The Development of Heat Pump and Thermal Storage in China

Zhang Shicong
China Academy of Building Research
• China’s Energy Challenge and Target
• Development of Heat Pump in China
• Development of Thermal Storage in China
• APEC-Heat pump water heater activities
The total energy consumption in China

- In 2011, China consumed 3.4 billion tce, almost 1/5 of global TPES. The number keeps on increasing to 3.62 billion tce in 2012, Annual GDP of 2012 was 7.8%.
The energy structure in China

**Energy Supply**
- Coal: 76.5%
- Oil: 9.4%
- Gas: 9.8%
- Hydro, Nuclear and Wind: 4.3%

**Sectoral Energy Consumption**
- Agriculture: 11.0%
- Industry: 71.5%
- Residence: 7.7%
- Transportation: 7.7%
- Others: 2.0%
Some date to take glance at China

- In 2012, China produced 716 million tons of crude steel, more than 46.3% of the worldwide production.
- In 2012, China produced 2.18 billion tons of cement, more than 60% of the worldwide production.
- In 2012, more than 193 million of new vehicles were sold in China. It is the highest sales in history.
- In 2012, China 42million LCD TVs was sold in China. More than 82% of global household appliances in 35 product groups were made in China.
- In 2012, exported air conditioners, refrigerators/freezers, washing machines, and TV/monitors from China occupied 47% of worldwide export.
Drivers of energy demand: Urbanization

- In the past 20 years, the percent of population in urban area increased more than 1% every year in China.
Drivers of energy demand: Urbanization

<table>
<thead>
<tr>
<th>Country (2011)</th>
<th>Car Holdings (cars/1000 persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>812</td>
</tr>
<tr>
<td>Germany</td>
<td>634</td>
</tr>
<tr>
<td>Japan</td>
<td>589</td>
</tr>
<tr>
<td>South Korea</td>
<td>379</td>
</tr>
<tr>
<td>Russia</td>
<td>271</td>
</tr>
<tr>
<td>Brazil</td>
<td>259</td>
</tr>
<tr>
<td>South Africa [2009]</td>
<td>162</td>
</tr>
<tr>
<td>China</td>
<td>83</td>
</tr>
</tbody>
</table>

![Bar chart showing energy demand drivers: Urbanization]
Key Challenges

**Limited energy resources**
- Oil and gas reserves is only 6% of average level of the world

**Limited environmental capacity**
- Serious air pollution, water pollution and soil pollution: Fog Haze in Beijing!

**Low energy efficiency**
- Energy consumption per GDP is the twice of the average level of the world

**Assurance of energy security**
- In 2012, more than 58% of oil is imported
Importance of Energy Efficiency in China

- In 2012, GDP per capita in China is only No. 89 in the world and 1/9 of USA
- China’s GDP is anticipated to be doubled in 2020 than it in 2010
- Resources and environment are the two main constrained factors for China’s economic and social development
- The only choice of China: Energy efficiency & Energy Conservation
- Since 1980s, improvement of energy efficiency has been selected as the basic policy for China’s energy strategy
Turning point of energy efficiency in China – 11th FYP

• During 2006 - 2010 (11th Five-Year Plan period)
  – A mandatory target for energy efficiency improvement of 20% was brought forward (actual 19.1%)
  – Annual economic growth rate of 11.2% with energy consumption growth rate of 6.6%
  – Total energy savings: 630 million tce
  – Improvement of energy efficiency in key sectors
    • Thermal power: 10.0 %
    • Steel: 12.1 %
    • Cement: 28.6 %
## Key Targets of 2011 – 2015 (12th Five-Year Plan period)

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of energy intensity (tce/GDP)</td>
<td>[16%]</td>
</tr>
<tr>
<td>Energy savings (tce)</td>
<td>670 million</td>
</tr>
<tr>
<td>Reduction of energy intensity of industries (tce/industrial added value)</td>
<td>[21%]</td>
</tr>
<tr>
<td>Energy consumption of unit output (thermal power, steel, cement, aluminum, copper refinery etc.)</td>
<td>International advanced level</td>
</tr>
<tr>
<td>Energy efficiency of new equipment (Fans, pumps, air compressors, transformers)</td>
<td>International/national advanced level</td>
</tr>
<tr>
<td>Energy efficiency of new appliances (ACs, refrigerators, washing machines, motors)</td>
<td>International leading level</td>
</tr>
</tbody>
</table>
● China’s Energy Challenge and Target
● Development of Heat Pump in China
● Development of Thermal Storage in China
● APEC-Heat pump water heater activities
Market of ASHP

AC household number in 100 families

2010 VS 2009 ---31% increase
2011 VS 2010 ---20% increase

2012 VS 2011 ----25% decrease.
Main Reason:
1. Market Saturation and consumer confidence going down.
2. Influence of Incentive policies in 2009-2010
3. The regulation of real estate policy

AC Export from 2000 to 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Million unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>8</td>
</tr>
<tr>
<td>2010</td>
<td>33</td>
</tr>
</tbody>
</table>

2010                   2005                   2010
Design standards of ASHP and Unitary AC

- 《The minimum allowable values of the energy efficiency and energy efficiency grades for unitary air conditioners》 GB 19576-2004

- 《Low ambient temperature air source heat pump (water chilling) packages- Part1: Heat pump (water chilling) packages of industrial and commercial or commercial and similar application》 GB/T 25127.1-2010

- 《Low ambient temperature air source heat pump (water chilling) packages- Part2: Heat pump (water chilling) packages of household and similar application》 GB/T 25127.2-2010

- 《Unitary air conditioners》 GB/T17758-2010
HPWH starts late in China. At the beginning of the 21st Century, the HPWH industry was developed gradually with the encouragement of national energy and environmental policies. Now, the market share of HPWH displays rapid development.
For air-source heat pump:

- Home appliances to the countryside policy

For heat pump water heater:

- The government system of compulsory procurement of energy-saving products. In late 2011.
In recent years, GSHP industry has been rapidly developed in China, and the application cases have increased every year. According to relevant statistics, China's GSHP applications area reached 240 million square meters by the end of 2012.
GSHP Policy

- 2005, Ministry of Construction promoted GSHP as one of 10 New Technologies
- 2006, National Energy Adm & Ministry of Construction jointly published National Standard for GSHP
- 2006, Ministry of Finance & Ministry of Construction issued special fund to provide subsidies to National Demonstration projects for renewable energy used in buildings
- 2012, Ministry of Finance & Ministry of Construction issued special fund to provide subsidies to National Demonstration projects for green ecological urban.
GSHP Application and Practice

From Prof. HAO BIN, CSTC of MOHURD.
Standards and Manuals of GSHP

- National Technical Standard for GSHP System Design & Installation
  GB50366-2005

- 2001《GSHP Design & Installation Guideline》
- 2004《WSHP System Design》
- 2006《GSHP System Design & Application》
- 2008《China GSHP Development Research Report》
- 2013《China GSHP Development Research Report》
Typical Projects

Beijing Yongyou Software Park (Phase I)

Phase I Area: 1.84 Million Sq.Ft.
Total Cooling Load: 15,784 KW
Total Heating Load: 1,339 KW
Domestic Hot Water: 1,722 KW
Total 616 Double “U” Vertical Bore-holes (150 mm diameter), Each 120 M deep, 5 M spacing
Total Cost: RMB 41.98 Million
Operating Cost (Heating & Cooling): RMB 32 per Sq.M.
Completion Date: 2007.7
Beijing Yizhuang Lincoln Complex

Area: 194,000 m²
Total Cooling Load: 2,800 KW
Total Heating Load: 2,800 KW
Total 695 Single “U” Vertical Bore-holes Each 69 M deep plus 5,000 M Horizontal Loop
Operating Cost: Cooling, RMB 20.12 per Sq.M.; Heating, RMB 18.31 per Sq.M.
Completion Date: 2010.11
Beijing Zhongguancun Int’l Center

Area: 156,000 Sq.M.
Total Cooling Load: 15,188 KW
Total Heating Load: 11,700 KW
Total 1060 Double “U” Vertical Bore-holes Each 123 M deep
Completion Date: 2008.7
Typical Projects

Headquarter of CABR-Institute of Building Environment and Energy
Renewable energy utilization

- BIPV
- Cooling Storage
- Heating Storage
- GSHP 40 vertical boreholes
- Solar Collector
- Absorption Chiller
- Solar heating

2013-10-23
System COP

**Sewage Source**
(Ave. 3.27, Median 3.1)

**Ground Water**
(Ave. 3.17, Median 3.1)

**Ground Coupled**
(Ave. 3.19, Median 3.3)

**Surface Water**
(Ave. 3.12, Median 3.1)

From Prof HAO BIN, CSTC of MOHURD
Prediction

- Alternative capacity to conventional energy with different application forms under three scenarios in 2015 and 2020 respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>Scenario</th>
<th>Solar Thermal</th>
<th>Photovoltaic</th>
<th>Shallow Geothermal Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Now</td>
<td>73.66%</td>
<td>2.29%</td>
<td>24.05%</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>63.74%</td>
<td>4.79%</td>
<td>31.47%</td>
</tr>
<tr>
<td></td>
<td>Reference</td>
<td>54.71%</td>
<td>6.40%</td>
<td>38.89%</td>
</tr>
<tr>
<td></td>
<td>Enhanced</td>
<td>52.35%</td>
<td>7.28%</td>
<td>40.37%</td>
</tr>
<tr>
<td>2015</td>
<td>Baseline</td>
<td>51.87%</td>
<td>9.42%</td>
<td>38.71%</td>
</tr>
<tr>
<td></td>
<td>Reference</td>
<td>33.47%</td>
<td>14.74%</td>
<td>51.79%</td>
</tr>
<tr>
<td></td>
<td>Enhanced</td>
<td>29.04%</td>
<td>18.07%</td>
<td>52.89%</td>
</tr>
<tr>
<td>2020</td>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enhance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• China’s Energy Challenge and Target
• Development of Heat Pump in China
• Development of Thermal Storage in China
• APEC-Heat pump water heater activities
Tianjin Culture Center

Tianjin Culture Center is a district made up of several buildings including museum, art gallery, library, theatre, etc. the total building area is 800,000 m2. Three heating and cooling stations were built and the pipe system was connected each other.

The GSHP was adopted to provide heating, cooling. Each heat pump can work at three different state: heating, cooling, ice making. The Assistant heating source is from city district heating net.

The TES system includes 226 sets of steel coil with a total storage capacity of 233,684 kWh, which were produced by EVAPCO Co.
Chongqing Jiangbei Central Business Park

Total building area is 3,320,000 m². The central heating and cooling station has an investment of 1.4 billion Yuan. Surface water heat pump and Centrifugal chillers system was used. The total ice storage capacity is 272,532kWh.
QingDao HaiDu International Business Building

**Project introduction:** This is a multi-function building integrated with commercial, hotel, and supporting office. The building has a total area of 66,296 m², with 15 floors above and two floors underground. B2 is the garage, and a supermarket was in B1. The commercial area covers from the first floor to the fourth floor, above the fourth floor, the building was divided into two single (A & B) sub-buildings. A is mainly for office building and building B is hotel and appendix office work.

**Technology property:** integrated with multiple energy saving technologies, such as: Energy storage by water, water source heat pump, condensing heat recovery and so on.
The project was designed by CABR from March to Oct., 2008.
Constructed by JiGao Co. from December 2008, to February 2010.

The performance is good, satisfied by the user. **Get the government subsidy of “national renewable energy demonstration project”**.

As the demonstration project, this project was checked and accepted by related departments which was organized by Ministry of Construction.

**Acceptance results:**
Average COP: 4.67  Average SCOP: 3.84  
Yearly energy saving amount: 228.3 ton standard coal/year;  
CO2 reduction: 563.9 ton
Load condition

According to the hourly load calculation results, the designed cooling and heating load is 6,180 and 4,550 kW respectively. Heating load for domestic hot water is 380 kW.

The water source heat pump was adopted to provide heating, cooling & domestic hot water for the hotel and whole building.

Two water-to-water heat pump units and one water cooled chiller unit were adopted by air-conditioning and heating system. Designed cooling and heating load are 1,200 & 1,550 kW per unit respectively. Domestic hot water was supplied by a water source heat pump with a heat capacity of 380 kW. The inlet and outlet temperature of the source water was designed as 15/30 °C in cooling mode and 15/5 °C in summer mode, respectively.
Outline of the Energy Storage Design

To take advantage of peak-valley price difference and reduce the source groundwater demand, part load water storage system was adopted in this project.

Daily total cool storage amount is designed as 10,500kWh with a chilled-water storage volume of 1100 m³. The designed Charge and Discharge temperature is 4/13 °C.

Daily heat storage amount is designed as 10,080kWh with a heat storage volume of 600 m³. Heat storage and release temperature is 55/38 °C.

One water-source heat pump system was served as cooling and heating system as well.

The fan coil and air handling system utilized a large temperature difference type, the supply and return temperature in cooling mode was designed as 7/15 °C, while in the heating model, it is 43/35 °C. Total heat recovery system was adopted in the fresh air handling system.
Monitor and Control system
Chilled-water charge and discharge testing

Cool storage was started at around 21:00 and end at around 5:00; discharging started from 9:30 and end at 20:00.

The discharged cool can satisfy the full cooling load during the transitional seasons.

Sensors interval is 400mm vertically, and thermocline thickness is estimated 500~800mm from the test, which is acceptable between 300 to 1000mm.
Warm-water charge and discharge testing

Thermal storage was started at around 1:00 and ended at around 7:00; discharging was started from 11:00 and ended at 19:00.

The discharged heat quantity can serve full cooling load during the transitional seasons.

The thermocline thickness is estimated as 800-1000mm.
- China’s Energy Challenge and Target
- Development of Heat Pump in China
- Development of Thermal Storage in China
- APEC-Heat pump water heater activities
APEC EGEE&C Project on Standards and Test Methods for Heat Pump Water Heaters

On behalf of the Asia-Pacific Economic Cooperation’s Expert Group on Energy Efficiency and Conservation (APEC EGEE&C), CLASP – in partnership with the Australian Department of Resources, Energy, and Tourism, the Korea Testing Laboratory, and the International Copper Association – is analyzing standards and test methods of heat pump water heaters with the aim of developing proposals for internationally-comparable energy efficiency test methods, metrics, and classes for use in future policy measures.

April 12th 2013
SEAD-funded APEC-CAST
Project Updates

41st Meeting of the APEC
Expert Group on Energy Efficiency & Conservation

11 April 2013

Anna Lising--Senior Associate of CLASP

CAST--Collaborative Assessment of Standards and Testing Methods
SEAD--Super-efficient Equipment and Appliance Deployment Initiative
CLASP--The Collaborative Labeling and Appliance Standards Program
Primary objectives:
- Promote harmonized test procedures
- Support development of aligned energy efficiency standards and labels (S&L) in APEC economies
- Fund one or more projects each year over a 5 year period.

Objective: Identify projects that can be launched in early 2012 and will advance S&L development in APEC economies.

Collaboration between EGEE&C and the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative:
- SEAD-funded APEC-CAST initiative
- Leverage technical expertise provided through the SEAD international technical collaborations

Administrator: The Collaborative Labeling and Appliance Standards Program (CLASP), as the SEAD Operating Agent.
<table>
<thead>
<tr>
<th>SEAD-funded APEC CAST Project</th>
<th>APEC Economy Sponsor</th>
<th>Project Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation and initial draft of harmonized test methods and level definitions for <strong>heat pump water heaters</strong></td>
<td>Australia Department of Climate Change and Energy Efficiency (DCCEE)</td>
<td>DCCEE, CLASP, George Wilkenfeld and Associates, Korea Testing Laboratory, International Copper Association</td>
</tr>
</tbody>
</table>

**Project description:**

- Analyze existing regional, national, and international test methods, as well as test methods and standards in development
- Test 3 heat pump water heaters using 5 different test methods to compare strengths and weaknesses of each
- Recommend internationally-comparable test methods, standards, and efficiency level definitions
## Project schedule:

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2012</td>
<td>Project kick-off</td>
</tr>
<tr>
<td>March 2013</td>
<td>Technical analysis of existing test methods report distributed for stakeholder review</td>
</tr>
<tr>
<td>12 April 2013</td>
<td>International consultation workshop</td>
</tr>
<tr>
<td>February – June 2013</td>
<td>Testing and modeling and simulation</td>
</tr>
<tr>
<td>September 2013</td>
<td>Final report</td>
</tr>
<tr>
<td>Fall 2013</td>
<td>Report dissemination workshop</td>
</tr>
</tbody>
</table>

*Please contact Anna Lising at [alising@clasponline.org](mailto:alising@clasponline.org) with any questions or comments.*
Conclusion

1. Energy and environment became the may challenge of China followed with fast economy Growth, Central government pay more and more attention and set more stringent targets on this topic.

2. HP keep on growth, with the government promotion, especially direct subsidies.

3. Large TS system combined with GSHPs are being widely used.

4. AHPNW should coordinate with the APEC project on HPWH.
Thank you!

ZHANG Shicong. Research Center for Development Strategy
China Academy of Building Research. Institute of Building Environment and Energy.
Tel: 010-84270181    Fax:010-84283555
Beijing. 30# Beisanhuandonglu. 100013
zhangshicong01@126.com