near Zero Energy Building

- Office, R&D facility, 4025m^2, cold climate zone
- Energy Intensity **25 kWh/(m^2.a)** (37kWh/(m^2·a) total energy)
- **0 fossil fuel** for space heating
- Cooling energy ↓ **50%**
- Lighting energy ↓ **75%**
- Led to development of China's NZEB standard.

#2 Zhu Hai, China, Xingye Research and Office Building, expected completion by year-end 2015

- 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%**

Demonstration projects yield meaningful technological progress

Summary of Accomplishments & Remaining Work

CERC-BEE 2014-2015 progress

- **Joint technical accomplishments**
  - **25 patents** filed,
  - **6 products** launched
  - Adoption of **8 codes**
- **Increased industry engagement**
  - U.S. adding **2 new partners** in Q4 2014
  - **3 more partners** anticipated in 2015
- **Active collaboration**
  - Steering committee meeting in Beijing; Annual meeting in Berkeley; Joint management meetings
  - Numerous CERC 2.0 planning meetings
  - **100% joint US-China R&D** projects
  - Progress on demo sites yield **joint technological** progress

Tasks remaining for CERC 1.0

- **Strengthen the technical quality of projects through**:
  - ✦ 10 BTO program managers on board for technical supervision
  - ✦ Participating in BTO peer review and merit reviews
  - ✦ Technical Advisory Committee to provide quality control
- **Drive innovation, achieve commercialization, & deliver tangible outcomes**
- **Ensure enduring and expanded research- industry partnerships**
- **Working closely with each other to develop CERC 2.0 implementation plans**

BUILDINGS ENERGY EFFICIENCY CONSORTIUM

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CERC Steering Committee Meeting

Improving the Cost-Effectiveness of Air Barriers

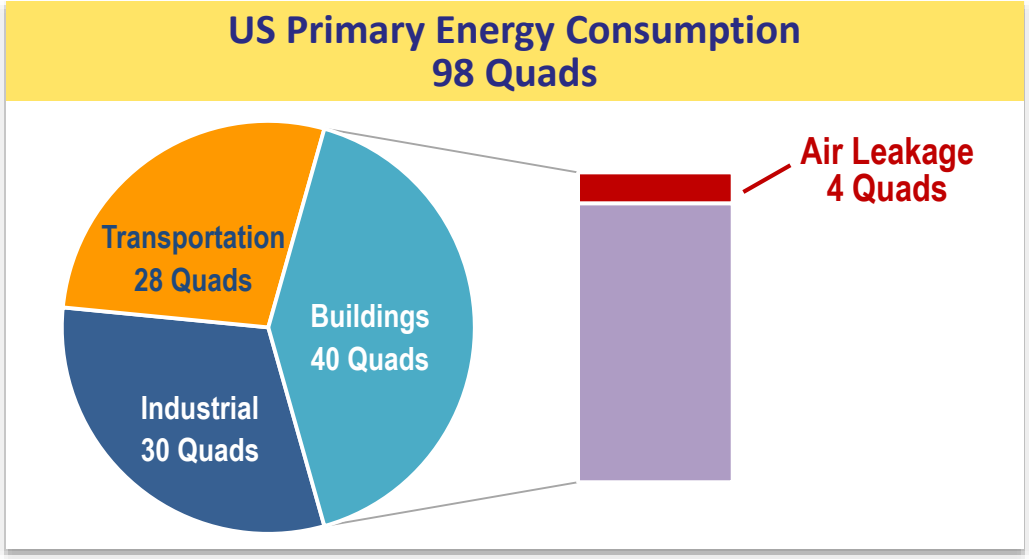
Diana Hun, PhD
Oak Ridge National Laboratory

Washington DC
June 1, 2015

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

Problem and Impact

- Air leakage
  - Accounts for 10% of US building energy consumption
  - Affects energy use and indoor air quality in China



Office of Energy Efficiency and Renewable Energy, Building Energy Data Book

- New air barriers can potentially reduce infiltration-related energy losses by over 50%
  - Novel materials
  - Superior air sealing
  - Excellent long-term performance
  - Foolproof installation
  - Lower installed cost
  - Less time to install

One-Step Sprayable Liquid Flashing

LIQUIDARMOR™

Video courtesy of Dow Chemical

Current Technologies

Liquid flashing
Needs bridging materials

Peel & stick
Time consuming and prone to error

- Seamless air and water sealant
- One-step, sprayable, water-based, liquid flashing
  - Bridges gaps up to ¼" (6 mm) wide without supporting materials
  - 3-4 times faster installation than flashing tape
  - Easily conforms to any shape
- Excellent adherence to common building materials
  - Residential and commercial construction
  - New and existing buildings
- Patent US 8,641,846 B2
- Introduced to US market as LIQUIDARMOR™

LIQUIDARMOR™ Market Deployment

CABR's tests indicate that LIQUIDARMOR™ improved airtightness around windows

CABR – Beijing

Illinois

North Carolina

Texas

Photos courtesy of Dow Chemical and CABR

Primer-Less Self-Adhered Membrane

3M 3015

Video courtesy of 3M

Current Technologies

Typical asphalt-based self-adhered membrane requires priming of substrate. Failure can occur if primer is not adequately dried.

- Air, water, and vapor barrier
- Excellent adherence to common building materials without priming
  - Up to 2 times faster installation than membranes that require priming
  - Residential and commercial construction
  - New and existing construction
- Low temperature application ~ 0°F
- Introduced to US market as 3M 3015
- ORNL/3M were awarded $1.1M to continue research on improvements in airtightness

3M 3015 Market Deployment

CABR – Beijing

CABR will issue the first national guidelines that recommend air barriers in low energy buildings

Minnesota

Massachusetts

Minnesota

Photos courtesy of 3M

Future Retrofit Application

- Pilot project in Shanghai
  - Maximize preservation of existing structure
  - Develop models for low-cost green retrofits
  - Demonstrate innovative technologies
- 9 sites to be redeveloped from 2015 to 2019
  - Potential future projects for the Dow and 3M technologies

Existing Building

Redevelopment Design

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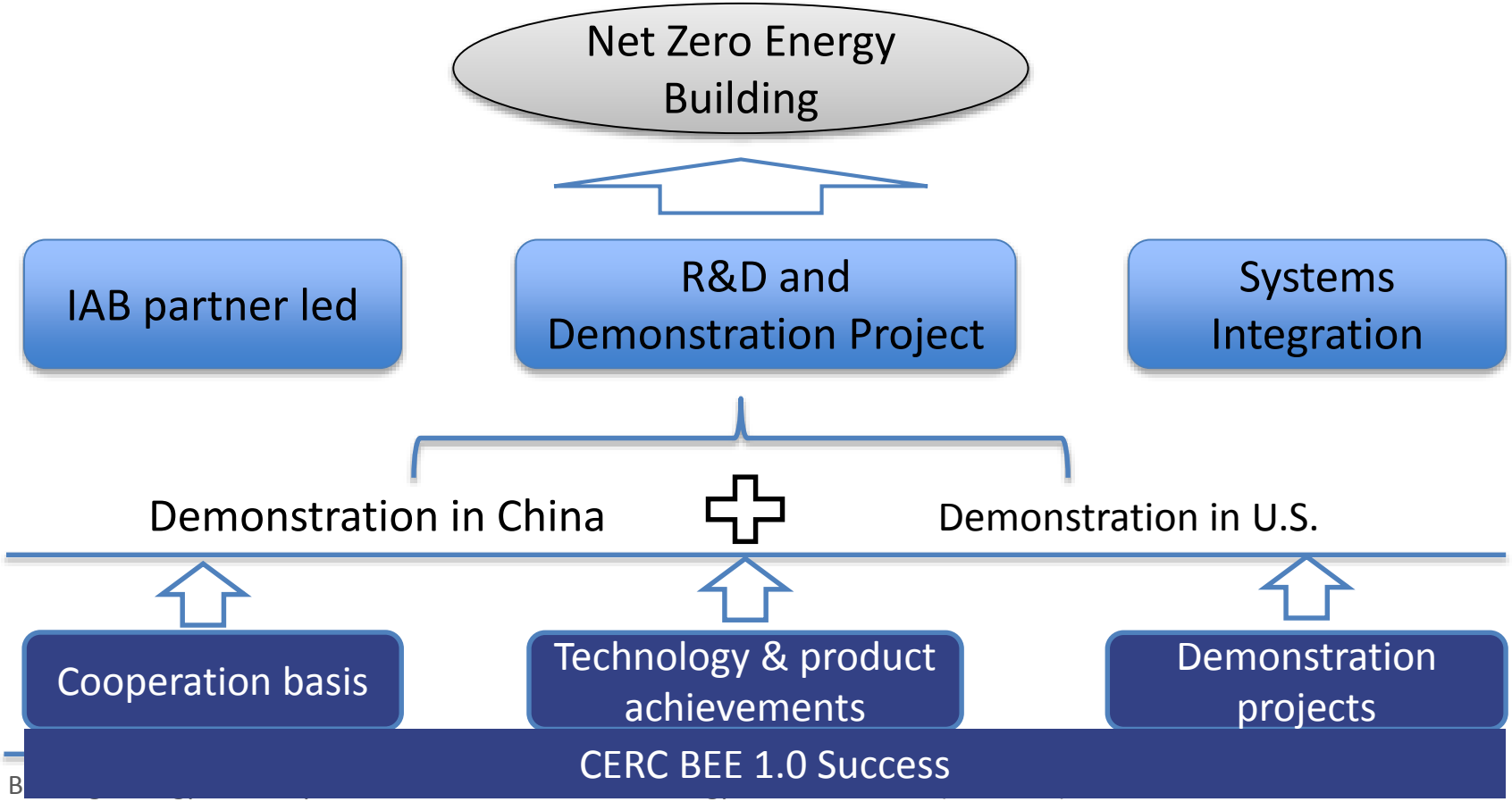
CERC-BEE 2.0 Plan--Toward Net Zero Buildings

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 Target and Approach

Vision

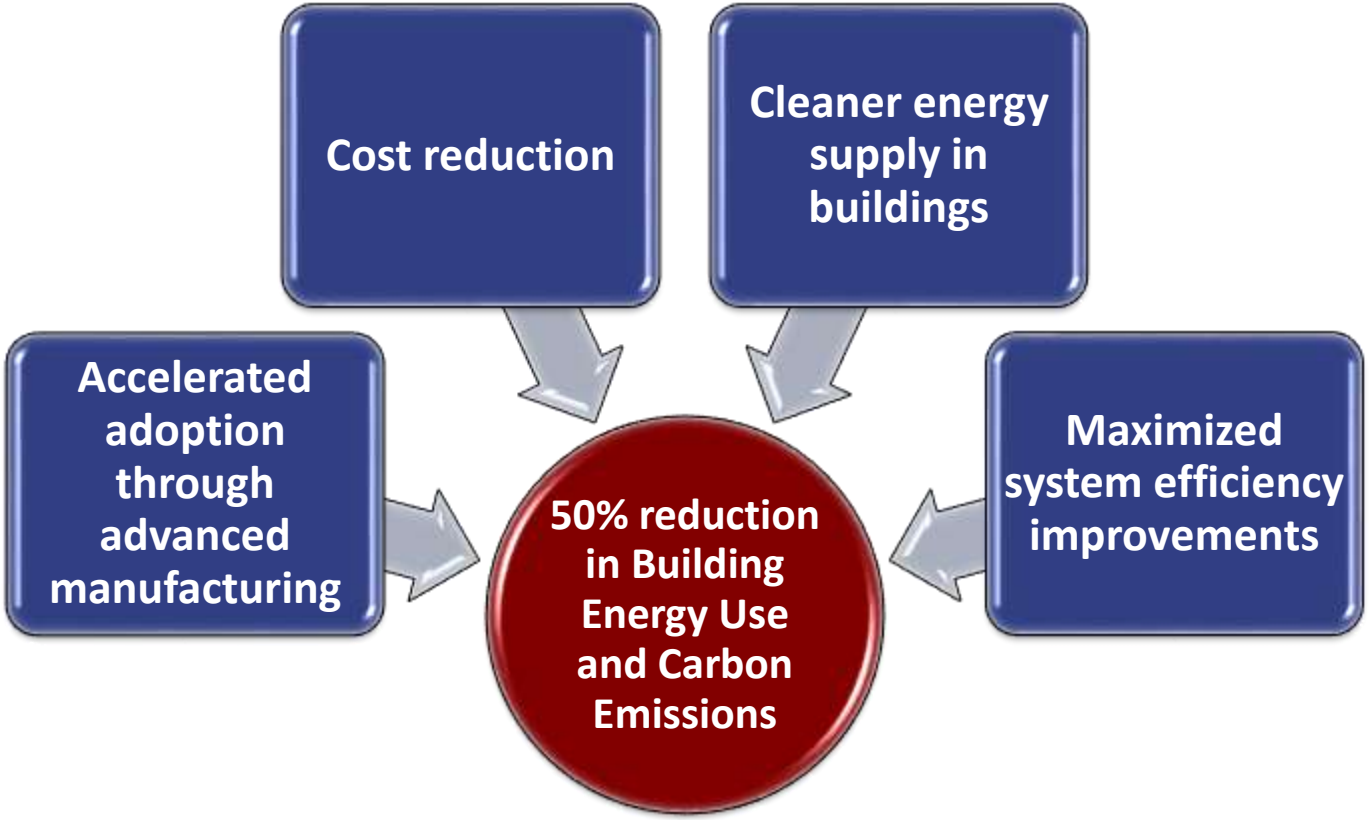
Build on the foundation of knowledge, technologies, human capabilities, and relationships that accelerate and scale up the development and deployment of very low energy buildings in the U.S. and China.



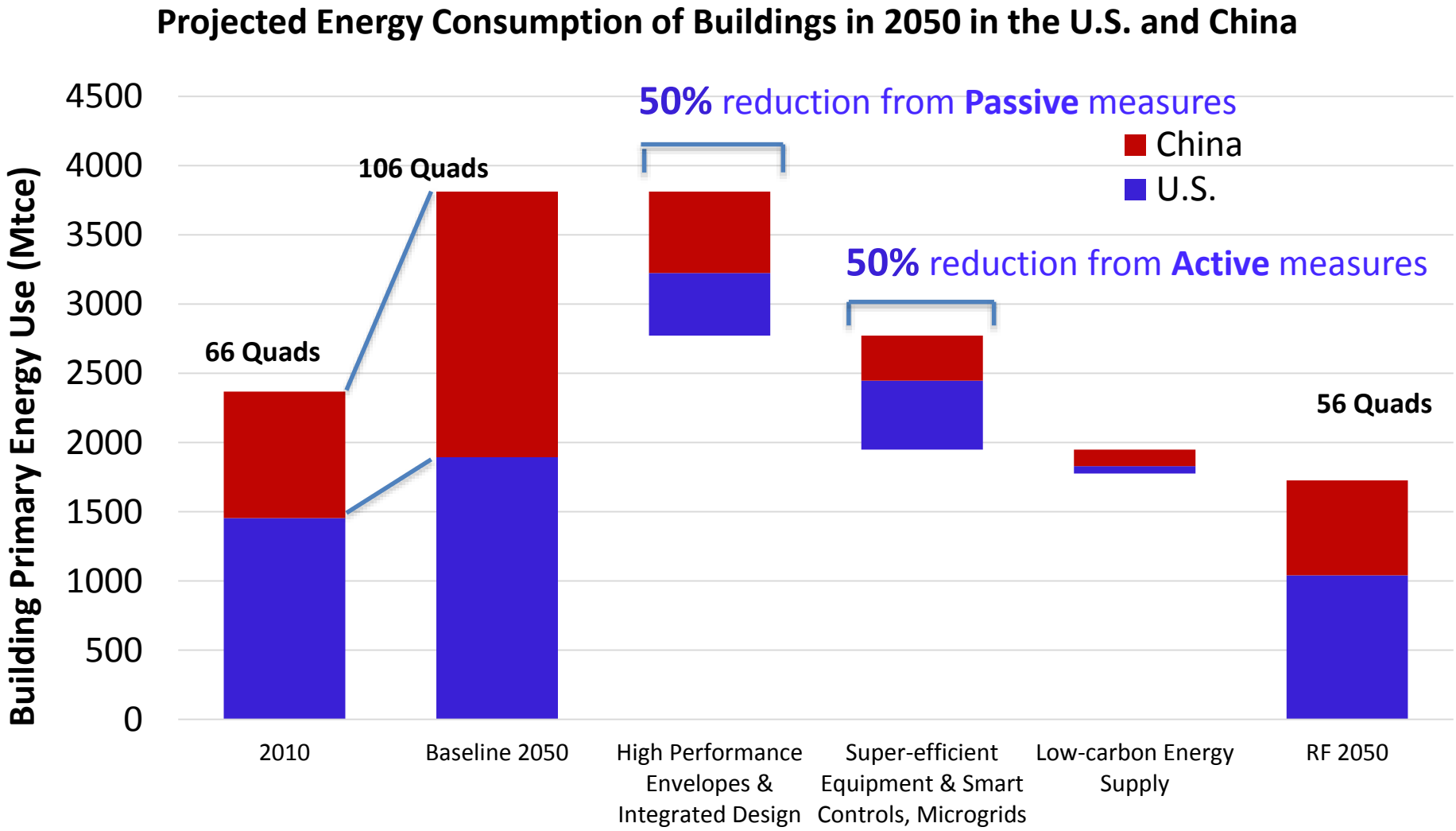
CERC-BEE 2.0 Being Bolder and Ambitious

Vision

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



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

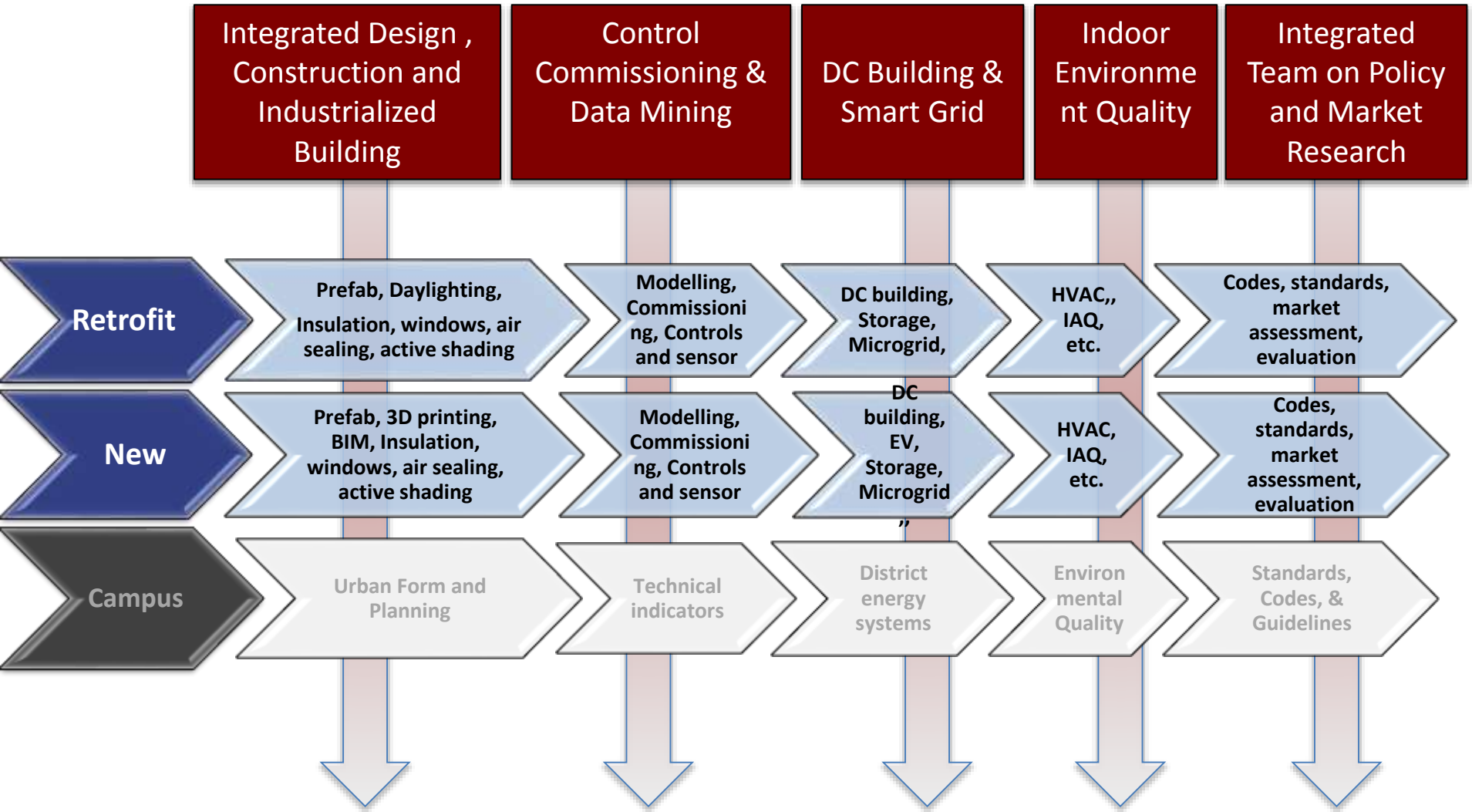
CERC-BEE 2.0 Benefits

- Macro level
  - Showcase global leadership in reducing energy consumption & carbon emissions.
  - Enhance the influence of U.S. and China in BEE throughout the world.
  - Develop clear targets and approaches for building energy efficiency in the U.S. and in China.

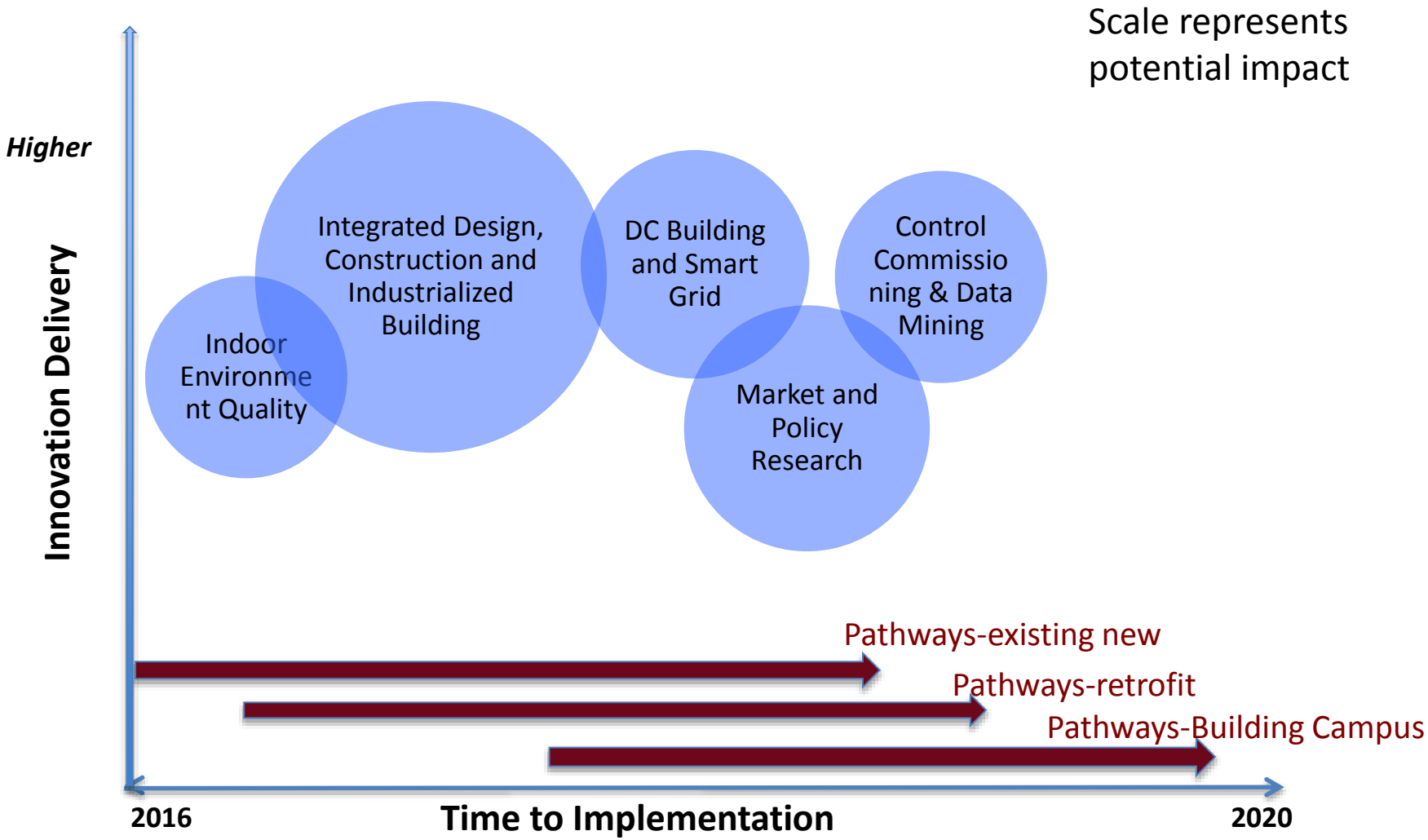
- Theory and Technology
  - Share Joint IP of technology and products.
  - Enhance exchange in the area of building energy efficiency, including training, technological innovation, and systems theory.

- Market
  - Promote trade in building energy efficiency products and technologies between the U.S. and China.
  - Expand market size and promote economic development through BEE activities

Three Pathways for Integrated Technology Development



CERC-BEE 2.0 Portfolio Management Plan



Solving Complex Global Problems Requires Interdisciplinary Non-competitive Collaboration

Integrated Design, Construction and Industrialized Building

- Developers and designers
- Construction company
- Technology vendors
- Research institutes
- Government

Building Commissioning & Data Mining

- Users
- Technology vendors
- Research institutes
- Government

Integrated Design, Construction and Industrialized Building

Problem: Façade energy-saving features are limited by: (1) construction practices, (2) work-force skill levels, (3) codes and standards that must simplify for low skills, (3) poor workman-ship even when simple, and (4) high labor costs.

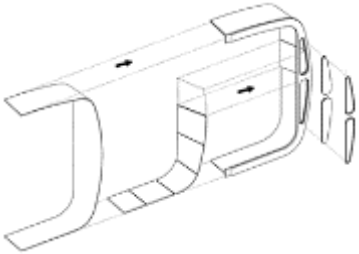
Impact: Facade integrated design and prefab construction: provides a platform for optimal integration of energy saving features into facades for new construction or existing building re-skins.

Energy saving features that can be integrated: (1) insulation, (2) air sealing between windows and walls, (3) fixed-operable-and-dynamic solar shades and windows, (4) daylight harvesting shelves and tunnels, (5) solar water heating, and (6) provisions for HVAC and natural ventilation.

Industrialized building:
(1) Design standardization, (2)Factory production, (3) Construction Assembly , (4) Decoration integration, (5) management informatization.

4. Construction or Retrofit

1. Integrated Design



3. Prefab Façade Modules

2. Prefabrication

Control Commissioning & Data Mining

Problem

- Sensing and control systems in commercial buildings are difficult to adapt to individual and group occupant preferences and to a range of personalized and zone-based control devices.

Approach

- Develop and demonstrate self-organizing, occupant-responsive sensing and control systems for commercial buildings leveraging wireless, internet-enabled interfaces, sensing networks and control devices.

Localized Sensing

- Smart phone interface, wireless mesh sensors, energy harvesting, workstation occupancy, security access, occupant location (voluntary)

Localized Comfort Systems

- Workstation-based fans, ventilation, filtration, radiant heating, temperature control, sound masking, task lighting, zone lighting
- Zone-based window blinds, electro-chromic windows, zone/perimeter lighting, sound masking, underfloor/overhead/displacement systems

Occupant-based Communication and Control

- Personal comfort preferences (learned), eco-comfort preferences, zone comfort optimization, workstation device interface, building operator notifications, emergency notifications, energy/comfort dashboard, maintenance requests, demand response event notification

Energy/Comfort Dashboards

Occupancy-Based Control

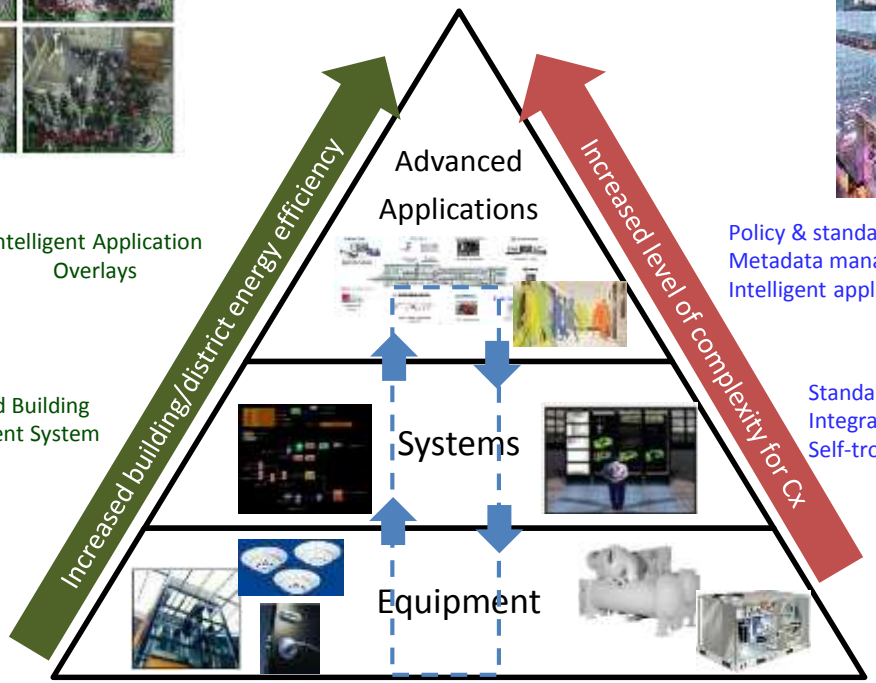
Personalized Comfort Systems

Control Commissioning & Data Mining

Enabling sustainable energy efficiency for intelligent building systems and solutions

Sistine Chapel (2014)
CO2 levels management

iSquare Hong Kong (2015)
30% energy savings predicted



Intelligent Application Overlays

Integrated Building Management System

Fire & Security
Elevators
Chillers; HVAC
Lighting; Shading

Policy & standards
Metadata management
Intelligent applications

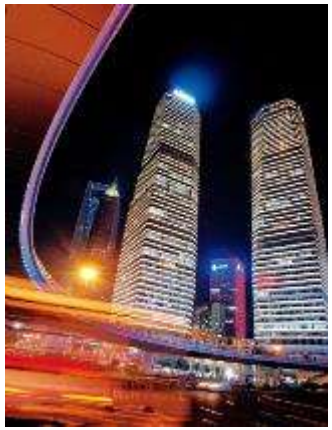
Standard data flow
Integrated visualization
Self-troubleshooting

Diagnostics Prognostics
Field service tools
Auto-Cx and Re-Cx

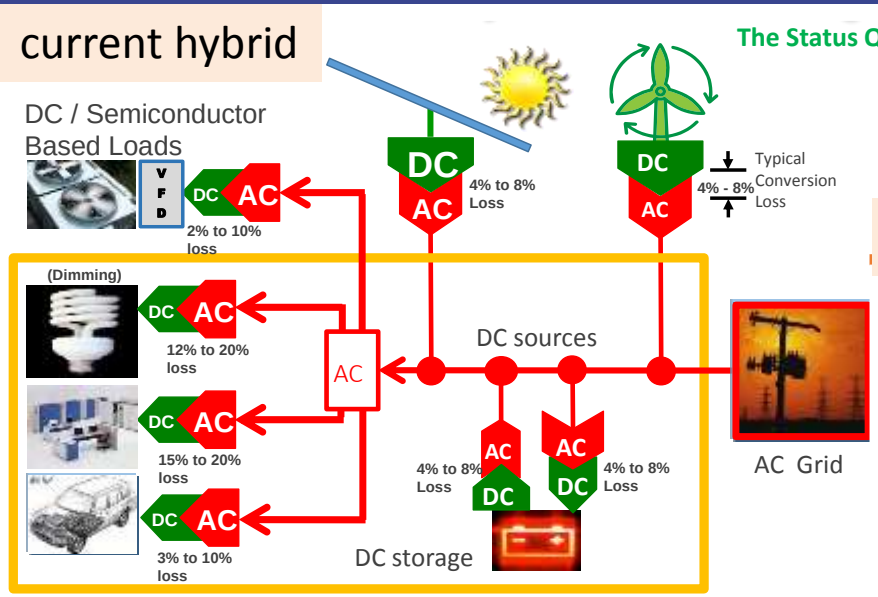
Office Building - India (2013)
Improved Ventilation through Diagnostics

Shanghai Engine Center (2009)
44% Energy Savings

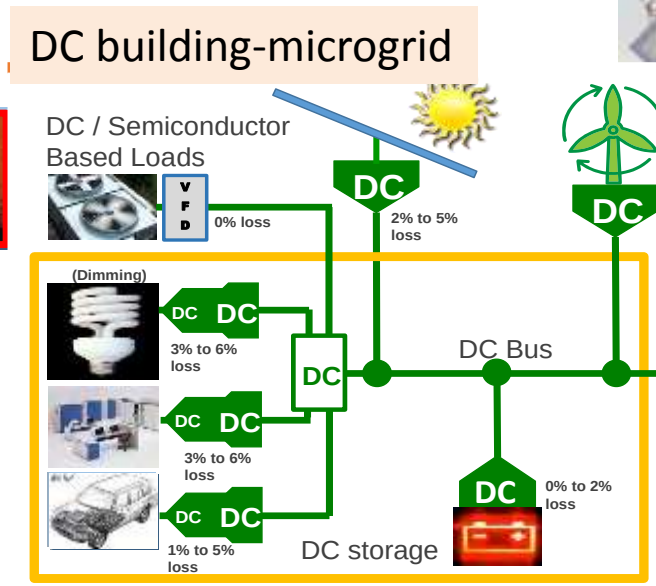
Shanghai IFC (2012+)
11,200 tons of carbon/year eliminated



DC Buildings and Smart Grid



source: Emerge Alliance



- **Higher Efficiency**
- **Minimal Conversion Loss**
- Lower Operating Expense
- Safer

- Fewer Components
- More Reliable
- Less Real Estate
- Reduced Carbon Footprint

- Current hybrid buildings with on-site generation-storage require many energy conversions.
- Current commercial buildings have about 1/3 efficient loads involving DC, i.e. electronics, lighting, variable speed motors, etc. and the fraction is growing.
- Eliminating conversions DC ➔ AC ➔ DC saves 10-20% electricity consumption.
- DC has other power quality advantages, so future buildings may use both.
- China conditions amenable to development of DC building systems

CERC 2.0 Preliminary Roadmap and Outcomes -Net Zero Energy Building

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

Zero

Beyond

2020

- Roadmap for 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

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For More Information:

http://cercbee.lbl.gov

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