Sino-German Technical Cooperation
Energy Efficiency in Existing Buildings
Project Output

Report on EEEB Demonstration Project Building No. 12
Huixin West Street, Beijing

Beijing Uni-Construction Group Co., Ltd.
March 2010
Sino-German Technical Cooperation
Energy Efficiency in Existing Buildings
Project Output

Report on EEEB Demonstration Project Building No. 12
Huixin West Street, Beijing

Beijing Uni-Construction Group Co., Ltd.
March 2010
Report on EEEB Demonstration Project Building No.12
Huixin West Street, Beijing

Beijing Uni-Construction Group Co., Ltd.
March 2010

Sino-German Technical Cooperation
Energy Efficiency in Existing Buildings (EEEB)

Overall term of the EEEB-Project: 2005-2010
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Project Director: Xu Zhiyong

Cooperation Partners:
Department of Building Energy Efficiency and Science & Technology (DOST)
Of the Ministry of Housing and Urban-Rural Development (MoHURD)
Project Director: Tong Guichan
List of Contents

I  Project overview ................................................................................................................... 1
II  Project background ............................................................................................................... 3
III Project design .................................................................................................................... 5
IV  Scope and construction techniques .................................................................................. 11
V   Construction organization and quality management .......................................................... 31
VI  Resident work ...................................................................................................................... 34
VII Retrofitting effects and evaluation .................................................................................... 38
VIII Economic and social benefits ......................................................................................... 53
IX  Major lessons and significance of dissemination ............................................................... 57
I Project overview

The energy efficiency project in Building No. 12, Huixin West Street, Beijing was a pilot EEEB project of the Beijing Municipal Commission of Housing and Urban-Rural Development and one of the second phase pilot projects of the Sino-German Technical Cooperation Project of “Energy Efficiency in Existing Buildings”. It was also a significant activity regarding the topic of Research and Application regarding the Energy Efficiency Improvement of Walls in Existing Buildings. It was organized by the Beijing Municipal Commission of Housing and Urban-Rural Development and implemented by Beijing Uni-Construction Group Co., Ltd. (BUCC). Led and supported by the Department of Science & Technology and Building Energy Efficiency of the Ministry of Housing and Urban-Rural Development and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), the project was commenced on September 28, 2007 and implemented in two stages: in stage 1, lasting until December 10, 2007, the retrofitting of the external thermal insulation of external walls, external doors and windows and the installation of an indoor air system and of heat meters for the boiler room and the outdoor pipe network were completed; in stage 2, lasting from March 15, 2008 to June 30, 2008, the remaining works such as the modernization of the indoor heating system, the waterproof and the insulation of rooftops were accomplished.

Leading concepts, techniques and practices for energy efficiency in existing buildings were introduced from Germany and the successful practices of EEEB in Tangshan were learned and applied to the project. Through the retrofitting practice in Building No. 12, the right approach towards building energy efficiency (BEE) for the situation in China and the specific situation of Beijing were explored.

The project was designed based on the concept of “comprehensive retrofit”, i.e. combining energy efficiency enhancing measures with maintenance and retrofitting, and included retrofitting the building envelope, the heating system and the ventilation system. Technologies regarding seven aspects were adopted: An external thermal insulation system for external walls, waterproof and insulation for the rooftop, energy-saving doors and windows, indoor heating system retrofitting, outdoor pipe network retrofitting, improvement of heat source’s energy efficiency and a fresh air system. With respect to the external thermal insulation for external walls and the fresh air system, materials and processes from Germany were imported. An advanced, suitable and feasible set of BEE techniques was developed through the absorption and application of the leading concepts, materials and techniques from Germany and significantly improved the technical skills for BEE in China.

Through the practical retrofitting of Building No. 12, the project team worked out a set of effective ideas and methods in construction organization and management as well as in resident work and made a valuable attempt in financing. These became valuable experiences for the further implementation of large-scale energy efficiency retrofitting in Beijing.

All tasks in the Terms of Reference (TOR) for the EEEB project in Building No. 12 were successfully accomplished. Residents’ comfort was largely increased and moisture condensation and mildew on interior walls were eliminated. As verified by examination and measurements, the expected objectives were achieved.

As the first energy efficiency retrofitting demonstration project in Beijing, this project had an enormous effect on society and played a positive role of dissemination and demonstration for large-scale energy efficiency retrofitting in Beijing.

Chronology of the energy efficiency retrofitting of Building No. 12, Huixin West Street:
May 2006  BUCC listed the energy efficiency retrofitting project in Building No. 12, Huixin West Street at the Municipal Government under the topic of Research and Application regarding the Energy Efficiency Improvement of Walls in Existing Buildings and applied for a municipal research project regarding energy efficiency retrofitting.

Jan. 2007  Before the retrofitting, energy consumption measurements and analysis were carried out and the heat transfer coefficient of walls was determined; the first resident survey was conducted.

Feb. 2007  BUCC, the Energy Efficiency Office of Beijing Municipal Commission of Housing and Urban-Rural Development and GTZ held an initial meeting and determined the preliminary retrofitting plan.

Apr. 2007  The energy efficiency retrofitting project in Building No. 12, Huixin West Street was approved by the experts organized by the Municipal Commission of Housing and Urban-Rural Development.

May 2007  The project was nominated to the Ministry of Housing and Urban-Rural Development (MOHURD), formerly named Ministry of Construction (MoC), as a demonstration project for Beijing.

Aug. 2007  The Department of Building Energy Efficiency and Science & Technology of MOHURD established the energy efficiency retrofitting project in the Huixin West Street Compound as one of the second wave demonstration projects in demonstration cities of the Sino-German Technical Cooperation Project EEEB in China.

Aug. 2007  Representatives of the residents in Building No. 12, Huixin West Street and some of the residents visited the demonstration projects in Tangshan.

Aug. 2007  The experts from Germany’s BBP proposed a retrofitting plan; the final plan was established upon technical exchange and discussion between Chinese and German partners and submitted to the Department of Building Energy Efficiency and Science & Technology of MOHURD for approval.

Sep. 2007  Bid invitation for external windows, external thermal insulation for external walls, fresh air system and equipment related to heat source and outdoor pipe network.

Sep. 2007  The second door-to-door resident survey was carried out and an agreement regarding the energy efficiency retrofit was concluded with each household.

Sep. 2007  The commencement ceremony for the demonstration project in Building No. 12, Huixin West Street was held and the first stage of retrofitting started.

Nov. 2007  Interviews on the project in Huixin West Street were made by Topics in Focus, a CCTV news program, and Nov. 2007  The retrofitting of Building No. 12 was reported on by TV and by print media including BJTV and Beijing Daily.

Dec. 2007  The work in the first stage of the demonstration project in Building No. 12 was completed and the closing meeting for the first stage was held on Dec. 26.

Mar. 2008  Engelbert Lütke Daldrup, Secretary of State at the German Federal Ministry of Transport, Building and Urban Development, visited the project Building No. 12, Huixin West Street.

Apr. 2008  Plan optimization for the second stage and bid invitation for equipments such as radiators were completed; the work in stage 2 was commenced.

May 2008  Xiong Daxin, Vice Chairman of the Beijing Municipal Committee of the Chinese People’s Political Consultative Conference (CPPCC) and some CPPCC members visited the project.

Jun. 2008  The work of the second stage was completed.

Aug. 2008  MOHURD and GTZ jointly inspected and finally accepted the energy efficiency retrofitting project in Building No. 12, Huixin West Street.
II Project background

2.1 Status quo of energy efficiency in China

Due to China’s fast-paced economic development, the gross energy consumption in buildings has been increasing annually, with its percentage of total energy consumption rising from 10% at the end of the 1970s to around 30% in recent years. BEE has become a crucial factor for the implementation of the sustainable development strategy.

Therefore, the Proposal of the Communist Party of China (CPC) on the Formulation of the Eleventh Five-Year Plan for National Economy and Social Development puts forward to “construct a resource-saving, environment-friendly society”, “accelerate technical transformation for energy efficiency and consumption reduction in enterprises”, and “develop energy-efficient, land-saving buildings and healthy, resource-saving modes of consumption”. In addition, the proposal establishes energy conservation as a basic national policy to promote the match between economic development and population, resources and the environment. The Energy Conservation Law of the People’s Republic of China was enacted to implement the energy-conservation, environmental protection policy and carry out the sustainable development strategy in the form of legislation. In November 2004, the Mid- to Long-Term Energy Conservation Plan was issued by the National Development and Reform Commission (NDRC) to plan energy efficiency retrofitting of 25% of existing buildings in large and medium-sized cities, where building energy efficiency (including energy efficiency of the building stock) was listed as one the top ten energy efficiency priorities.

Beijing has always been playing a leading role for building energy efficiency in China. The 65% energy conservation in buildings (DBJ01-602-2004) design standard, the third BEE design standard, was promulgated in 2004 and has been effective since then. Furthermore, the improvement of energy efficiency in existing buildings was included as a key task in Beijing’s Eleven Five-Year Plan for BEE. Among the existing residential buildings in Beijing, more than 93 million m² of gross floor space are not energy efficient, of which more than 63 million m² (including 19 million m² of prefabricated houses) were built after 1976 with an 8th degree in anti-seismic performance and are worthy of improvement. The heat consumption per m² in these non-energy-efficient buildings is higher than stipulated in the current design standard, thus causing a great waste of energy. For this reason, Beijing’s Eleven Five-Year Plan for BEE puts forward to speed up the work on retrofitting, requires searching for retrofitting methods, financing methods, an evaluation of the comprehensive cost and energy conservation performance of retrofitting through trial projects and aims for retrofitting 4 million m² of existing residential buildings.

2.2 General condition of Building No.12 before the retrofitting

Huixin West Street Compound is located in Beijing’s Chaoyang District, close to the Northern 4th Ring Road and only 2 km away from the main venue of the Beijing Olympic Games – the “Bird’s Nest”. The compound consists of four buildings with pre-cast walls, constructed in the late 1980s with an identical structure and using a gas boiler as their own heat supply.

Building No. 12 in the southernmost part of the compound is the one involved in the demonstration project with a floor area of 11,000 m², 18 floors and 144 flats. The building was constructed in 1988 with an inner-casting and outer-hanging prefabricated slab structure, energy efficiency requirements were neither considered in the design, nor during construction. This type of structure, which is a typical non energy-efficient building, has been obsolete for some time and the relevant design drawings are missing now. The site examination revealed that although reparations of the building were made for several times, after 20 service-years, leakage and breakage appeared in some places on the external walls, the indoor temperature in winter was rather low, moisture condensed on some walls and there was mildewing as result. These defects gave rise to frequent complaints from the occupants.
Prior to the retrofit of building No. 12, the project team carried out an energy efficiency measurement with the following results:

### 2.2.1 Heat transfer coefficient of building envelope

#### 2.2.1.1 Heat transfer coefficient of external wall

The external walls of Building No.12 are made of 280mm thick ceramic concrete. According to the field measurement of the external wall of Building No.12 by the China Academy of Building Research (CABR), the heat transfer coefficient was 2.04 W/(m²K), much higher than the required design standard of Beijing for 65% energy conservation, which is 0.60 W/(m²K).

#### 2.2.1.2 Heat transfer coefficient of roof

In the original design, there was a layer of 250 mm-thick aerated concrete on the roof, but its interior condition was not clear. The heat transfer coefficient was measured by the Beijing No. 2 Construction Quality Testing Center to be 1.26 W/(m²K), also higher than the required design standard of Beijing for 65% energy conservation of 0.60 W/(m²K).

### 2.2.2 Indoor comfort

Some households reported leakages, moisture condensation and mildew on the inside of external walls as shown in Figure 2.2.2-1. The testing results with infrared thermal imager indicated that the temperature of the internal surface on the external wall in the spots of moisture condensation and mildew was about 9°C as shown in Figure 2.2.2-2, which was 2-3°C lower than that on the external wall next to it. This means that there was a thermal defect in the external wall in this place, which seriously affected the insulation performance of the external wall and resulted in a low level of comfort for the households. Many residents complained that due to the low indoor temperature in winter, they had to wear wadded jackets and use electric heaters.

### 2.2.3 Heat Consumption

In order to obtain basic information on the indoor heating and actual energy consumption in Building No.12, Huixin West Street and provide basic data for the development of a retrofitting plan, the building's heat energy consumption was measured. This work, which was conducted using the portable ultrasonic flow meter method, was commissioned to CABR. According to the test, the heat consumption of Building No.12 was 78.6 kWh/m²a (26.2 W/m²), higher than the 30% energy conservation standard of Beijing (75.9 kWh/m².a). Therefore, Building No.12 was not energy-efficient and needed an energy efficiency retrofit.

For this reason, BUCC applied for Building No.12 Huixin West Street to be accepted as a pilot project of EEEB in Beijing and made many preliminary preparations. After the expert approval organized by the Municipal Commission of Housing and Urban-Rural Development was completed, the project was established in Beijing and supported with municipal funds for new wall materials. In the meantime, the project was included in the second phase of demonstration projects in demonstration cities of the Sino-German Technical Cooperation project “Energy Efficiency in Existing Buildings” and received technical and financial support from GTZ.
III Project design

In spite of the existing EEEB projects in China, the comprehensive energy efficiency retrofit of high-rise residential buildings was still uncharted territory. Due to limited funds, at the beginning of the project the planned scope was restricted to the building envelope without consideration of heating system, fresh air system etc. It was planned to apply general domestic and foreign practices in external thermal insulation when improving external walls.

With the strong support from MOHURD and the Beijing Municipal Commission of Housing and Urban-Rural Development and the vigorous effort of BUCC, the retrofitting project was included in the second phase of demonstration projects of the Sino-German Technical Cooperation project “Energy Efficiency in Existing Buildings” and was supported by GTZ with leading technologies and funds.

Arranged by GTZ, the relevant project staff members travelled to Tangshan to visit the first demonstration project of the Sino-German Technical Cooperation, exchanged ideas with the competent department of Tangshan Municipal Government and the workers responsible for the project in Tangshan, learned from their experience in the fields of technical, organizational, management and resident work, etc., witnessed the energy efficiency performance of the buildings and understood the residents’ perspective towards the retrofit. After the visit, the project team had acquired full knowledge of the focuses and difficulties of energy efficiency retrofitting, building a sound foundation for the smooth implementation of the project on Huixin West Street, Beijing.

Since the project was listed as a demonstration project of the Sino-German Technical Cooperation, the original design needed to be adjusted. For this purpose, GTZ engaged BBP Engineering Design & Construction Consulting from Germany to provide technical support. Mr. Schellhardt and Mr. Ball proposed a design plan in line with the requirements of German Codes upon field examination, information collection, theoretical analysis and calculation. Furthermore, Mr. Lehman and Mr. Hao Xiangyang, general managers of the German company Lunos New Fresh Air System, made a careful calculation of the air resistance of the ventilation shaft and produced an improvement plan for a new fresh air system.

As there are differences between China and Germany regarding general conditions, energy efficiency level, standards and codes in terms of engineering techniques, etc., some aspects of the German plans were not suitable for China. However, as the project was a pilot project of the Beijing Municipal Commission of Housing and Urban-Rural Development, a demonstration project of the Sino-German Technical Cooperation with MOHURD, as well as the first comprehensive energy efficiency project in a high-rise panel wall residential building, the aim was to make it a project involving high technology and outstanding technical characteristics. At the same time, it was aimed to make the project representative, applicable and suitable for multiplication.

Therefore, the project team, which repeatedly communicated and discussed with the German experts, made adjustments and adaptations based on the specific conditions in China while fully taking into consideration the German partners’ design plans. Finally, the project team worked out an energy efficiency design plan which was not only remarkable from a technical point of view, but also suitable for application and dissemination in China.

3.1 Design objectives

As the energy consumption profile in the existing building was complex, and specific requirements for energy efficiency were lacking in the current energy efficiency design standard, the initial heat energy consumption after completion of the retrofitting project was set to be in compliance with the heat consumption of buildings in the 65% energy conservation design standard of Beijing (as shown in Table 3.1). Under this premise, the target heat transfer coefficient of each part of the building envelope was determined upon thermal equilibrium calculation based on standard limit values according to the actual situation of the project. At the same time, the energy consumption in the improved Building No.12 could be measured by area and by room in order to prepare for a reform of the heat metering and billing system in the future.

Table 3.1 Requirements in the 65% energy conservation design standard of Beijing

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Limit Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building heat loss indicator</td>
<td>W/m²</td>
<td>14.65 (approx. 43.95 kWh/m²)</td>
</tr>
<tr>
<td>Heat transfer coefficient of external wall</td>
<td>W/(m²K)</td>
<td>0.60</td>
</tr>
<tr>
<td>Heat transfer coefficient of roof</td>
<td>W/(m²K)</td>
<td>0.60</td>
</tr>
<tr>
<td>Heat transfer coefficient of external window</td>
<td>W/(m²K)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

3.2 Boundary conditions before retrofitting

Beijing, where Building No.12 Huixin West Street is located, is in a cold climate region, for which the heating design parameters are shown in Table 3.2.
Table 3.2 Design parameters of heating in Beijing

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days of heating period (Z)</td>
<td>d</td>
<td>125</td>
</tr>
<tr>
<td>Average outdoor temperature during the heating period (t_e)</td>
<td>℃</td>
<td>-1.6</td>
</tr>
<tr>
<td>Average indoor temperature during the heating period (t_i)</td>
<td>℃</td>
<td>16</td>
</tr>
<tr>
<td>Average relative humidity during the heating period (φ_e)</td>
<td>%</td>
<td>50</td>
</tr>
<tr>
<td>Degree days (Ddi)</td>
<td>℃ • d</td>
<td>2450</td>
</tr>
</tbody>
</table>

Building No.12 was 26.4m long, 20.4m wide, with 18 floors and a floor area of approximately 11,000m². The boundary conditions are detailed in Figure 3.2-1 and Figure 3.2-2.

3.3 Retrofitting Design

Original design:

3.3.1 External wall insulation

The external wall was originally constructed using the inner casting and outer hanging method. Based on this method, 70 mm-thick EPS insulation was adopted in accordance with the 65% energy conservation requirements of Beijing. The calculated heat transfer coefficient was 0.53 W/(m²•k).

3.3.2 External doors and windows

In the retrofitting project, all external windows in public areas would be replaced. Because of sparse room in the public areas, the public external windows would be replaced by double glazing PVC sliding windows in consideration of traffic noise. A replacement of the external windows of the households was not planned.

3.3.3 Roof

Insulated and waterproof inversion type roofs would be reconstructed on the waterproof layer. 6 cm-thick XPS was to be used as the insulation material.

3.3.4 Heat source

Installations for fume collection, outdoor temperature compensation and meters for water, electricity and heat would be added to the boiler system.

Plan changes

After it was decided that the retrofitting of Building No.12 Huixin West Street would be carried out within the framework of the Sino-German Technical Cooperation Project EEEB, GTZ and the German experts put forward a comprehensive energy efficiency proposal and detailed technical solutions for the improvement of the external building envelope and the heating system based on the techniques and experience acquired in Germany. Upon thorough research by the Chinese and German experts and solicitation of opinions from the Beijing Municipal Commission of Housing and Urban-Rural Development and MOHURD, significant changes were made to the original plan to achieve a match of the external envelope insulation system and the optimized design of the heating system. Particularly in the treatment of many joints, Germany’s state-of-the-art techniques and products were adopted. The following retrofitting principles were established in the end:

1) Substitute all household external windows with inward side-hung energy-efficiency windows, replace the indoor heating system and the outdoor pipe network and improve the outdoor temperature compensation system of the boiler room.
2) Add a fresh air system to further reduce heat loss while guaranteeing indoor air quality.

3) Increase the thickness of the insulation layer, introduce a full set of German technologies and techniques and focus on the treatment of all kinds of nodes.

4) Enhance fire-protection construction measures in high-rise buildings.

Final plan:

3.3.5 External wall thermal insulation

1) A 100 mm-thick EPS board system was adopted for external wall thermal insulation and a mineral wool fireproof insulation strip was provided on the upper edge of windows. The external wall thermal insulation was extended to 15 cm above the apron and closed up using aluminum alloy support on the bottom. The window well's external wall at the first storey of the basement was insulated as well. The remaining part of the external wall at the same level was provided with 50 mm internal insulation made of insulation mortar, as shown in the figure.

3.3.6 External doors and windows

1) All external windows in the whole building were replaced to be compliant with the requirements of the current energy efficiency standard. Inward swinging side-hung bridge-cut-off aluminum alloy windows were selected as household external windows and pivoted windows of the same series were chosen as external windows for public corridors.

2) All windows were installed at the same level with external walls and insulation boards covered the window frames. Joints were treated with expansion sealing strips.

3) External door and window opening: the upper edge of the window was made of a mineral wool plate with a 200 mm high fireproof insulation strip, reaching 300 mm beyond each side of the windows. A pre-fabricated water dripping element was adopted for the upper edge of the window opening. Metal windowills (with flanging on both sides) were added.

4) Burglar mesh was installed inside the structural window opening on the first and second floors. No mesh was required on the third floor or above.

5) An insulating and fire-protecting safety-door was installed.

3.3.7 Roof

1) 60 mm-thick XPS with an additional waterproof layer was added to the existing insulation and waterproof construction on the roof.

2) Insulation of thermal pipe trenches of roof equipment and parapet walls were improved.

3) The parapet walls were protected with metal plates on the top.

4) Full external insulation would be provided for the elevator well on the roof.
3.3.8 Fresh air system

As the air tightness of external windows was improved, in this EEEB project, for the first time a fresh air system for residential buildings was adopted to alleviate indoor energy loss while improving the quality of indoor air and ensuring human health and comfort so as to achieve the purpose of energy efficiency, environmental protection and creating healthy living conditions.

In the fresh air system, negative pressure was used for ventilation. Based on the theory of atmospheric balance, exhaust fans were installed in bathrooms and toilets to intake fresh air through the air inlets with silencing and dustproof functions which were mounted on the external walls of rooms. The fans can run at three different speed levels and adapt air volume according to the need.

Considering the high ventilation resistance due to the rough surface of the original ventilation shafts, in order to ensure the ventilation function and effect of the fresh air system, on the roof, non-powered fans were fitted to the 5 outlets of the ventilation shafts of 5 toilets (8 flats per floor, of which 2 flats shared 3 airways; in total 5 airways for toilets).

3.3.9 Retrofitting of heat source

The heat source for the compound was changed into 32 natural gas-fuelled Slant/FIN atmospheric module boilers in four groups with 8 burners per group in 2001. Load adjustment was made by group and the burners were not adjustable. The primary and secondary sides of the heat source were connected by plate heat exchanger. The design temperature of supply/return water for heating was 70 °C /55 °C on the secondary side and the heating efficiency was 72%, higher than the required heating efficiency of boiler in the Design Standard for Energy Efficiency of Residential Buildings DBJ 11-602-2006. The module boilers with built-in outdoor temperature compensation were able to adapt the number of boilers running to the set indoor temperature of the apartments and the outdoor temperature, and thus adjust the supply water temperature on the primary side, thereby meeting the current energy efficiency requirements for heat sources. The following measures were taken:

1) The climate compensators were relocated to a height of about 2.5 m outside the northern wall of the boiler room.
2) A primary thermal calculator and a filtering device were added on the secondary side of the heat source.

3.3.10 Outdoor pipe network

The heat source users in the compound were Building No. 12 and three additional residential buildings with the same floor area and height. Building No. 12 was the nearest to the heat source. The following measures were taken:

1) Self-operated flow balancing valves were installed at the thermal inlets of the compound's thermal pipe network in all buildings to reduce heat loss due to a hydraulic imbalance of the outside network.
2) Thermal metering devices and water filtering devices would be mounted to the thermal inlets in all the buildings.
3) As a result of the indoor pipe network transformation in Building No. 12, the system resistance has increased and a secondary booster pump was added to the thermal inlet.
4) An automatic three-way valve was added to the thermal inlet in Building No. 12 and a temperature sensor was installed in the room at the northwest corner on the ground floor to allow automatic adjustment of the opening of the valve according to the temperature signal from the sensor to keep the indoor temperature at 18 °C. In this way, overheating of indoor spaces or heat dissipation as a result of the thermal insulation of the building envelope can be avoided. The automatic thermostatic valves in each room can reduce the indoor heating capacity, while the bypass of the electric three-way valve allows the outdoor network to run with a constant flow.

3.3.11 Indoor pipe network

1) The heating system for the over-ground part of the building was divided into upper and lower sections which met on floor 9. Both of the systems were changed into an upside-feed-and-underside-return system with a vertical single-pipe and bypass pipes. A heating system was added on basement -1 of the building in the form of an upside-feed-and-upside-return double pipe system. The original system on floor -2, the civil defense floor, remained unchanged.
2) All the original radiators in the building were changed into steel flat pipe radiators. An additional group of radiators of the same type was equipped in each heated room on basement -1. No radiator covers were installed.
3) Every group of radiators in the residential part was equipped with a flow-through automatic thermostatic valve to allow temperature control in each room.
4) In the places where the heating system was divided on floor -1 and floor -2, secondary thermal meters and flow control valves were installed. Heat cost allocators were installed for all radiators in the over-ground residential part to allow metering by household.

3.3.12 Others

Other activities which were taken simultaneously with the above for the improvement of the living environment:

1) Removal and re-installation of air-conditioners;
2) Removal of structures attached to walls, including guardrails, sunroofs, etc.
3) Painting of entrance door and installation of doors at staircase and corridors, fire door repair on all floors, check and improvement of lighting in public areas;
4) Installation of uniform burglarproof mesh for all windows;
5) Extension of fume exhausting pipes in corridors inside the building to the outside.

3.4 Comparison of relevant theoretical calculation values before and after energy efficiency retrofitting

In Table 3.4-1., the main energy efficiency indices and requirements of the 65% Energy Efficiency Design Standard of Beijing are shown and compared with the respective data for Building 12 before and after the retrofit.

<table>
<thead>
<tr>
<th>Item</th>
<th>Before retrofit</th>
<th>After retrofit</th>
<th>Standard of Beijing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Building heat consumption indicator (W/m²)</td>
<td>Heat load indicator for heating design (W/m²)</td>
<td>Coal consumption indicator for heating (kg/m²)</td>
</tr>
<tr>
<td></td>
<td>25.9 (approx. 77.7 kWh/m²*a equivalent)</td>
<td>67.5 (approx. 202.5 kWh/m²*a equivalent)</td>
<td>19.5 (approx. 18.81L fuel equivalent)</td>
</tr>
<tr>
<td></td>
<td>12.01 (approx. 36.03 kWh/m²*a equivalent)</td>
<td>26.3 (approx. 78.9 kWh/m²*a equivalent)</td>
<td>7.23 (approx. 6.97L fuel equivalent)</td>
</tr>
<tr>
<td></td>
<td>14.65 (approx. 43.95 kWh/m²*a equivalent)</td>
<td>32 (approx. 96 kWh/m²*a equivalent)</td>
<td>8.82 (approx. 8.5L fuel equivalent)</td>
</tr>
</tbody>
</table>

Indexes such as heat transfer coefficient of the building envelope and the building heat consumption after the retrofit met the requirements of the 65% Energy Efficiency Standard in the Design Standard for Energy Efficiency in Residential Buildings DBJ11-602-2006.

3.5 Design summary and reflections

With the aid and support of GTZ, the design for this project was changed from a simple design for an external thermal insulation improvement to a comprehensive energy efficiency design encompassing the building envelope, the heat source system for heating and a fresh air system, therefore not only enriching the design but also improving its technical level. Through communication and discussion with the German energy efficiency experts, the technical staff members of the project team obtained an in-depth understanding regarding Germany’s policies, technologies, concepts, and approaches on energy efficiency in existing residential buildings, which exerted an enormous influence on the design ideas, approaches and technologies for the energy efficiency retrofit of Building No. 12.

Based on the energy efficiency design plan for Building No. 12 proposed by the German experts, the project team adopted it as much as possible to the specific conditions in China so as to make it not only maintain the German design idea but also fit the Chinese context. At the same time, the design staff members gained the following insights on the current status and level of energy efficiency in China during the design process:

3.5.1 BEE design is a highly comprehensive systematic work

A key to the success of BEE is to apply the above mentioned technologies in accordance with the specific conditions of existing
buildings so as to achieve the best balance between technique and cost, while preventing the retrofit from conflicting with relevant codes currently in effect. The retrofitting plan may not necessarily be the best in technical terms, but out of comprehensive consideration, it should be the most appropriate.

3.5.2 Case by case analysis

1) According to the code, the stair well shall be insulated, but the width of the stair well shall meet the requirements of the fire prevention code and the flat's area shall also not be reduced. This work item was not performed in Building No. 12, nor was it necessary from the perspective of energy efficiency. This is because as long as the building envelope was well insulated and airtight and insulation measures were adopted for both the climbing hole on the rooftop and the entrance door to the building, a sound insulation effect had been achieved. Applying insulation to the stair well would not only have been costly but also risky for fire control and was thus not recommended.

2) According to the code, to change the indoor heating system into the traditional vertical double-pipe system was theoretically the most desired option. However, not all the households accepted the system modification within their flats, and to add vertical pipes would have caused a large area of floor slabs to be chiseled and the waterproof of toilets to be damaged. Considering these disadvantages, the system of vertical single-pipe plus by-pass was finally adopted in Building No. 12.

3) According to the German experts' request, electric fans should have been installed on the rooftops for the fresh air system. But in consideration of the limited maintenance skill of the property management and the difficulty in collecting the shared electricity charge, non-powered fans were adopted.

3.5.3 Select the best option under specific financial conditions

If there were sufficient funds, a relatively higher standard may have been considered to accommodate sustainable development. For instance, to use the 100 mm-thick expanded polystyrene insulation board in Building No. 12 increased the energy efficiency level; to apply the mineral wool fire insulation strip to the upper edge of the window openings improved the fire prevention standard; and to add the fresh air ventilation system guaranteed air quality and lowered the energy consumption caused by opening windows, etc.. However, if the funds are tight, a comprehensive consideration shall be taken, and the retrofitting measures shall be taken based on their contribution to energy efficiency. For example, firstly improve the external wall, the external windows, the rooftop, temperature control valves and thermal metering; secondly, retrofit the heat source and outdoor network, and finally the indoor system (pipes and radiators). By making full use of limited funds and integrating energy efficiency techniques in a scientific way, we can achieve an optimal energy efficiency effect.
IV Scope and construction techniques

4.1 Scope of BEE

According to the design, three aspects, i.e. the building envelope, the heating system and a fresh air system, were included in the project and 7 measures for energy efficiency were applied as set out below:

<table>
<thead>
<tr>
<th>(1) Building envelope</th>
<th>External wall insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roof insulation and waterproof</td>
</tr>
<tr>
<td></td>
<td>Energy efficiency window</td>
</tr>
<tr>
<td>(2) Heating system</td>
<td>Indoor heating system improvement</td>
</tr>
<tr>
<td></td>
<td>Outdoor pipe network system improvement</td>
</tr>
<tr>
<td></td>
<td>Heat source improvement</td>
</tr>
<tr>
<td>(3) Fresh air system</td>
<td>Fresh air system for residential buildings</td>
</tr>
</tbody>
</table>

4.2 Construction technique of external wall thermal insulation

As a focus of the Sino-German technical cooperation to help the Chinese partner master Germany’s external thermal insulation techniques, a full set of techniques, materials and field instructions provided by the German external thermal insulation company were adopted in the external wall thermal insulation improvement in Building No. 12 and BUCC was responsible for the construction methods. The project team invited MAXIT and STO, two German external thermal insulation companies, to submit bids, and finally selected the external insulation technique of MAXIT.

Before the external thermal insulation workforce entered the site, the project organized field technicians and worker representatives to have a technical training in MAXIT’s base in Changping District so as to understand and get familiar with the installation methods and procedures of German external thermal insulation systems. On the construction site, MAXIT assigned technical professionals to perform demonstration and guidance for the workers to ensure every worker master the construction techniques.

A special team of experts made up of personnel in charge of technology from the technical center of BUCC and the Architectural Design Institute as well as foreign experts from MAXIT was set up on-site to solve the technical problems arising during the construction process through consultation.

Compared with the practices of external thermal insulation in China, more attention was paid to detail treatment in German practices, where 7 new techniques of node treatment including brackets at the bottom, internal and external corners, dripping eaves at windows, metal windowills, expansion sealing strips on window sides, fire insulation strips and heat insulation for the exhaust pipes of the gas-fired heater were applied. These techniques were practical, convenient and efficient and for the first time were adopted in an energy efficient retrofit in China.

4.2.1 Construction for the external thermal insulation of external wall

For the basic structure of external thermal insulation, see Figure 4.2.1-1.

![Figure 4.2.1-1 Basic structure of external walls for thermal insulation](image-url)

The processes of external thermal insulation of external wall are as follows:

- Preparation of construction and materials
  - Line setting
  - Baseline setting
  - Install the bracket
  - Adhere EPS boards
  - Install anchoring elements
  - Prepare facade 410 adhesive mortar at bottom
  - Apply facade 410 surface mortar
  - Lay meshes
  - Decorate mortar
  - Apply facade 410 surface mortar
  - Silicon coating
  - Acceptance
(1) Preparation of construction and materials

Firstly, the outer surface of the external walls needs to be examined to ensure that the surface and the used adhesive mortar meet the defined adhesive strength, i.e.

\[ F = B \cdot S \geq 0.10 \text{N/mm}^2. \]

Of which, \( F \) ---- defined adhesive strength (N/mm²)

\( B \) ---- measured adhesive strength of substrate and the adhesive mortar (N/mm²)

\( S \) ---- area ratio of adhesion

Based on the above requirement, the project team has tested the effect of substrate adhesion of the existing walls. For the results, see Table 4.2.1.

**Table 4.2.1 Testing data of the pulling force of substrate**

<table>
<thead>
<tr>
<th>Testing parts</th>
<th>Content</th>
<th>Pulling capacity of probe (kN)</th>
<th>Pulling force (MPa)</th>
<th>Form of damage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External wall of the first floor</strong></td>
<td>Adhere test-piece to granitic plaster base plane</td>
<td>3.49</td>
<td>0.81</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.64</td>
<td>0.62</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.33</td>
<td>0.78</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td>Adhere test-piece to granitic plaster base plane (with preceding sanding treatment for base plane)</td>
<td>3.48</td>
<td>0.81</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.55</td>
<td>0.83</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.26</td>
<td>0.76</td>
<td>The surface of granitic plaster is damaged</td>
</tr>
<tr>
<td></td>
<td>Adhere adhesive mortar to granitic plaster base plane, adhere test-piece</td>
<td>2.55</td>
<td>0.60</td>
<td>The mortar is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.23</td>
<td>0.29</td>
<td>The test-piece is not firmly adhered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.68</td>
<td>0.39</td>
<td>The mortar is damaged</td>
</tr>
<tr>
<td><strong>External wall of typical floor</strong></td>
<td>Adhere test-piece on coating</td>
<td>2.51</td>
<td>0.59</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.69</td>
<td>0.40</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.09</td>
<td>0.49</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.13</td>
<td>0.50</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.26</td>
<td>0.61</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.62</td>
<td>0.61</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td>Apply adhesive mortar on coating, adhere test-piece</td>
<td>1.22</td>
<td>0.28</td>
<td>The coating peels off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.20</td>
<td>0.51</td>
<td>The mortar is damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.52</td>
<td>0.31</td>
<td>The coating peels off</td>
</tr>
</tbody>
</table>
According to the testing results, the project team cleansed the existing walls and directly adhered the EPS boards. To ensure safety, the adhesion area was defined to be at least 50%.

When cleaning the substrate, it is necessary to first clean the original pulverized and loose outer painting layer. Regarding the finish plaster with cracks and hollowness, the repair, reinforcement and leveling work is indispensable. The façade\textsuperscript{410} polymer mortar, 3–4 mm in the form of streaks, shall first be used for surface treatment. Then S06 mortar shall be used for leveling.

(2) Line setting

In line with the building’s facade design and the technical requirement of the external thermal insulation of external walls, the project team set out the horizontal and vertical control lines on outer doors and windows, moldings, decorative suture lines, etc.

(3) Baseline setting

Vertical steel ropes need to be hung on the corners (external corner and internal corner) of the building and other related places, if necessary. Horizontal ropes need to be spanned at the appropriate spots on each floor so as to control the verticality and flatness of the polystyrene board.

(4) Prepare façade\textsuperscript{405} adhesive mortar

The amount of clean tap water for 25kg polymer mortar façade\textsuperscript{405} for the external thermal insulation of outer walls is 4.5 – 5.0kg. After rapid stirring for 3 – 5min, adding clean tap water, there should be no dry powder or blocking. Set the polymer mortar aside for 10min and stir lightly before application. Then, the polymer mortar can be used.

(5) Adhere EPS boards

The maximum width and height of the EPS boards for external thermal insulation shall be 1200mm and 600mm, respectively. Irregular parts may be cut on site. Attention shall be paid to ensure that the cut edge is vertical to the surface of the board. At the corners of the entire wall, EPS boards with a minimum size of more than 300mm shall be used.

Attach the EPS boards in a horizontal order and adhere the boards to each other through staggered points, boards at external and internal corners should be interlaced. Joints between boards shall not be at the corners of doors and windows.
EPS boards shall be pressed in a gentle and even manner. Check the flatness and verticality with the 2m guiding ruler and layer board at times. It shall never be overlooked to clear the overflowing adhesive mortar to ensure that no mortar remains between the boards. Ensure close connection between boards, use foaming polyurethane to fill crevices with a more than 2mm width. The height difference of the edge points shall not be larger than 1.5mm. Otherwise, use sand paper or a special grinding machine for polishing and subsequently clear the suspended particles on the surface.

Insulation anchors produced by German companies E-Jot and Fischer have been used in the project. The installation of anchors shall be conducted at least 24h after the adhesion of the polystyrene boards. The depth of the holes shall be at least 18cm in accordance with the design. Yank the drilling machine for several times to remove all the powder in the holes. While making the coating system, screw in anchor nails. The pressing disc should press the corners of the polystyrene boards.
Figure 4.2.1-9 Drill holes for anchor bolts and install anchor bolts

There should be no less than 4 anchors per m² for the façade below a height of 50 m and at least 6 for the part above 50 m. Principally, anchors shall be spread evenly, but more may be installed near the external corner of the wall.

Figure 4.2.1-10 Arrangement of anchor bolts

(7) Prepare façade surface mortar

Special workers shall be assigned to prepare the polymer mortar façade for the external thermal insulation of outer walls. The workers shall be responsible for strict measurement and mechanical stirring, which should last 4 – 5 min in order to ensure an even mixture. The amount of clean tap water matching 25 kg polymer mortar façade for the external thermal insulation of outer walls is 4.5 – 5.0 kg.

Preparing the surface mortar, please note:
① No cement, sand or other materials beyond façade may be used in case too much water is added to the mixture.
② Protect the mixed mortar from sunshine and wind so as to avoid drying and crusting. Increase water to adjust the consistency in case of high temperature;
③ The amount of the mixed materials for one time shall be moderate. The mortar shall be used up within 2 hours and no dry and hardened mortar shall be used;
④ Construction shall be carried out when the temperature is between 5 °C and 35 °C and suspended in case of rain, heavy wind and direct sunlight. Protection measures shall be adopted when necessary;

(8) Apply façade surface mortar

Check carefully whether the surfaces of the thermal insulation boards are clean, all dirt and dust removed, and the surfaces flat and even. All rugged parts shall be removed.

After the installation and acceptance of the EPS boards, the polymer mortar shall be plastered. Plastering shall be performed with two layers: the base layer and the surface layer. Apply surface mortar with a thickness of 4-5 mm as the base layer to the polystyrene boards. After that, alkali-resistant glass fiber meshes, used at the four corners of the doors and windows and at the internal and external corners shall be pressed into the mortar immediately.

The base layer shall be applied within 20 days after the installation of the EPS boards.
(9) Lay meshes

Tighten up the meshes and apply them to the base level within the time limit when the mortar still has good operability. Use the trowel to press the meshes into the surface mortar, with a sequence "from the middle to the surrounding parts". Press the meshes flat, making sure they do not crinkle. Lap joints for the lateral length and the longitudinal length shall be at least 100mm and 80mm, respectively.

Figure 4.2.1-12 Lay meshes

Figure 4.2.1-13 Press in mesh

(10) Apply facade410 surface mortar to the surface layer

Apply the surface mortar with the thickness of 2 mm as surface layer before the surface mortar on the bottom layer solidifies. The overall thickness of the surface mortar shall be at least 6 mm. The mortar shall not be continuously kneaded to avoid hollowness.

Figure 4.2.1-14 Apply surface mortar

Figure 4.2.1-15 Overlap meshes

The break of construction of mortar application shall be at physical parts such as expansion joint, balcony, etc. for the convenience of further overlap work. Wet-on-wet overlap shall be ensured so as not to form permanent imprint. If during the process a pause is needed, attention shall be given that the surface mortar does not completely cover the laid meshes. Instead, the edge of the finished surface mortar, meshes and the mortar of base layer shall together form step-shaped slopes, with the space no less than 150 mm, so as to avoid that the flatness of the lap points of the meshed is beyond deviation.

(11) Work on external finish layer

Construction on the external finishing may be performed only if the base layer of the surface mortar has met the requirement.

4.2.2 Construction techniques for key nodes

(1) Construction techniques for the bracket at bottom

After the treatment of the substrate, install a stainless steel bracket for the first row of EPS boards on the first floor (Figure 4.2.2-1). The bracket, which serves as a base plane for the EPS boards, can prevent them from moving downwards after adhesion thereby ensuring the EPS boards at the same level (Figure 4.2.2-2).
(2) Construction techniques for internal and external corners

After the installation of the EPS boards, embed angle meshes at internal and external corners before applying the mortar as bottom layer (Figure 4.2.2-3, Figure 4.2.2-4), as they can ease the plastering at these spots and ensure the construction quality (Figure 4.2.2-5),

(3) Construction techniques for dripping eaves of windows

The treatment of normal dripping eaves is illustrated in Figure 4.2.2-6. Prefabricated dripping eaves (Figure 4.2.2-7) have been chosen for pre-embedding in this project, thus effectively facilitating the treatment of dripping eaves at the window (Figure 4.2.2-8, Figure 4.2.2-9).

When pre-embedding dripping eaves, it is essential to timely adjust their location and to avoid using the trowel to directly press and plaster dripping profiles, so as not to press dripping profiles into the mortar.
(4) Construction technique for windowsills

For the standard processing method for windowsills, see Figure 4.2.2-10. Due to the complexity of the method, water may permeate between the window and the external thermal insulation layer in case of mishandling. Prefabricated windowsills were used in the project (Figure 4.2.2-11). The method has the following advantages:

1) Waterdrips, which directly divert rainwater to the ground, are installed on metal window boards so as to avoid water flowing along the window frame and damaging the wall as result.
2) Self-expanding sealing tape and silicone adhesives are used for the double water-proof treatment of joints at the windowsill boards and the window frame, ensuring excellent water-proof performance.
3) Metal window boards enhance the bearing capacity of the windowsills.
4) Thermal insulation is adopted under the window boards, thereby solving the problem of thermal bridges.
(5) Construction technique for sides of window openings

Self-expanding water-proof sealing tape, which improves the waterproof performance, is added between the thermal insulation layer and the window sides.

(6) Construction technique for fire-protection insulation strip

In this project, for the first time in China in an energy efficiency retrofit of an existing residential building, fire-protection for the thermal insulation was taken into consideration and fireproofing insulation strips were installed at the above the windows.
For the installation of fire-protection insulation strips, see Figure 4.2.2-15. Mineral wool, which possesses similar insulation qualities as EPS boards, but much better fire-protection characteristics, is used as a thermal insulation material at the place shown in the drawing. In case of fire, the fire-protection insulation strip made of mineral wool can postpone the spreading of the fire upwards from the window, so that the residents may have enough time to escape.

The Chinese product of mineral wool applied in the project possesses a lower strength. The following measures are adopted to ensure the safety of the adherence between the mineral wool and the substrate:

1) Wrap up the mineral wool with glass fiber meshes and apply a layer of plastering mortar to enhance the overall performance of the mineral wool (Figure 4.2.2-16).
2) Embed glass fiber meshes in the spaces reserved for the mineral wool and retroflex the mineral wool boards (Figure 4.2.2-17).
3) Fasten the mineral wool boards with special anchor bolts (Figure 4.2.2-18).
4.3 Roof insulation technique

The roof retrofitting consists of four parts — roof-floor insulation, insulation of gutter and parapet, waterproof layer and drainage system of the roof. Due to the fact that the machines in the equipment room, which is located on the roof, have been in service for a long period and have to be repaired frequently, the previous roof design without human access did not meet practical requirements, so the roof insulation layer was changed from 20mm-thick cement and sand mortar to 30mm-thick C20 pea stone concrete. Meanwhile, in consideration of the increased pressure of concrete on the roof, which may destroy the original waterproof layer, a new waterproof layer is added on the insulation layer. …

4.3.1 Roof Insulation

Roof insulation is carried out in a mixture of both inversion type and upright type. In order to guarantee the waterproof effect and prevent occupants on the top floor from being disturbed by rain during construction, the original waterproof layer on the roof is retained, and the thermal insulation boards are directly applied onto the waterproof layer. For this project, Dow Chemical Company's 60 mm STYROFORM insulation board with a heat transfer coefficient of 0.28W/m.K and a water absorption rate of merely 0.24%, which can guarantee the thermal insulation effect on the roof, is chosen.

The insulation material is connected to the base layer by adhesion. After the base layer is cleaned, the insulation boards are pasted on the roof layer with polymer mortar as adhesive. Next, a protective layer of polymer mortar is applied on the surface of the insulation boards, which is further enhanced by glass fiber meshes. After the protective mortar reaches the final set the cushion layer of pea gravel concrete is constructed. The concrete is mixed on-site. The material delivered to the site shall be sent to a qualified laboratory.
for a mixture test. The on-site mixing operation shall be conducted strictly according to the mixture ratio notification provided by the laboratory. Concrete casting shall be carried out in sections. The surface of the finished cushion layer shall be smooth, clean, and without cracks.

4.3.2 Thermal insulation for gutter and parapet wall

Due to the poor smoothness of the inner structure of the gutter, the adhesion approach is inadvisable as insulation method for the gutter and the STYROFORM XPS boards are connected to the gutter structure by fixed fittings. The insulation boards are cut into a suitable size and fixed with \( \phi 8 \times 100 \) mm fixtures on the gutter’s top panel and inner side. The density of fixed fittings amounts to 4 to 5 pieces per square meter.

As insulation method for the parapet wall, the insulation boards are connected to the structure with both adhesive and anchors. Paste the insulation board on the top of the parapet with polymer mortar; fix the board by hammering the anchors and build a protection layer of polymer mortar.

4.3.3 Parapet top drainage

Similar to the handling of the windowsills, the aluminum alloy dripping boards are installed on the top of the parapet wall. The dripping boards shall be formed into final shape by the manufacturer according to the designed dimension and delivered to the site. The dripping boards can be installed after 24 hours upon the completion of the parapet insulation construction. The dripping boards are fixed by the anchors which penetrate through the metal boards and the XPS boards and into the structural wall by about 40 mm. The slope of metal boards is 10% toward inner side and the anchor holes are sealed with sealing gel. Metal boards are linked together by linking sheets. In this project, the parapet top has not been fully covered by a top dripping board, where the potential risk of crack exists. Improvement shall be made in this regard. The correct processing is that the top pressing board shall extend at least 15 cm downward on both sides with a water drip installed.
4.4 External window retrofitting technique

Swing-in hollow plastic steel windows were selected as the original solution. However, the households in Building No. 12 have purchased and installed sliding or swing-in plastic steel windows themselves before the retrofit, but with varying quality. To ensure the energy saving effect of Building No. 12 and at the same time in order to motivate the households to replace windows, in the window bidding meeting organized by the Beijing Municipal Commission of Housing and Urban-Rural Development, the project team eventually chose the bridge-cut-off aluminum alloy windows made by the East Asian Aluminum Company for flats and bridge-cut-off top-hung aluminum alloy windows for the public sections of the building.

4.4.1 Bridge-cut-off aluminum alloy window frame technique

The heat transfer coefficient of aluminum alloy is high, but it can be reduced dramatically through bridge-cut-off treatment through polyurethane infusion. The window consisting of an infused bridge-cut-off aluminum alloy frame and a 5+15+5mm hollow double-glass fully meets the requirements of current energy-saving standards. The window frame takes advantage of the high strength of aluminum alloy and the low heat transfer coefficient of polyurethane, which compensate each other, thereby combining thermal insulation with good appearance, durability and environmental soundness.

With respect to the window glass in this project, rubber space bars were applied, which have experienced severe deformation. After repair work time and again by the manufacturer, the effect remained poor. Moreover, the rubber space bar was not equipped with moisture absorbent. Therefore, it is recommended to select standard aluminum alloy space bars. For each window, there shall be at least 2 lock points.
4.4.2 External window installation technique

There are two methods for the installation of external windows: In center of the external wall and on its outside (Figure 4.4.2-1, Figure 4.4.2-2). Currently, most domestic windows are installed in the center, while in energy efficiency retrofitting projects overseas, windows are all installed on the outside. Initially, the concern about possible water leakage from the structural seam between the window and the wall put window manufacturers under much pressure. After careful analysis and research, the project team adopted the German experts’ suggestion and chose the outside installation method, with which the frame of the windows will be installed in alignment with the façade. Compared with the centered installation method, outside installation has the following advantages:

1) with this method the treatment of the junction between external thermal insulation and window’s frame can be easily implemented and so that the cost is reduced and the work speed increased.

2) The overall insulation performance of the window is good, because the common weaknesses associated with window side insulation are not to be found.

In principle, all the windows in this project shall be installed outside. In special cases, centered installation is also acceptable, but its external framework must be insulated. For the households swing-in windows were adopted, while for public areas top-hung windows were selected due to the limited space available and thus guarantee the passage of residents.

In case the window is installed on the outside of the external wall (Figure 4.4.2-2), the structural seam must be sealed tight. Self-expanding water-proof sealing tape is recommended for this purpose. After the inside is filled with polyurethane foam, it is advisable to attach another seal of silicone.

4.4.3 Installation process for windows and doors

The steps of the installation process are the following: preparation — measurement and line setting — preparation of windows and doors — boring holes for frame installation — fixture sheet installation — frame fixing—sashes installation and adjustment — foam bar insertion and frame sealing — accessory parts installation — inspection and clean-up — testing and approval.

(1) Preparation

The following tools and devices are needed for installation: toothless saw cutter, manual electric drill, percussive drill, nail
gun, thread plummet, nylon thread, steel measuring tape, manual suction cup, gel injector, glass cutter, and safety belt, etc.

Preparation prior to the arrival of materials: A material processing plan for the project shall be made according to the implementation schedule and the actual on-site progress. The manufacturing process shall be logically arranged to guarantee the timely supply of the products.

(2) Dismantling of old windows

According to the schedule, it is necessary to dismantle the original steel windows and aluminum alloy windows of all households.

(3) Measurement and line setting

First, check the opening in which the window is to be installed. The size of the opening shall be at least 15 mm bigger than that of the door or window. All the neighboring openings for the same type of doors or windows shall be kept on the same lines; both the vertical and horizontal lines of the opening shall be straight.

During the installation of the balcony windows, a positioning pivot, if required, shall be installed about 100mm under the windows, the material of which shall be the same as that of the window frame to guarantee a bridge-cut-off can be formed.

(4) Preparation of doors and windows

Before installation, the quantity, type, specification, direction and shape of the doors and windows shall be checked according to design drawings and technical disclosures; hardware pieces, self-expanding sealing tapes, fasteners, etc, shall be complete.

(5) Installation of fixture pieces

At the installation position, rivet the fixture pieces and the frame together. The fixture pieces shall be positioned 150-200 mm away from the window corner, the middle mullion and the middle transom; the distance between 2 fixture pieces shall not exceed 600mm.

(6) Window frame fixation

Place the window frame into the installation opening, and then insert thin wooden wedges into the 4 corners of the framework for temporarily fixation of the middle transom’s symmetric position. Then, specify the installation position in the transverse direction of the wall according to the design requirement. Place the alignment rule at the diagonal position in the opening of the external wall. The window frame and the rule shall contact to each other close, otherwise the gap between the EPS board and the frame will be too big resulted in difficulty in sealing work. Adjust the vertical, horizontal and rectangular position of the frame; the allowable tolerance shall conform to relevant standards. After the installation position is determined, fix the window by means of concealed installation and apply gel on it.

(7) Sash installation and adjustment

Place the sash in the fixed frame and make adjustments, ensuring the upper and the lower horizontal lines of the sash parallel to those of the frame, as well as the sash open freely within it.

(8) Insert foam rod to seal the frame

The expansion seam between the framework and the opening is filled with elastic materials such as polyethylene foam panels and rods, which are to be dusted and sealed with sealing paste. The paste and the wall shall be sealed tightly for a neat appearance.

(9) Installation of accessory parts

In sequence, install all accessory parts on the door and the window and further fix them. No parts shall be missed and the positioning shall be proper.

(10) Check and clean-up

The installed doors and windows shall be carefully protected. Check in time if the protective membrane peels off. Windows or doors which have been installed shall not be used as material transportation passages. Mounting scaffolds or hanging heavy objects on doors and windows is strictly forbidden, as are hacking and trampling on the frames, the sashes and the window hinges. During the cross operations, it is strictly forbidden to bump the doors and the windows. Check all the measurements and accessory parts for the doors and windows to make sure nothing missed. Wash all the doors and windows with clean water. The window framework’s external protective film must be stripped off before pasting EPS boards.

4.5 Fresh Air System

For the first time, the residential ventilation system (Figure 4.5-1) from Germany’s LUNOS Company has been introduced in this energy efficiency retrofitting of existing buildings, which has effectively improved indoor air quality, ensured human health and comfort, reduced indoor energy loss and thus protected the environment.
Process of Installation:

1) Drill a round hole with the diameter of 110mm in the external walls of the balcony and the rooms according to the position marked in the drawing. (Figure 4.5-2, Figure 4.5-3)

2) Upon completion of the external insulation on the external wall, insert the ventilation tube into the drilled hole, which shall be further sealed and secured with foaming agent; then install the outdoor grid and the indoor panel.

3) Ventilator installation in bathroom: Fix the ventilator on the ceiling with m6 expansion bolt; replace the previous iron grid of the ventilating shaft with round-formed outlet; connect the fresh air inlet to the ventilator with the ventilating tube; mount the switch box on the wall near the bathroom door; lay the sheathed wire from the switch box to the bathroom door; finish wire connection at the specified position on the top of the ventilator. (Figure 4.5-5)
4) Install powerless ventilators at the exit of the ventilating shaft on the roof. Install powerless ventilators at the exits of 5 bathroom ventilation passages (8 households per floor, 3 ventilation passages are shared, each by 2 households; there are totally 5 bathroom ventilation passages). When air flows, powerless ventilators can rotate automatically, thus speeding up the air flow upward from the bathroom passage and enhancing the ventilation function of the fresh air system. (Figure 4.5-6)

4.6 Heating Source retrofitting (as previously introduced)

4.7 Outdoor Pipeline Network Retrofitting

1) At the inlet to each building of the compound’s heating pipeline network, self-serving balance flow valves, thermal meters and water filters are installed.

2) Considering the increased resistance in the renovated pipeline network inside Building No. 12 as a result of retrofitting of indoor pipelines, a secondary pressure-booster pump is installed at the thermal inlet.

3) Install an electric three-way regulating valve at the heating inlet to Building No.12, and regulate the thermal supply of the indoor system based on the temperature of the temperature sensor in the least favorable room.

4) Use the bypass of the three-way regulating valve to keep constant flow in the outdoor network.

5) Since only Building No.12 has converted its heating system to variable flow one, by adding a bypass at the system entry, the outside thermal network remains as a constant flow system. Thereby, the original plan of installing devices of frequency conversion on the secondary side circulation pump is cancelled.

4.8 Indoor Pipeline Network Retrofitting

The implementation of the original design of the vertical double-pipe system requires the consensus of all the households. However, it is impossible for the households to reach consensus in the short term, and it is a technical challenge to construct the double-pipe system. Although the thermal effect of the vertical single pipe plus the bypass system is slightly inferior to that of the double pipe system, the vertical imbalance of the original single pipe system has been improved greatly by installing bypass pipes and thermostatic valves on heat radiators. After comprehensive consideration, the Beijing Uni-Construction Group, as executing unit, suggested the original system be changed to the vertical single-pipe plus bypass system, which had undergone the discussion of experts and was finally approved. The specific retrofitting is as follows:

1) In the apartments above the building ground there are two heat supply zones. The old system has been changed to down streaming vertical single-pipe system with bypass; in the first basement a double-pipe heating system with down streaming Principe has been installed ; in the second basement of the building the original system was kept.

2) The original radiators in the building are all changed to steel flat-tube radiators. Radiators of the same type are installed in each room to be heated on the basement-1. No radiator-covers are allowed.

3) For each set of home radiators, single-tube low-resistance thermostatic valves are installed.
4) At each branch of the overall system, which lies between the first and the second basement, a thermal meter and a flow control regulating valve are installed respectively. A heat cost distributor is installed on each of the home radiators above the ground.

The heating system retrofitting is carried out according to relevant design documents and the Technical Procedures for Beijing Engineering Construction and Installation (by division), as well as the technical instructions of equipment manufacturers. The steps of construction are as follows:

(1) Pipeline installation

After the arrival of pipes, quality shall be checked first and pipes can be used only when the quality meets the requirement. Remove the rust, iron crumbs, oil smear and dust from the steel pipe surface to expose the metallic nature, which is then brushed twice with red oxide anti-rust paint except for a part of 100mm at each end of the steel pipe.

Before pipe alignment, a special cleaning process shall be applied to clear the litters inside in the pipe. A pipe end groove shall be ground if the pipe's diameter is no less than 50mm, and the slope of the groove shall preferably be 45°. The pipe shall be hung to the right position by hoist chain before applying spot weld. There shall be 4 welding spots for the pipe with a diameter bigger than 100mm, and 3 for the pipe with a diameter less than 100mm. Straighten the pipe before welding. Welding defects such as dregs and bubbles are strictly forbidden. Anti-corrosion oil painting shall be carried out after welding. The gap between the pipes shall be 1.5mm to 3 mm and the alignment deviation shall be less than 1mm.

Welded pipes are adopted for the heating system. Thread connection is chosen for DN≤32 mm and welding connection for DN > 32 mm. During welding, the outer diameter of the pressed bend must be the same as that of the pipe. The slope of the heating pipe shall be kept at 3‰. The welding seam on the crossing-wall pipe shall be at least 30 cm away from the wall. Crossing-wall pipe shall be inside the steel sleeve and use batched jute to seal the sleeve end.

The surface of the welded pipes shall be smooth, uniform and neat; the joint shall be thoroughly welded, without defects like cracks, weld beadings, dregs, molten splashes, etc. While being installed, pipes shall remain straight horizontally and vertically, with the height conforming to the design requirement.

(2) Radiator installation

As important equipment of the heating system, radiators are delivered to the site by the manufacturer. The appearance of radiators shall be checked. A minimum of 2% of the total shall be spot-checked in pressure filling, and no less than 1% of the total on site shall be delivered to laboratory for sample reexamination. After qualification, the radiators are installed according to relevant construction process standards and the manufacturer's instruction manuals.
(3) Install thermostatic valve and one-way valve

Before installation, the valve cavity shall be wiped and cleaned until dirt, fiber and dust granule are fully removed. Before installation, the valve pressure test and the sealing test shall be carried out respectively for spot check. The pressure test criteria shall conform to the specification requirement. 10% of all valves shall receive sampling check; the valves for main control shall be checked 100%. The pipe valves and the instruments shall be installed strictly according to the drawing.

While installing the one-way valve and the temperature control valve, keep the water flow direction consistent with the direction of the valve’s arrow.

Valves shall be installed at places where related operation is convenient.

On the valves for cut-off and the regulation, there shall be obvious marks to indicate the flow direction and the switch direction.

(4) Pipe support

The pipe support must be installed according to the drawings and the Indoor Thermal Pipe Support and Suspension 95R402 as reference; meanwhile, the support structure shall be sturdy as well as aesthetic.

(5) Pressure meters shall be installed according to the following requirements:

The meter shall be installed at the position convenient for observation and flushing, and be prevented from the impact of high temperature, freeze and vibration. A buffer bend shall not be forgotten.

(6) Pipeline insulation

The Pipeline and Equipment Insulation (98T901) shall be enforced.

(7) System flushing and water pressure test

After the construction of the system, flush the system with the maximum flow. Keep all the valves open during flushing until the effluent water is limpid and clear without impurities. The flushing is qualified when the effluent water has the same quality as the influent water.

While conducting the water pressure test, the water pressure shall be lifted or reduced slowly. When the water pressure rises to the rated pressure, pause and check if leakage or other abnormalities occurs; then raise the pressure to the testing pressure and keep it for 20 minutes, the pressure drop shall not exceed 0.2mpa; finally return to the rated pressure and check.

(8) Install heat cost distributor

In order to realize metering of heat supply, an evaporative heat cost distributor is installed on each set of radiator.
4.9 Outlook after retrofitting

Figure 4.8-5 Heat cost distributor installed on the radiator

Figure 4.9-1 Building No.12 under retrofitting

Figure 4.9-2 Building No.12 after retrofitting
V Construction organization and quality management

5.1 Project organization and management

Before launching the project, a complete institutional system has been established, including the project steering team, the project executive office, the design department, the construction department, the resident work department, the technology promotion department, and other functional departments. Meanwhile, according to the suggestion of the Ministry of Housing and Urban-Rural Development, a system of routine meetings has been set up, thereby optimizing the mechanism for project coordination, management, report and communication, and an effective supervision and management system as well as a procedure for quick problem solving have been formed.

Huixin West Street Energy efficiency Retrofitting Project Steering Team

Duty: Be fully responsible for the project planning, policy making, as well as supervision and management of project's execution.

Project Executive Office

Duty: Be fully responsible for the operation of the project, enforce policies formulated by the steering team, arrange the work of all the departments, and coordinate the relationship between different parties. Be responsible for project budget, cost control, capital management, bidding and tendering management, external coordination, administration, logistics, etc.

On-site Headquarters

Duty: Be fully responsible for the execution of the demonstration project on site; enforce policies made by the project office; coordinate the relationship between various parties.

Design Department

Duty: Be responsible for the formulation of design plans, the design of construction drawings, the negotiation and adjustment on construction alteration, assisting bidding, tendering and later inspection.

Construction Department

Duty: Be responsible for planning, arrangement, scheduling, quality and safety of construction; coordinate and solve technical issues during construction; be responsible for collecting, assorting, and filing engineering materials as well as collecting and assorting engineering information; be responsible for training technicians and workers; be responsible for auditing work amount, material consumption and the work of service.

Resident Work Department

Duty: Conduct door-to-door investigation and material collection; sign energy efficiency retrofitting agreements with residents, charge retrofitting fees from residents; work with the construction department to coordinate the relations with the residents during construction.

Technology Promotion Department

Duty: Be responsible for editing and producing two videos covering technology integration and project promotion; be responsible for formulating technology summary report, project summary report, etc.

During the first stage of the project, three rounds of monthly routine meetings were held, which involved responsible persons from the four parties — the Department of Science & Technology and Building Energy Efficiency of MoHURD, the Beijing Municipal Commission of Housing and Urban-Rural Development, GTZ, and Beijing Uni-Construction Group. During the meetings, major issues concerning design alteration such as the location of newly-installed windows and ventilator type selection for the fresh air system were solved. Prior to the second-stage implementation, expert discussions were organized specifically on the heating system alteration plan submitted by Beijing Uni-Construction Group.
5.2 On-site organization and management

After the project was launched, the on-site headquarters, which was in full charge of the management, supervision and coordination on the project site, was established. In spite of the negative factors such as the tight schedule, the difficult task, etc, the headquarters elaborately organized all tasks and procedures, fully conducted management and strictly controlled project safety, quality and progress.

An on-site expert team was set up, consisting of the persons in charge of technical issues from the technical center of Uni-Construction Group and the design institute as well as the foreign experts from Maxit. The team members were responsible for solving the technical problems during construction.

During the second-stage retrofitting, taking into account frequent in-house operations and weather changes, the on-site headquarters divided on-site managerial tasks into segments. Experienced managers were assigned to take charge of the construction of the heating system and of roof respectively; meanwhile, specified personnel were dispatched to communicate with the households.

Prior to formal construction, technicians of the headquarters presented technical details to the construction company according to the requirements of design documentation, relevant specification and standards, and organized the thermostatic valve manufacturer to demonstrate installation on the site for the construction workers. During construction, managing personnel of the headquarters conducted all-round inspection and supervision on the site on each workday in spite of the hot weather so as to be kept informed about the project quality and progress and therefore identified and solved problems as soon as possible. The headquarters regularly held on-site coordination meetings (participants included the headquarters, supervision entity, design entity, construction company, etc) to discuss the matters concerning construction and solve problems about quality, schedule, alteration, and negotiation, etc.

To ensure construction safety, based on the principle of “safety first, precaution crucial”, a safe production steering team headed by the on-site chief commander was established, and state laws and regulations on safe production and construction safety were enforced strictly. Meanwhile, safe production regulations were formulated in accordance with the features of the project and seriously executed.

To guarantee project quality, the project team strictly executed relevant inspection and acceptance specifications formulated by the state and Beijing Municipality and carried inspection and acceptance step by step. For the materials delivered to the site, in addition to reviewing the inspection qualification report provided by the manufacturer, evidential sampling and testing was also conducted. During construction, inspection was strictly carried...
out according to the construction process and quality requirement. Inspection and acceptance were conducted upon completion of each segment. Finally, comprehensive inspection was conducted on major performances, such as the insulation system’s pulling strength, insulation structure, etc.

The project supervision system was adopted in the second-stage construction. The supervision entity was responsible for the overall supervision and management on project quality, schedule, safety, cost, etc. Also, the supervision entity was responsible for the inspection and acceptance during construction and on completion in strict accordance with relevant inspection and acceptance specifications formulated by the state and by Beijing Municipality step by step. The materials delivered to the site were inspected and accepted according to relevant inspection standards. For products requiring sample retesting, the supervision entity organized witnessed on-site sampling and testing. On-site sampling and retesting were conducted for steel-column flat-tube radiator and XPS board used in the project. During construction, after the completion of each procedure, inspection and acceptance were conducted according to relevant programs; the following procedure could be started only after the previous one was qualified.
VI Resident work

In comparison with new building projects, the energy efficiency retrofitting of existing buildings is most different in terms of the consideration of the normal life of the residents during construction; replacing windows and renovating heating systems require work inside the apartments. Therefore, in order to conduct retrofitting smoothly, it is pivotal to win the understanding and support of the residents. BUCC as a construction company faces great difficulties in handling resident work. The project team's initial investigation and analysis on the opinions of the households towards the retrofitting showed the following major difficulties in resident work:

1) The composition of the households was complex, including employees of BUCC, returned households, tenants (the apartment ownership belonged to BUCC), co-tenants (the apartment belonged to BUCC and two families co-rent it), and rental households (apartment owner).

2) Residents did not fully understand energy efficiency retrofitting, its significance and benefits; as a result, they initially showed little enthusiasm for the retrofitting work.

3) A preliminary financing mode was initiated for the retrofitting project, demanding households to bear part of the retrofitting fees. This was opposed by households.

4) Frequent in-house operations had to be carried out during construction (to dismantle and install air conditioners and windows, to install the fresh air system, to dismantle and install the heating system), which caused the households' repulsion.

5) Most household members worked during weekdays and were therefore not at home except on weekends, which brought about difficulty to the project team.

6) Project safety and disturbance to the residents.

To tackle these challenges, BUCC, supported by Xiaoguan Sub-district Office of Huixin West Street, established the resident work department consisting of personnel of BUCC, Beiyu Property Company of Uni-Construction Group, Xiaoguan Sub-district Office, Huixin West Street Neighborhood Committee, and Huixin West Street Property Station subordinate to BUCC. Aiming at resolving the difficulties in resident work, in particular the following tasks have been carried out: promotion regarding energy efficiency retrofitting; household basic information and opinion survey and coordination; signing retrofitting agreements, formulating a reasonable standard for charging fees, charging retrofitting fees; coordinating in-house construction; persuasion of households reluctant to participate.

6.1 Energy efficiency retrofitting promotion

During the planning stage of energy efficiency retrofitting of Building No.12 in early 2007, the project team handed out emerging saving promotion brochures and posted notices. However, surveys showed most of the households had a poor understanding of the retrofitting and an indifferent attitude. After serious study and discussion, the project team decided to carry out more publicity programs, which were mainly as follows:

1) The project team invited community employees and resident representatives to Tangshan to visit that city’s energy efficiency retrofitting projects for the purpose of learning about the retrofitting effect personally. Later, the visitors to Tangshan acted as multipliers and voluntarily introduced to their neighbors the significance and effect of energy efficiency retrofitting.

2) Resident work conferences to promote energy efficiency retrofitting and issuing retrofitting notices in the name of the community.
3) Meetings with the participation of community employees, building unit representatives and activists on retrofitting to introduce to residents the concept of energy efficiency retrofitting.

4) Taking the street committee office as a sample room, where the windows were replaced with energy-saving ones for the visit of all the households in the building.

These publicity programs evoked great repercussions among the households. Especially after visiting the demonstration retrofitting projects in Tangshan, the households changed their attitudes fundamentally. The supporting rate rose from less than 30% to 86%.

6.2 Baseline survey and coordination among households

There are 144 households in Building No.12. Grasping the basic information of these households and understanding their attitudes on energy efficiency retrofitting helped to carry out the arrangement and decision-making on energy efficiency retrofitting. For this purpose, the project team successively conducted attitude surveys on energy efficiency retrofitting, a household basic information survey, opinion survey and coordination on external window retrofitting and housing technology retrofitting solutions.

6.2.1 Attitude survey on energy efficiency retrofitting

In early 2007, the project team conducted the first in-house survey in the form of questionnaire and acquired a survey result, which showed indifferent reaction of the households. The project team gathered only 47 questionnaire forms as feedback from the 144 households, which showed 85.1% of these households were willing to accept external wall insulation and roof insulation. In terms of funding, 74.5% of the households were unwilling to pay any part of the retrofitting fees, while 55.3% were willing to use part of the public maintenance fund. In terms of the external windows, 57.4% of the households were unwilling to bear expenses to replace the original external windows not meeting the energy-saving standards; even with an allowance worth 30% of the cost, 46.8% of the households still expressed their unwillingness.

6.2.2 Survey on basic household information

In July 2007, before the retrofitting project was launched, the project team had conducted a survey on basic household information and the second survey on the attitude towards energy efficiency retrofitting. Based on the results of the in-house survey made in Tangshan, the project team formulated detailed in-house survey tables. With the help of the personnel involved in energy efficiency retrofitting from Tangshan, the project team conducted a trial survey in 8 households and obtained a general understanding of the in-house survey procedures and content. Then, surveys in all the households followed. The investigators worked overtime, making use of evenings and weekends when the occupants were at home to fill in the in-house survey forms and to take photos. The result showed that there were 118 individually-owned apartments and 26 BUCC-owned ones among the 144 apartments in Building No. 12. The households were mostly retired employees with middle or low income.

6.2.3 Attitude survey on external window retrofitting and corresponding coordination among residents

After extensive publicity, in order to learn the households’ attitude towards external window retrofitting, the project team carried out another survey. The feedback showed that although the majority of the households had recognized and accepted energy efficiency retrofitting, some of them still not agreed to replace the external windows. Their main reasons were: First, they have carried out indoor decoration and have installed new types of energy-saving external windows by themselves in recent years. Accordingly, they worried about the troubles and possible disruption the project might bring forth. Second, they did not have enough knowledge regarding the new type of energy-saving windows and needed further information in this regard; third, they were not satisfied with previous settlement on matters with the property company and as a result were skeptic. The resident work department insisted on two principles: hollow steel windows with very poor energy-saving effect must be replaced and households’ will should be respected. The department, together with the community street committee, made a thorough explanation for the households refusing to replace external windows. In addition, the relevant persons in charge of the sub-district office personally did the persuasion work. As the retrofitting project progressed, the households’ experience with the bridge-cut-off aluminum alloy window’s advantages regarding energy saving, noise reduction and durability resulted in a gradual change of their attitude. Finally, the windows of 108 households among the 144 were replaced.
6.2.4 Attitude survey on indoor heating system retrofitting and corresponding coordination among households

During the second stage, the replacement of radiators and heating pipes as well as the installation of thermostatic valves should be carried out in the apartments; the water pressure test after installation also needed households’ cooperation; particularly, the agreement of every household was a must for the installation of the vertical double-pipe system, therefore the resident work in the second stage was more difficult than in the previous one. Guided by the idea of building a harmonious society and people orientation, many dialogues with the households and another survey on households’ opinion concerning the vertical double-pipe system as a retrofitting solution, were carried out before the new beginning of the construction. As to be seen from the survey result, it was not possible for the households to reach consensus in the short run due to the following three reasons: first, in recent years, some households had conducted private, individual retrofitting measures in their apartments and as a result their heating pipes had been covered. The pipes had to be dismantled in order to install a double-pipe system, which would exert negative influence on indoor decoration; second, newly mounted vertical pipes would destroy the suspended ceiling and floor decoration, particularly, the pipe replacement in bathrooms would damage the waterproof layer and lead to potential leakage, for which, the households demanded restoration or equivalent compensation; Third, during the first stage of retrofitting, some households did not sign the retrofitting agreement due to long-standing problems and previous issues. This time, they still insisted that they would not agree until these problems had been solved. Therefore, the project team was seeking technical solutions while further advancing persuasion on households. Finally, with the great support of MoHURD, GTZ, and the Beijing Municipal Commission of Housing and Urban-Rural Development, the vertical double-pipe system was changed to a single-pipe system with bypass after expert discussion. Meanwhile, the previously designed heat radiators with high-frequency welding were changed to steel-column flat-tube radiators. The project team accepted the residents’ opinions and adopted their more reasonable and feasible solutions, which laid a solid foundation for the successful completion of the second stage of retrofitting.

6.3 Conclusion of retrofitting agreements and charging of retrofitting fees

After extensive publicity on energy efficiency retrofitting and detailed in-house survey, the project team signed retrofitting agreements with the households prior to project construction, in which the content and goal of retrofitting were elaborated, the rights and obligations of the two sides were specified, and the fee-charge standard was defined. The signing of the retrofitting agreement guaranteed the smooth implementation of the energy-saving project.

To make sure energy efficiency retrofitting went smoothly, the project team charged household fees in a prudent manner. Aiming at minimizing the apartment owners’ burden and sticking to the principle of “those who benefit should also invest”, the project team requested the owners to take on part of the retrofitting fees.

6.3.1 Principle of retrofitting charges

1) External wall insulation, external windows in the corridors, outdoor pipeline networks and heating source belonged to the public, so the retrofitting fee was undertaken by the project team.

2) The households should take on part of fees for the following three items: (1) replacement fees for external windows; (2) replacement fees for radiators; (3) fresh air system fees.

6.3.2 Range of fees

Considering the income level of the households in Building No.12 and drawing on the experience obtained in Tangshan, the project team made in-depth research and serious discussions and decided that the average fees for each household in Building No.12 were CNY 2,000. The specific proportion and amount were differentiated according to different apartment models, as shown in the table below:
Table 6.3.2-1 Fee standard for retrofitting items

<table>
<thead>
<tr>
<th>No. of Apartment</th>
<th>Fresh Air (10%)</th>
<th>Heat Radiator (30%)</th>
<th>Window (40%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>544</td>
<td>1856</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>440</td>
<td>1453</td>
<td>1993</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>440</td>
<td>1460</td>
<td>2000</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>256</td>
<td>820</td>
<td>1176</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>256</td>
<td>820</td>
<td>1176</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>440</td>
<td>1460</td>
<td>2000</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>544</td>
<td>1856</td>
<td>2500</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>568</td>
<td>1932</td>
<td>2700</td>
</tr>
<tr>
<td>Household with lease contract</td>
<td>0</td>
<td>0</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Household with social redress</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

6.3.3 Time schedule of fee collection

The project team decided to take the approach of “charging fees after construction”. After the second stage of retrofitting came to an end, relevant fees were begun to be charged. 121 households in total were involved. The majority of them paid fees on time after the retrofitting, except for a few households who refused to pay giving various excuses.

6.4 Management of in-house construction and corresponding coordination among households

During construction, the members of the project team tried their best to eliminate the households’ doubts and meet their reasonable requirements. Careful organization and appropriate arrangement were carried out to reduce the times of in-house operations which needed appointments in advance. The operations were carried out carefully to reduce disturbance of the households and damage on indoor decoration. Meanwhile, special workers were deployed to tackle the problems and complaints of the households in time. With the implementation of all these measures, the project team won the understanding and support of most of the households.

6.5 Negotiation with households refusing retrofitting

Although the majority of the households supported energy efficiency retrofitting, very few households declined to cooperate for various reasons, thereby exerting negative influence among the others and bringing about resistance to resident work and difficulty for project construction.

A few years ago, a household on the second floor had a conflict with the property company on boiler house retrofitting which had not been solved so far. This household rejected signing an agreement on energy efficiency retrofitting, activities such as dismantling the window barrier and, regardless of the advantage of energy-saving windows, replacement of the hollow steel windows which had been used for nearly 20 years. In principle, the project team fully respected the points of view of the households and would not force them to replace external windows. But the external windows of this household were outdated hollow steel windows which had very poor insulation, and if not replaced, would severely influence the overall effect of the retrofitting project. Therefore, workers of the project team, the street committee and the sub-district office paid several visits to the household and repeatedly tried to convince the family members. Eventually, the household agreed to replace the external windows.

A hanging cradle was used in external insulation construction. To ensure the smooth move of the cradle, window barriers had to be dismantled. A household on the sixth floor held the view that window barriers, according to the Property Law, belonged to private property, which the construction workers had no right to dismantle and which must be compensated for if dismantled; the household also requested compensation well above the market price. The project team could not reach agreement with the household even after many negotiations. On serious deliberation, the team concluded that the resident work policy must be consistent and that exceptional cases of compensation should not be allowed for any reasons, otherwise the charge of household fees of the whole project would be hindered. Therefore, as a result of failed persuasion, the attempt to dismantle the window barrier was given up. Although much inconvenience occurred to the construction in this regard, the window barrier has been retained up to now.

Figure 6.5-1 Not-dismantled window barrier
VII Results and evaluation

To fully master the energy efficiency of Building No.12 and accurately assess the energy-saving effects, the project team developed a comprehensive testing program after the completion of the retrofitting Phase 1.

7.1 Coverage of testing

For the specific test coverage, see Table 7-1:

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Timeline</th>
<th>Test Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal testing of building envelope</td>
<td>2006~2007 Heating Season</td>
<td>External walls and roofs prior to retrofitting</td>
</tr>
<tr>
<td></td>
<td>2007~2008 Heating Season</td>
<td>External walls after retrofitting</td>
</tr>
<tr>
<td></td>
<td>2008~2009 Heating Season</td>
<td>Roofs after retrofitting</td>
</tr>
<tr>
<td>Testing of indoor temperature and humidity</td>
<td>Heating Season of 2006<del>2007, 2007</del>2008, 2008~2009</td>
<td>Representative rooms facing different directions at first levels, mid-levels, and top levels</td>
</tr>
<tr>
<td>Testing of household heating supplies</td>
<td>2008~2009 Heating Season</td>
<td></td>
</tr>
<tr>
<td>Efficiency of boiler and pipe networks</td>
<td>2008~2009 Heating Season</td>
<td></td>
</tr>
<tr>
<td>Electricity and gas consumption of boiler room</td>
<td>2001~2009 Heating Season</td>
<td></td>
</tr>
<tr>
<td>Air-tightness of Building</td>
<td>2001~2009 Heating Season</td>
<td></td>
</tr>
<tr>
<td>Surveys on Household’s energy-saving behavior</td>
<td>2008~2009 Heating Season</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-1 Coverage for Energy-saving Testing of Building No. 12, Huixin West Street

7.2 Results and analysis of energy efficiency testing

7.2.1 Thermal testing of building envelope

(1) Infrared thermographic testing

Thermal infrared imagers have been applied to test the building envelope. The testing is divided into outdoor tests and indoor tests, with the results and analysis listed as follows:

Figure 7.2.1-2 Infrared photo

It can be seen from Figure 7.2.1-2 that the surface temperature of each storey of external walls is almost the same, indicating relatively consistent external thermal insulation performance of the external walls. The surface temperature of the external walls is slightly higher than the outdoor temperature, showing excellent external thermal insulation performance.

Figure 7.2.1-1 North-facing facade after retrofitting
The comparison of the infrared photos of the external windows taken before and after the energy efficiency retrofitting shows that the outer surface temperature of the external windows after the retrofitting is evidently lower than that before the retrofitting. Prior to retrofitting, the color of external windows on the photo appears to be orange-red, indicating that the temperature of its external surface is relatively high. By comparison, the color of the external windows appears to be blue after retrofitting, indicating that the temperature of its external surface is relatively low, which means less heat is transferred to the outside via the external windows.

The above testing results show that the thermal insulation performance of the building's external windows has been evidently improved. The energy efficiency retrofitting has reduced not only the heat transfer and consumption via the external windows, but also the heat consumption caused by penetration of cold wind due to the damages on most of the external windows in the stairways.
The inner surface temperature of the external wall is about 20 ℃, 2-4 ℃ lower than the indoor temperature and significantly higher than the outdoor temperature (minus 3 ℃ while testing). Prior to the energy efficiency retrofitting, the inner surface temperature of the external wall of some apartments was 7-9 ℃. It is evident that the external thermal insulation of the external walls after the retrofitting has been improved considerably.

(2) Heat transfer coefficient testing

The heat flow meter method has been applied to carry out the heat transfer coefficient testing over the external walls and the roofs, with the results listed as follows:

External wall: 2.04 W/m².K (before retrofitting) -0.39 W/m².K (after retrofitting)
Roof: 1.26 W/m².K (before retrofitting) -0.41 W/m².K (after retrofitting)

The results show that the heat transfer coefficient of the external walls and the roofs has been significantly lowered after the retrofitting, meeting Beijing's building energy efficiency standard of 65%.

7.2.2 Tests related to heat energy consumption

(1) Indoor temperature tests

The indoor temperature tests were conducted through an automatic temperature recorder in each of the representative household. The average indoor temperature of each household in each test period is listed as follows:

January 11, 2007 - January 24, 2007: The average indoor temperature of Building No. 12 (before retrofitting): 17.3 ℃
January 12, 2008 - January 21, 2008: The average indoor temperature of Building No. 12 (after retrofitting of external walls, external windows and outdoor pipe networks of the building): 25.2 ℃

January 22, 2009 - January 31, 2009: The average indoor temperature of each building (after retrofitting of roof and indoor heating system):

Table 7.2.2-1 Average Indoor Temperature in Each Heating Season

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Building No.</th>
<th>Average Indoor Temperature (℃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 (Not Retrofitted)</td>
<td>20.3</td>
</tr>
<tr>
<td>2</td>
<td>6 (Not Retrofitted)</td>
<td>19.7</td>
</tr>
<tr>
<td>3</td>
<td>10 (Not Retrofitted)</td>
<td>21.0</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>23.8</td>
</tr>
</tbody>
</table>

The tests carried out in a consecutive three years have shown that the indoor temperature has been considerably enhanced after the energy efficiency retrofitting of the external walls and the windows. Although the automatic flow regulation mechanism existed at the heating entrance of the building, the indoor temperature still appeared to be a bit too high due to the absence of the room-based temperature control mechanism, with households complaining of overheating. After the retrofitting of the indoor heating systems including installing thermostatic valves at each radiator, the indoor temperature has been lowered to a reasonable level. With the reduced heating demand of Building No.12, the heating supplies for the other three buildings become relatively higher. As result, the indoor temperature of the other three buildings also sees a slight increase compared with that in 2007.

(2) Indoor humidity tests

The indoor humidity tests were carried out by placing an automatic humidity recorder in each household among the selected households of Building No.12 after the retrofitting and Building No.4 without retrofitting. The test lasted from February 23 to March 15. The relevant data are as follows:

Average indoor humidity of Building No. 12: 31.3%
Average indoor humidity of Building No. 4: 26%

(3) Testing of heat supply

Prior to the 2007-2008 heating season, an ultrasonic heat meter was installed at the building’s heating inlet to measure the actual heat supply. Due to the debugging, the heat meter did not start testing and recording of heat supplies until December 17, 2007. For the total heat supply data of the building, see Table 7.2.2-2 and Table 7.2.2-3.
Table 7.2.2-2 Heat supply data for the 2007-2008 heating season

<table>
<thead>
<tr>
<th>Building No.</th>
<th>Testing Period</th>
<th>Total Heat Supply (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>17.12.2007-15.3.2008</td>
<td>1942 (Notes)</td>
</tr>
<tr>
<td>6</td>
<td>17.12.2007-15.3.2008</td>
<td>1864</td>
</tr>
<tr>
<td>12</td>
<td>17.12.2007-15.3.2008</td>
<td>1331</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7100</td>
</tr>
</tbody>
</table>

Notes: Due to the failure of the heat meter placed at Building No.4, the relevant figures were deduced from the difference between the total heat supply of the boiler room and the heat supplies of the other three buildings after considering the transfer efficiency of the pipeline network.

Table 7.2.2-3 Heat supply data for the 2008-2009 heating season

<table>
<thead>
<tr>
<th>Building No.</th>
<th>Testing Period</th>
<th>Total Heat Supply (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8.11.2008-15.3.2009</td>
<td>2662</td>
</tr>
<tr>
<td>6</td>
<td>8.11.2008-15.3.2009</td>
<td>2625</td>
</tr>
<tr>
<td>10</td>
<td>8.11.2008-15.3.2009</td>
<td>2633</td>
</tr>
<tr>
<td>12</td>
<td>8.11.2008-15.3.2009</td>
<td>1968</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9888</td>
</tr>
</tbody>
</table>

(4) Examination of heat consumption indicator

For detailed methods and process for the examination of the heat consumption indicator, see relevant testing reports. The results of the heat consumption indicator in each heating season are listed as follows:

2006-2007 heating season (before retrofitting): 26.16 W/m² (or 78.48kWh/m²•a)

2007-2008 heating season (after the retrofitting of external walls, external windows and outdoor pipe networks): 14.58 W/m²

2008-2009 heating season (after the retrofitting of roof and indoor heating system): 14.25 W/m²

The theoretical calculated value of designed heat consumption indicator is 12.01 W/m² (36.03 kWh/m²•a). The main reason for the difference between the data is only analyzed from qualitative perspective: theoretical calculation was carried out on the basis of the average outdoor temperature at -1.6 °C, the indoor fresh air exchange rate of 0.5 times/h, and indoor heating temperature at 16°C in winter. The actual indoor and outdoor temperatures during the testing periods, however, may be different and the residents’ manual opening of windows for air change may have also resulted in different values of air exchange. In addition, there are also factors like free indoor heat gain and the amount of cold air infiltration through the gate of the building, which was often left open by residents, that could not be accurately determined. Further quantitative analysis need in-depth measurement and evaluation, which could provide valuable reference data for the development of criteria in assessing energy savings of existing buildings after the retrofitting.

(5) Comparison of measured heat energy consumption values during an entire heating season

To fully understand the energy-saving effects after the retrofitting, we compared the measured heat energy consumption values during the entire 2008 ~ 2009 heating season between Building No.12 and Building No.4, 6 and 10 without retrofitting. The results are listed as follows:

The conversion formula between the unit of heat energy consumption GJ and kWh is: 1GJ = 278 kWh

Table 7.2.2-4: A Comparison of heat energy consumption per unit floor area between Building No.12 and Building No.4, 6 and 10 without retrofitting.
Given the fact that the heating retrofitting of Building No.12 covered the heating of the basement as an addition, which means that it increased the total heating area, the calculation of energy-saving results measured by heating area may explain this kind of difference more clearly.

Table 7.2.2-5: Comparison of heat energy consumption per heating area between Building No.12 and Buildings No.4, 6 and 10 without retrofitting

<table>
<thead>
<tr>
<th>Building No.</th>
<th>Heating area ( m^2 )</th>
<th>Indoor temperature ( ^\circ C )</th>
<th>Heat energy consumption ( kWh/a )</th>
<th>Energy consumption Per heating area ( kWh/m^2/a )</th>
<th>Energy-saving ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>10179.94</td>
<td>23.00</td>
<td>547104</td>
<td>53.74</td>
<td>34.55%</td>
</tr>
<tr>
<td>10</td>
<td>8967.87</td>
<td>21.32</td>
<td>731974</td>
<td>81.62</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>8967.87</td>
<td>19.47</td>
<td>737256</td>
<td>82.21</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>8967.87</td>
<td>20.29</td>
<td>740036</td>
<td>82.52</td>
<td>--</td>
</tr>
</tbody>
</table>

If the difference of indoor temperatures is also taken into account, the values only need to be revised in line with the indoor temperature as the outdoor temperature and the number of heating days are the same. Referring to the formula proposed by the German experts for the Tangshan project, heating supplies are all revised to those at an indoor temperature of 18 \( ^\circ C \). An increase of 1 \( ^\circ C \) in indoor temperature results in 6% increase of heat energy consumption. Therefore, the average indoor temperature of the three buildings without retrofitting is 20.36 \( ^\circ C \). See Table 7.2.2-6 for the energy-saving results:

Table 7.2.2-6: Comparison of heat energy consumption after revision to 18\( ^\circ C \) per heating area between Building No.12 and Building No.4, 6 and 10 without retrofitting

<table>
<thead>
<tr>
<th>Building No.</th>
<th>Heating area ( m^2 )</th>
<th>Indoor temperature ( ^\circ C )</th>
<th>Actual energy consumption ( GJ )</th>
<th>Revised energy consumption</th>
<th>Energy-saving ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GJ</td>
<td>kWh/a</td>
</tr>
<tr>
<td>12</td>
<td>10179.94</td>
<td>18</td>
<td>1968</td>
<td>1514</td>
<td>420892</td>
</tr>
<tr>
<td>Average values of 4, 6 and 10</td>
<td>8967.87</td>
<td>18</td>
<td>2640</td>
<td>2313</td>
<td>643014</td>
</tr>
</tbody>
</table>
(5) Examination of indoor thermal comfort

The project team has applied portable thermal comfort meters to conduct indoor thermal comfort examination in Building No.12. The test results are listed as follows:

Measured Mean Value (PMV) of Indoor Thermal Comfort on January 22, 2008: 0.63
Measured Mean Value (PMV) of Indoor Thermal Comfort on March 5, 2009: 0.53

Notes: The thermal comfort PMV between -0.5 - +0.5 implies comfortable level, less than -0.5 cold, higher than 0.5 hot.

(6) Heat metering

Prior to the 2008 - 2009 heating season, evaporative heat cost distributors were installed on the radiators. At the end of the heating season, the values recorded by the heat cost distributors were read. Combined with total heating supplies recorded by the building heat meters during the entire heating season, each household’s share of heating supplies during the heating season could be calculated. The values are sorted out per apartment type and floor number as follows:

Table 7.2.2-7 Evaporation volume of heat cost distributors for different apartment unit types and floors

<table>
<thead>
<tr>
<th>Type</th>
<th>reading value of the first floor /m²</th>
<th>Reading value of standard floor /m²</th>
<th>Reading value of top floor /m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 01</td>
<td>0.264</td>
<td>0.285</td>
<td>0.311</td>
</tr>
<tr>
<td>Type 02</td>
<td>0.243</td>
<td>0.297</td>
<td>0.317</td>
</tr>
<tr>
<td>Type 03</td>
<td>0.19</td>
<td>0.189</td>
<td>0.292</td>
</tr>
<tr>
<td>Type 04</td>
<td>0.16</td>
<td>0.167</td>
<td>0.258</td>
</tr>
<tr>
<td>Type 05</td>
<td>0.265</td>
<td>0.221</td>
<td>0.224</td>
</tr>
<tr>
<td>Type 06</td>
<td>0.273</td>
<td>0.266</td>
<td>0.245</td>
</tr>
<tr>
<td>Type 07</td>
<td>0.308</td>
<td>0.281</td>
<td>0.227</td>
</tr>
<tr>
<td>Type 08</td>
<td>0.429</td>
<td>0.336</td>
<td>0.642</td>
</tr>
</tbody>
</table>
It can be seen from the above table that there is a great difference in heating consumption among different types of apartments. For users with higher heating consumption, the main reason was that the power of indoor radiators was evidently too high, the radiators have too many units and the dimension of the self-installed non-standard radiators was large, delivering too much heat radiation (such as the Type 08 of Apartment on the top floor), which also further indicates that the amount of a household's heating consumption is directly related to the number of radiator units, apartment location and floor area.

(7) Examination of building air tightness

The examination is aimed to compare the air tightness of the building envelope that has undergone retrofitting with that of buildings without retrofitting. The indoor testing was carried out in 6 households with different types of apartments and located on different floors in Building No. 12 and Building No. 4 respectively. See Table 7.2.2-8 for the testing results:

Table 7.2.2-8 Results of building air tightness examination

<table>
<thead>
<tr>
<th>Apartment Number, Building No.12</th>
<th>Building leakage under pressure 10Pa (m³/h)</th>
<th>Times of air exchange under pressure 10Pa (times/h)</th>
<th>Apartment Number, Building No.4</th>
<th>Building leakage under pressure 10Pa (m³/h)</th>
<th>Times of air exchange under pressure 10Pa (times/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>108#</td>
<td>175</td>
<td>1.4</td>
<td>101</td>
<td>410</td>
<td>3.28</td>
</tr>
<tr>
<td>201#</td>
<td>75</td>
<td>0.6</td>
<td>108</td>
<td>240</td>
<td>1.85</td>
</tr>
<tr>
<td>1003#</td>
<td>150</td>
<td>1.25</td>
<td>905</td>
<td>260</td>
<td>3.47</td>
</tr>
<tr>
<td>1006</td>
<td></td>
<td></td>
<td>1206</td>
<td>360</td>
<td>3.43</td>
</tr>
<tr>
<td>1501</td>
<td>100</td>
<td>0.79</td>
<td>1702</td>
<td>700</td>
<td>5.93</td>
</tr>
<tr>
<td>1703</td>
<td>120</td>
<td>1.01</td>
<td>1708</td>
<td>200</td>
<td>1.54</td>
</tr>
<tr>
<td>Mean value of Building No. 12</td>
<td>124</td>
<td>1.01</td>
<td>Mean value of Building No. 4</td>
<td>361.6</td>
<td>3.25</td>
</tr>
</tbody>
</table>

The test results illustrate that the air tightness of Building No. 12 after the retrofitting is far better than that of Building No. 4 without retrofitting.

(8) Actual operating efficiency of boiler

Table 7.2.2-9 actual operating Efficiency of Boiler

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Testing items</th>
<th>Measured value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total heating supplies delivered by the boiler</td>
<td>10278000</td>
</tr>
<tr>
<td>2</td>
<td>Total heating generation by natural gas</td>
<td>13929076</td>
</tr>
<tr>
<td></td>
<td>actual operating efficiency (mean value) of the boiler (ratio between the measured values of Item No.1 and No.2)</td>
<td>74%</td>
</tr>
</tbody>
</table>
9) Examination of outdoor pipeline transmission efficiency

Table 7.2.2-10 Outdoor pipeline transmission efficiency

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Testing items</th>
<th>Measured value (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total heating supplies to Building No. 12</td>
<td>1968</td>
</tr>
<tr>
<td>2</td>
<td>Total heating supplies to Building No. 10</td>
<td>2633</td>
</tr>
<tr>
<td>3</td>
<td>Total heating supplies to Building No. 6</td>
<td>2625</td>
</tr>
<tr>
<td>4</td>
<td>Total heating supplies to Building No. 4</td>
<td>2662</td>
</tr>
<tr>
<td>5</td>
<td>Sum (1+2+3+4)</td>
<td>9888</td>
</tr>
<tr>
<td>6</td>
<td>Total heating supplies delivered by the boiler</td>
<td>10278</td>
</tr>
<tr>
<td>7</td>
<td>Pipeline transmission efficiency (ratio between the measured values of Item No.5 and No.6)</td>
<td>96%</td>
</tr>
</tbody>
</table>

7.2.3 Statistics on electricity and gas consumption of the boiler

Table 7.2.3 Statistics on electricity and gas consumption of the boiler

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Timeline</th>
<th>Annual consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption</td>
<td>2000-2007 Heating Season</td>
<td>144150 kWh</td>
</tr>
<tr>
<td></td>
<td>2008-2009 Heating Season</td>
<td>94740 kWh</td>
</tr>
<tr>
<td>Gas consumption</td>
<td>Heating Season 2000-2007, excluding 2005-2006 Heating Season (when there was limited natural gas supply due to supply shortage in Beijing)</td>
<td>408252.75 m³</td>
</tr>
<tr>
<td></td>
<td>2008-2009 Heating Season, after retrofitting</td>
<td>357798 m³</td>
</tr>
</tbody>
</table>

Figure 7.2.3-1 Electricity Consumption and Gas Consumption of the Compound-based Boiler

Note:
- 小区锅炉用气用电量表: Electricity and gas consumption of the community-based boiler
- 年天然气耗量: Annual consumption of natural gas
- 年动力电耗量: Annual dynamic power consumption
- 改造前: Before retrofitting
- 改造后: After retrofitting

The above table shows the heating consumption of Building No.12 was lowered after the retrofitting, while the electricity and gas consumption of the boiler room also decreased, indicating evident economic benefits.

7.2.4 Surveys of household energy-saving behavior

The project team conducted surveys on the basis of the Photopicture, which shows the opening times of the windows and also on the basis of the thermostatic valves adjusted by the households during the 2008-2009 heating season.

(1) A survey on window-opening by households

The task group selected a day in early winter, mid-winter and late winter, respectively, to record the times of window-opening by the households on an hourly basis. The results are shown in Table 7.2.4-1
Table 7.2.4-1 Statistics on window-opening

<table>
<thead>
<tr>
<th>Observation time</th>
<th>Weather conditions</th>
<th>Number of windows opened in different directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A noon in early winter 12:00</td>
<td>Sunny, north wind, wind scale 2-3 or higher to 4, 2-12°C</td>
<td>East 11, South 26, West 8, North 9</td>
</tr>
<tr>
<td>A noon in middle winter 12:00</td>
<td>Sunny, north wind, wind scale 2-3, -8-2°C</td>
<td>East 7, South 26, West 9, North 2</td>
</tr>
<tr>
<td>A noon in late winter 12:00</td>
<td>Cloudy with light snow, south wind, wind scale 2-3, -5-1°C</td>
<td>East 5, South 16, West 7, North 2</td>
</tr>
</tbody>
</table>

The above observation results show that despite the installation of the fresh air system, residents were still used to opening windows for ventilation, and more windows facing south were open in case of direct sun exposure.

(2) Survey on the use of thermostatic valves

The task group carried out indoor survey on March 14, 2009, covering a total of 116 households. See the survey results in Figure 7.2.4-1 and Figure 7.2.4-2.

![Figure 7.2.4-1 Use of thermostatic valves by households](image)

**Notes:**
- 住户温控阀调节情况: Adjustment of thermostatic valves by households
- 从未调节: Never adjusted
- 偶尔调节: Occasionally adjusted
- 经常调节: Often adjusted

![Figure 7.2.4-2 Satisfaction levels of households regarding indoor temperature](image)

**Notes:**
- 住户对室内温度满意度: Satisfaction level of households regarding indoor temperature
- 满意: Satisfied
- 偏热: Too hot
- 偏冷: Too cold

The above survey results show that although the indoor temperature reached 23.8 °C, slightly higher than the design norm, most of the residents still expressed their satisfaction. Despite repeated user-training sessions over the temperature control device delivered to the residents, most residents were not used to using thermostatic valves to adjust the indoor temperature. It may be concluded that the residents’ behaviors in using energy can be really changed only when the heat charge based on consumption is introduced.

7.2.5 Measurement of residential electricity consumption in Huixin West Street Compound

In order to evaluate the influence of the energy efficiency retrofitting on household electricity consumption, the project team has manually recorded the monthly electricity consumption of the residents in the 4 buildings in the Huixin West Street Compound. The team members manually recorded the reading of the electricity meter of each household around the 10th day of each month and calculated the electricity consumption of each household. For the electricity consumption from December 2008 to September 2009 in the 4 buildings in the Huixin West Street Compound, see Table 7.2.5-1.
Table 7.2.5-1 A summary of household electricity consumption in Huixin West Street Compound

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4#</td>
<td></td>
<td></td>
<td>21275</td>
<td>24890</td>
<td>21971</td>
<td>24737</td>
<td>20506</td>
<td>18143</td>
<td>20495</td>
<td>22621</td>
<td>18952</td>
</tr>
<tr>
<td>6#</td>
<td></td>
<td></td>
<td>21961</td>
<td>24547</td>
<td>21466</td>
<td>24268</td>
<td>18871</td>
<td>17860</td>
<td>22614</td>
<td>23347</td>
<td>18018</td>
</tr>
<tr>
<td>10#</td>
<td></td>
<td></td>
<td>24518</td>
<td>25899</td>
<td>23853</td>
<td>23062</td>
<td>19729</td>
<td>19188</td>
<td>23066</td>
<td>24233</td>
<td>20908</td>
</tr>
<tr>
<td>12#</td>
<td></td>
<td></td>
<td>22606</td>
<td>23414</td>
<td>23445</td>
<td>25356</td>
<td>22081</td>
<td>18041</td>
<td>17252</td>
<td>21719</td>
<td>16999</td>
</tr>
</tbody>
</table>

It's found during the survey that there were some individual households in each of the buildings not living there permanently. We treated these households in a different manner by deducting their electricity consumption from the total consumption and obtaining the mean household electricity consumption based on the actual number of the other households. As the indoor temperature during this heating season met the heating need in each building, there was less electricity consumption on the part of the residents for supplementary heating during the winter. But the statistics also reflect the difference between the household electrical appliances of the buildings. It is easy to find from Table 19 that there is no big difference in electricity consumption during December 2008 – June 2009. In April and May, the electricity consumption of Building No.12 even exceeded that of the other three buildings. But after the summer fully started and their was an increased electricity consumption by air conditioners, the electricity consumption of Building No.12 appeared to be considerably lower in comparison. According to the statistics obtained during the entire survey period, Building No.12 has saved around 6,000 kWh in electricity consumption in with comparison with the average electricity consumption of the other three buildings.

To facilitate comparison, we place the average electricity consumption of Building No.4, 6 and 10 next to that of Building No. 12, see the results in Figure 7.2.5-1. It can be seen from the figure that, in June and July 2009, the electricity consumption of Building No.12 saw the biggest decrease of around 25% than the average electricity consumption of the other three buildings. According to the statistics supplied by Beijing Meteorological Bureau, the average temperature in Beijing in June was 25.7°C, 1.5°C higher than in normal years. In particular, the average temperature in late June was as high as 28.8°C, the highest during the same period since 1951 and with 8 days having peak temperature above 35 °C. Therefore, it can be concluded that the reduced electricity consumption is partly attributed to temperature. The energy efficiency retrofitting has reduced the use of air conditioning, which shows that the energy efficiency retrofitting can not only save heat energy consumption, but also reduce air-conditioning energy consumption during summer in northern China.

Figure 7.2.5-1 Comparison between Building No. 12 and the three buildings without retrofitting on average value

Note:
12号楼户均: Average household value for Building No.12
未改造楼平均值: Average household value for the three buildings without retrofitting

7.2.6 Conclusion

It can be found from the test results that the measured value of the heat consumption indicator of Building No.12 before the energy efficiency retrofitting was 26.16 W/m², and the measured value of the heat consumption indicator after the first phase of energy efficiency retrofitting was 14.58 W/m², indicating that the thermal insulation performance of the external walls and the windows of the building has been evidently improved. The qualitative testing by applying the infrared thermal camera to examine the thermal performance of the building also shows an improvement of the overall thermal insulation performance of the external walls and the windows of the building. The temperatures of supply water and return water for Building No.12 are similar with those of the other three buildings, but the flow volume has been reduced by 1/3, and the average indoor temperature has been maintained at 25°C, 6°C higher than that of the other three buildings. It can be found from the comfort testing results that the indoor temperature of Building No.12 was too high, while the building’s heat consumption saw a marked decrease. After the retrofitting of the roof and the indoor heating systems in the second phase, Building No.12’s heat consumption indicator dropped further to 14.25 W/m². Gas
consumption has also decreased significantly. The average indoor temperature of the building was 23.5°C and still has potential for energy-saving compared with the designed interior temperature. In addition to the existing adjustment of the heat inlet to the building, publicity efforts could be further strengthened to encourage the residents to use thermostatic valves and fresh air systems to further tap the potential of energy-saving of Building No.12.

7.3 Analysis of condensation on the inner wall surface

After retrofitting of the existing walls, the project team not only needed to observe whether indoor condensation and mildew had been eliminated, but also should consider whether the use will produce condensation on the inner wall surface in order to ensure a long life the external insulation. We therefore carried out calculations and analysis based on the testing results.

7.3.1 Basic parameters of wall materials:

Table 7.3.1-1 Basic parameters of the wall materials of Building No.12

<table>
<thead>
<tr>
<th>Name of materials</th>
<th>Thickness δ mm</th>
<th>Heat transfer coefficient λ W/(m·K)</th>
<th>Thermal storage coefficient S W/(m²·K)</th>
<th>Thermal inertia indicator D</th>
<th>Water vapor permeability coefficient μ ng/(m·s·Pa)</th>
<th>Water vapor resistance H m²·s·Pa/ng</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramsite concrete</td>
<td>280</td>
<td>0.84</td>
<td>10.36</td>
<td>3.52</td>
<td>8.75</td>
<td>0.032</td>
</tr>
<tr>
<td>EPS</td>
<td>100</td>
<td>0.050</td>
<td>0.36</td>
<td>0.72</td>
<td>4.5</td>
<td>0.0222</td>
</tr>
<tr>
<td>Plaster mortar</td>
<td>5</td>
<td>0.93</td>
<td>11.37</td>
<td>0.06</td>
<td>5.83</td>
<td>0.0009</td>
</tr>
<tr>
<td>Overall water vapor resistance of the wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0481</td>
</tr>
</tbody>
</table>

7.3.2 Calculations of thermal resistance inside envelope according to Formula 7-1

\[ R = \frac{δ}{λ} \] (7-1)

Of which,

- \( δ \) — Thickness of materials layer (m)
- \( λ \) — Heat transfer coefficient of materials (W/m·K)

For calculation results, see Table 7.3.1-2

Table 7.3.1-2 Calculations of thermal resistance of various parts of the walls of Building No.12

<table>
<thead>
<tr>
<th>Thermal resistance ( R ), m²·K/W</th>
<th>Structure wall ( R_s )</th>
<th>EPS board ( R_e )</th>
<th>Plaster mortar ( R_p )</th>
<th>Overall thermal resistance ( R_o )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.3402</td>
<td>2</td>
<td>0.005</td>
<td>0.04</td>
</tr>
</tbody>
</table>

7.3.3 Calculation of temperature distribution inside external thermal insulation wall with facing tiles.

The temperature distribution at each interface of the comprehensive walls of Building No. 12 in winter:

\[ \theta_1 = \frac{\theta_i - \theta_e}{R_s + R_{e,i}} \] (7-2)

Of which,

- \( \theta_i \) — calculated indoor temperature (°C), adopting the mean value of measured indoor temperatures, which is 23.2°C;
- \( \theta_e \) — average outdoor temperature during the heating season (°C), adopting the measured value of 3.5°C;
- \( R_s \), \( R_e \) — heat transfer resistance of the envelope and inner surface heat transfer resistance (m²·K/W);
- \( R_{e,i} \) — thermal resistance between calculated interface of condensation and internal surface of the envelope (m²·K/W).

See Table 7.3.1-3 for calculation results
Table 7.3.1-3 Temperature of interfaces of walls of Building No.12

<table>
<thead>
<tr>
<th>Interface</th>
<th>☀i</th>
<th>☀1</th>
<th>☀2</th>
<th>☀e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (℃)</td>
<td>22.9</td>
<td>20.1</td>
<td>3.9</td>
<td>3.8</td>
</tr>
</tbody>
</table>

7.3.4 Calculations of actual partial pressure of water vapor $P_m$ on each interface

<table>
<thead>
<tr>
<th>Temperature (℃)</th>
<th>23.8</th>
<th>22.9</th>
<th>20.1</th>
<th>3.9</th>
<th>3.8</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated partial pressure of water vapor $P_s$ (Pa)</td>
<td>2947.7</td>
<td>2791.8</td>
<td>2351.8</td>
<td>807.9</td>
<td>801.3</td>
<td>785.3</td>
</tr>
</tbody>
</table>

For simplicity, two cases have been considered in the calculation of the water vapor partial pressure. Case 1: based on the maximum value of measured average indoor relative humidity of 41%, average indoor temperature of 23.2℃, outdoor relative humidity of 23%, and the outdoor average temperature of 3.5℃; Case 2: all the above conditions, but assuming a minimum average indoor relative humidity of 21%. For the calculation results based on Formula 7-3 and Formula 7-4, see Table 7.3.1-5.

$$H_0 = H_1 + H_2 + \ldots + H_n$$ (7-3)

$$P_m = P_i \cdot P_s \cdot \frac{1}{H_0}$$ (7-4)

7.3.5 For Determination of Condensation on the inner wall surface of Building No. 12, see Figure 7.3.1-1

Figure 7.3.1-1 Judgment of condensation within the walls of Building No.12

Note:
Judgment of condensation on the inner wall surface
Saturation vapor pressure
Water vapor partial pressure in case of maximum average indoor humidity
Water vapor partial pressure in case of minimum average indoor humidity

It can be found from the figure that whether the average indoor humidity is at the maximum or the minimum, no crossover of the actual water vapor partial pressure and the saturated vapor pressure at each interface is seen at the chart. Therefore, there would be no condensation on the inner wall surface after the installation of external thermal insulation at Building No.12.

7.4 Analysis of the contribution to energy-saving by main components of the building envelope

7.4.1 Basic information of Huixin West Street Building No.12

For the area of major components of the envelope of Huixin West Street Building No.12, see Table 7.4.1

Table 7.4.1 Area of parts of Huixin West Street Building No.12 (m^2)
### Direction Area of External Windows Area of External Walls Area of Roof Total Floor Area

<table>
<thead>
<tr>
<th>Direction</th>
<th>Area of External Windows</th>
<th>Area of External Walls</th>
<th>Area of Roof</th>
<th>Total Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>303.24</td>
<td>1804.74</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>South</td>
<td>791.82</td>
<td>1749.96</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>West</td>
<td>304.92</td>
<td>1804.19</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>North</td>
<td>259.14</td>
<td>1753.20</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td>Total</td>
<td>1659.12</td>
<td>7112.08</td>
<td>595</td>
<td>10119.94</td>
</tr>
</tbody>
</table>

#### 7.4.2 Testing results for thermal performance of building envelope and heat consumption indicator of the building

For the sorted results of thermal performance testing of building envelope, see Table 7.4.2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Thermal transfer coefficient of building envelope W/m$^2$.K</th>
<th>Heating consumption indicator of the building W/m$^2$.K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before retrofitting</td>
<td>After retrofitting</td>
</tr>
<tr>
<td></td>
<td>External Wall</td>
<td>External Window</td>
</tr>
<tr>
<td>Item</td>
<td>2.04</td>
<td>0.36</td>
</tr>
</tbody>
</table>

#### 7.4.3 Select revision coefficient value $\varepsilon_i$ of thermal transfer coefficient of building envelope

Given the heat gain from solar radiation and heat loss caused by sky radiation, the revision coefficients shall be selected for heat transfer coefficients of the building envelope before analysis and calculation. The specific values are shown in Table 7.4.3.

<table>
<thead>
<tr>
<th>Type</th>
<th>External Window</th>
<th>External Wall</th>
<th>Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>South</td>
<td>East, West</td>
<td>North</td>
</tr>
<tr>
<td>Single-glazed window</td>
<td>0.57</td>
<td>0.78</td>
<td>0.88</td>
</tr>
<tr>
<td>Double-glazed window or double windows with single glass</td>
<td>0.50</td>
<td>0.74</td>
<td>0.86</td>
</tr>
</tbody>
</table>

#### 7.4.4 Calculation and analysis of heat losses through thermal transfer of major components of the building envelope before and after the retrofitting

For the calculated heat consumption through thermal transfer of each major component of the building envelope before retrofitting, see Table 7.4.4-1.

$$ q_i = (t_i - t_e) \varepsilon_i \cdot K_i \cdot F_i $$  \hspace{1cm} (7-5)

Of which: $t_i$ —— average indoor calculated temperature of all rooms, 16°C for general residential buildings; $t_e$ —— average outdoor temperature during the heating period, -1.6°C for Beijing region; $\varepsilon_i$ —— revision coefficient of thermal transfer coefficient of the building envelope, see Table 7.4.3; $K_i$ —— thermal transfer coefficient of the building envelope, W/m$^2$.K; $F_i$ —— envelope area, m$^2$, see Table 7.4.1.
For the proportion of heat consumption through thermal transfer of major components in the total thermal transfer and heat consumption before the retrofitting, see Figure 7.4.4-1.

![Figure 7.4.4-1 Proportion of heat consumption through thermal transfer of major components of the building envelope before the retrofitting](image)

**Note:**
- 外墙: External walls
- 外窗: External windows
- 屋面: Roof

The figure shows that the heat consumption of external walls through thermal transfer accounts for the largest part among all the components of the building envelope. Therefore, the retrofitting of external walls has a great impact on total heat consumption by means of transfer. Secondly, the weight of external windows is also not to be neglected. As Building No.12 has multiple stories, the share of the roof is relatively small. In fact, heat consumption due to air infiltration should also be considered in the thermal calculation. However, based on Beijing's building energy efficiency standard of 65%, the air infiltration heat consumption is related to the number of air exchanges per hour, a result of 0.6 times the total volume of the building multiplied by a coefficient of 1.92. For Building No.12, the heat consumption through air infiltration is approximately 19.7% of the total heat consumption through thermal transfer. As it is difficult to assess the weight of each component's heat consumption through thermal transfer, no detailed analysis is offered here.

Similarly, for the calculated heat consumption through thermal transfer of each major component of the building envelope after the retrofitting, see Table 7.4.4-2.

**Table 7.4.4-2 heat consumption through heat losses of major components of the building envelope after the retrofitting (W)**

<table>
<thead>
<tr>
<th>Part</th>
<th>External walls</th>
<th>External windows</th>
<th>Roof</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal transfer and heat consumption</td>
<td>37649.22 W</td>
<td>52670.99 W</td>
<td>3545.70 W</td>
<td>93865.91 W</td>
</tr>
<tr>
<td>Total heat loss amount</td>
<td>112948 kWh</td>
<td>158010 kWh</td>
<td>10637.1 kWh</td>
<td>281598 kWh</td>
</tr>
<tr>
<td>Heat loss amount per unit area</td>
<td>15.88 kWh/m²</td>
<td>95.23 kWh/m²</td>
<td>17.88 kWh/m²</td>
<td></td>
</tr>
</tbody>
</table>

For the proportion of heat losses through thermal transfer of all major components after the retrofitting, see Figure 7.4.4-2.

![Figure 7.4.4-2 Proportion of heat consumption through thermal transfer of major components of the building envelope after the retrofitting](image)

**Note:**
- 外墙: External walls
- 外窗: External windows
- 屋面: Roof

It can be seen from the figure that the proportion of heat consumption through thermal transfer of every component of the building envelope among the total saw some changes, as the external thermal insulation has adopted 10cm EPS boards, resulting in a 82.35% drop of the thermal transfer coefficient after the retrofitting, indicating that the decrease of heat consumption through thermal transfer is very great. After the retrofitting, the thermal transfer coefficient of the external windows was reduced to 2.8 W/m²K, still much higher than that of the other parts of the envelope. To conclude, although the external windows accounted...
for an area smaller than the external walls, the weight of the thermal transfer and heat consumption's impact was considerably enhanced, exceeding that of the external walls. With respect to the roof, which accounts for a relatively small area proportion in a multi-storey building, although the roof has also seen a considerable decline in its thermal transfer coefficient, the overall weight of the roof's impact saw little change in general.

### 7.4.5 Contribution to energy-saving by major components of the building envelope

We can also make a comparison from another perspective, i.e. the contribution to energy-saving through the retrofitting. Specifically, it would be a comparison between the energy-savings of each component with the overall energy-savings before and after the retrofitting. See the results shown in Figure 7.4.5-1.

![Figure 7.4.5-1 Comparison of energy-saving contribution ratio of the components of the envelope](image)

**Note:**
- External walls
- External windows
- Roof

Based on the above analysis, it is clear that for the energy efficiency retrofitting of Huixin West Street Building No.12, the retrofitting of the external walls is the most effective among the envelope components, as its contribution ratio in the total energy-savings exceeds two-thirds. Following are the external windows. As Building No.12 is a high rise one, the contribution ratio of the roof to the energy-savings is relatively small. Technically, if external windows with better performance are selected to reduce the thermal transfer coefficient, their contribution ratio to energy-savings will be even higher, but at significantly higher costs.
## VIII Economic and social benefits

### 8.1 Analysis of the economic benefits of energy efficiency retrofiting

8.1.1 Project cost and cost analysis

For the details of the project construction costs, see Table 8.1.1-1:

Table 8.1.1-1 Details of the total cost of the energy efficiency retrofitting project

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Item</th>
<th>Total Cost (CNY)</th>
<th>Repair &amp; Maintenance Coverage</th>
<th>Energy-savings Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>External Thermal Insulation Work</td>
<td>1588791</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Cost of materials</td>
<td>790260</td>
<td>790260.</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>Construction cost of external thermal insulation</td>
<td>198636</td>
<td>198636.</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td>Brushing of stairway and the first basement floor</td>
<td>131116</td>
<td>131116.14</td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td>Air-conditioners relocation</td>
<td>102522</td>
<td>102522.</td>
<td></td>
</tr>
<tr>
<td>(5)</td>
<td>Replacement of fire-proof doors</td>
<td>18732</td>
<td>18732.6</td>
<td></td>
</tr>
<tr>
<td>(6)</td>
<td>Sill plate processing and installation</td>
<td>155845</td>
<td>155845</td>
<td></td>
</tr>
<tr>
<td>(7)</td>
<td>Hanging Cradle leasing</td>
<td>188820</td>
<td>188820</td>
<td></td>
</tr>
<tr>
<td>(8)</td>
<td>Lighting for stairway and lobby</td>
<td>2857</td>
<td>2857</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td><strong>989303</strong></td>
<td></td>
<td><strong>2401476</strong></td>
</tr>
<tr>
<td>2</td>
<td>Energy-saving windows</td>
<td>565652</td>
<td>565652</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Outdoor pipe network retrofitting</td>
<td>137087</td>
<td>137087</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fresh air system</td>
<td>72790</td>
<td>72790</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Indoor heating system</td>
<td>896653</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Replacement of pipe network and radiators</td>
<td>787077</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>Installation of thermostatic valves</td>
<td></td>
<td></td>
<td>109576</td>
</tr>
<tr>
<td>6</td>
<td>Roof</td>
<td>129806</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>Water-proof work</td>
<td>49520</td>
<td>49520</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>Thermal insulation work</td>
<td>80285</td>
<td>80285</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Subtotal</strong></td>
<td><strong>989303</strong></td>
<td></td>
<td><strong>2401476</strong></td>
</tr>
</tbody>
</table>
The cost analysis of the above table shows that the energy efficiency retrofitting of Building No.12 involved high costs, which is mainly attributed to the following reasons:

1) German external insulation system has been adopted. If relevant technologies could be assimilated and absorbed, the cost of energy efficiency retrofitting on external thermal insulation will be further reduced.

2) To enhance the enthusiasm of residents in replacing windows and ensure the smooth completion of the retrofitting, the external windows adopted in the project are bridge-cut-off aluminum alloy windows. Plastic-steel windows, that meet Beijing's building energy efficiency standard of 65%, would have further reduced the cost for external windows.

3) The construction period was delayed due to the 17th National Congress of the Communist Party of China, abnormal weather conditions as well as the learning curve for construction technologies from Germany, etc, resulting in higher labor cost and increased leasing fees of hanging cradles.

4) Based on the requirements of a pilot project, testing fees were higher due to more research and testing items than for normal projects.

5) Some parts of retrofitting covered should actually be included within the normal scope of maintenance rather than the energy-saving category.

8.1.2 Economic evaluation of the retrofitting

(1) Profits of heating brought about by the energy efficiency retrofitting

The energy consumption of Building No.12 after the retrofitting has been significantly reduced which resulted in lower gas and electricity consumption, etc. Due to practical constraints, the results of energy retrofitting are mainly based on theoretical calculations. In this project, the compound has an independent boiler room, the energy-savings, thus, are directly reflected in the consumption of natural gas and electricity. The project team has tracked the consumption of natural gas and the consumption of electricity by the boiler room before and after the retrofitting:

Excluding the exceptional 2005-2006 heating season when there was a limited natural gas supply due to a gas crisis in Beijing, the average annual natural gas consumption of the compound's boiler room over the several years before the retrofitting of Building No. 12 was 408,252.75 m³. The natural gas consumption for the 2008-2009 heating season after the retrofitting of Building No.12 was 357,798 m³, indicating savings of around 50,454.75 m³. Without considering the factor of increased indoor temperature, the savings equal an annual natural gas savings around 4.96 m³ per square meter.

Therefore, the subsequent savings per square meter amounted to: 4.96×1.95 = 9.67 CNY/m².

Simultaneously with the reduced natural gas consumption, the actual electricity consumption of the boiler room has also been reduced to 94,740 kWh from 144,150 kWh before the retrofitting, equivalent to annual savings of 4.85 kWh per square meter.

Therefore, the subsequent power savings per square meter amounted to: 4.85×0.43 = 2.09 CNY/m².

The total heating savings after the retrofitting are about 11.76 CNY/m² as the sum of the above-mentioned items. If only the costs of energy efficiency retrofitting are considered, the static investment payback period would be 22.58 years.

(2) Potential economic benefits of the energy efficiency retrofitting

As a matter of fact, the economic benefit of energy efficiency retrofitting is also reflected in lower electricity billing resulting from the significantly reduced use of auxiliary heating and cooling equipments like electric heaters in winter and air-conditioners in summer.

Before the energy efficiency retrofitting, there existed serious issues like leaks and mildew on the external walls of Building No.12.

<table>
<thead>
<tr>
<th>Other costs</th>
<th>1 Design fees</th>
<th>30000</th>
<th>30000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Supervision fees</td>
<td>10000</td>
<td>10000</td>
</tr>
<tr>
<td></td>
<td>3 Resident work fees</td>
<td>81337</td>
<td>81337</td>
</tr>
<tr>
<td></td>
<td>4 Testing and research fees</td>
<td>242000</td>
<td>242000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>363337</td>
<td></td>
</tr>
<tr>
<td>Cost per unit (CNY/m²)</td>
<td></td>
<td>95.04</td>
<td>265.62</td>
</tr>
</tbody>
</table>
Although maintenance had been conducted several times by the property company, the results were not satisfactory. The waterproof maintenance expenses on the external walls amounted to more than CNY 500,000 and the water-proof maintenance expenses to more than CNY 40,000 until the beginning of retrofitting. After the energy efficiency retrofitting, the expenditure on maintenance has been significantly reduced as the improved thermal insulation of the walls effectively addressed the issues of leaks and mildew.

External thermal insulation has ensured that the walls are not affected by the climate, improved the durability of the walls and extended the service life of the building, thus maximizing the returns of the state’s and resident’s investments.

8.2 Social benefits

8.2.1 Prominent energy-saving effects

After the retrofitting, Building No.12’s energy-saving effects have been remarkable, saving 4.96 m³ natural gas and 5.40 kWh (including savings of air-conditioners in summer) per square meter, equivalent to standard coal savings of around 4.96 × 1.2143 + 5.40 × 0.4 = 8.18 kg of standard coal CO₂ emission reduction per square meter per year: 22.66 kg/m² (emission coefficient of CO₂: 2.77)

After the retrofitting, Building No.12's CO₂ emission reduction is about 249 tons per year.

There are about 63 million square meters of residential floor area in need of retrofitting in Beijing. If the energy-savings of Building No.12 were applicable to all the buildings concerned, Beijing could save energy equivalent to 515,300 tons of standard coal while reducing 1,427,400 tons of CO₂ emissions.

8.2.2 Improved indoor comfort, promoting the construction of a harmonious society

(1) The indoor comfort has been improved since the retrofitting

After the energy efficiency retrofitting, the indoor comfort has been greatly improved. Taking household #2 as an example, the indoor temperature has been enhanced by 6 - 7°C from the previous 16°C, eliminating the need of auxiliary heating enabled by heaters that had been applied for many years, while thick cotton jackets and cotton-padded shoes also become unnecessary. The condensation and mildew previously found on the inner side of the external walls have also disappeared. After the replacement of new energy-saving windows, the indoor noise level has also seen a considerable decline. In summer, the use of air-conditioners starts later than usual and at a much lower frequency.

(2) Residents’ awareness and willingness on energy-saving have been greatly elevated

With the gradual progress of the retrofitting, the residents have obtained personal experience and are aware that energy efficiency retrofitting benefits both the country as a whole and its citizens. Most of the residents of Building No.12 have not only accepted the energy efficiency retrofitting, but also actively supported the efforts in indoor retrofitting, thereby motivating many residents of the other three buildings of the compound to take the initiative and contact the street committee to express their support of the energy efficiency retrofitting and the retrofitting of their buildings in the same year.

8.2.3 Pilot and model effects

“Energy conservation and emission reduction” are currently hot issues in China. As the first demonstration project on comprehensive energy efficiency retrofitting of existing buildings in Beijing, the project has exerted a tremendous impact among the general public.

During and after the construction, many media, including CCTV, Beijing TV and Deutsche Welle, conducted interviews on the site. The interviews were aired through programs such as CCTV-1’s CCTV News, Topics in Focus, Morning News as well as Beijing News and BTV-5 News, etc. Meanwhile, more than a dozen print media also published related articles.

Beijing Municipality issued the Special Implementation Plan on Energy Efficiency Retrofitting for Existing Buildings in Beijing and several other relevant documents in 2008. Given the success of Building No.12’s energy efficiency retrofitting, the Beijing Municipal Commission of Housing and Urban-Rural Development has organized a visit to Building No.12. Representatives from relevant departments of the Commissions of Housing and Urban-Rural Development from 18 counties and districts have intensively studied and discussed with BUCC and household in the building.

The officers from Beijing Municipal People’s Political Consultative Conference, China Development Bank, Shandong Provincial Department of Construction as well as the State Secretary of Germany’s Federal Ministry of Transport, Building and Urban Development also visited Building No.12. More than 20 entities, including Ningxia Yinchuan Housing Administration Bureau, China Construction Industry Association Material Branch and Heli District of Tianjin Municipality also initiated contacts with the project team and organized special personnel to visit Building No.12 to study the case.

The media reports and field visits have greatly impelled the efforts regarding existing building energy efficiency retrofitting in Beijing and related areas, bringing about enormous social benefits.
Figure 8.2.3-1 Interviewed by Topics in Focus, CCTV

Figure 8.2.3-2 Visit by the State Secretary of Germany's Federal Ministry of Transport, Building and Urban Development
IX Major lessons and significance of dissemination

With the great support of MoHURD, GTZ and the Beijing Municipal Commission of Housing and Urban-Rural Development, the energy efficiency retrofitting project Huixin West Street Building No.12, which lasted nearly ten months, has achieved a complete success as planned by BUCC through meticulous organization and stringent management. With this first demonstration project on comprehensive building energy efficiency retrofitting in Beijing, BUCC has taken the first step in the implementation of energy efficiency retrofitting in Beijing, carrying out exploration and making an attempt in design planning, construction technology, construction management, public awareness promotion as well as financing methods, thereby obtaining a wealth of experience and insightful lessons.

9.1 Energy efficiency retrofitting technologies are fundamental

The fundamental purpose of energy efficiency retrofitting is to conserve energy, i.e. choosing appropriate retrofitting technologies to allow existing buildings to achieve the goal of energy conservation. In choosing appropriate technologies, a comprehensive range of factors, including technology costs, efficiency and the ease of implementation must be taken into account. The following specific points shall be considered:

9.1.1 Choose proven technologies

For the external thermal wall insulation, there are many available insulation technologies. But for energy efficiency retrofitting of existing buildings, the status of substrates is complex, there are many joints to be handled and the disturbance to residents shall also be minimized. Therefore, products with a higher degree of technical maturity shall be given priority. As an energy efficiency demonstration project of the Sino-German technical cooperation, the Building No.12 Project has adopted a complete set of technologies of the EPS-based external thermal insulation composite system (ETICS), which are most widely used in Germany. Also, the project has taken new attempts on dealing with various joints including internal and external corners, windowills and dripping eaves in line with German practice. Based on Germany's proven experience, structural fire protection measures have been added. Still, the fact that some insulation materials needed to be imported, since domestic production had not been realized has posed an adverse impact on the construction progress. Nevertheless, the adoption of proven German experience has enhanced the technology level of thermal insulation construction in China and resulted in better results. The renovated Building No.12 represents the concept for future application of energy efficiency retrofitting technologies. In the future, with the localization of external thermal insulation materials, the energy efficiency retrofitting technologies for external walls will be applied in a standard way and in a wider scope.

9.1.2 Choose feasible technologies

(1) It is not necessary to have the most advanced technologies, but the adopted technologies should be the most appropriate.

Although the demonstration project was carried out through the technical cooperation between China and Germany, the team has not copied and also cannot completely copy Germany's retrofitting technologies, as the situations in China and Germany are rather different. Instead, a set of retrofitting technologies suited to the actual situation in China has been adopted based on learning from and absorbing Germany's experience. The retrofitting of the indoor heating system serves as an example. In Germany, a vertical dual-pipe system is mostly used for retrofitting, but the implementation is subject to a 100% approval of households. By comparison, given the fact that in China the property rights have largely been transferred to private owners, it is difficult to reach complete consensus among all the residents in the short term. Consequently, the project team has selected a single-pipe system with bypass, which delivers slightly less desirable results. As a result, the retrofitting project has not only been completed on schedule, but also showed comprehensive energy-saving effects.

(2) The technologies shall be modular for flexible choices

Comprehensive energy efficiency retrofitting requires various technologies. Due to the differences between buildings, not all technologies can be implemented. Therefore, the modularization of energy efficiency retrofitting technologies will play a very crucial role. Modularization means that as long as energy efficiency standards and design requirements are met, some technologies out of a variety of retrofitting technologies could be selected and combined or implemented in phases in line with actual conditions. Meanwhile, each modular technology can also have various configurations to ensure the ultimate energy efficiency results.

9.1.3 Choose economic technologies

On the basis of modularization of energy efficiency retrofitting technologies, the input-output ratio of each module shall be carefully analyzed. The selected modular technologies shall be as economic as possible. Meanwhile, the economic analysis of each module shall not be confined to the period of retrofitting. Instead, the assessment shall be carried out in light of the entire life-cycle of the building. Appropriate retrofitting technologies and plans shall be developed in line with the specific climate of different regions.
9.2 Resident work is a key for energy efficiency retrofitting

The support and participation of the residents is indispensable for energy efficiency retrofitting. Therefore, to raise the awareness of the residents must be a key priority. To this end, the project team has specially set up a taskforce responsible for affairs related to the residents. In sum, based on the experience with the Building No.12 Project, the following four recommendations can be made:

(1) Launch a publicity campaign to enhance the awareness of energy efficiency retrofitting

First of all, the success factors for a publicity campaign shall be carefully selected. In addition to introducing the national energy situation and relevant national laws and regulations regarding energy efficiency, key efforts shall be made to explain relevant benefits to residents taking into account their actual situation. Before the retrofitting, Building No. 12 had a poor thermal insulation performance, leading to low indoor temperatures in winter as well as condensation and mildew on some walls. These problems have been the main focus of residents’ concerns and complaints and shall be addressed immediately. Therefore, the focus of the publicity campaign shall be put on the retrofitting’s benefits to the residents, pointing out that energy efficiency retrofitting is conducive to energy conservation and can greatly improve indoor living comfort, which benefits both the country as a whole and the common people.

Secondly, publicity campaigns shall be carried out using various means, such as resident gatherings, the display of objects used in retrofitting as well as project visits. Thus, residents can personally feel the benefits of energy efficiency retrofitting.

(2) Make appropriate arrangements to improve the efficiency of indoor work

During the construction of energy efficiency retrofitting, the dismounting and installation of air conditioners, windows and heating systems as well as fresh air systems requires indoor work. Too frequent and long-time indoor work may provoke the antipathy of residents, thus hindering the smooth construction. Therefore, careful planning and coordination as well as appropriate arrangements are necessary to minimize the times of indoor work while enhancing indoor construction efficiency. To this end, the project team has mainly taken the following measures:

1) Implementation of an appointment system for indoor construction, with appointments generally being made 3 days in advance;
2) Appropriate planning, to complete as many construction operations as possible each time;
3) Improve construction efficiency; the dismounting and installation of all windows of each apartment must be completed in one day;
4) Construction workers must wear uniforms and ID-cards issued by the project team and adhere to the principles of civility and courtesy.

(3) Carry out in-depth investigations to learn about the opinions of the residents

The residents’ support and cooperation are significant for ensuring the smooth implementation of the project. Therefore, the project team shall, in light of the progress of the project, carry out in-depth and detailed investigations on residents’ opinions and attitudes towards energy efficiency retrofitting, including their attitudes towards energy efficiency retrofitting, fees to be charged, replacement of windows after the start of the construction, positions of window installation and heating system retrofitting. The analysis and conclusions shall be worked out based on survey results, especially residents’ reasons for opposing the retrofitting so as to serve as the basis for the project team’s decision-making.

(4) Maintain close contacts to resolve conflicts promptly

For various reasons, conflicts with the residents may arise during the construction. Therefore, the project team has installed telephones in the field office, designating special personnel responsible for recording the residents’ opinions and complaints. In case of any identified problems, appropriate measures shall be taken in time to prevent the conflicts from aggravating.

9.3 Relevant policies are critical to energy efficiency retrofitting

Although China’s efforts in energy efficiency retrofitting for existing buildings have just started, governments of all levels have fully recognized its importance and have been working hard to promote the implementation. For this purpose, MoHURD has issued a series of regulations, including the Regulations on Energy Conservation in Civil Buildings. Beijing Municipal Government also issued the Special Implementation Plan on Energy Efficiency Retrofitting for Existing Buildings in Beijing and several other relevant documents. Nevertheless, many supporting policies and regulations are still being formulated, which still to some extent restrains the progress of energy efficiency retrofitting in existing buildings. As one of the pilot projects, we have experienced different problems which require further improvement of relevant policies, laws and regulations in order to promote the large-scale energy efficiency retrofitting of existing buildings. Based on the practical experiences of the Huixin West Street project, the project team suggests that the following issues shall be considered:
1) Relevant laws and regulations shall be further optimized, while the relations between the stakeholders in energy efficiency retrofitting shall be clarified. Interested enterprises should be motivated to participate in energy efficiency retrofitting by offering preferential tax treatment or other political incentives, ensuring orderly and smooth energy efficiency retrofitting of existing buildings in urban areas. At the same time, for newly enacted laws and regulations, supporting policy documents shall be issued as soon as possible. For instance, the enactment of the Property Law in China has strengthened the protection of private property and greatly enhanced people's awareness of rights protection, marking a further step in China's efforts for building a society under the rule of law. However, many building parts affected by energy efficiency retrofitting, for instance, the external walls and pipelines inside a building, concern the interests of not only one household but the entire compound. It requires further elaboration and clarification through relevant laws and regulations to necessary property definitions. Otherwise, if individual residents refuse to accept the retrofitting of relevant parts or abuse the opportunity to seek high compensation, the implementation of energy efficiency retrofitting of an entire building energy or relevant energy-saving results may be greatly affected, which would seriously dampen the enthusiasm of the implementation entities or force these entities to give up.

2) Speed up the updating of relevant standards in line with the latest developments in energy efficiency retrofitting. Currently, for energy efficiency retrofitting of existing buildings, although relevant industrial and local standards are available, some provisions no longer meet current requirements as the background for the development of relevant standards has changed a lot. Meanwhile, in view of the particularities in energy efficiency retrofitting of existing buildings, if the project items can only partly be implemented due to resists of some residents or due to some circumstances, the issue of how to consider such a seemingly unfinished project and how to get the acceptance also needs deep consideration. It is recommended that existing standards shall be revised as soon as possible based on the experience drawn from energy efficiency retrofitting pilot programs.

3) The heating system reform shall be carried out as soon as possible, based on results of pilot programs, enhancing people's awareness of energy conservation while promoting energy-saving behavior as well as people's enthusiasm for energy efficiency retrofitting. After a considerable rise of the indoor temperature following the modernization of the building envelope, the important part which the residents' energy-saving behavior plays becomes very evident. If energy conservation cannot be directly linked to the residents' economic interests, it is difficult to ensure the final energy-saving results by merely relying on the household's energy-saving consciousness.

4) Establish a market-oriented mode of operation for energy efficiency retrofitting under the guidance of the government, thus realizing the industrialization of energy efficiency retrofitting and increasing enterprises' interest in participating in energy efficiency retrofitting initiatives.

5) Establish an assessment and monitoring system for energy efficiency retrofitting.

9.4 Financing is a bottleneck

Financing has always been an important factor constraining energy efficiency retrofitting of existing buildings. The retrofitting of Building No.12 had the financial support of Beijing Municipal Government's Wall Retrofitting Fund as well as the support of Germany's GTZ. In addition, the construction entity BUCC also has rendered support for the project. The residents of the building also assumed a small share of the costs. On the whole, however, its financing method is difficult to copy.

As the payback period is long, the effect of energy efficiency retrofitting for existing buildings in China at present is more tangible with regard to social benefits. Although the government offers a subsidy of 45 CNY/m² for the retrofitting of existing buildings, this is still far from being enough. The residents living in a kind of building such as Building No. 12 mostly belong to lower-income groups, with limited capacity to take on costs for energy efficiency retrofitting. Therefore, it is also unrealistic for residents to provide a larger part of the funds. For entities owned buildings with which the ownership of the apartments has already mostly been transferred to the residents themselves after the housing reform, it is fair to say that there is no links between the entities and the ownership any longer. For this case, the enterprises might lack motivation for the retrofitting.

Therefore, in promoting energy efficiency retrofitting of existing buildings, also financing approaches and models in line with different conditions shall be developed, and financing channels shall also be expanded to ensure funding sources for energy efficiency retrofitting. Therefore, it is recommended that different approaches be adopted to deal with buildings of different ages. In case of energy-inefficient buildings built before the implementation of energy efficiency standards, the low energy efficiency is mainly due to the absence of relevant policies and standards. Therefore, it is recommended that the government should increase the financial support. The participation of the beneficiaries on financing issues can draw more initiatives and attention of the quality. In contrast, with respect to buildings constructed after the implementation of energy efficiency standards in Beijing, the responsibility shall
lie on the relevant parties, i.e. all the costs associated with energy efficiency retrofitting shall be borne by the concerned developer.

In response to the global financial crisis, China has launched a 4 trillion CNY stimulus package to expand domestic demand and invigorate the economy, including a focus on energy conservation and emission reduction. The energy efficiency retrofitting of existing buildings can on the one hand promote energy conservation and emission reduction, and on the other hand, improve residents' living conditions. In addition, energy efficiency retrofitting can also stimulate the development of building-related industries, an initiative that would help to improve people's livelihood and build a harmonious society. Therefore, it is recommended to seize this opportunity to further promote the energy efficiency retrofitting of existing buildings in China, thereby creating a sound social environment.

9.5 Significance of the energy efficiency retrofitting project

The Huixin West Street project is the first comprehensive energy efficiency retrofitting demonstration project regarding existing residential buildings in Beijing and also a demonstration project under the Sino-German technical cooperation project endorsed by MoHURD. With the pilot project, advanced ideas, technologies from Germany have been introduced and experiences have been collected. The capacity strengthening of the project team of BUCC has realized, including the reasonable and feasible design of energy efficiency retrofitting, construction and testing of existing buildings and paved the way for energy efficiency retrofitting of existing buildings in line with the specific conditions of Beijing and China as a whole. The project has provided a solid reference for Beijing's future retrofitting.

As the project's implementation entity, BUCC has benefited from the cooperation with the German side and from the German engineering practice. The project was especially helpful for BUCC in terms of design, construction and management:

1) BUCC has accepted the design concept of "integrated thermal insulation and comprehensive retrofitting", shifting from a design concept simply focusing on meeting thermal transfer coefficient indicators towards a design philosophy that allows the project team, aiming at the actual situation of existing buildings, to comprehensively consider the integration of these technologies, reaching the optimum balance between technologies and cost-effectiveness in addition to meeting the energy saving related objectives.

2) BUCC has grasped the full set of Germany's external thermal insulation construction technologies and joint processing technologies, with the construction team for external thermal insulation gaining useful trainings while improving their construction technology level. The wider application of these technologies can further enhance the group's construction quality and technical strength in external thermal insulation.

3) BUCC has grasped the comprehensive testing technologies and analytical means and methods for building energy efficiency.

4) BUCC has accumulated experience in terms of resident work, organization and management of energy efficiency retrofitting of existing buildings. BUCC has been successfully applying these experiences in the retrofitting of the other 3 buildings in the same compound.

5) BUCC has improved the image of its brand and enhanced its technical capability regarding external thermal insulation.

The Beijing Municipal Commission of Housing and Urban-Rural Development spoke highly of the project. The following citation from the application certificate issued by the Commission for the Huixin West Street energy efficiency retrofitting project, shall serve as the conclusion of this report.

"The project provides the technical basis for future energy efficiency retrofitting of existing buildings in Beijing. The Huixin West Street Building No.12 comprehensive energy efficiency retrofitting project has been a positive role model for us to organize and carry out large-scale energy efficiency retrofitting of existing residential buildings.

Upon the completion of the project, we organized relevant personnel from all districts and counties' Commissions of Housing and Urban-Rural Development to visit Huixin West Street for field study. As a result, the successful experience and technologies of Huixin West Street Building No.12 have been applied in each district and county. Until today, several districts and counties, including Chaoyang District, have turned to the retrofitting model of Building No.12 in implementing their respective energy efficiency retrofitting.

By reviewing the research results and practical experience of this project, Beijing has issued 3 documents, namely the Special Implementation Plan on Energy Efficiency Retrofitting for Existing Buildings in Beijing, the Administrative Measures on Energy Efficiency Retrofitting Projects for Existing Buildings in Beijing and the Assessment Guidelines for Energy Efficiency Retrofitting for Existing Buildings in Beijing, which serve as a basis for carrying out energy efficiency retrofitting for existing residential buildings."