

## **U.S.-China Clean Energy Research Center Building Energy Efficiency (CERC-BEE) Systems, Economic Analysis, and Modeling Project**

Addressing Market Barriers to Expand the Market for U.S.-China CERC-BEE Technologies up to Billions Annually by 2025.



**Cost-effective, technology pathways for high-performance and net zero energy buildings (NZEB).**



**Automated, open-source tool to cost-effectively target retrofit opportunities at scale.**



**New financial products to leverage capital markets and make building energy efficiency an asset class.**

**Lawrence Berkeley National Laboratory**

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# Project Summary

## Timeline:

Start date: April 1, 2016

Planned end date: March 31, 2021

## Key Milestones:

1. Automated retrofit targeting tool source code posted to GitHub (FY18Q3).
2. First innovative financial product for building energy efficiency launched (FY18Q3).
3. Harmonized US and China NZEB definitions and certification processes (FY20Q2).

## Budget:

### Total Project \$ to Date:

- DOE: \$1.085M
- Cost Share: \$3.9M

### Total Project \$:

- DOE: \$1.84M
- Cost Share: \$5.4M

## Key Partners:

### United States:

- Lawrence Berkeley National Laboratory
- ASHRAE TC 7.6
- Citi
- ICF International
- Institute for Market Transformation
- Investor Confidence Project
- International Finance Corporation
- International Living Future Institute
- Johnson Controls, Inc.
- Natural Resources Defense Council
- Rocky Mountain Institute
- U.S. Green Buildings Council
- United Technologies Corporation
- World Resources Institute Building Efficiency Accelerator

### China:

- China Ministry of Housing and Urban-Rural Development Center for Science and Technology of Construction
- Agricultural Bank of China
- China Academy of Building Research
- China Association of Building Energy Efficiency
- China State Construction Engineering and Corporation
- Ma'Anshan Rural Commercial Bank (MRCB)
- Shenzhen Institute of Building Research
- Sinowestar
- Tsinghua University

## Project Outcomes:

- Cost-effective, technology pathways for net zero energy buildings (NZEB) and U.S.-China harmonized standards.
- Automated, open-source tool to cost-effectively target building retrofit opportunities at scale in the U.S. and China.
- Innovative financial products and tools to leverage capital markets and make building energy efficiency an asset class.

# Team

## New Outcome-Based NZEB Research

FY18/19 Technology Pathways Research



FY19 Field Validation



CERC-BEE NZEB Demos

FY19/20 China Harmonizes to U.S. Standards



FY20/21 Outcome-based Performance Targets



NYC Shanghai

## Open-Source Retrofit Targeting Tool

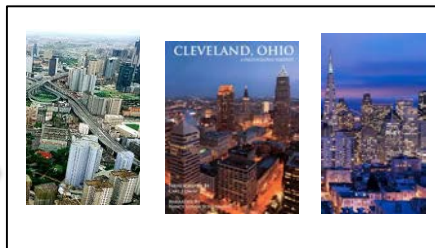
FY16-18 Database and Source Code



FY19 Prototype



FY19/20 Field Validation



Shanghai Cleveland California

FY20/21 U.S.-China Program / Tools Integration



## Financing

FY16/17 Financing Barriers Assessment



FY18-20 Develop, Validate, and Scale New Financial Products



FY18-20 Develop and Validate Standardized Financing Procedures and Tools



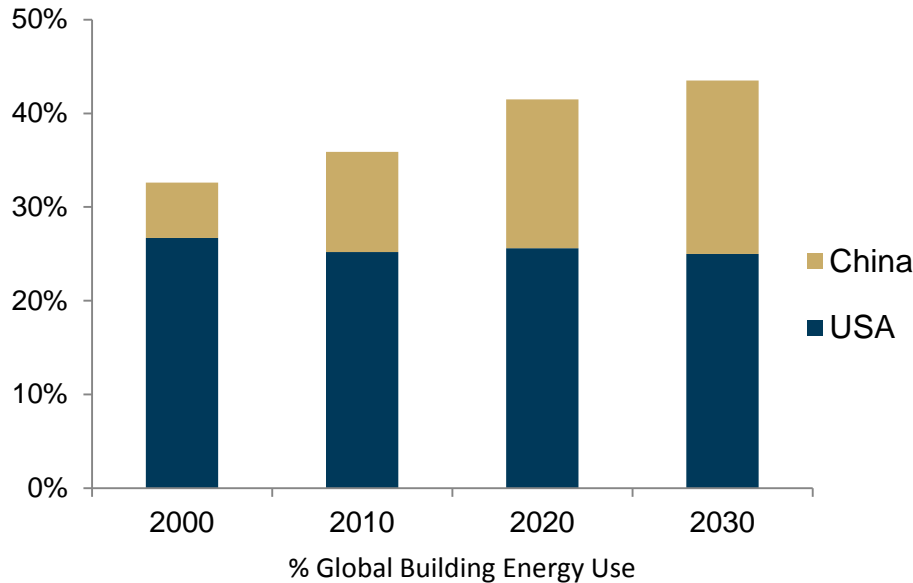
FY20/21 Input into Long-Term Financing Mechanisms



# Challenge

## Problem Statement:

U.S. and China account for close to 40% of total global building energy use.



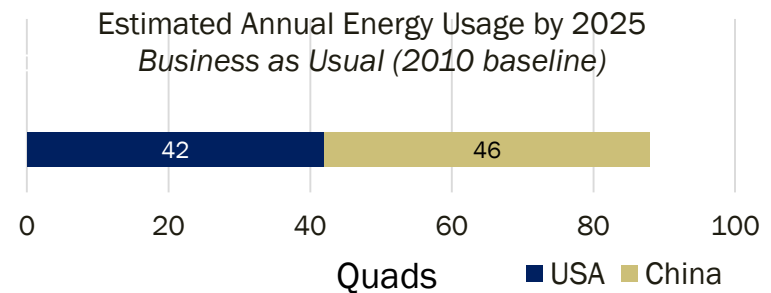
## Target Market:

- Designers and developers of **new commercial and residential** buildings in the US and China.
- Owners, operators, tenants, energy service companies (ESCO), and financiers of **new construction and existing commercial building retrofits** in the U.S. and China.
- National and local building energy **policymakers**.

## Barriers to Better Buildings:

- **New Buildings:**
  - Lack of cost-effective technology pathways to scale NZEB in major climate zones in U.S. and China.
  - Lack of harmonized U.S.-China NZEB definitions and certifications.
- **Existing Buildings**
  - Hundreds of billions of dollars of untapped EE upgrade opportunities.
  - Lack of automated tools to efficiently and cost-effectively target buildings for energy efficiency (EE) upgrades at scale.
  - Building EE is not considered an asset class.

## Market Size:



# New NZEB Research: Team, Approach, Outputs

## Partners, Subcontractors, and Collaborators



INTERNATIONAL  
LIVING FUTURE  
INSTITUTE™

NYC Mayor's Office of  
Sustainability



nbi

iBR  
深圳市建筑科学研究院  
Shenzhen Institute Of Building Research



Shenzhen Institute of Building  
Research CERC-BEE NZEB  
Demonstration Building

FY18Q3-FY19Q2:  
Cost-Effective Best-  
Practice Technology  
Pathway to Achieve  
NZEBs in Major U.S.-  
China Climate  
Zones.

- Field validation

## Long-Term Outputs and Outcomes

- ✓ **New specifications:** Chinese NZEB definitions and certification processes harmonized to U.S.
- ✓ **Performance targets:** to achieve future building sector/societal energy reduction goals, which may include NZEB goals.
- ✓ **Publications:** 1 peer-reviewed paper/journal article and 3 reports on cost-effective, best-practice technical specifications to achieve NZEB.
- ✓ **Demonstrations:** CERC-BEE NZEB demonstrations; outcome-based performance targets for New York City and Changning, Shanghai.

FY20Q3-FY21Q2:  
**Outcome-based  
Performance  
Targets** to achieve  
future building  
sector/societal  
energy reduction  
goals, which may  
include NZEB  
goals.

- NYC and Shanghai

### Distinctive Characteristics:

- Identifies NZEB technology and cost barriers and methods for overcoming barriers.
- Field validation of cost-effective technology pathways in CERC-BEE NZEB buildings.



# Open-Source Retrofit Targeting Tool: Team, Approach, Outputs

## Partners, Subcontractors, and Collaborators



- Distinctive Characteristic:**
- Emphasize building EE technology **co-development**; testing and **demonstration in China and U.S.**; and **scale-up in both countries.**
  - Tool based on **ASHRAE IMT and JCI LEAN.**
  - Open-source, **modular, online, and 100% automated format to target retrofits.**
  - Fully automated approach for **change point selection advancing the industry.**
  - Performs **M&V Option C.**



FY16Q3-FY17Q2: Chinese Building Energy Database

FY17Q3-FY18Q2: Open-Source Retrofit Targeting Tool Source Code Posted to GitHub

FY18Q3-FY19Q2: Web-based tool and mobile app prototype in China.

- Evaluate opportunities to integrate with DOE, ENERGY STAR, ASHRAE, and US Green Building Council (USGBC) tools and programs.

## Long-Term Outcomes and Outputs

- ✓ **New specifications:** Open-source tool incorporated into U.S. and China national/local benchmarking/disclosure/retrofit/commissioning programs.
- ✓ **Publications:** 1 peer-reviewed paper/journal articles and 5 reports/guidebooks.
- ✓ **Software:** Open-source retrofit targeting tool.
- ✓ **Guidebooks:** ASHRAE Best-Practice Energy Audit Book tool integration.
- ✓ **Training:** ASHRAE professionals training.
- ✓ **Demonstrations:** Changning, Shanghai, California, and Cleveland, Ohio.

Y19Q3-FY20Q2: Pilot Projects

- Shanghai.
- California.
- Cleveland.

FY20Q3-FY21Q2: Integrate with U.S.-China tools and programs

- DOE, ENERGY STAR, ASHRAE, and/or USGBC tools.
- US and China state/municipal benchmarking/disclosure programs.
- US and China Better Buildings Programs.



# Financing: Approach, Team, and Outputs

## Partners, Subcontractors, and Collaborators



### Distinctive Characteristic:

- Leverage **IFC China Climate Finance Advisory Program**: 9 partner banks and \$2.29 billion in finance for EE/RE projects.
- Chinese bank/developers **financial product co-development**.
- Partnership with **Agricultural Bank of China (ABC)** (US\$2.8T assets) – the 4<sup>th</sup> largest bank in the world – and **MRCB** – world’s 1<sup>st</sup> green commercial bank (US\$ 7.5B assets).

## Long-Term Outcomes and Outputs

- ✓ **New specifications**: Input into China’s “Implementation Plan and Long-Term Mechanism for Building Energy Saving and Green Building Development Through Green Finance” and U.S. Better Buildings Financial Navigator.
- ✓ **Publications**: 1 peer-reviewed paper and 3 reports/guidebooks.
- ✓ **Workshops**: 2 workshops (Barriers and ICP IREE Certification).
- ✓ **Products**: 2 financial products launched; 1 ICP tool, template, or protocol launched.
- ✓ **Training**: Building EE finance curriculum delivery to 200 individuals.
- ✓ **Demonstrations**: Financing and IREE Certification Pilot for CERC-BEE technologies with CGBC, USGBC, Landsea or others.

FY16Q3-FY17Q2:  
**Financing Barriers Assessment**

- Technical
- Credit

FY17Q3-FY18Q2: IFC-MRCB-ABC-Citi-ICP Partnership

- New financing products to mitigate credit risk
- New procedures and tools to mitigate technical risk

FY18Q3-FY19Q2: Develop New Financial Products and Standardized Procedures and Tools

- New green mortgage product and building EE upgrade product
- Introduce the ICP Certification Process for Investor Ready Energy Efficiency (IREE)™ in China

FY19Q3-FY20Q2: Pilot New Financial Products and Standardized Procedures and Tools

- ABC, MRBC, USGBC, CGBC, Landsea, ICP IREE, CERC-BEE

FY20Q3-FY21Q2: Input to U.S-China Long-Term Mechanisms for Financing

- China “Building Energy Efficiency and Green Building Financing Implementation Plan and Long-Term Mechanism”
- U.S. Better Buildings Financial Navigator



# Impact

## New Buildings Outcomes:

- **Technology pathways** for cost-effective, high-performance and NZEB buildings.
- Harmonized U.S. and China **NZEB definitions and certification processes** for the benefit of U.S. industry.
- **Outcome-based performance targets and advanced design guidelines** to align with future building energy efficiency levels.

## Existing Buildings Outcomes:

- **Cost-effective financial analyses and targeting of high-impact, technology and performance upgrades** for buildings via open-source on-line tools and/or mobile Apps.
- **Capital deployed at scale** for building energy efficiency as a result of innovative financial products and standardized procedures in U.S. and China.

## 2025 Annual Project Impact

2025 Annual Savings	US	China	Total
Energy savings (quads)	2.5	3.2	5.7
Percent savings (2010 base year)	6%	7%	13%
CO <sub>2</sub> reductions (MtCO <sub>2</sub> )	240	300	540

This contributes to achieving BTO’s goal to **reduce U.S. building EUI by 30% by 2030** and CBI’s program goal to **reduce U.S. market leaders’ EUI by 35% by 2025** (against 2010 levels).



# Progress: Open-Source Retrofit Targeting Tool

## FY16Q3-FY17Q2: Chinese Database

- ~ **800 Chinese hotels** for comparative analysis and lessons on the characteristics of high-performance, low-energy buildings.
- **120+ Chinese buildings** for open-source retrofit tool customization incoming (offices, hotels, university, hospitals).
- **Partnership with China Association of Building Energy Efficiency (CABEE)** on future data collection.

## FY17Q3-FY18Q2: Launched China Building Energy Saving Tool (BEST) Mobile App and Incorporated into Chinese Standards and Programs



- Incorporated into China's *Energy Performance Benchmarking & Public Disclosure (EPB&PD) in Large Public Buildings* pilot program.
- Initiating work to add retrofit analytical features to the BEST on-line tool and mobile app.

**FY17Q3-FY18Q2: Prototype Open-Source Retrofit Targeting** tool, an open-source on-line tool and mobile app to target high-impact building technology and performance upgrades and quantify economic returns.

### 1. Processes building and weather data using Python code.

```

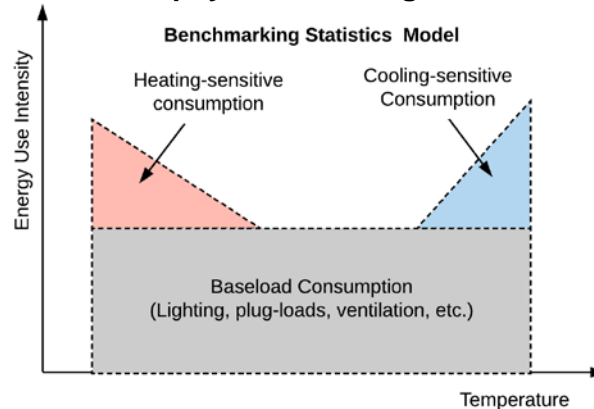
class Building:
    """Building class"""
    def __init__(self, name, address, latitude, longitude, area, volume, etc.):
        self.name = name
        self.address = address
        self.latitude = latitude
        self.longitude = longitude
        self.area = area
        self.volume = volume
        # ... other attributes

class Weather:
    """Weather class"""
    def __init__(self, date, temperature, humidity, etc.):
        self.date = date
        self.temperature = temperature
        self.humidity = humidity
        # ... other attributes

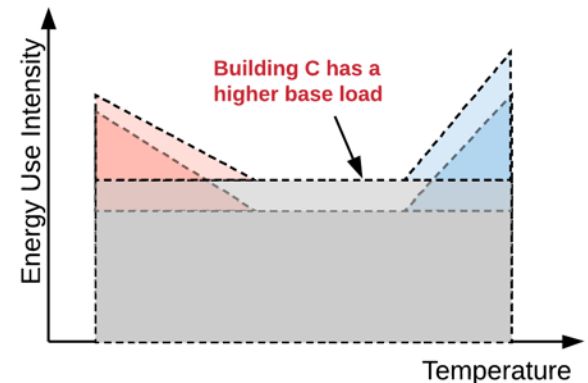
# Example usage
building = Building("Building A", "123 Main St", 38, 116, 10000, 100000)
weather = Weather("2017-01-01", 5, 60)

# ... more code for data processing
    
```

### 2. Automatically generates five coefficients of building performance with physical meaning.



### 3. Working with JCI to augment Python code to identify building technology and performance upgrades and estimate associated cost savings.



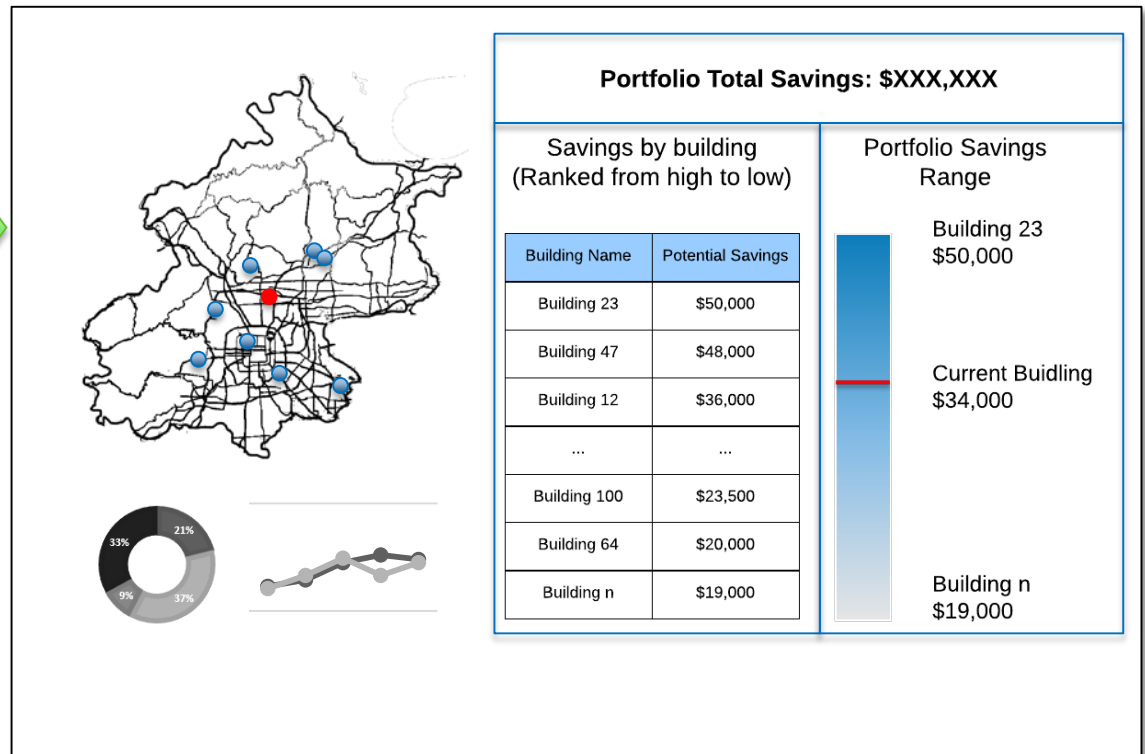
# Progress: Open-Source Retrofit Targeting Tool

FY18Q3-FY19Q2: Initiating retrofit targeting tool web-based tool and mobile app prototype development in China.

## Current: BEST Portfolio and Building Summary



## Planned: BEST Portfolio Summary

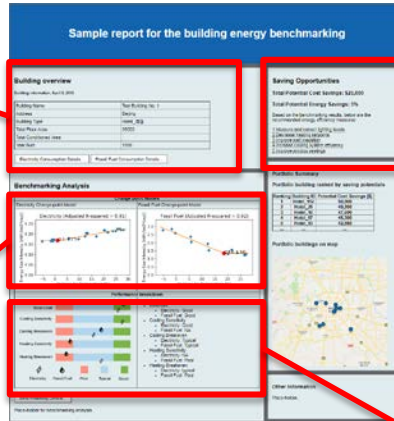


# Progress: Open-Source Retrofit Targeting Tool

## Planned: BEST Building Summary

### Building Overview

Building ID: Hotel 001  
 Address: Beijing  
 Building Type: Hotel  
 Floor Area: 3,5000 m<sup>2</sup>  
 Year Built: 1999



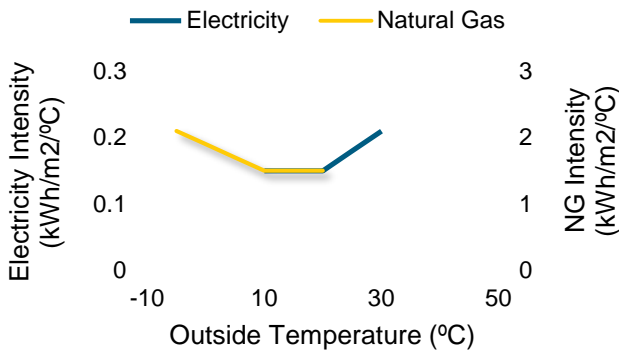
### Saving Opportunities

**Total Potential Cost Savings:** \$25,000  
**Total Potential Energy Savings:** 5%

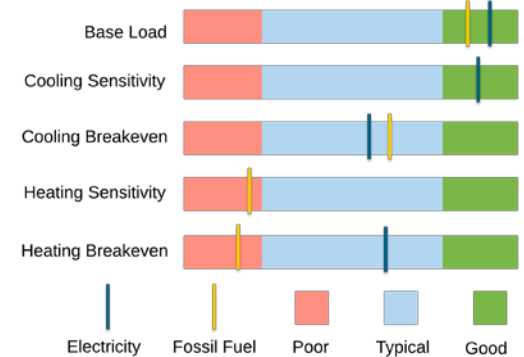
Energy Efficiency Measures:

1. Measure and correct lighting levels
2. Decrease heating set points
3. Improve wall insulation

### Inverse Models

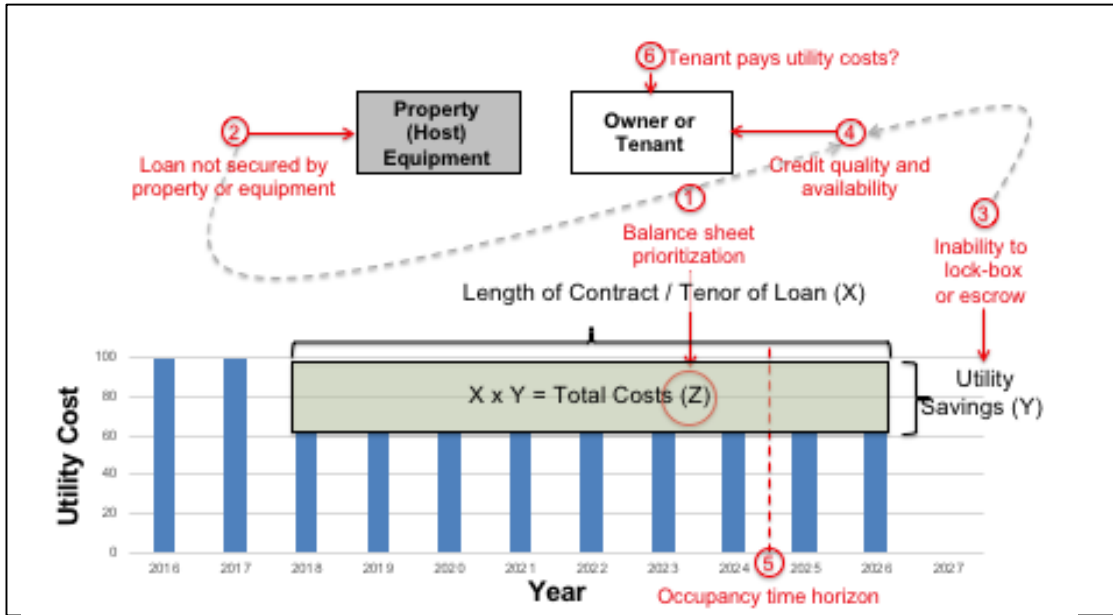


### Performance Benchmarking



# Progress: Financing

## FY16Q3-FY17Q2: Assessment of Barriers



## FY17Q3-FY18Q2: Citi-IFC-ABC-MRCB Pilot Project Launch



- LBNL and Citi to serve as Co-Chairs of IFC's R&D and Financial Product Innovation Working Group.
- Training for 200+ bankers to establish partnerships and foster innovation on building EE financing in leading U.S. and Chinese banks.

## FY18Q3-FY19Q2: Preparing 1<sup>st</sup> Green Financial Product Launch



	USGBC LEED		CGBC Three-Star	
Certified level	Annual Interest Rate (IR) Discount		Certified level	Annual IR Discount
LEED CERTIFIED	-			
LEED SILVER	0.1%		1-Star	0.1%
LEED GOLD	0.2%		2-Star	0.2%
LEED PLATINUM	0.3%		3-Star	0.3%

### Green Mortgage Product

1. Preferential interest rate (avoids mistakes of Citi)
2. Matching consumer line of credit up to 500,000 RMB for 3 years.
3. Exemption of early repayment penalty.
4. Considering "Matching Energy Savings Account."

# Stakeholder Engagement

**Goal:** Support widest possible adoption of technologies, tools, and products.

**Strategy:** Partner with key government and industry stakeholders; conduct field validation at city, district, building, or corporate-level; evaluate impact; disseminate results; integrate into national/local/corporate specification, tools, and/or programs.

## NZEB Technology Pathways:

- **Partners:** ILFI, NBI, UTC, RMI, NYC, CABR, MOHURD, and Changning District, Shanghai.
- **Field Validation:** CERC-BEE NZEB demonstration buildings.
- **National/Local Level Coordination:** Influence MOHURD NZEB definition and certification; influence Changning District, Shanghai and NYC outcome-based building targets.

## Open-Source Retrofit Targeting Tool:

- **Partners:** ICF, JCI, NRDC, DOE, ENERGY STAR, ASHRAE, WRI BEA, USGBC, CABEE, CABR, Sinowestar, MOHURD.
- **Field Validation:** U.S. and China state/municipal benchmarking/disclosure programs (Changning District, Shanghai; Cleveland; and California).
- **National/Local Level Coordination:** Integrate tool with DOE, ENERGY STAR, ASHRAE, and/or USGBC tools and programs; U.S. and China state/municipal benchmarking/disclosure programs; and U.S. and China Better Buildings Programs.

## Financing:

- **Partners:** IFC, ABC, MRCB, LANDSEA, Citi, ICP, Paulson Institute, USGBC, and CGBC.
- **Field Validation:** Financial products and standardized procedures and tools verified with IFC, MRCB, ABC, CGBC, USGBC, Landsea and ICP.
- **National/Local Level Coordination:** Products and tools incorporated into MOHURD “Building Energy Efficiency and Green Building Financing Implementation Plan and Long-Term Mechanism” and U.S. Better Buildings Program Financial Navigator.





# Remaining Project Work

## *New* NZEB Technology Pathways

- **FY18Q3-FY19Q2:** Develop Cost-Effective Technology Pathways to Achieve NZEBs in Major Climate Zones. Field Validation of Technology Pathways.
- **FY19Q3-FY20Q2:** Harmonization of Chinese NZEB Definition and Certification with U.S. Standards.
- **FY20Q3-FY21Q2:** Develop Outcome-based Performance Targets Aligned with Future Building Efficiency Levels for New York City and Changning, District, Shanghai.

## *Mid-Project* Open-Source Retrofit Targeting Tool

- **FY18Q3:** Continue to Improve Post Open-Source Retrofit Tool and Post to GitHub.
- **FY18Q3-FY19Q2:** Develop Prototype Web-based/Mobile App Retrofit Targeting Tool.
- **FY19Q3-FY20Q2:** Pilot Retrofit Targeting Tool in One Jurisdiction in U.S. and One in China.
- **FY20Q3-FY21Q2:** Integrate Retrofit Targeting Tool into U.S. and Chinese National/Local Tools/Programs.

## *Mid-Project* Financing

- **FY18Q3-FY19Q2:** Develop New Financial Products and Standardized Procedures and Tools.
- **FY19Q3-FY20Q2:** Pilot New Financial Products and Standardized Procedures and Tools.
- **FY20Q3-FY21Q2:** Contribute to China and U.S. Long-Term Mechanisms for Financing.

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# Thank You

**Lawrence Berkeley National Laboratory**  
**Carolyn Szum, Program Manager, Assistant Group Lead China Energy Group**  
**510-486-4106, [ccszum@lbl.gov](mailto:ccszum@lbl.gov)**

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# REFERENCE SLIDES

# Project Budget

**Variances: None.**

## Cost to Date:

- (b) Funds received: \$772,500
- (c) Cost to-date (Mar 2018): \$601,764
- **U.S. Industry Cost-share**
- (a) Contributions to-date: \$1,402,000

FY18Q3-FY19Q2 Industry Cost Share (\$K)		
US Industry Partner	In-Kind	Total
Autodesk	40.4	40.4
CECEP	50	50
Citi	100	100
ASHRAE	25	25
ICP	50	50
ILFI	31.5	31.5
JCI	1,849.5	1,849.5
Lutron	100	100
NRDC	25	25
RMI	75*	75*
USGBC	29.5	29.5
UTC	25*	25*
WRI BEA	25	25
<b>Total</b>	<b>2,525.4</b>	<b>2,525.4</b>

## Budget History

FY16Q3-FY18Q2 (past)		FY18Q3-FY19Q2 (current)		FY19Q3-FY21Q2 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$710K	\$1,402K	\$375K	\$2,525.4	\$750	\$1,500





# Project Plan and Schedule

CERC-BEE Fiscal Year (FY): April 1 to March 31  
 Project Start: April 1, 2016  
 Project End: March 31, 2021

Activity	Task	BTO FY16		BTO FY17		BTO FY18		BTO FY19		BTO FY20		BTO FY21	
		CERC-BEE FY2016	CERC-BEE FY2016	CERC-BEE FY2017	CERC-BEE FY2017	CERC-BEE FY2018	CERC-BEE FY2018	CERC-BEE FY2019	CERC-BEE FY2019	CERC-BEE FY2020	CERC-BEE FY2020	CERC-BEE FY2021	CERC-BEE FY2021
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
3. Finance	1 Barriers Assessment			D	G								
	2 Establish IFC-MRCB-ABC-Citi-ICP Partnership												
	3 Develop New Financial Products and Standardized Procedures and Tools.									D			
	4 Pilot New Financial Products and Standardized Procedures and Tools.											D	
	5 Contribute to China and U.S. Long-Term Mechanisms for Financing.												

“D”: a deliverable during that quarter. “G”: a Go/No-Go decision  
 ◆ Milestone met on time. ◆ Missed milestone.

Completed  
 Current/Future work