



# #F1: Research on Very Low-Energy Building O&M Methods

2014 Building Technologies Office Peer Review



# Project Summary



## Timeline:

Start date: 1/1/2011

Planned end date: 12/31/2015

## Key Milestones

1. Completed energy benchmarking tools for hotels and commercial offices in China; 12/31/2012
2. Published research paper on construction, equipment, EE technology, and O&M characteristics of very low-energy hotels; 12/31/2013

## Budget:

Total DOE \$ to date: \$467,000

Total future DOE \$: \$100,000

## Target Market/Audience:

- 1.3 billion m<sup>2</sup> of urban hotel and commercial office space in China (*CABR estimate*);
- 17 US member companies of US-China Energy Cooperation Partnership (ECP) EE Building & Design Working Group (Honeywell, UTC, GE, Dow, etc.);
- US DOE BTO and China MOHURD.

## Key Partners:

Center of Science and Technology of Construction (CSTC), Ministry of Housing and Urban-Rural Development (MOHURD)

China Academy of Building Research (CABR)

Sustainable Energy Partnerships (SEP)

## Project Goal:

- Develop and pilot national building energy database, benchmarking tool, and policy framework in China that will:
  - Drive energy and CO<sub>2</sub> reductions in Chinese buildings;
  - Drive sale of US EE technologies in China;
  - Drive innovation in Chinese policy, including inclusion of benchmarking in China's 13<sup>th</sup> Five Year Plan.
- Conduct research to inform evolution and advancement of US building energy policy, drawing on lessons of China, such as:
  - Application of on-line, energy monitoring to increase efficiency and effectiveness of data collection;
  - Innovative building energy policies (i.e., Shenzhen ETS)

# Purpose and Objectives



## Problem Statement:

- China and US are largest energy consumers and CO<sub>2</sub> emitters globally.
- Buildings in China and US account for 23% and 39%, respectively, of each country's consumption, and **combined 14% of total CO<sub>2</sub> emissions**.
- The **US-China Energy Research Center Building Energy Efficiency (CERC BEE)** consortium seeks to conduct joint US-China research on BEE technologies and practices to achieve very low-energy buildings in both countries.

## What China and the US Need:

- China's building stock is estimated at 43 billion m<sup>2</sup>, five times the size of the US, and growing at 2 billion m<sup>2</sup> annually (*=21 new Empire State Buildings added per day!*)
- **China needs tools to equitably measure existing building performance** to: set operating standards; identify buildings for retrofit; and identify best practices.
- **US policymakers need to improve efficiency and reliability of data collection and to evolve codes, standards, and policies** in response to new market conditions.
- The US can learn from innovations in China on on-line monitoring, emissions trading, and energy quotas (Shenzhen ETS, building energy quota).

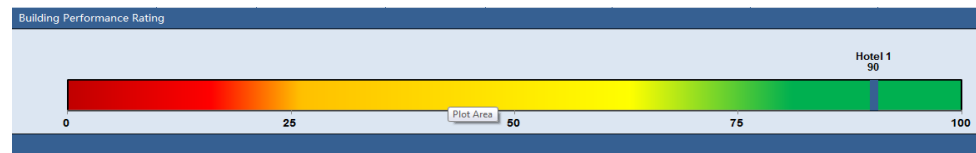
## Target Market and Audience:

- **1.26 billion m<sup>2</sup> of urban commercial office and hotel space** in China, consuming an estimated **405 billion kWh annually** (and adding 5% annually to total market size).
- **US building EE technology companies**
- US DOE and China MOHURD.



## Impact of Project (by December 2015):

- A piloted building energy database, benchmarking system, and policy framework for public buildings in China.
- US building technology and solution providers trained on use of benchmarking system to sell energy services (through US-China ECP platform).
- China incorporates benchmarking into 13<sup>th</sup> Five Year Plan.
- US DOE informed on China's real-time energy monitoring and innovations in building energy performance codes, standards, and policies (e.g., Shenzhen ETS).



*Operational Rating System*

# Projected Energy, CO<sub>2</sub>, and US Technology Sale Impact



## Projected Energy and CO<sub>2</sub> Impact in China

|                                    | Total m <sup>2</sup> Benchmarked (1%) | Total Savings from Benchmarked Buildings (kWh) | GHG Emission Reduction (MtCO <sub>2</sub> e) | Wind Turbines Installed |
|------------------------------------|---------------------------------------|--|--|-------------------------|
| <b>Short term: 2016 2017 (2yr)</b> | 29,400,000                            | 1,169,197,200                                  | 949,797                                      | 262                     |
| <b>Med-term: 2016 2020 (5yr)</b>   | 78,000,000                            | 6,086,232,000                                  | 4,944,151                                    | 1,362                   |
| <b>Long-term: 2016 2025 (10yr)</b> | 171,000,000                           | 23,784,354,000                                 | 19,321,220                                   | 5,321                   |

*This assumes 1% of total commercial office and hotel square meters (new and existing) benchmark annually for a total of 20% for each space type over 10 years. We assume each building saves an average of 10% in energy usage through implementation of O&M improvements, which is shown to be achievable based on 10+ years of ICF experience in China.*

## Projected US Technology Sale Impact

|                                    | Total m <sup>2</sup> Investing in Technology (%) | Estimated Retrofit Cost Per Square Meter (USD) | Total Sales (USD) |
|------------------------------------|--|--|-------------------|
| <b>Short-term: 2016 2017 (2yr)</b> | 1,470,000  | \$82.93  | \$121,904,883     |
| <b>Med-term: 2016 2020 (5yr)</b>   | 3,900,000  | \$82.93  | \$323,427,000     |
| <b>Long-term: 2016 2025 (10yr)</b> | 8,550,000  | \$82.93  | \$709,051,500     |

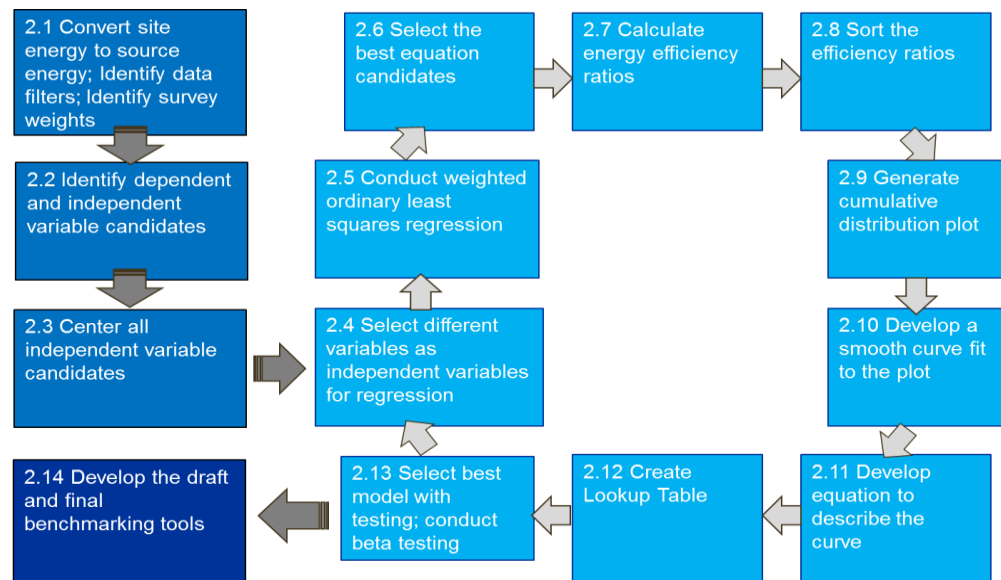
*This assumes 5% of benchmarked buildings will invest in new technologies at an estimated retrofit cost per square meter of 523.03 RMB (\$82.93). Retrofit costs per square meter are estimated based on retrofit costs of lighting, space heating/cooling and advanced elevators from a solution proposal done by CABR, Feb 2012 – Energy Efficiency retrofit plan for China Southern Grid office building. These are roughly in-line with Urban Land November/December 2009 report citing hole building green retrofits can cost anywhere from \$27 to \$75 per square meter - [https://www.esbnyc.com/documents/sustainability/uli\\_building\\_retro\\_fits.pdf](https://www.esbnyc.com/documents/sustainability/uli_building_retro_fits.pdf)*

# Approach



## Approach:

- Database development draws on US Commercial Building Energy Consumption Survey (CBECS) and US DOE Building Performance Database (BPD).
- Benchmarking tool development draws primarily on ENERGY STAR methodology, with customizations for China (i.e., data points for normalization).
- Policy framework draws on ENERGY STAR and NRDC research (focus on building energy services market and leveraging ESCOs to provide benchmarking, etc.)



*Methodology for Tool Development*

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

# Key Issues



## Key Issues:

- Access to data for benchmarking: Most Chinese building energy data sets **not publicly available**.

## Resolution:

- ICF partnered with Horwath HTL and China Tourist Hotel Association (CTHA) to conduct an annual “Energy Benchmark Survey,” providing **access to data for ~700 hotels annually**.
- ICF and China Property Management Institute (CPMI) partnership provided data sufficient for **1<sup>st</sup> iteration commercial office benchmarking tool**.

2010 全球饭店业务统计, 中国问卷 - 能源统计  
2010 Worldwide Hotel Industry Study, China Survey, Energy Benchmarking Survey

中国旅游饭店业协会 China Tourist Hotels Association  
浩华管理顾问公司 Horwath HTL

Please contact us should you require an electronic version of the questionnaire at:  
如需获取电子版问卷, 请联系浩华管理顾问公司: [szhang@horwathhtl.com](mailto:szhang@horwathhtl.com) or 010-8518-1833

**Energy Benchmarking Survey / 能源统计**

English Name of Property: \_\_\_\_\_  
酒店中文名称: \_\_\_\_\_

Q.1 Number of guest rooms?  
问题 1: 贵酒店客房数目? \_\_\_\_\_ Rooms / 间

Q.2 Total hotel floor space?  
问题 2: 贵酒店楼面面积? \_\_\_\_\_ Square metres / 平方米

Q.3 Number of floors?  
问题 3: 贵酒店楼层数量? \_\_\_\_\_ Floors / 层

Q.4 Average annual occupancy (percentage)?  
问题 4: 贵酒店年平均住宿率? \_\_\_\_\_ %  
\* Average percentage of rooms that are occupied in the hotel during the course of a year.

Q.5 Number of employees during the main shift?  
问题 5: 酒店正常运营状况所需员工数量? \_\_\_\_\_

\* Answer "yes" if this property includes cooking facilities to support room service, restaurants, conference space, and/or banquet facilities. Answer "no" if the hotel's food service consists only of continental breakfast service or other pre-packaged or light offerings that do not require a full service kitchen. Answer "no" if this property only includes equipment in employee break rooms, vending machines, and/or kitchens in guest suites.

Q.8 Number of commercial refrigeration units?  
问题 8: 酒店制冷设备数量?

| Type / 类型           | Numbers / 数量 |
|---------------------|--------------|
| Walk-in / 大冷藏室      |              |
| Open / 开放式冰柜 (冰箱)   |              |
| Closed / 封闭式冰柜 (冰箱) |              |
| <b>Total / 合计</b>   |              |

Q.9 Any pools in your hotel? If yes, please specify the type, number, and total cumulative size of the pools.  
问题 9: 贵酒店是否有泳池? 如有, 请提供泳池面积。

| Type / 类型 | YES | NO | No. | Total Cumulative |
|-----------|-----|----|-----|------------------|
|           |     |    |     |                  |

Horwath-CTHA Annual “Benchmark Survey”

## Data for 54 Grade A and B commercial offices :

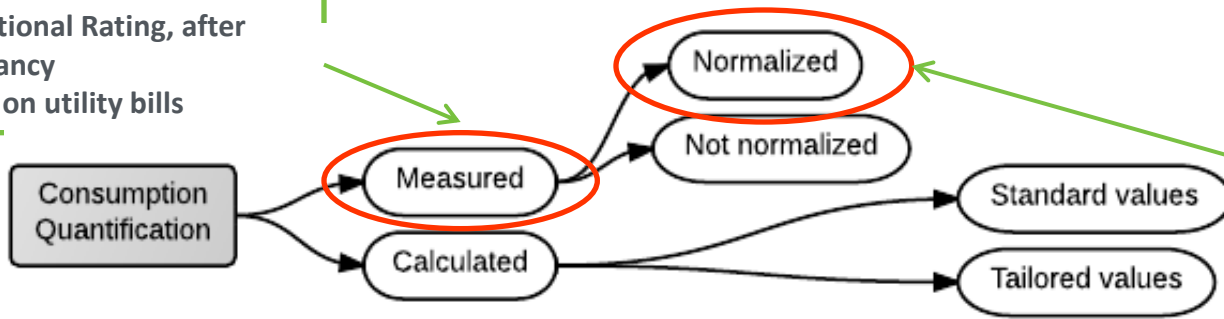
- 19 in Beijing (2% of total office stock)
- 11 in Dalian (17% of total office stock)
- 9 in Guangzhou (2% of total office stock)
- 15 from other cities.



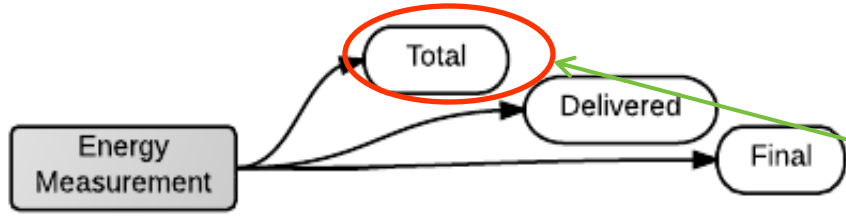
# Distinctive Characteristics

- Approach based primarily on ENERGY STAR, with customizations for China (i.e., data points for normalization).

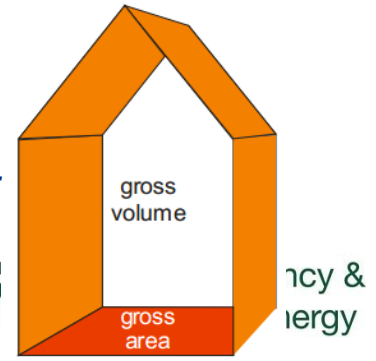
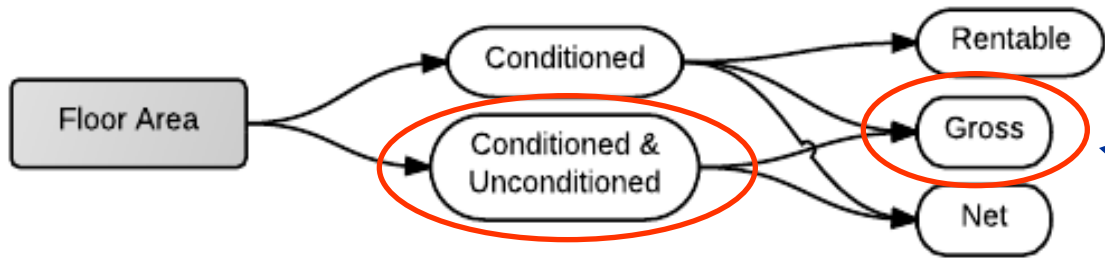
- Operational Rating, after occupancy
- Based on utility bills



- Hotels**
  - Star category
  - Number of Rooms
  - Number of Workers
  - Location (HDD/CDD)
  - Number of Walk-in Commercial Refrigeration Units
  - Gross Floor Area
- Offices**
  - CDD
  - Building Annual Operation Hours (hour)
  - Number of Staffs (person)
  - Floor Area of Heated/Cooled (SM)



- Source or Primary Energy Use

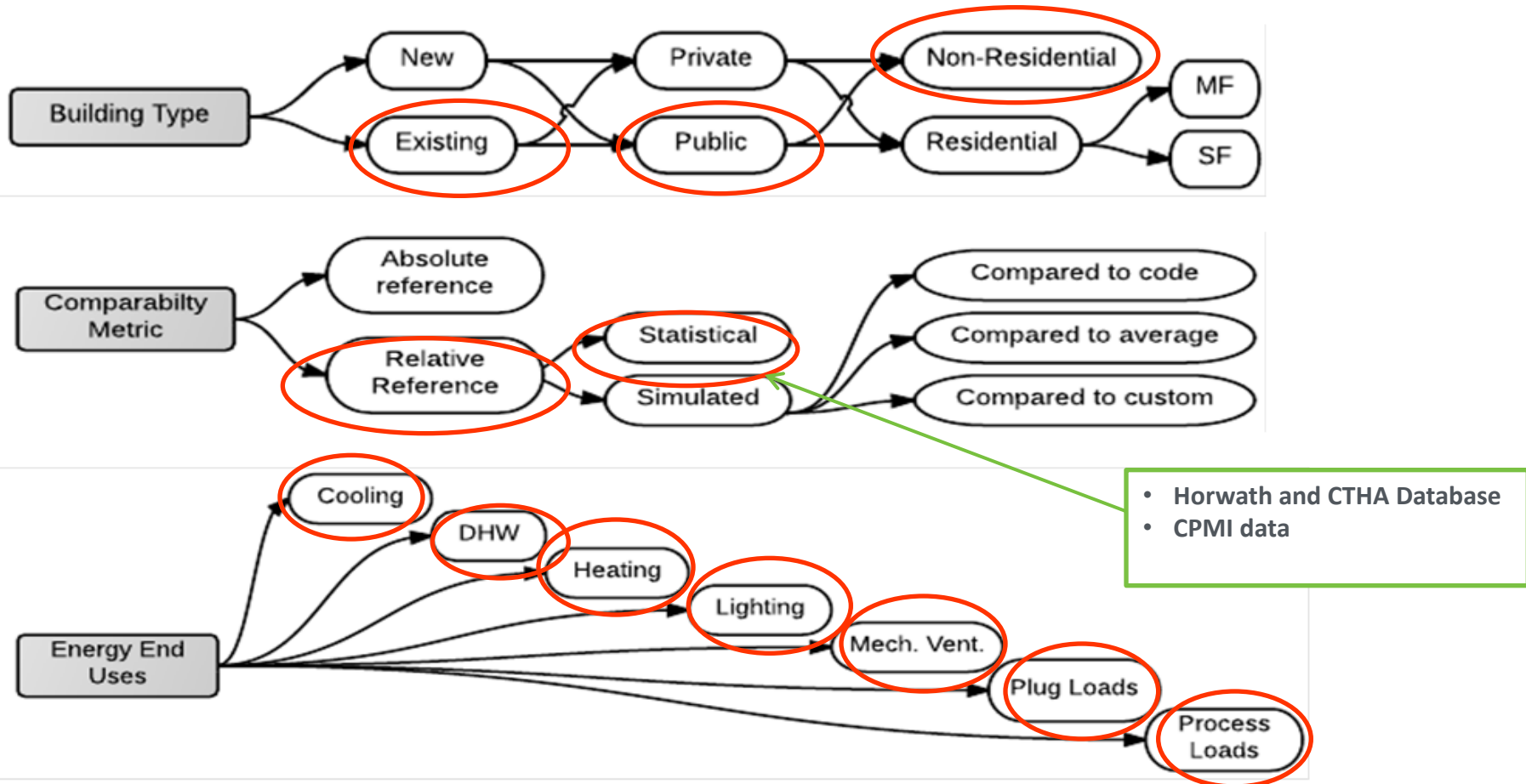






# Distinctive Characteristics

- Approach based primarily on ENERGY STAR, with customizations for China (i.e., data points for normalization).





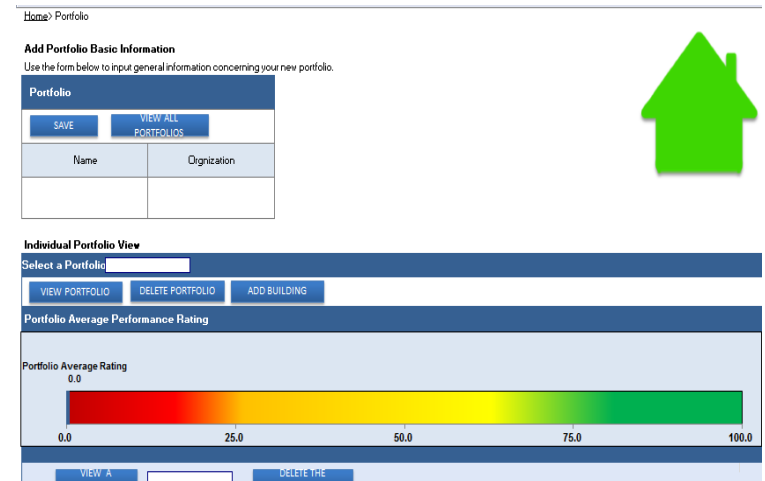
## First Prototype Comparative Building Benchmarking Tools for Hotels and Commercial Offices in China

### On-line Hotel Benchmarking Tool



<http://www.cabr-cecc.com/>

### Commercial Office Benchmarking Tool Prototype



- **Chinese hotel benchmarking models** explain 78.3%, 66.6%, and 78% percent of the variance in energy consumption for 5-Star, 4-Star, and 3-Star hotels, respectively.
- **Chinese commercial office benchmark model** explains 89% of the variance in energy usage.
- **US ENERGYSTAR benchmarking models** explain 87.3% of the variation of source energy of hotels and 79.1% of the variation of source energy for commercial offices.

# Accomplishments



| Construction                      | Best Energy Performing Hotels in China (Top 25%)   | Poorest Energy Performing Hotels in China (Bottom 25%)  |
|-----------------------------------|--|---|
| <b>Envelope</b>                   | Mostly concrete envelope (60%).  | Mostly glass envelope (50%).  |
| <b>Wall insulation</b>            | Nearly three-quarters use wall insulation (70%).   | Over half use wall insulation (57%).  |
| <b>Windows</b>                    | Hollow double glazing window most popular<br>High instances of operable windows (22%).   | Hollow double glazing window most popular (75%).<br>Few instances of operable windows (6%).   |
| <b>Glass</b>                      | Most use glass with film painting (57%) and more than one-third use normal glass (38%).  | Most use glass with film painting (43%) and nearly one-third use low-e glass (29%) or normal glass (29%).   |
| <b>Equipment</b>                  |  |   |
| <b>HVAC Cooling</b>               | Water-loop chiller unit- screw is most popular (41%). Split AC/VRV and renewable energy source heat pumps found only in above-average performers | Water-loop chiller unit- screw is most popular (56%). Direct combustion lithium bromide absorption chiller found only in below-average performers           |
| <b>HVAC Heating</b>               | Natural gas boiler is most popular (53%), but high instances of district steam use (40%).  | Natural gas boiler is most popular (86%), followed by direct combustion lithium bromide absorption chiller (natural gas) (14%). No district steam use (0%). |
| <b>HVAC Main Air Distribution</b> | Fan-coil units (FCU) + primary air units (PAU) and FCUs with PAUs + VRV/Split AC most popular. More Split AC/VRV (24%)                           | Fan-coil units (FCU) + primary air units (PAU) and FCUs with PAUs + VRV/Split AC most popular. No Split AC/VRV (0%).  |
| <b>Water Heating</b>              | On-site boiler most popular (65%). District hot water/steam only in above-average performers.  | On-site boiler most popular (100%). No district hot water/steam (0%).   |

# Accomplishments



| Lighting                      | Best Energy Performing Hotels in China (Top 25%)  | Poorest Energy Performing Hotels in China (Bottom 25%)  |
|-------------------------------|---|---|
| <b>Major Indoor Lighting</b>  | More use of low pressure sodium, high pressure sodium, metal halide, and high pressure mercury lamps. Use of LFL, CFL, and LEDs similar to poor performers. | LFLs, CFLs, and LEDs widely used.   |
| <b>Lighting Control</b>       | More use of manual control (59%).   | More use of manual control (57%) and high instances of automation (43%).  |
| <b>EE Technology</b>          |   |   |
| <b>EE Technology HVAC</b>     | High instances of VFD (65%) and economizer (75%). CO2 sensors installed (17%).  | High instances of VFD (100%) and economizer (75%). No CO2 sensors installed.  |
| <b>EE Technology Water</b>    | High instances of low-flow showerhead (67%).  | High instances of low-flow showerhead (75%).  |
| <b>EE Technology Lighting</b> | Use of occupancy sensors (22%) and controllable dimmers (23%).  | Use of occupancy sensors (25%) and controllable dimmers (100%).   |
| <b>O&amp;M</b>                |   |   |
| <b>O&amp;M HVAC</b>           | Open windows during cooling season (100%), manual control of HVAC (64%).  | Close windows during cooling season (100%), automated control of HVAC (50%).  |
| <b>O&amp;M Lighting</b>       | High instances of scheduling (79%).   | High instances of scheduling (100%).  |
| <b>O&amp;M Management</b>     | Energy audit (69%), energy retrofit last three years (100%), EE purchasing plan (85%). Track data (100%) and designated energy manager (100%).              | Energy audit (50%), energy retrofit last three years (75%), EE purchasing plan (75%). Track data (100%) and designated energy manager (100%). |



# Lessons Learned

- **Concrete envelope and operable windows** offer better levels of energy efficiency and energy conservation.
- Best EE lamps on the market (**low and high pressure sodium and metal halides**) found only in **top performing hotels**.
- **District steam, split AC/VRV systems, and renewable energy source heat pumps**, found only in **above-average hotels**.
- While both top and poor energy performing hotels utilize EE technologies, **top performing hotels were more likely to manually control HVAC equipment and to have invested in an outside audits or energy retrofit** in the past three years
- Certain construction characteristics, such as **glass envelope and direct combustion lithium bromide absorption chillers (natural gas)** should be avoided.



# Market Impact

## Market Impact:

- Two prototype benchmarking tools completed for China.
- 200 property managers from 21 Chinese provinces introduced to benchmarking through training workshops with CPMI.
- US-China ECP committed to leveraging benchmarking tool to advance sale of US EE technologies through training for member companies.
- MOHURD CSTC committed to incorporating benchmarking into China's 13<sup>th</sup> Five Year Plan.
- Impacts on CO<sub>2</sub> and US technology sales will begin in early 2016 (after pilot phase).

## US China ECP EE Building & Design Working Group Member Companies

- ICF
- UTC
- AECOM
- Applied Materials
- Autodesk
- Calera
- Caterpillar
- Dow
- Eastman
- First Element Energy
- First Solar
- General Electric
- Honeywell
- IBM
- Intel
- JCI
- Sage





# Project Integration and Collaboration

## Project Integration:

- ICF and CABR may leverage **World Bank China Energy Benchmarking and Public Disclosure (EPB&PD)** Project to disseminate tools in Beijing and Ningbo (for replication in other cities) (2014-2016).
- ICF involving **Tsinghua University's Yan Da** to offer insight into impact of modeling/simulation on energy performance benchmarking system.
- In coordination with **US-China ECP** to train US technology suppliers on use of benchmark to sell energy services.

## Partners, Subcontractors, and Collaborators:

- Ministry of Housing and Urban-Rural Development (MOHURD) Center for Science and Technology of Construction (CSTC) (*Chinese Counterpart and Principle Investigator (PI)*)
- Sustainable Energy Partnerships (SEP) (*US PI*)
- Lawrence Berkley National Laboratory (LBNL) (*Collaborator and Advisor*)
- China Academy of Building Research (CABR) (*Collaborator and Advisor*)
- Tsinghua University (*Collaborator and Advisor*)
- Natural Resources Defense Council (NRDC) (*Collaborator and Advisor*)

**Estimated In-kind Support:** ~US\$10,000 (CABR and Tsinghua involvement in monthly meetings with MOHURD, CSTC, and ICF.)





## Presentations on Benchmarking:

- 2013 MOHURD International Conference on Green and Energy-Efficient Building & New Technologies and Products Expo
- 2011, 2012 Asia Hotel Forum
- 2011 International Youth Summit on Climate Change
- 2011 China Hotel Development and Finance Conference

## Papers on Benchmarking:

- 2014 MOHURD International Conference on Green and Energy-Efficient Building & New Technologies and Products Expo Paper: *Construction, Equipment, Technology, and Operational Characteristics of Very Low-Energy Hotels in China.*





# Next Steps and Future Plans

## Next Steps and Future Plans:

- Following completion of prototype database, benchmarking system, and policy framework in China –
  - Promote **uptake into 13<sup>th</sup> Five Year Plan**.
  - Promote coordination of efforts on benchmarking across multiple stakeholders – **World Bank, CABR, CSTC, NRDC, IPEEC**.
  - Focus on – **benchmarking program formation on a national level, accompanied by program-delivered technical assistance** for reducing energy use in the existing building stock. Largely training, and could link to certification for building energy management.
  - Focus on – **Identifying US industry leaders** (GE, Honeywell, etc.) to utilize benchmarking to sell US energy services in China.
  - Promote continued identification of **lessons for US from China's real-time energy monitoring** and innovations in building energy performance codes, standards, and policies.



# REFERENCE SLIDES



# Project Budget

**Project Budget: \$467,000 Total, Expended 78% To-Date (\$365,174)**  
**Additional Funding: \$200,000 cost-share from USAID (2011-2012)**

| Year         | Planned           | Actual            | Variance | Explanation  |
|--------------|-------------------|-------------------|----------|--|
| Year 1       | \$135,000         | \$135,000         | \$0      | Work on target to develop benchmarking tools for China.  |
| Year 2       | \$135,000         | \$150,000         | +11%     | Received budget increase due to importance/value of work.  |
| Year 3       | \$135,000         | \$82,000          | -39%     | MOHURD priorities shifted to research methods on O&M, smaller budget allocated for more limited R&D SOW. |
| Year 4       | \$135,000         | \$100,000         | -26%     | MOHURD priorities shift back to benchmarking, smaller budget requested for more limited SOW with CSTC.   |
| Year 5       | \$135,000         | TBD               | TBD      |  |
| <b>Total</b> | <b>\$ 675,000</b> | <b>\$ 467,000</b> |          |  |

## Budget History

| FY2011– FY2013<br>(past) |            | FY2014<br>(current) |            | FY2015<br>(planned) |            |
|--------------------------|------------|---------------------|------------|---------------------|------------|
| DOE                      | Cost-share | DOE                 | Cost-share | DOE                 | Cost-share |
| \$367,000                | \$200,000* | \$100,000           | TBD        | \$100,000           | TBD        |

\* Estimated cost-share from USAID US-China Sustainable Buildings Partnership in 2011 and 2012.

# Project Plan and Schedule



| Project Schedule                                 |  |              |              |              |              |              |              |              |              |              |              |              |
|--|--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Project Start: 1/1/2011                          | Completed Work                               |              |              |              |              |              |              |              |              |              |              |              |
| Projected End: 12/31/2015                        | Active Task (in progress work)               |              |              |              |              |              |              |              |              |              |              |              |
|  | ◆ Milestone/Deliverable (Originally Planned) |              |              |              |              |              |              |              |              |              |              |              |
|  | ◆ Milestone/Deliverable (Actual)             |              |              |              |              |              |              |              |              |              |              |              |
|  | FY2013                                       |              |              |              | FY2014       |              |              |              | FY2015       |              |              |              |
| Task   | Q1 (Oct-Dec)                                 | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) |
| <b>Past Work</b>                                 |  |              |              |              |              |              |              |              |              |              |              |              |
| Q2 Milestone: Develop survey questionnaire       |  | ◆            |              |              |              |              |              |              |              |              |              |              |
| Q3 Milestone: Conduct survey with 100 hotels     |  |              | ◆            |              |              | ◆            |              |              |              |              |              |              |
| Q4 Milestone: On-site investigation              |  |              |              | ◆            |              |              |              |              |              |              |              |              |
| Q1 Milestone: Case studies                       |  |              |              |              | ◆            |              |              |              |              |              |              |              |
| Q2 Milestone: Final Year 2 Report                |  |              |              |              | ◆            | ◆            |              |              |              |              |              |              |
| <b>Current/Future Work</b>                       |  |              |              |              |              |              |              |              |              |              |              |              |
| Q3 Milestone: Draft data taxonomy and tool       |  |              |              |              |              |              | ◆            |              |              |              |              |              |
| Q4 Milestone: Final taxonomy, draft tool, policy |  |              |              |              |              |              |              | ◆            |              |              |              |              |
| Q1 Milestone: Pilot data taxonomy in city        |  |              |              |              |              |              |              |              | ◆            |              |              |              |
| Q2 Milestone: Updates to benchmarking tool       |  |              |              |              |              |              |              |              |              | ◆            |              |              |
| Q3 Milestone: Pilot tool and policy in city      |  |              |              |              |              |              |              |              |              |              | ◆            |              |

# A Project of CERC-BEE (US-China Clean Energy Research Center Building Energy Efficiency Consortium)



**Pioneering U.S. China Innovation for Widespread Adoption of Very Low Energy Buildings Through Partnerships and Real World Impact**

**U.S. Research Leads**

**U.S. Industrial Partners** (Funding +40% Annual Average Growth Rate)

**Research Strategy → Huge Impact:**

- U.S./China construction market ~ 2B m2
- CO2 savings ~ 100Mt/year by 2025

**Technologies, Software**

**Demonstration Buildings, Commercial Impact, Tools and Guidebooks**

**Wide Adoption Very Low Energy Buildings**

**New Patent Applications**

**Market**

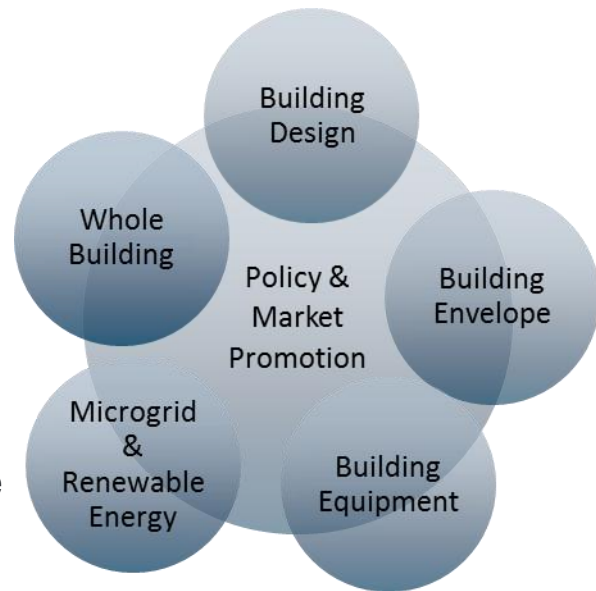
**Policy**

**ABOUT:** CERC-BEE is a five year, \$50M program created by the U.S. Department of Energy and Chinese Ministry of Science and Technology.

**R&D TEAMS:** U.S. national laboratories, and U.S. and Chinese universities, and research institutes team up with industry partners to accelerate innovation and deployment.

**SELECTED RESEARCH OUTCOMES:**

- Launched eight new products and developed two software tools (e.g. Cloud tool for microgrids, 40 new users from China)
- Won R&D Top 100 Award for GSHP by Climate Master
- Exceeded IP goals: ~ 25 patents filed, 4 approved; inventions disclosed and more in process (e.g. sprayable liquid flashing, cool roof materials)
- Developed 20 standards (e.g. LBNL involved in new Chinese commercial building code revision)
- Published 135 Chinese and 54+ US academic research papers



Website: [cercbee.lbl.gov](http://cercbee.lbl.gov)