4th U.S.-China Energy Efficiency Forum
September 25, 2013

Compiled Presentations from Track 1, Breakout Session 2/Afternoon

High Performance Buildings
Collaboration on Building Code and Labeling System

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Lawrence Berkeley National Laboratory

September 25, 2013
Building Energy Efficiency Code and Labeling System

Concept
• Assist China develop commercial and residential building codes
• Disseminate building simulation tools (e.g. DOE-2) to China for building code development
• Help China to develop a window rating and labeling program

Opportunity
• Evaluate energy savings of China’s new commercial building code (GB50189-2013, 65% savings based on the 1980’s baseline)
• Bring tools developed in the U.S. to China’s building code development

Successes
• Assisted drafting the first national building energy standard (GB50189-2005) development
• Participated in the development of residential energy standards for the Hot Summer Cold Winter region (JGJ134-2001)
• Help China setup a pilot window rating and labeling program, drawn from U.S NFRC. Pilot location was in Guangzhou province.
• Provided training of DOE-2 and other building simulation software

Collaborators:
• China Academy of Building Research (CABR), Guangdong Institute of Building Research
Buildings: Training in Developing New Building Codes

- New Residential Building Code
- Improved New Heating Zone Residential Building Code
- Shanghai Commercial Code
- New Residential Building Code

Public building energy efficiency code

- Severe Cold
- Cold
- Hot Summer Cold Winter
- Temperate
- Hot Summer Warm Winter

- Improved New Heating Zone Residential Building Code
- Shanghai Commercial Code
- New Residential Building Code

China's climate zones:
- Severe Cold: 北部地区
- Cold: 中部地区
- Temperate: 南部地区
- Hot Summer Warm Winter: 热带地区
Building Energy Efficiency

Collaboration with China

• US-China Agenda 21 energy efficient demonstration office building in Beijing; 中美21世纪节能示范办公楼 (美国能源部中国科技部合作项目,1998年始,2003年底完成)

• Establishment of energy efficiency design standard for residential buildings in the HotSummer Cold-Winter Region in Central China (promulgated Oct. 2001); 协助制定夏热冬冷地区住宅节能设计标准 (2001年10月颁布)

• Establishment of energy efficiency design standard for residential buildings in the HotSummer Warm-Winter Region in South China (promulgated Oct. 2003); 协助制定夏热冬暖地区住宅节能设计标准(2003年10月颁布)

• Development of national energy efficiency design standard for public buildings (expected completion end 2004); 协助制定国家公共建筑节能设计标准(2004年底完成)


Building Code Structure

Building codes in China:

- National level: one commercial building code (GB50189), and three residential building code (JGJ 26, 134, 75) – defined on climate zone basis
- Local level: provinces can have their own building code, some provincial level codes are stringent than national level code (e.g. Tianjin, Shanghai, Jiangsu..)

Commercial building code -- GB50189:

- China’s commercial building code
  - equivalent to ASHRAE 90.1
- First released in 1993
  with initial focus on hotel
- Last update in 2005
- New code will be release at the end of 2013

Source: Wu 2003
Commercial building code

Commercial building code -- GB50189:

- Use 1980’s commercial building characteristics as baseline (100%)
- Last update in 2005 achieved 50% energy savings from 1980’s baseline
- New update in 2013 aims to achieve 65% energy savings → To be validated!

Importance of commercial building code

- Commercial building floor space increases from 2.8 billion m² (1996) to 7.1 billion m² (2008). Approximately, 0.5 billion m² new construction was built per year.
- Per capital, increases from 7.4 m²/person (1996) to 11.5 m²/person (2008)
- Will continue to increase in next 20~30 years because of fast urbanization
Reference Buildings – Models to Support Building Codes

**Office Buildings**
- Small Office: 1 floor, 5,500 ft²
- Medium Office: 3 floor, 53,630 ft²
- Large Office: 12 floors, 498,588 ft²

**Lodging**
- Small hotel: 4 floors, 43,200 ft²
- Large hotel: 6 floors, 122,120 ft²

**Schools**
- Primary School: 1 floor, 73,960 ft²
- Secondary School: 2 floors, 210,890 ft²

**Healthcare**
- Outpatient Healthcare: 3 floors, 40,946 ft²
- Hospital: 5 floors, 241,351 ft²

16 X 16 X 3 = 768 models!
Reference Buildings – Models to Support Building Codes

- A Chinese shopping mall reference prototype developed by LBNL and its Chinese partners
- LBNL is working with CABR to identify key parameters to conduct reference building survey and modeling.

Shanghai Shopping Mall Energy End Use Breakdown

- Cooling: Electricity: 20.2%
- Interior Lights: Electricity: 10.3%
- Exterior Lights: Electricity: 17.5%
- Fans: Electricity: 7.7%
- Pumps: Electricity: 3.8%
- Refrigeration: Electricity: 3.8%
- Interior Equipment: Electricity: 6.0%
- Exterior Equipment: Electricity: 0.7%
- Heating: Gas: 30.2%
- Interior Equipment: Gas: 2.8%
- Heat Rejection: Electricity: 0.8%
Thank You!
Questions?
Building Energy Codes Development and Enforcement: Progress and Comparative Lessons

Sha Yu and Meredydd Evans

Pacific Northwest National Laboratory
Fourth U.S.-China Energy Efficiency Forum
September 25, 2013
Overview

- Building energy use and codes impacts
- Building codes development and enforcement
  - Rural energy code in China
  - Enforcement system in China and the U.S.
- Lessons learned
- Market opportunities
Building Energy Demand in the U.S. and China

- Buildings in the U.S. and in China will experience increasing share of electricity during the 21st century.

- Per capita energy demand continuing to increase in China over the century, while per capita energy demand in the U.S. steadily decreasing.

- Overall development of fuel mix in the buildings sectors between the two countries will continue to be very different.

Impacts of building codes and climate policy in China

- Energy codes could significantly reduce building energy use.
- Economy-wide carbon policy has a limited effect on building energy demand and direct CO$_2$ emissions.
- High compliance is essential for any noticeable impact.

China began to adopt building energy codes in the 1980s. Now there is one code for commercial buildings. Three other codes cover large residential buildings in different climate zones: severe cold/cold, hot summer-cold winter and hot summer-warm winter. Energy code for rural buildings went into effect in May 2013.
Energy Code for Rural Buildings

► Despite fast urbanization, rural buildings still account for a big share of total building stock in the near term (40% today and around 25% at 2030).
► Rural buildings demand more energy than urban buildings at least in the near term.
► Designs and energy uses in urban and rural buildings are different.
Contents of the Rural Energy Code

- Architectural layout and energy efficiency design
- Building envelope insulation
- Heating and ventilation system
- Lighting
- Renewable energy use
  - Solar, biomass, geothermal, etc.
Rural Building Energy Codes: Key Considerations

- Understanding building trends, stakeholders

- Making enforceable codes
  - Who will enforce?
  - How will buildings learn of and interpret requirements?
  - How can we build capacity and make this easy?

- Challenges of small buildings
  - Variety of buildings
  - Limited capacity
  - Wide variety of construction materials
Key code enforcement steps in Chinese building construction
Construction site inspection roles

Construction Company
Quality control system

Construction Supervision Company
Checks work onsite; orders tests; prepares documentation on compliance

Testing Labs
Tests components from construction site

Quality Control and Testing Station
Collects and reviews documentation; conducts periodic site inspections; prepares completion report

Developer
Takes completion report to Construction Administration Dept.

Construction Administration Dept.
Accepts and files documents; issues occupancy permit
Lessons Learned

For China

- Enforcement in smaller towns and rural areas.
- Testing and ratings.
- Easier access to training and more user-friendly information.
- Increasingly rigorous codes.

For the U.S.

- The extensive use of third parties in code compliance.
- The “industrialization” of the construction and code compliance processes.
- An example of integrating design and code compliance software.
Market Opportunities

- Codes help build demand for a range of building energy efficiency products like insulation, efficient windows and lighting.
- New post-occupancy and ‘stretch’ code requirements are also building the market for services like building commissioning, energy audits, and performance contracting.
- Because of their large impact on market deployment, codes can also make it easier for companies to obtain value from innovation and R&D.
DEMAND RESPONSE:
U.S. EXPERIENCE AND OPPORTUNITY
FOR COLLABORATION

Bo Shen
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The 4th US-China Energy Efficiency Forum
Arlington, Virginia | September 25, 2013
DR is a reduction in customers’ electricity consumption over a given time interval relative to what would otherwise occur in response to a price signal, other financial incentives, or a reliability signal (California Energy Commission)

According to FERC, the DR resource contribution from all U.S. programs was 72,000 megawatts in 2011, about 9.2% of the U.S. total peak demand. This was an increase of 13,000 megawatts from the 2010 survey results
Benefits Brought by DR

- Avoided new capacity, minimizing the lock-in effect of power plant operations
- Reduced capacity use leading to reduced fuel use and associated emissions, resulting in significant cost savings especially during the peak
- Reduction in line losses, more significant when lines are heavily loaded during the peak
- Flatter load curves improve overall power generation efficiency
- Makes economic sense: In many systems, 10% of costs incurred to meet demands which occur less than 1% of the time
- Creates a cost-effective dispatchable resource, allowing greater integration of renewables
Policies Enables DR Expansion

- EPACT 2005 mandates the elimination of barriers to DR participating in the wholesale market
- FERC Order 719 (2008) permits load aggregators to bid DR directly into organized markets
- FERC Order 745 (2011) requires that DR resources are paid the wholesale market price for energy, placing demand side resources on equal footing with generation
- Cost recovery
- Loading orders
- Peak demand mandates (e.g., 4.5% peak demand reduction target by 2015 in PA)
Market Expansions Allow DR to Play a Role

Wholesale market changed from an energy-only market to include some new types of markets

- **Capacity Market to ensure adequate resource availability:** customer load curtailments offered as system capacity to compete with conventional resources. Customers typically receive day-of notice of events and face penalties for failure to curtail when called upon.

- **Ancillary Services Market to support reliable grid operations:** customers bid dispatchable load curtailments as operating reserves or regulation services. If their bids are accepted, they paid the market price for committing to be on standby. Participants must be prepared to respond to a dispatch more frequently and accurately, requiring the employment of different load control strategies from capacity programs designed to shed load during infrequent, peak periods
Smart Grid Technologies Facilitate DR Applications

Open ADR
- An open standard-based protocol to widely and openly communicate price and reliability signals across networks

Auto DR
- A platform that provides fully automated signaling from a utility or ISO/RTO to provide automated connectivity to customer control systems preconfigured with load reduction strategies

Automated DR
- A program/system that initiates the preconfigured curtailment strategy without the need for human intervention at the end-user’s site.
China’s National DSM City Pilot

- NDRC and MOF jointly initiated a national program of Comprehensive DSM City Pilot in 2012
- Four cities (Beijing, Suzhou, Foshan, Tangshan) selected to conduct the pilot which will last three years
- Incentives provided by Ministry of Finance and matched by local government to support real-time electricity usage information platform, efficiency measures, DR, M&V, and capacity building
- MOF funding level: for permanent load reduction: ¥ 440/kW (east) and ¥ 550/kW (west/midland); for temporary load shifting: ¥ 100/kW
- Incentive is result-oriented and penalty imposed for missing the target
Objectives of National DSM City Pilot

- Effectively reduce peak load and energy use
- Develop DSM application demonstration park
- Create online electricity monitoring platform
- Develop electricity management standard
- Cultivate power quality service/curtailment service sector
Electric Use Monitoring and Service Platform

- Devices installed at key process/equipment for real time acquisition of information on electric loads, electricity consumption, power quality, and temperature
- Data transmission platform to transmit the collected data to the centralized monitoring platform through a web-based application
- Web-based interface for real time visualization of load, electricity consumption, power quality, and power factors, etc
- Detailed usage data assessed by the third party to identify energy saving and peak load reduction opportunities and detect fault. Service provided to the customers recommending improvement
- General information accessed and analyzed by the government for planning and decision-making
Collaboration in DR Development

Activities so far:
- Information sharing of the international best practices in DR applications
- Technical discussion on developing a system modeled after Open ADR
- Performance-based power rationing tool to improve China’s direct load curtailment
- Introduction of DR performance measurement & verification methods

Next steps
- Technical and policy research support to pilot cities in designing their DR program
- Promote a wider adoption of DR technologies and strategies
- Improve existing pricing structure to induce DR
- Create incentive program to attract DR participation
- Maximize the opportunity of real-time usage info platform
- Identify opportunities for fast DR
Thank you!

Contact: BoShen@lbl.gov
Advanced Building Decision Tools Collaboration

Wei Feng
劳伦斯伯克利国家实验室
2013年9月
Advanced Building Decision Tools Collaboration

- COMBAT: Commercial Building Analysis Tool for Energy Efficiency Retrofit
- DER-CAM: Distributed Energy Resource Customer Adoption Model
Commercial Building Analysis Tool for Energy-Efficient Retrofits (COMBAT)

**Purpose:** Analyze commercial building retrofit energy savings and investment cost-effectiveness

**Related Tools:** EnergyPlus

**Audience:** Retrofit practitioners, policy makers, facility managers, and engineers (w/o building energy modeling knowledge)

**Developer(s):** China Energy Group at LBNL


**Limitations:** Only applies to China’s hot summer cold winter climate zone with hotel and shopping mall building types

**Impacts summary:** Trained 50+ people in Shanghai in 2012 including key policy makers. Retrofit of shopping mall or hotel can yield 20%~30% energy savings in Shanghai.

**Potential:** More building types and climate zones could be added to the tool. Work with universities (such as Tongji University) to develop and disseminate it.
Commercial Buildings Retrofit and COMBAT

Background:

- Commercial (public) buildings retrofit is targeted to save 14 Mtce in China’s 12th FYP.
- Central and local governments create large incentive programs for commercial building retrofit.
- In Shanghai’s Changning district, over 100 buildings need retrofit in the 12th FYP.
- No tool existed for quick assessment of energy savings and investment cost-effective as the results of retrofit.

Current impacts:

- COMBAT is developed with collaboration from Tongji University and NRDC Beijing office. The tool has been used for analysis in a few retrofit projects in Shanghai. A training workshop was held in Shanghai in 2012 to train Chinese local government officials, U.S. companies, and Chinese ESCOs on the use of the tool for their retrofit analysis.
- Provide training and work with ECP-China, U.S. companies (e.g. Trane, Autodesk, Schneider Electric) and Chinese ESCOs.
- Selected collaborators: Tongji University, NRDC Beijing office, Shanghai Energy Conservation and Supervision Center.
- Selected project using COMBAT: 4 shopping malls and 2 hotels have used COMBAT and compared its calculation results with measured results. More buildings are using the tool in Shanghai’s Changning district.
COMBAT: Verifications of Chinese Buildings

- 4 shopping malls and 1 hotel
- Calculated savings in line with measured data

<table>
<thead>
<tr>
<th>Building</th>
<th>Energy Consumption Before Retrofit (Megawatt hours/Year)</th>
<th>Energy Savings (Megawatt hours/Year)</th>
<th>Energy Saving Rates</th>
<th>Economic Benefits (RMB/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Calculated</td>
<td>Actual</td>
<td>Calculated</td>
</tr>
<tr>
<td>Building A</td>
<td>38,847</td>
<td>7,902</td>
<td>20.3%</td>
<td>6,299,256</td>
</tr>
<tr>
<td>Building B</td>
<td>33,512</td>
<td>1,950</td>
<td>5.8%</td>
<td>1,506,165</td>
</tr>
<tr>
<td>Building C</td>
<td>73,044</td>
<td>4,952</td>
<td>6.8%</td>
<td>3,825,256</td>
</tr>
<tr>
<td>Building D</td>
<td>8,287</td>
<td>419</td>
<td>5.1%</td>
<td>323,361.4</td>
</tr>
<tr>
<td>Building E</td>
<td>14,229</td>
<td>3,337</td>
<td>23.5%</td>
<td>3,461,041</td>
</tr>
</tbody>
</table>

Relative Error:
- Building A: -37.7%
- Building B: -43.0%
- Building C: 1.6%
- Building D: 47.3%
- Building E: 10.4%

Actual:
- Building A: 5,737
- Building B: 1,364
- Building C: 5,033
- Building D: 795
- Building E: 3,723

Relative Error:
- Building A: -17.1%
- Building B: -17.8%
- Building C: 18.9%
- Building D: 56.6%
- Building E: -3.3%
COMBAT Demonstration: Inputs

Building characteristics inputs

Retrofit measure inputs

Default cost-effective analysis
COMBAT Demonstration: Outputs

Energy savings analysis
Payback analysis

Individual measure’s cost-effective analysis
**Purpose:** produces optimal investment decisions and dispatch for technologies as fuel cells, PV, solar thermal, electric / heat storage, heat pumps, EVs, etc.; it minimizes annual energy costs, CO$_2$ emissions, or multiple objectives of providing services to buildings (~100-2000 kW peak)

**Related Tools:** none

**Users:** more than 350 DER-CAM web-clients to date for the simple investment version (multiple versions with different copyrights are available at [http://der.lbl.gov/der-cam/how-access-der-cam](http://der.lbl.gov/der-cam/how-access-der-cam), stochastic versions for EVS and other technologies as PV exist or are currently under design)

**Developer(s):** developed for 12 years by LBNL, collaboration with China and other countries

**Availability:** simplified investment web version via [https://microgrids2.lbl.gov/](https://microgrids2.lbl.gov/) (WebOpt); English and Chinese, SI units. Funded by US DOE, CEC

**Limitations:** not all features are provided in the simplified web version, in general more work is needed on passive measures

**Impacts summary:** 40 online accounts from China, 73 online accounts from U.S.; University and teaching, building managers and operators, cost reductions up to 30% and CO$_2$ reductions up to 100% (in ZNEB mode) due to well guided decisions (see next page)

**Potential:** Expand functionality to be able to develop a district energy system optimization toolkit for China’s low carbon district/city energy system analysis; cheap and simple real time building management service over the web (multiple requests from national and international companies)
Distributed Energy Research and Impacts

Background:

- China’s 12th FYP highlights CHP and other distributed energy as one of its important energy goals
- 1000 distributed natural gas generation in the 12th FYP (each less than 5MW)
- NEA’s 12th FYP states that 30 national-level microgrid demonstration projects will be built by the end of 2015
- China State Grid’s new policy on distributed energy grid connection (less than 6MW)

Current impacts:

- LBNL is working with the Chinese Academy of Science (CAS) – Institute of Electrical Engineering (IEE), and NEA on the development criteria and evaluation methods for 12th FYP’s 30 national-level microgrid demonstration projects by using the DER-CAM tool developed by LBNL.
- Work with ECP-China and U.S. DER companies (e.g. DOW, ICF, Capstone, Honeywell) on China projects.
- **Selected collaborators:** Tianjin University, Tongji University, Shanghai Energy Conservation and Supervision Center, Shenzhen Microgrid Lab, Shenzhen Institute of Building Research, CAS-IEE, Xiamen University, Hefei University
- **Selected DER and microgrid projects LBNL is working on using DER-CAM:** Shanghai Changning Central hospital, DongAo Island (Zhuhai, Guangdong), Tianjin University Microgrid Lab (MOST’s 973 project), Shenzhen Microgrid Lab, Shanghai Chongming Island microgrid project
DER-CAM: Active User Accounts Around the World

Active user account statistics

Legend:
- Yellow: SVOW
- Blue: WebOpt
Sankey diagram shows how distributed energy is transport, converted and balanced.
• **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs

• **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs
DER-CAM Demonstration: Outputs
VisualEPlus 2.0 Introduction

Purpose: a GUI in Chinese and English for the EnergyPlus program, focusing on graphical modeling of HVAC system, and analysis of output results.

Related Tools: no other similar GUI in Chinese; intended to be used in conjunction with Open Studio for building modeling.

Users: building energy practitioners, academia, and students interested in building energy simulation with EnergyPlus, particularly in China.

Developer(s): Tongji University (lead) and Shandong University in collaboration with White Box Technologies, Inc. and ORNL.

Availability: Chinese version launched November 2012 [http://bsim.tongji.edu.cn/custom.asp?mk=1&id=244]; English version planned launch June 2013 to be available at [www.whiteboxtechnologies.com](http://www.whiteboxtechnologies.com) and ORNL for users outside of China.

Limitations: Simulation GUIs are very complicated software; to limit effort and meet greatest need, VisualEPlus 2.0 concentrates on two areas only – HVAC modeling and report analysis; program is still “buggy” with many areas for improvement.


Potential: VisualEPlus makes EnergyPlus acceptable to the Chinese building energy modeling community, which can then play an important role in building energy efficiency design, standards development, and R&D in China, just as EnergyPlus does in the US.
Building model needs to be generated by other programs (i.e., Open Studio) & loaded into VisualEPlus 2.0.
VisualEPlus 2.0 Demonstration: HVAC Modeling GUI

- “Drag-and-drop” style graphical modeling for HVAC systems
- 109 HVAC components in 28 categories
- 11 HVAC templates
Visualize simulation result in both standard and customized reports for user selected variables, during user selected time periods, and at various time intervals.
Thank You!
Questions?
CERC-BEE Cooperative Research
Applications and Exploitations of
Advanced Decision Tools

Shilei Lu  Associate Prof.

TIANJIN UNIVERSITY

2013.9.25  WASHINGTON D.C.
Main research topics

1. Collaborative research in verification of DER-CAM and energy operation optimization (LBNL)
2. Collaborative research in evaluation of the GSHP project with eQUEST (ORNL)
3. Building heat transfer model development of PCM by TRNSYS (Independent research)
1. Collaborative research in verification of DER-CAM and energy operation optimization (LBNL)

**Background:**

- There are some application cases of DER-CAM in the United States, whereas there is little application case in China.
- DER-CAM lacks energy systems model, passive building energy-saving technical modules, meteorological data and price system of energy of China, etc.

**Assignment:**

- To improve relative modules of DER-CAM
- Select demonstrating building to validated the feasibility of DER-CAM
- Select existing buildings to optimize DER-CAM operation
- Select new buildings to find an optimization design method of energy system by using DER-CAM

DAR-CAM is a kind of integrated software designed to select optimal building energy-saving technology, select optimal energy system, direct energy saving operation and evaluate the effect of different operating periods.
1. Collaborative research in verification of DER-CAM and energy operation optimization (LBNL)

1. Saidi office building in Chongqing
2. TJU 26# building in Tianjin
3. Wanke office building in Shenzhen
4. SYJZU office building in Shenyang
5. TJU new library in Tianjin
Proof scheme

- Designbuilder was used for model establishment and basic settings
  1. Activities Settings
  2. Lighting Settings
  3. Plug load
  4. HVAC
  5. Structure Settings
- DER-CAM was used for the design of energy system
  Cooling, Space Heating and Water Heating (Week, weekend and peak)
**Equipment list**

<table>
<thead>
<tr>
<th>Equipment No.</th>
<th>Equipment Name</th>
<th>Equipment Power (W)</th>
<th>Equipment Quantity</th>
<th>Total Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Fluorescent Lamp</td>
<td>18</td>
<td>1000</td>
<td>18000</td>
</tr>
<tr>
<td>2</td>
<td>Computer</td>
<td>300</td>
<td>210</td>
<td>6300</td>
</tr>
<tr>
<td>3</td>
<td>Printer</td>
<td>638</td>
<td>20</td>
<td>12760</td>
</tr>
<tr>
<td>4</td>
<td>Split AC</td>
<td>750</td>
<td>48</td>
<td>36000</td>
</tr>
<tr>
<td>Laboratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fluorescent Lamp</td>
<td>18</td>
<td>700</td>
<td>12600</td>
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<tr>
<td>6</td>
<td>Experimental Equip</td>
<td>-</td>
<td>-</td>
<td>4200</td>
</tr>
<tr>
<td>Equipment Room</td>
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<tr>
<td>7</td>
<td>Water Pump</td>
<td>45000</td>
<td>3</td>
<td>135000</td>
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<td>8</td>
<td>Fluorescent Lamp</td>
<td>18</td>
<td>20</td>
<td>390</td>
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<td>9</td>
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<tr>
<td>10</td>
<td>Air Curtain</td>
<td>12000</td>
<td>3</td>
<td>36000</td>
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<td>11</td>
<td>Elevator</td>
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<td>30000</td>
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<td>2695</td>
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<td>13</td>
<td>Staircase Lamp</td>
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<td>42</td>
<td>588</td>
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<tr>
<td>14</td>
<td>Exhaust Fan</td>
<td>150</td>
<td>12</td>
<td>1800</td>
</tr>
<tr>
<td>Supplementary Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Building energy-subentry measure**

<table>
<thead>
<tr>
<th>Power distribution No.</th>
<th>Circuit No.</th>
<th>Varying Ratio</th>
<th>Circuit Purpose</th>
<th>Electricity meter No.</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA1-1</td>
<td>1-WL2</td>
<td>1000/5</td>
<td>Main Power</td>
<td>D1</td>
<td>Multifunctional Harmonic</td>
</tr>
<tr>
<td>AA1-3</td>
<td>1-WL3</td>
<td>200/5</td>
<td>Lighting/Equipment</td>
<td>D2</td>
<td>3 Phase 4 Wire</td>
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<tr>
<td>AA1-6</td>
<td>1-WL4</td>
<td>200/5</td>
<td>Lighting/Equipment</td>
<td>D3</td>
<td>3 Phase 4 Wire</td>
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<td>AA1-5</td>
<td>1-WL5</td>
<td>200/5</td>
<td>Lighting/Equipment</td>
<td>D4</td>
<td>3 Phase 4 Wire</td>
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<td>1-WL6</td>
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<td>D8</td>
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</table>
Test data and Simulated data

inspection data—separate metering

Simulation data analysis (including total energy consumption and subentry energy consumption)
The simulation results are similar to the DER-CAM analysis results.

<table>
<thead>
<tr>
<th>Results</th>
<th>Utility Electricity Consumption(kWh/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designbuilder Simulation (Do-nothing in DER-CAM)</td>
<td>1,260,365.1</td>
</tr>
<tr>
<td>Energy Monitor System (Do-nothing in DER-CAM)</td>
<td>1,280,562.3</td>
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<tr>
<td>Difference percentage(%)</td>
<td>1.6%</td>
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</tbody>
</table>
DER-CAM for optimizing operation

Four kinds of technologies (PV, Solar Thermal, GSHP and Existing Chiller) were used in optimization of simulation results.

January Heating:
- Natural Gas for Heat in case least cost in JAN;
- Heat from Heat Pumps in case the largest emissions reductions in JAN.

July Cooling:
- Cooling from Electric Chiller in case least cost in JUL;
- Cooling from Heat Pumps combines with Electric Chiller in case the largest emissions reductions in JUL.
DER-CAM for optimizing operation

July Electricity

Figure 1 shows Base Electricity Load in JUL; Figure 2 shows PV should be used to replace part of Electricity Load in case the largest emissions reductions in JAN.

July Heating

Figure 1 shows Base Hot Water Load in JUL; Figure 2 shows Solar thermal should be used to replace part of Hot Water Load in case the largest emissions reductions in JAN.
Next step

1、Optimizing operation of *TJU 26# Building by using DER-CAM*

At present, the data of subentry energy consumption was under our belts, we are collecting the data of each room to make the information of operational aspect as detailed as possible.

2、Optimizing operation of *new building by using DER-CAM*

Select TJU new library and combine with local energy resource, climate and energy cost, etc.
2. Collaborative research in evaluation of the GSHP project with eQUEST (ORNL)

Similarities: more applications in the north are Family Home, distributed and has small construction area, while in China, most applications are large public buildings and residential districts. In addition, the development velocity of the U.S.A. slows down, China develop rapidly.
2. Collaborative research in evaluation of the GSHP project with eQUEST (ORNL)

Application scale is growing year by year

Test time: 2~3 days, not whole year operation
Energy saving ability: appoint conventional energy efficiency of system, efficiency value
Payoff period: static

Simulation time: 8760 hours
Energy saving ability: gshp system and conventional system are simulated in the same loading condition, dynamically and targeted
Payoff period: set electricity price freely
An Overview of Cases

**Sewage-SHP**
- Beijing residential building: 42,000m²
- Shenyang school building: 35,000m²
- Dalian commercial building: 19,000m²

**Seawater-SHP**
- Dalian residential building: 255,000m²

**GWHP**
- Inner Mongolia school building: 102,000m²
- Beijing residential building: 83,600m²
- Shenyang office building: 22,000m²
- Shenyang hospital building: 100,000m²
- Beijing commercial building: 100,000m²
- Beijing commercial building: 40,000m²
- Beijing commercial building: 80,000m²
Testing Content

Water temperature:
- Evaporator supply and return
- Condenser supply and return
- User supply and return
- Well water supply and return

Flow:
- Evaporator cycle
- Condenser cycle
- User cycle
- Well water cycle

Electrical consumption:
- Heat pump units
- Circulating water pump
- Submersible pump
- Others

renewable energy demonstration program:
- Inspection platform get temperature, flow and electrical consumption data directly
- 10min/collection
- 30min/collection
- 1 day/collection
Calculate quantity of energy saving of GSHP by operating GSHP system and conventional system (chiller + boiler) in the same building model.
Quantity of energy saving

Payback time

Electric Consumption (kWh)

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<th>Dec</th>
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<td>127.4</td>
<td>123.2</td>
<td>126.9</td>
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<td>369.0</td>
<td>460.5</td>
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</table>
1. Collect operation curves of major GSHP in China and add to eQUEST database.
2. Find the actual optimum operation of each equipment by analyzing operation strategies in eQUEST model.
3. Building heat transfer model development of PCM by using TRNSYS

1. PCM apply in cool storage in summer

Encapsulating PCM with energy storage slab, and integrate in two ways: the PCM set outside the construction (PCMOW), the PCM set inside the construction (PCMIW).

![Graph showing temperature comparison between PCMOW and PCMIW]

- **PCMOW**
  - Crack-resistance mortar
  - Waterproofing layer
  - Binding mortar
  - Glass-fiber reinforcement cement board
  - Polystyrene board
  - PCM panel (CA)
  - Crack-resistance mortar
  - Binding mortar
  - Perforated brick

- **PCMIW**

![Interior view of a building with PCM application]

- **Graph parameters**
  - 2012/8/28 0:30
  - 2012/8/29 4:00
  - 2012/8/30 7:30
  - 2012/8/31 11:03
  - 2012/9/1 15:00

- **Legend**
  - Outdoor temperature
  - PCMOW indoor temperature
  - Reference indoor temperature
  - PCMIW indoor temperature
1. The PCM simulation module of Energyplus is based on enthalpy-temperature correspondence method, a fit curve is defined by pointing different temperature correspond to different enthalpy, thus all phase change process are considered as an integration process. Using the finite difference method, established an equation of energy, and made its discrete solutions. While only one enthalpy-temperature curve could be inputted in the PCM simulation module, melting process and solidification process can not be distinguished.

2. The transformation of PCM may not be a complete process, mostly the process is an incomplete transformation in actual conditions.

3. Supercooling of PCM should be considered.
Creating PCM Heat Transfer Calculations Module based on TRNSYS

**TYPE272**

By introducing the coefficient *Latent heat utilization*, optimized the enthalpy-temperature correspondence method, incomplete transformation in actual conditions could be solved very well. This simulation module also take supercooling of PCM into account.
Natural cool storage: Simulation and Experimentation of PCMIW,PCMOW

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<th>时间 (day)</th>
<th>温度(℃)</th>
<th>室内温度测试值</th>
<th>室内温度模拟值</th>
<th>室外干球温度</th>
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<th>$\bar{d}$</th>
<th>$S_d$</th>
<th>$\bar{d} \pm 1.96S_d$</th>
<th>一致性界限外点数的百分比</th>
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<td>0.42</td>
<td>1.24/-0.40</td>
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<td>0.51/-0.84</td>
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<td>1.04/-0.53</td>
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<td>东墙内壁温度</td>
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<td>0.61</td>
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<td>1.44/-0.23</td>
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<td>0.66</td>
<td>0.57</td>
<td>1.78/-0.46</td>
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<td>-0.54</td>
<td>0.54</td>
<td>0.52/-1.60</td>
<td>4.17%</td>
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</tbody>
</table>
Put forward the optimal combination of PCM and COOL ROOF in different climatic region, which has important implications for power peak shaving and valley filling of power load, reducing building energy consumption and improving the indoor thermal environment.
Next: The Research of PCM integrated Solar House

To search a new method of coupling of solar energy and PCM. Using efficient collector to collect solar energy and store in PCM, releasing when needed, to maintain a stable thermal environment.
Thank you!

Email: lvshilei@tju.edu.cn