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Energy Conservation Strategy Research for Residential Building Refurbishment in Urban area of China

**A thesis submitted to the Politecnico di Torino,
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XXIV Cycle PhD Candidate

Yu ZHANG

(B.Arch, M.Arch)

Supervised By
Prof. Roberto Pagani

Coordinator of PhD Research ITAC in Poltecnico di Torino
Prof. Marco Filippi

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DECLARATION

I hereby declare that this thesis is the result of my own independent work and investigation, except where otherwise stated. Other sources are acknowledged by explicit references. This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree. I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organizations.

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Signed……………………. (Candidate: Yu ZHANG)

Date ………………………

“I have learned that, beyond death and taxes, there is at least one absolutely indisputable fact:
Not only does human-caused global warming exist, but it is also growing more and more dangerous, and at a pace that has now made it a planetary emergency.”

Al Gore (2006)
An Inconvenient Truth

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Abstract:

At present, energy crisis and climate change caused by GHG became the biggest problem that attracts global attention and China plays an important role in this environment battle. Currently, China is under the rapid urbanization progress and in the key period of society transformation. As a populous country which keeps a rapid economy growth, China has to face to huge energy demand which is mainly consumed in urban area.

The topic of present research is a critical problem in Chinese cities. Residential building which related with citizens' normal life is a decisive factor for society development. Looking to the world, EU had leaded a successful way for residential building energy efficiency and refurbishment. The excellent practice in EU could be an inspiration to China which is lack of technical and research support. The general goal of this research is to establish a comprehensive energy conservation refurbishment strategy framework and formulate innovate technical procedures and methodology for residential building in urban area of China. Literature review, professional interview, data collection, case study, questionnaire investigation, comparison analysis and some other research tools were adopted in present research.

By the literature review of the building energy consumption status quo both the world and China, the reasons for implementing energy conservation refurbishment in existing residential buildings in urban area of China is summarized and classification induce is made for Energy-saving and Energy-utilization through the study about existing relevant regulations and standards for residential building in China. The feasibility of improving residential building refurbishment in urban area of China is demonstrated by two aspects: both the requirement in China and advance experiences of EU. What is more, as representative of excellent experience in EU, project ENPIRE is particularly introduced. The research of residential building refurbishment in urban area of China related with multi-subjects, relevant domain knowledge had been researched in three aspects: data collection of existing residential buildings; analyzing method and energy efficiency technology which suitable for residential building refurbishment. In the scheme stage, through the analysis of the characteristic and developing trend of residential building in China, refurbishment goal is fixed; professional methodology and management support are fixed through the interview and questionnaire investigation aimed to architects and officer. When the comprehensive energy conservation refurbishment strategy framework is established, proper technology measures and design methodology for residential building refurbishment in urban areas had been proposed in details. In addition, series case studies are analyzed to prove the feasibility of this research.

The outcome of present research demonstrates the reason and necessary for implementing energy conservation strategy for residential building in China cities; Developing trend of residential building refurbishment in China is analyzed and a comprehensive residential building refurbishment strategy framework is achieved; The comprehensive energy conservation refurbishment strategy framework is divided into 4 steps: Energy survey phase, Discussion and setting ambitions, Analysis of energy options and optimizing of energy options, Implementation. With each step, detailed design methodology and technologies are proposed.

Besides setting up the innovation design framework of energy conservation residential building refurbishment, present research hammers away at connecting present topic with low carbon sustainable urban plan to consider low carbon issue in an overall level. (1) The final comparison in present research made a summary of residential building refurbishment project between EU and China. Through the analysis and lessons learnt from case studies, the universal comparison is made out to drive towards the right develop direction of residential building refurbishment in China. (2) In regulations aspect, the consideration of low carbon in residential building induce the central government and local authority to implement a detailed energy efficiency policy and regulations for residential building both for refurbishment and new constructions. (3) In the meanwhile, in allusion to the tradition and current situation of energy efficiency research in China, an innovation point of view that improving energy performance and comfort level in residential building and community synergistically has been proposed and it will be made further research with establishing evaluation system for residential building in China in next step. (4) With respects to urban plan level, emerging trends of sustainable development for existing residential community refurbishment in urban area of China have been presented.

Currently, China is effecting to develop low carbon sustainable urban planning methodology, as an essential part of the building sector in urban plan framework, the result of present research could be the guidance for decision-makers and architects to improve energy efficiency in residential building and sustainable urban plan.

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Chapter 1 Introduction

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- RESEARCH METHODOLOGY
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1 Introduction

China is developed in a fossil-based energy consumption mode in the process of rapid urban and building development. China is the No.1 building construction country in the world. What is more, China had replaced US became the No.1 energy consumption country in the world in 2010. According to the Annual Report on China's Energy Development (Cui, 2010), 18% of the world's energy is consumed in China, while energy intensity of China is three times that of the United States, five times that of Japan. Experts predict that the serious pollution caused by deformed economic development is near the upper limit of ability to shoulder of environment. In case the development of China is not controlled to a sustainable mode in the next few years, China's "economic miracle" will soon burst.

In the process of rapid urban development with high-speed economic development in China, residential building which has related everyone’s normal life is the base not only for urban development but also for society development. With the improvement of urbanization, the requirement for residential building is kept increasing and demand of residential building in urban area has been changed with the implementation of “Reform and Opening-up” policy since 1980s. High energy consumption in existing residential building sector in urban area of China is became an urgent problem needed to be solved but neglected in previous studies. If China wants to keep the high-speed economic development and harmonious society, it’s impossible to keep building new residential buildings and enlarge the number and scale of city. Limited by urban territory and local economic budget, implementation of energy conservation of existing residential building in urban area is the best solution for meeting the new demand of residential building and reducing energy consumption in urban area of China.

In order to control China's fossil-based energy consumption in the process of rapid urban development and improving quality of residential building in urban area of China, present research attempts to establish a set of procedures for energy conservation for existing residential building refurbishment in urban area of China with appropriate technology and methods. The results of this research intend to formulate a universal working framework particularly suitable for existing residential building refurbishment in Chinese cities. Through this approach, all Chinese municipalities can reduce carbon emission in residential buildings and devise low carbon sustainable urban development in accord with the actual situations of their own, and architects can assist the local authorities to design and execute the low carbon actions in residential community and district. The findings also intend to arouse the public awareness of climate change in China and invite all stakeholders participate this strategic battle against global climate change.

1.1 Research background

- **Environmental crisis of 21st century**

Plenty of researches proved that global warming has been fast accelerated in last century (IPCC, 2007). CO_2 and other Greenhouse Gases (GHGs) contributed by combustion of fossil fuels are accused of the direct causes of global climate change. The Kyoto Protocol in 1997, Bali Road Map in 2007, and a series of Conferences of the Parties (COPs) in last fifteen years (1995-2010) all repeatedly emphasized that reducing carbon emissions is important and essential for the global economic and environmental sustainability.

Since the "Reform and Opening-up" policy is proposed, China accomplished great economic improvement but consumed too much natural resource and made serious environment pollution. The contradiction between economic development and environment pollution is clashed sharply. China is a developing country with huge population, per capita energy is lower compared with other countries in the world. Cause of rapid development and great resolve of building energy consumption, the problem of low efficiency of energy use imminent. Energy insecurity and rising prices of conventional energy sources are also major threats to economic and political stability (Jacobson, 2009), which prompted countries around the world to pay close attention on this issue. Various energy technologies, especially those related to renewable energy, acquire opportunities to develop rapidly. However, improvement of energy technologies and development of alternative energy only consider solutions from the viewpoint of energy supply, they are still incomplete without consideration from the perspective of controlling energy consumption.

In response to energy crisis, Chinese government pays much attention in energy efficiency in recent years. In 2004, National Development and Reform Commission (China) published <Energy Efficiency Mid and Long Term Plan> and fixed energy efficiency as the long strategy for economic and society development. In 2006, the Chinese State Council published <The Eleventh Five-Year Plan for National Economic and Social Development of The People's Republic of China> and fixed aim of reducing 20% energy consumption and 10% carbon emission. At last, national energy consumption reduced 19.1% while reduction of SO_2 and CO_2 were 14.29% and 12.45%. In 2011, < The Twelfth Five-Year Plan for National Economic and Social Development of The People's Republic of China > (Chinese State Council, 2011) and fix the aim that by the end of 2015 get energy reduction of 16% and 10% carbon emission. In this period, energy consumption is concentrated in industry, transportation and building three fields, and in recent years, energy consumption in building sector is kept increasing. In the same time, a lot of energy is consumed for new constructions while energy demand of existing buildings is increased with the development of comfort requirement. Energy conservation in building sector is implemented in energy saving in new constructions, energy efficiency in existing buildings and renewable energy application.

- **Integration technology for building**

In China, there is 4,300 billion m^2 existing building and 1,380 m^2 is in urban area.(Jiang et al.,2009) Energy conservation refurbishment for existing building is one important part of building energy saving work and could improve comfort level of existing buildings. It is active factor for improving social and built environment development. By learning advance experience of energy conservation refurbishment of existing building in Europe, China could shorten the gap with developed countries and achieving sustainable development in short time.

With the development of technology, energy efficiency technology is adopted more and more in building because reduction of cost and practical applicability. With these integration technologies, energy efficiency measures can be implemented easier. Under the central government's lead, local governments have improved the support to the renewable energy application. For example, Shenyang made the development planning, which stated the Ground-source Heat Pump technique will be used by 650million m^2 building at the end of 2010. Chongqing provides the financial support at the benchmark of RMB800/kw to the projects using renewable energy for heating and cooling, and RMB900/kw to the projects using renewable energy for water heating.(Cai et al. 2009).

For residential building, the key points of implementation of energy efficiency technology are concentrated in: (1) Outdoor built environment improvement including avoiding cold wind affiliation in winter, natural ventilation in summer and heat-island phenomenon control in summer; (2) residential building energy efficiency includes thermal performance improvement of building envelope; (3) energy efficiency improvement of heating/ cooling system etc. There is interaction among these three aspects and they are influenced by local climate and environment conditions. So when we consider of energy efficiency in process of residential building design, we should take into account the indoor living environment, construction details, building design, residential community plan and even urban plan.

- **Improving of residential building**

With the rapid economic development in China, more and more energy is consumed for the improvement of people's living conditions. Most of the existing housings, however, were built with poor thermal qualities, and the energy efficiency of these buildings is very low. The potential for reduction of energy consumption in existing residential buildings is high, given that urban area of China, less than 6% of existing residential building is designed follow energy efficiency regulations and consume 100-150% energy consumption per square meters in China more than that of western countries.

Existing buildings in this paper are referred to the buildings designed and constructed before the energy conservation standard of China was executed or designed in accordance with the past energy conservation standard which are far behind building development in China. Because of the historic reasons, there was almost no or little consideration of energy conservation in these existing buildings; therefore, the thermal performance of the existing buildings is very bad, and the indoor thermal environment quality is quite poor. The energy consumption of existing buildings is about twice than the requirement of the energy conservation standard; and three times than the standard of developed countries with the similar climate conditions. There are large quantities of existing buildings in China with high energy consumption and low thermal comfort. Therefore, it is of great emergency to carry out research and practice on the renovation for them.

In Table 1.1, we can get a general view of energy efficiency residential development in the typical megacity in China ----Shanghai which locates in the economic and technology developed area of China, we can find that work for energy efficiency residential building is not begun until 2002 and developed slowly. Although Shanghai is the most developed city in China, there is a huge amount of existing residential building needed to be refurbished. The need of existing residential building energy conservation refurbishment is more urgent in other cities in China.

Table 1.1 residential building general development of Shanghai city, China (Jiang et al. 2009)

Year	Existing residential building ($10,000m^2$)	New residential construction ($10,000m^2$)	Increase of energy efficiency residential building ($10,000m^2$)	Total energy efficiency residential building ($10,000m^2$)
2002	26906	/	107	107
2003	30560	3654	320	427
2004	32560	2000	600	1027

Compared with the new energy efficient buildings, the amount of existing buildings in China is much more but refurbishment time is much shorter. So we can get more and faster energy-saving effect by existing residential building refurbishment.

1.2 Research target and scope

The significant role of China in the global economic development has now been widely recognized, simultaneously, the responsibility of China for implementing low carbon emission to environment is clearly definite. The importance to keep energy security and mitigate the environmental deterioration has been broadly acknowledged by Chinese administrators. However, in building sector, China is still running in the fast lane towards urbanization based on fossil fuels; the biggest challenge in front of all the Chinese cities is the tremendous conflicts between energy supply in urban area and demand due to urbanization development, low comfort and high cost of residential building and increased requirement by urban population growth. The contradiction between energy and living environment is primarily embodied by the energy consumption cost, living comfort and equivalent emissions.

The main purpose of this study is to *establish a framework of design strategy and methodology for residential building refurbishment in urban area of China*. By studying of the advantage research and case studies in Europe, complete methodology and appropriate technology would be proposed as the result of this research. Exploratory research for refurbishment for residential community is also drawn up to link with low carbon sustainable urban planning strategy. The result of this research would cover the shortage of energy conservation design strategy for existing residential building refurbishment and also put forward the instructional principles for low carbon emission city development.

In the other hand, because the energy efficiency is started late in China compared with developed countries; there is no specific systematic research on existing residential building refurbishment strategy in national level, neither in local level. The work of this research intends to help the decision-makers and planners to improve the environmentally sustainable development at city scale, especially focusing on mitigation of carbon emission in the process of fast urbanization. In China, the high price of residential building in city seriously limit the survival of new migration by urbanization process and also middle and low incoming class in the city. The reason caused this contradiction can be summarized into two aspects: land-use management and real estate industry control for new construction residential buildings; refurbishment for existing residential buildings. Solving the contradiction between increasing demand for residential building and shortage of land and energy is the basement for guarantee economic and social development of China. Furthermore, it has significances for the world.

- **Residential building refurbishment in European cities**

In Enrope, reserch about energy conservation can be divided into three steps. First step is energy saving buildings, since the beginning of 1970s, the oil crisis caused by two world wars made developed countries realized the importance of energy saving and began to limit energy consumption in building sector; the second step is energy conservation in buildings, since 1980s last centry, developed countries implemented the energy conservation work in controling energy consumption in new construcntions and in the other hand, improved the retrofit of existing buildings. Some European countries had finished first round of exsitng building energy conservation retrofitting. The third step is energy efficiency in buildings means improving energy effieicncy by innovation technologies. And from 1990s until now, the building energy conservation research is concentred in building sustainable develoement which is aimd at using least energy to get most economic and social effectiveness. in Europe, there is research on the topic of Zero-heating standard, Zero-CO_2 emission standard, Autonomous Standard and Passive house and etc.

The building energy conservation research in Europe is started early and got andvanced experiences . Most European countries had finished energy conservation refurbishment twenty years ago.

- **Residential building refurbishment in cities in China**

Compared with Europe, research of building energy conservation in China is started late. The first exploration of energy conservation refurbishment for residential building in China is finished in 1997 in Harbin city by the cooperation of Canadian experts. One seven-storied residential building in Harbin is refurbished in the aim of improving thermal performance of building envelope and energy efficiency of heating system. This attempt supplied real practice experiences for figuring energy efficiency regulation in China and became a successful demonstration in China.

After that, several residential building refurbishment project is done in China but there is not systematic research on this topic is done in China. Until 2005, there was residential building energy conservation refurbishment project done in Tangshan with the cooperation of German experts. With the refurbishment of building envelope and heating system, indoor environment is improved a lot while energy consumption is reduced.

We can get the conclusion that energy conservation refurbishment for existing residential building is an important issue for building and city development in China, but the research on this topic is progressed slowly. We got some materials about the existing research result on energy conservation for existing residential building refurbishment, in Table 1.2 we can find the number of research thesis in recent years. We made the search with key words of residence and energy efficiency retrofit/ reconstruction/ refurbishment, the results shows that there is few existing researches on this topic.

Table 1.2 previous research and time

Energy efficiency retrofit + Residence	Before 2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Building science	3	3	0	3	1	18	6	9	11	12	20	11	97
Economic	0	0	0	0	0	11	4	7	10	2	4	2	40
Other	0	0	0	0	0	1	0	0	0	0	0	0	1
Total	3	3	0	3	1	30	10	16	21	14	24	13	138

According to database CNKI (National Knowledge Infrastructure)

In urban area of China, there is urgent need to determine a design methodology concerning energy conservation issues and environmental sustainability which adapts to their socio-economic development simultaneously. There is still absent of research work committing in this field. In this context, the main aim of present research is: "**To establish an innovation framework of energy conservation design strategy for Chinese cities and formulate procedure and methods to achieve the energy efficiency and low carbon emission of residential building in urban area.**" According to the current status and future demands of residential building development and considering the integration with residential community site plan and existing regulation system, the research will promote the energy conversion of residential building in urban area of China.

By achieving the main aim of this research, a number of objectives are derived. The main objectives of this research are as follows:

1. Summarizing existing problems of residential building in urban area of china and the feasibilities of implementing energy efficiency technologies in existing residential building in China;

2. Analyzing development trends of residential building refurbishment in urban area of china;

3. Studying the advanced experiences in European and the state of the art about energy conservation of residential building in urban area of china;

4. Setting up new strategy and methodology framework for energy efficiency of residential building refurbishment in urban area of china ;

5. Proposing advise to complete energy policies in building sector;

6. Suggesting the potential cooperation between EU and China on energy efficiency of residential building refurbishment;

7. Exploratory research for energy efficiency regeneration for existing residential community in urban area.

1.3 Research methodology

To achieve the above objectives, six main methods are employed in this research, namely: literature review, professional interview, data collection, case study, site investigation and comparison analysis.

1. Literature review

The theoretical foundation for the research is based on reviewing a series of literatures which are principally from four perspectives: the building consumption in the world and in China, the reason for implementing existing residential building refurbishment in China, regulations and standards for energy-saving and energy utilization of residential building in China.

2. Professional interview

To find existing problems in residential buildings and design process, first-hand materials could be got from Chinese professionals whose work is related with energy efficiency for residential building. Face to face and written interview are made with relevant staffs including local officer of building construction and urban plan, architects and urban planner, material producer and inhabitants in target residential buildings. Valuable materials could be got by communication.

3. *Data Collection*

Various data of economy, energy consumption, local climate and society development have been collected and analyzed in present research. The data sources include statistical yearbooks of investigated cities, legislations of governments, international reports, books and scientific periodicals, and websites of Chinese governments and international organizations.

4. *Case Study*

Case study will investigate the previous and ongoing practice cases both in China and EU respectively. Through the case study, the strategies, methods and techniques employed by them will be displayed. The advantages and disadvantages exiting in these cases will also be revealed, as references for formulating a universal procedure of energy conservation of existing residential refurbishment in urban area of China.

5. *Questionnaire Investigation*

Due to lack of apparent results about building design process in China, present research tries to investigate architects and urban planner who is working in the first level for fixing building plan in several Chinese cities and executes questionnaire with them. After analyzed the investigation result, we had a clear grasp of the real current status of building design and urban plan in China.

6. *Comparison Analysis*

In present research, comparisons will be executed two levels: comparisons about energy conservation legislations and regulations in EU and China; development of existing residential building refurbishment will be compared on the base of case studies from EU and China. Among some European and Chinese cities, there are many similar characteristics in climate, geography and historic background. The aim of these comparisons is analyzing the development direction of existing residential building refurbishment in China and feasibilities to transfer advanced European experiences to China and implement innovation strategies in residential building energy conservation refurbishment.

1.4 Research frame structure

There are seven chapters in present thesis. In Chapter 1 Introduction, the general background and scope of this research is analyzed. Study on previous study on this topic in Europe and China is the basement for further research. General organization of the whole thesis is introduced in this part.

Through the literature review, building energy consumption in the world level is summarized and comparison between that of Europe and China is made to improve the feasibility for making research on the topic of urban residential building refurbishment in China. By the analysis of influence elements for existing residential building in urban area, reasons for implementing residential building refurbishment project had been summarized into three aspects. Study on existing legislation and regulations for building in China is made and then the regulations which are specific for building energy efficiency and residential building design is categorized into different sustainable typologies.

In building sector, China is urgently need improvement of energy efficiency of residential building. In the other hand, Europe is playing a leading role in promoting emission reduction. There were several residential building refurbishment projects successfully implemented as the trendsetter of real practice for existing residential building energy conservation refurbishment. ENPIRE (Energy and Urban Planning in Restructuring Area) is one of the successful projects. The project is focused on the specific view of energy efficiency policy and technology for residential building refurbishment. 7 cities involved in the project, and at last 6 achieved the goal. We can get Instruction for residential building refurbishment project.

The existing residential building refurbishment is a topic which has relations with many fields. The research about energy conservation of existing residential buildings should consider from urban level, district level then to building level. So the data collection survey is an essential preparation. In order to distinct the composing of residential building energy consumption and direction of building energy-saving of residential building, we have to analyses the relationship between building energy consumption and characteristics of the city such like weather features, geography features as well as the body characteristics of residential building. Five cities (Harbin, Beijing, Xi'an, Nanjing and Guangzhou) which were selected from different climate zones have been chosen as the representative cities and the characteristics of each city have been summarized as the basement of urban and building analysis of these cities. Excluding the city and building energy consumption characteristics, different stakeholders would play different roles in the process of refurbishment. Energy price, family income, living environment sustainable policy and house ownership, all of these elements could influence the refurbishment. For organizing the sufficient work process to meet the demand of energy conservation, comprehensive analysis methodology such as AHP (Analytic Hierarchy Process) and ANP (Analytic Network Process) could be adopted for analyzing effect weight. In the meanwhile, considering economic and local elements, available technologies which could be fitted for local conditions is an essential step in the very beginning of residential building refurbishment project.

The strategy of Urban Residential Building Refurbishment in China could be divided into scheme stage and design stage. In the scheme stage, category and characteristic of existing residential building in China have been summarized. On the base of this summary, problems of existing residential building have been raised. At the same time, the study of existing residential buildings was penetrated into two aspects: professional's sides and administration sides. An investigation is made to architects from 10 selected first level cities. The questionary was made from three levels: general opinion about building energy efficiency technology and CO_2 emission reduction issues; importance of exiting energy efficiency regulations in building design process and development of residential building refurbishment project. From the information of this investigation, we can realize clearly that importance and technology of energy conservation for residential buildings should be improved a lot. From the administration sides, both from Top-down Promotion and Bottom-up Implementation sides, we can get Integrated-model Projections for improving energy efficiency for residential building in urban. From the development of urban plan, district environment promotion and building trend, there are sufficient Instinctive motives of residential building refurbishment in urban area of China. The improvement of residential building could be summarized into these points: Indoor temperature, indoor moisture, cold wind infiltration, living environment, and indoor noise. From the view of administration side, proper financial support should be proposed by the integration of local support.

In the design stage, the framework of working procedure for residential building refurbishment could be summarized into 8 steps: basic data collection; initial plan submittal; construction draft submittal; preparation of the approval documents; improve the construction plan; bidding and tendering; monitoring plan and implementation; project trailing and control. For each step, multiply players would take part into comprehensive actions to improve energy conservation. So the energy consumption process could be summed up into four steps: energy consumption survey phase; setting energy efficiency ambitions and embedding agreements; fixing energy options; implementation and monitoring. Specific energy efficiency principle and technologies would be proposed with the interpretation of different case studies. These case studies are selected because the advantage experiences for special part of the framework.

But there are serious problems in residential building refurbishment projects, from the professionals point, both the architects and managers are lack of energy efficiency knowledge for refurbishment project. And most of the workers are lacking of training for basic techniques. So supports from monitor, technology and funding should be organized at the beginning of the project.

- In the *Energy Consumption Survey* phase, energy consumption data and related building and city architecture features should be collected. A series of form for target building investigation could be made and be used for all this kinds of projects.
- In the *Discussion and Setting Ambition* phase, different stakeholders like inhabitants, architects, managers, construction organizations should be coordinated and get agreements for energy saving target. In this step, initial refurbish plan could be drafted and energy conversation level could be fixed into high, middle and low three levels. By comparisons and discussions, clear target could be determined on the coordination by all the players and agreement could be signed.
- Then, *Energy Options* could be selected on the base of agreements. The energy efficiency includes three aspects: Building thermo technical and related properties measurement; Energy consumption and emission reduction effectiveness; Function promotion of residential settlements. For each aspect, we will make the analysis with one Chinese case study which had been done to meet the point of requirement.
- For *Implementing*, project monitoring and maintains should be kept during the refurbishment process and also after refurbishment. Technology utilizing in construction organizing and construction supervision steps should be considered of. Uniform quality assurance acceptance standard could be drawn up.

In conclusion phase, exploratory research will be made in the direction of improving low carbon emission residential community and sustainable urban planning in China including: Lessons learnt by case studies; Roadmap of policy and integrated design for existing residential building refurbishment in China can be proposed; Improving energy performance and comfort level in residential buildings and community synergistically; Emerging trends of sustainable development for existing residential community refurbishment in urban area of China.

This thesis looks into the event in the architectural technology way. By analyzing the true fact, this study may give useful advice to the real practice. And at the same time, it also gives reference to the housing sustainable development work.

With the society development, energy efficiency technology is widely implemented in real building construction practice by in nowadays. Research about building energy conservation technology would make the contribution to sustainable building design and low carbon urban planning development. Comprehensive research for building energy efficiency would be made in framework and used as the guideline in building sector to improve building sustainable development in the future. In the meanwhile, through the inherent link between building design and urban plan, this kind of research is urgently needed for guarantee low carbon urban planning and to cope with climate change issue effectively. Especially for developing countries, relevant researches would be valuable guidance for society development, not only for China, but also for the whole world.

Building design is more than artist creation with amazing space combination or façade aesthetic. In civil architecture, architects have to coordinate multi-level issues like basic living requirement, sustainable urban plan, culture and spiritual need to improve healthy development of society and economic. There is compelling responsibility for architects to develop energy conservation building and low carbon urban plan promptly.

INTRODUCTION

1 Background / Target and Scope / Methodology / Frame structure

Basic Research

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- Reasons for implementing the refurbishment of existing residential buildings
- Regulation and standards for Energy-Saving and Energy Utilization of residential building in China

3 Feasibility for improving energy efficiency in existing residential building in urban area of China

- Clean energy strategy for residential building sector in China
- Emission reduction issues in Europe
- European case study (ENPIRE)

4 Methodology

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- Analyzing method
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- General problems of existing residential building in urban areas
- Develop trend of urban residential building in China

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- Investigation to the architects in China
- Improvement of importance for residential building refurbishment by professionals

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Working procedure / Enlightening significances / Refurbishment principle

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Discussion and Setting ambitions

- Coordinating multipartite participants
- Tools for setting ambitions and embedding agreements
- Joint agreements

Analysis of energy options and optimizing of energy options

- Methods and tools for energy options study
- Building thermo technical and related properties measurement
- Energy consumption and emission reduction effectiveness
- Functional improvement of residential settlements

Implementation

- Project management
- Project monitoring and maintains

Exploration Research

7 Conclusion

Lessons learnt / Roadmap of policy and integrated design /
Improving energy performance and comfort level in residential buildings and community synergistically /
Emerging trends of sustainable development for existing residential community refurbishment in urban area of China/

Research conclusion / Contribution / Limitation and Future scenario

Fig. 1.1 Research structure of present thesis

Chapter 2 Literature of review

- WHAT ARE BUILDING ENERGY CONSUMPTION TREND IN THE WORLD?
- WHAT ARE THE CHARACTERISTIC OF BUILDING ENERGY CONSUMPTION IN CHINA?
- WHY ENERGY EFFICIENCY SHOULD BE IMPLEMENTED IN EXISTING RESIDENTIAL BUILDINGS?
- HOW IS THE DEVELOPMENT SITUATION OF EXISTING ENERGY SAVING REGULATIONS?

2. Literature of review

The objective of this research is improving energy efficiency of residential building refurbishment in urban area of China. Improvement of energy efficiency of residential building is the primary goal. At the beginning, we have to make clear review of related influence factors for finding feasibility of present topic. In this chapter, on the base of research overview in the part of Introduction, we will enter into this research from three aspects: energy consumption, reasons for implementing energy conservation refurbishment for residential building and existing relevant regulations. Through the review of these literatures, the direction of further research could be fixed.

2.1 Building energy consumption

Energy consumption is becoming one of major problems in the modern society. The human race faces the exhaustibility of the fossil fuel supplies upon which it has grown to depend, while the use of those fossil fuels causes major environmental pollution (Brundtland Report, 1987). In Fig. 2.1, we can find that energy consumption during the past years and predication of energy consumption in next years, the development of energy consumption is kept increased in a rapid way. However, if the energy consumption is kept increased in this way, in 2030 the energy consumption would more than twice than that of 1980. In fact, the real development of energy consumption is increased faster than predicted. In 2008, the energy consumption reached 504.7 quadrillion Btu.

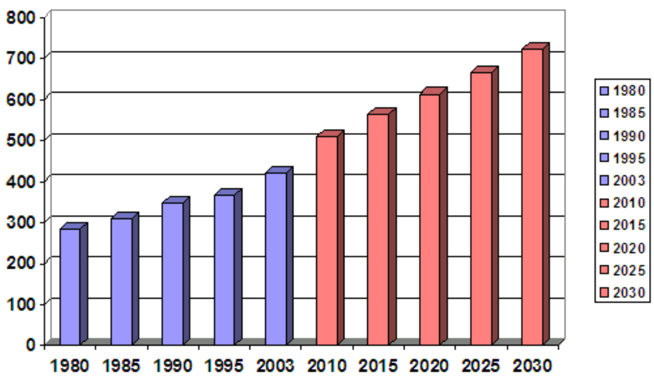


Fig. 2.1 World marketed energy consumption 1980-2030 /quadrillion Btu

Source: Drawn by *Explainthatstuff.com* using data from US Energy Information Administration (EIA), International Energy Annual 2003 (May-July 2005). Projections: EIA, System for the Analysis of Global Energy Markets (2006). Figures are in quadrillion BTU (British thermal units).

In building sector, energy consumption is increased rapidly with social development. The built environment is a key field for energy consumption: buildings are omnipresent and most of them use energy for heating, cooling and lighting. In the countries of the

Organization for Economic Co-operation and Development, the building sector accounts for one third of the total energy demand. (International Energy Agency, 2002)

Building energy consumption (BEC includes, in a broad sense, embodied energy (referring to the energy used for production and transportation of building materials, construction and retrofitting of buildings) and operating energy (for the operation and use of buildings during their life time for accommodating people with required services) (Sartori and Hestnes, 2007). The embodied energy, which relates more to the production sector than the tertiary sector, averagely accounts for only less than 20% of the total energy use in the full life-circle of buildings. The rest and greatest part is operating energy, which includes heating, cooling, lighting and electrical appliances, other building services and so on. Since our topic is about residential building, in present thesis we focus our attention mainly on operating energy use in residential buildings which is the type of building has closely relates with inhabitants.

2.1.1 Building energy consumption in the world

The world-wild economic explosion in the recent years resulted in sharply increasing of energy consumption. Although the current worldwide economic downturn dampens world demand for energy in the near term, as manufacturing and consumer demand for goods and services slows. In the longer term, with economic recovery anticipated, most nations return to trend growth in income and energy demand. By the research of the existing energy consumption data, we can get the reflection of the scenario in which current laws and policies remain unchanged throughout the projection period — world marketed energy consumption is projected to grow by 44 percent over the 2006 to 2030 period. Total energy demand in the non-OECD countries increases by 73 percent, compared with an increase of 15 percent in the OECD countries. (EIA, 2009)

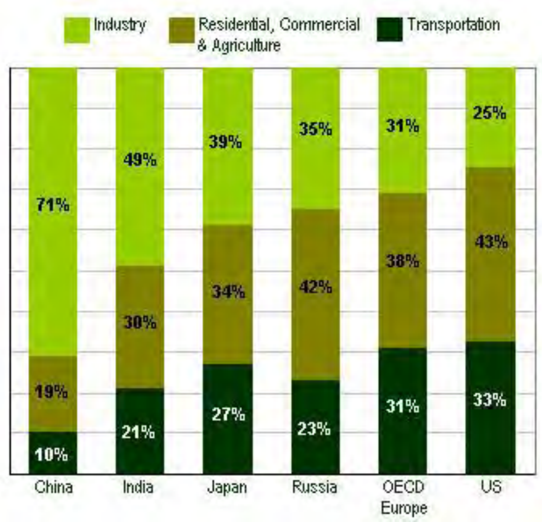


Fig. 2.2 Energy Demand by Sector, 2005
Source: Earth Trends 2008 (Using data from Rosen and Houser 2007)

In the meantime, building energy consumption as one of the main energy consumption aspect is increasing. It is clearly shown in the Fig. 2.2 that energy demand by sector in 2005. We can see that the energy consumption for the part of Industry and Residential and Commercial& Agriculture take the major part of the total energy consumption in these selected countries. What is more, in the consumption of the developed countries, energy consumptions for industry take less part than that of developing countries. Compared the data of China and US which have similar country area but different economic formations, it shows that energy consumption for industry takes more ratio in developing countries than in developed countries. That means efficiency of the contribution of energy consumption for GDP in China is much lower than the developed countries. There is still a long way for China to catch up with the energy efficiency levels during the developing period in the near future because of the change by step of the urbanization.

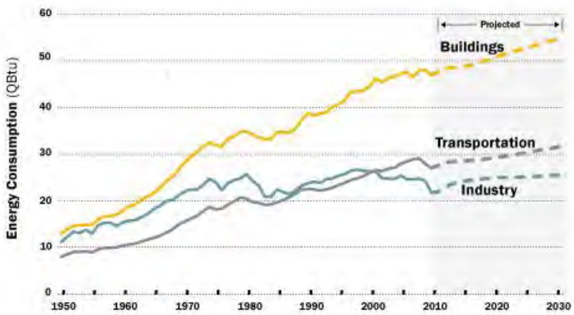


Fig. 2.3.a US Energy consumption by sector (Historic/Projected)
Source: Source 2010 2030.Inc/ Architecture 2030 all rights reserved
Data source: US Energy Information Administration

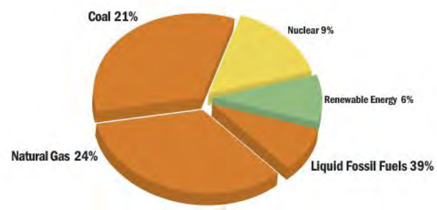


Fig 2.3.b Building sector energy consumption by Fuel Type 2009

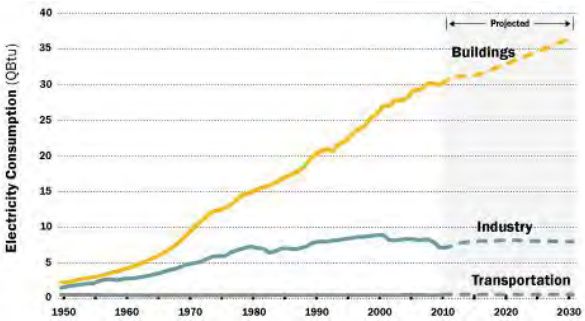


Fig. 2.4.a US Electricity Consumption by Sector (Historic/Projected)
Source: Source 2010 2030.Inc/ Architecture 2030 all rights reserved
Data source: US Energy Information Administration

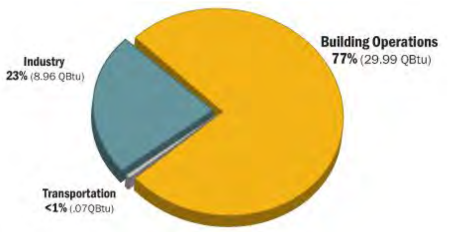


Fig. 2.4.b US Electricity Consumption by Sector 2009

As a research in the field of architecture, in this period, we can make the basic analysis on the developed countries, since the aim of this research is focusing on the residential building in cities. There are many immanent relations and similarities between them. We will analysis the building energy consumption in US which we can find comprehensive data for research. According to the pie chart of building sector energy consumption by fuel type (Fig. 2.3.a and Fig.2.3.b), we can see clearly that liquid fossil fuels and natural gas take the top two positions which are of 39% and 24% of the total. In the meantime, coal as a traditional energy takes 21% and the other type of energies like nuclear, renewable energy takes 9% and 6% respectively which are really little in the total.

If we make the energy consumption analysis by sector, what is increasing fastest is the building sector and according to the forecast it would grow in the same speed in the next 20 years while the growing speed of energy consumption for transportation and industry would grow little. If we make the electricity consumption analysis by sector, the problem is even more obvious. Electricity consumption for building operation takes 77% in the total and is about 29.99 QBtu (Quadrillion Btu.) in 2009 which is much higher than that of industry and transportation in US (Fig. 2.4.a and Fig. 2.4.b). We can see that the household and population will grow steady in the next 20 years (Fig. 2.5), so the energy consumption for building sector is a problem urgency to be solved in US. In fact it is not the problem only for US, but also for the other part of the world especially the more developed zones like Europe, Japan and etc. And these countries had already made some effect on this topic.

To the contrary, in China, the population is already over 1.34billion in 2011 and would keep growing in the rate of 0.57% (6th National Census of Population in China). Although modernization promotes exploitation and utilization of the resources, it also accelerates the speed of energy consumption. Unfortunately, the latter speed is much faster than the former one in China now. As the world's most populous country China has already been the first largest oil consumer, behind the U.S. Undergoing a process of industrialization in recent years, China is one of the fastest growing economies in the world, with real GDP growing at a rate of 8-10% a year. At the same time, China's need for energy is projected to increase by 150 percent by 2020. Thus, it can be seen that China will inevitably face a serious restriction in the supply of resources during the process of high speed urbanization and modernization.

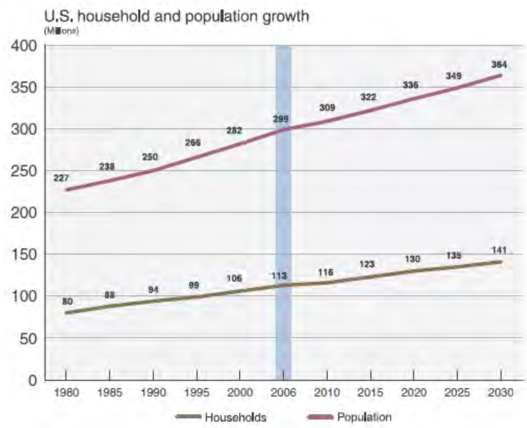


Fig. 2.5 US household and population growth
Resource: 2009 Building Energy Data Book, US department of Energy

2.1.2 Building energy consumption in China

The shortage of fossil energy is a universal problem for the whole world, but it is more critical in China than others. Table 2.1 shows the location of world's main fossil fuel reserves, China's proven reserves of anthracite and bituminous coal are 62,200 million tonnes and for sub-bituminous and lignite coal ---- 52,300 million tonnes. The total proven coal reserves are therefore 114,500 million tonnes and account for 13.5% of total world stocks. Chinese petroleum reserves presently account for 1.3% of the world total and China's proven reserves of natural gas are 1.9 trillion cubic meters and account for 1.1%of the world total (BP, 2007). As of the end of 2007, the ratio of reserves to production of oil, coal and natural gas are 11.3, 118 and 27.2 years, respectively. In spite of coal, China would diminish its oil and natural gas earlier than other parts of the world.

Table 2.1 Location of the World's Main Fossil Fuel Reserves in 2006

Region	Fossil fuel reserve (giga tonnes of oil equivalent)				Fossil fuel reserve (%)			
	Oil	Coal	Gas	Sum	Oil	Coal	Gas	Sum
North America	8	170	7	185	0.86	18.20	0.75	19.81
South America	15	13	6	34	1.61	1.39	0.64	3.64
Europe	2	40	5	47	0.21	4.28	0.54	5.03
Africa	16	34	13	63	1.71	3.64	1.39	6.75
Russia	18	152	52	222	1.93	16.27	5.57	23.77
Middle East	101	0	66	167	10.81	0.00	7.07	17.88
India	1	62	1	64	0.11	6.64	0.11	6.85
China	2	76	2	80	0.21	8.14	0.21	8.57
Australia and East Asia	2	60	10	72	0.21	6.42	1.07	7.71
Total	165	607	162	934	17.67	64.99	17.34	100.00
Data sources: WCI, 2007; BP, 2007.								

China is at the peak of urban construction at the present time. The rapid developing of urban construction influenced the rapid growth of building materials industry and building industry. The energy consumption which is used for building material production, transportation, building construction, reparation and demolition has taken 20%~30% at the amount of commodity energy consumption in China (THUBRC, 2009). Moreover, the energy consumption which is used while the building is operating such like for lighting, heating, air conditioner and electric appliances is called Building operation energy is huge because it is happening through the all process during the building is used. Generally speaking, during the life cycle of a building which is about 50~70 years, the energy that is consumed for materials or during the construction process only takes about 20% in the total consumption, while the most energy is consumed for building operation. In addition, the energy consumption for construction materials and building is happening with the industry production process. The energy conservation is relying on the technical development. But the purpose of the energy consumption for building operation is supplying services for residences. This part of energy is controlled by the users and is deeply influenced by the users' behaviors meanwhile by the energy efficiency technologies. So energy consumption for building operation is the key point for energy conservation research.

As we know, China is vast in territory, the climate environment is complex and economic development has differences. When we talk about the characteristics of energy consumption in China, we should make a reasonable classification for buildings in China. Then we can make the energy consumption characteristics and development more clearly and work more efficient.

The general characteristics of building energy consumption can be categorized into three points as below:

(1) There are huge differences of climate environment between the northern and southern China. The northern part needs heating during the winter time about six months one year but the southern part not, so the energy consumption for heating is totally different between the northern and southern part.

(2) There is a glaring discrepancy has emerged between the residential building energy consumption in urban and rural.

In one aspect, that's because the urban and rural use different type of energy: the urban energy consumption mainly depends on the commercial energy such as coal, electricity, gas etc.; rural energy consumption mainly depends on bio-energy such as straws and woods besides the coal and electricity.

In another aspect, there is a glaring discrepancy between the life style of urban and rural area in China. The nonproductive expenditure of urban inhabitants is three times of that of rural inhabitants.

So when we make the research about the energy consumption in China we should collect the data of urban and rural separately.

(3) With the different levels and scales of the buildings, the unit energy consumption excluding heating for public buildings has profound differences.

Now we can make the analysis on the basic of energy consumption data in China. By the statistic of CBEM (China Building Energy Model), during the period of 1996~2008, the totally energy consumption for building production has risen 1.5 times which increased from 259 million Tec to 655 million Tec. In 2008, the construction area in China is around 17.5 m^2 billion the energy consumption for building production was 655 million Tec (excluding the biomass), while it was 607 million Tec in 2007 which taken about 23% in the total energy consumption. (THUERC, 2010) It can be imagined that if China keep this increasing speed of construction area in building sector, by 2030 the construction area in China would reach 30 billion m^2 that means another China is would be built in the following decades. Energy consumption in building sector would be horrendous.

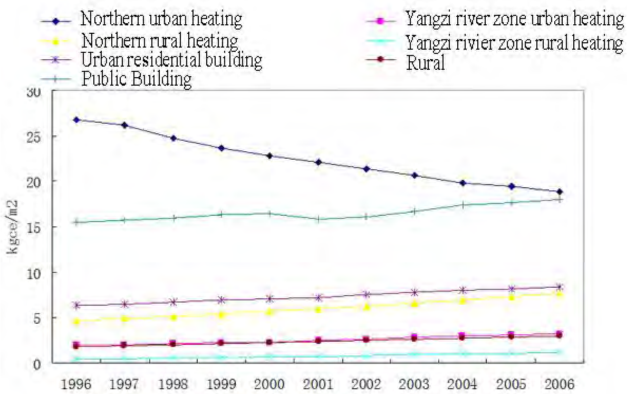


Fig. 2.6 Building energy consumption per unit floor area for different types of buildings (Jiang, 2011)

The increasing of building energy consumption is caused by improving of the internal environment, service supply and also the equipment, as the indication in the Fig. 2.6, except the decrease of energy consumption per unit area for heating in the northern China, the other kinds of energy consumption increased a lot from 10.5 kgce/(m^2 •a) to 15.2 kgce/(m^2 •a) . At the same time, the per-capita living space of urban residents is increasing with the increment of construction area. As the result of the improvement of urbanization, the construction area increased a lot, from 6,200 million m^2 to 20,400 million m^2 in 13 years.

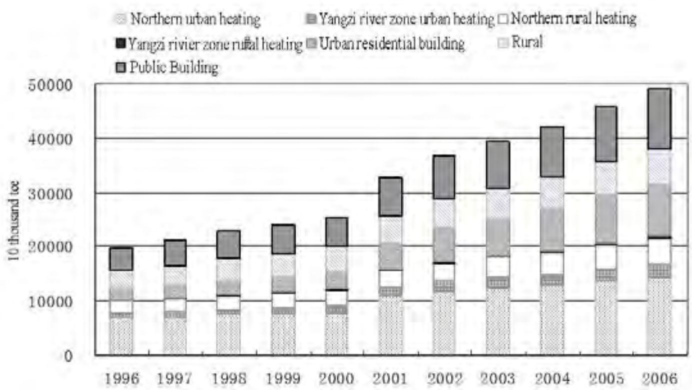


Fig. 2.7 Total building energy consumption for different types of buildings (Jiang, 2011)

We can get the conclusion on the basic of different types of buildings' energy consumption that energy consumption for public buildings and residential buildings excluding the heating both increased a lot. According to public date, the energy consumption for production (100 million tec) which is caused by these two kinds of building types have grown from 0.43(public building excluding heating), 0.21(residential building excluding heating) to 1.41, 1.20. It's the result of energy consumption increasing and construction area. (THUERC, 2010) The energy consumption for northern China heating has risen from 70 million tec to 153million tec which is caused by the increasing of the urban construction. For the energy consumption for heating in the hot summer and cold winter zones (refers to middle part of China), it is increasing with the development of living standard although it is little at present. The area for buildings with heating is increasing. We can also see clearly by the data (Fig. 2.7) that the energy consumption mushroomed from 19600 tec in 1996 to 49000 tec in 2006 and it will keeping increasing in the future.

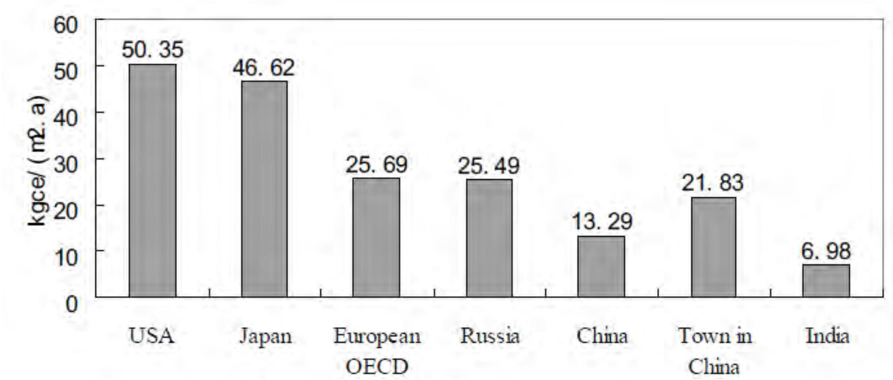


Fig. 2.8 Comparison on building energy consumption between China and developed countries
Source: THUBEC, 2008; EIA, 2007

Although building energy consumption in China is much lower than that of developed countries (Fig. 2.8). As we analyzed from the about data, with the improving of urbanization and the development of economic, the building energy consumption will rise sharply and keep rising. It must bring the huge pressure for energy supplying system not only in China but also the whole world. We must make the research for energy conservation imperatively. The energy consumption in town in China is higher than rural; the potential of improving energy efficiency in urban area of China attracted us to make research about residential building in urban area.

2.2 Reasons for implementing the refurbishment of existing residential buildings

Around 80 % of the energy we use on the earth today comes from fossil fuels, but all indications that cannot continue so much longer. As the distribution of remaining reserves of fossil fuels in the world which is shown in Table 2.1, Coal constitutes approximately 65% of the fossil fuel reserves in the world, with the remaining 35% being oil and gas. Compared with the size and location of reserves of oil and gas which are limited in the Middle East, coal remains abundant and broadly distributed around the world. Shafiee and Topal (2009) made a prediction about when fossil fuel reserves will be diminished, which indicates the fossil fuel reserve depletion times for oil, coal and gas are approximately 35,107 and 37 years, respectively.

It is clear that we must to be smarter in the way we use energy, not matter in which country you are. High oil prices not only directly affect the Chinese economy but also increase international tensions. Hence, in order to keep the economic growth steadily and continuously increasing, China must employ renewable energy instead of fossil-based energy and switch its development pattern to low carbon sustainable direction. By designing machines and appliances that do the same jobs but use less power, we can make the energy we have go much further. This is called energy efficiency (saving energy/ energy conservation) and it's like a completely possible way of keep sustainable development.

Just as we have discussed in last section, from the analysis of building energy consumption development of the world and China, the great potential of energy saving gap in residential building in urban area of China leads our research on residential building energy efficiency. In fact, there is external and internal need for improving existing residential building energy efficiency in urban are of China.

2.2.1 Economic aspects

China's relatively low building energy consumption is not the result of advanced energy efficiency technologies, nor a widespread awareness of the need for energy efficiency in buildings. Rather, it is related to China's current level of economic development, the standard of living of its people and also the traditional custom.

The economy is measured by the GDP (Gross Domestic Product). This is a measure of all products and services produced in a country .The GDP is commonly used to measure the economy and economic growth (Bank of Canada, 2007). There are also a number of problems with these measures. However, GDP can be used, along with other variables like infant mortality rate, freedom and literacy, to give a reasonable picture of national wealth and progress.

At same time, there are huge differences on economic level in China differs between cities and the countryside. The urban economy contributes more than 80% to the national total GDP and income with about 40% of the total population and 40% of total building stocks. While the rural economy takes less than 20% in the national GDP and income although both the population and ground area host about 60% of the total. Due to this significant difference, rural people have a lifestyle that is quite different from urban people. This fact brings huge differences in building energy consumption both in terms of per unit building floor area and per capita. Classification has to be made separately for urban buildings and rural buildings in order to present a clear picture of the Chinese building energy situation. (Table 2.2)

Table2.2 Macro Drivers in Residential Sector

	2000	2010	2030
Population (billion)	1,269	1,339	About 1.400
Urban population (million)	487.61	665,57	About 840
Urbanization rate (%)	35.6	49.68	About 60
GDP (US＄)	1,198	5,878	About 4,000
GDP per capita (US＄/person)	944	7,519	—
Household size	3.93	3.15	—
Urban household size	3.19	3.00	—
Living area (m^2/capita)	23.0	31.8	—
Urban living area (m^2/capita)	19.8	30.0	—

Data resource: National Bureau of Statistics of China, China statistical book

We have to underline that the "economic aspects" we mentioned here means not only about the macroscopically national economic but also all the factors which has direct or indirect relationship with the building energy consumption demands. So the scope of the economic aspects is various. It obtained some natural characteristics of the urban area which affect the congenital condition of the building location such as climate, geography, land planning, transportation etc. Human behavior which is the result of the social tradition is affected by the base of by the economic. In the meanwhile, energy supply is a main characteristic of the economic performance.

In a certain context, the energy supply service could directly response the economic situation. There are many examples, such as the quantity of combustible material necessary to attain the same interior temperature in a well-insulated building compared to one that is not. Another example is the amount of gasoline used to go a certain distance depends on the means of transportation, or the electricity used by an incandescent light bulb compared to a compact fluorescent bulb to get the same level of lighting. The new energy paradigm consists in creating an "energy system" that includes not only the energy sector (supply), but also the consumption of energy (demand) and ensures its development in such a way as to obtain energy services under optimal conditions in terms of resource supplies, economic and social costs, and local and environmental protection (Devernois and Krichewsky, 2010). So the productions, imputes, transportation, generation of materials for building and final energy such like oil, gas, coal, wood, biomass, solar, electricity and wind energy for building operating are all decided by economic factors.

In another hand, an active, well-operated built environment is constituted with multi-level stakeholders and comprehensive society structure. Through refurbishment for existing residential buildings, the utilization age of existing residential building could be extended; in the same time, the value of refurbished residential building could be promoted. Furthermore, cost for refurbishment is much lower than cost for a new residence. In a certain context, the low and middle income class in the city could get most benefit in existing residential building refurbishment. The problem is few people had awareness of energy efficiency and low carbon effect in residential building. There should be someone who could explain the possible benefit of existing residential building refurbishment to inhabitants and relevant stakeholders. In China, there is possible that local authority would play the leading role in energy conservation in existing residential building projects.

In addition, investments made in energy efficiency create jobs and employment. Manufacturing new construction materials, high-performance equipment, reinforcing building insulation, installing mass transit systems, developing expertise and consultancy, along with motivational and educational efforts, are all sources of new jobs. Economic and social development to meet internal demand is particularly important during this period of worldwide recession and reduction in international trade.

In sum, the effect of existing residential building refurbishment is clearly embodied in economic save for energy consumption, value promotion of existing building and motivation of local economic improvement, no matter whichever way we consider economic aspect of residential refurbishment, there is clear benefit for all stakeholders both in local and national level.

2.2.2 Sustainable growth of the requirement for the residential building

With a population exceeding 1.3 billion and economic growth over the past two decades averaging around 8 per cent (following market reforms commencing in the late 1970s), China's demand for energy has surged to fuel its rapidly expanding industrial and commercial sectors as well as households experiencing rising living standards. Today, China is the second largest consumer of energy products in the world behind the United States, consuming annually around 1.7 billion tonnes coal equivalent of energy.

Forecasts of growth in China's energy consumption are important for two reasons. First, continuation of the strong growth in energy consumption in recent decades will see underlying demand and supply imbalances in China increasingly affect global energy markets, particularly oil and natural gas. Second, long term forecasts are required to assess the need for future trade and investment strategies to ensure the security of China's energy supply.

Table 2.3 The variation of Chinese city number 1949-2007

City	1949	1978	Growth from 1949-1978	2007	Growth from 1978-2007
Total	132	193	61	655	462
Over 2million	3	10	7	41	31
1-2 million	7	19	12	81	62
500,000-1,000,0000	6	35	29	118	83
200,000-500,000	32	80	48	151	71
Below 200,000	84	49	-35	264	215

In Table 2.3, we can find that development trend of Chinese city number after 1949 when the People's Republic of China is founded. The explosion happened after 1978 that the number of city in China is increased sharply; in the meanwhile, the scale of city is extended a lot. Until now, there are over 30 big cities which have population over 2 million in mainland of China and there are several megacities like Beijing, Shanghai and Chongqing which has the population over ten million. The other characteristic is that the growth of big city is the most. That is the result of huge scale of industrialization in China after 1978. In addition, the existing cities with long history are developed into bigger scale with more population, in the same time, emerging cities were developed around these existing cities.

It’s shown in Table 2.4, that the urbanization in China can be defined into five steps from the foundation of PRC（People's Republic of China）in October 1949 till now. We divided these steps according to the cities development and the national policies. After the established of PRC the urban development experienced an expansion period which was benefited by the First-Five-Year –Plan from 1949 to 1961. The number of cities in China increased rapidly from 176 in 1958 to 208 in 1961 while the urban population expanded from 54 million to 69 million. Because of the economic depression and natural disaster, between 1962 and 1965, an unexpected casualty about 15million to 30 million population happened and the number of cities dropped from 208 to 168 while the urban population declined from 69 to 66 million. In the following lag period from 1966 to 1976, urban educated youths were forced to move to the rural areas or remote areas because of the Culture Revolution and the urban population grew from 67 to 74million but the proportion in the total population dropped from 9% to 8%. The fourth stage is stationary phase which was started since 1976 after the Culture Revolution and finished till the end of 20th century, the urbanization in China grew steady and the urbanization rate increased from 15.49% to 25.51%. Then the last stage is started from beginning of 21st century till now which can be called as explosion, more than half of the population in China is living in urban areas now and the rate is keeping increasing steadily year by year.

Table 2.4 Five Phrases of Chinese City Development

Stage	Time	Main events	Result
Expansion	1949-1961	Fixed the “First-Five-Year –Plan” and the urban development experienced an expansion period;	The number of cities in China increased rapidly from 176 to 208 while the urban population expanded from 54 million to 69 million;
Contraction	1962-1965	An unexpected casualty about 15million to 30 million population happened;	The number of cities dropped from 208 to 168 while the urban population declined from 69 to 66 million;
Lag period	1966-1976	Urban educated youths were forced to move to the rural areas or remote areas because of the Culture Revolution;	The urban population grew from 67 to 74million but the proportion in the total

			population dropped from 9% to 8%;
Stationary phase	1976-1999	With the Reform and opening policies, the economic and society developed steady and the urban scale developed stationary;	The urbanization rate increased from 15.49% to 25.51%;
Explosion	2000 till now	China is developing in a rapid speed which is astounded the world in these years.	There are more than half of the population in China is living in urban areas.
Data source: China Statistical Yearbook (NBS, China)			

Obviously, the explosion of urbanization leads the increasing of requirement for residential building in urban area. In one side, new immigration in cities need residential building but can afford the high cost for new residence community constructed in recent years; in the other side, amount of existing residential building in lower price but low quality of energy performance and built environment. Energy conservation refurbishment for existing residential building in urban area of China is the best way for meeting increasing requirement of residential building in urban area of China.

2.2.3 Energy efficiency at home

Influenced by western countries, energy efficiency is a new conception which is strongly popularized in urban area of China. We fixed out topic in urban area because the potential of energy saving in residential building is higher in urban area than that in rural because that there are more feasibilities of implementing energy efficiency technologies in residential building in urban area of China. In China, both intensity and gross energy use are much less in rural buildings than in urban buildings. General statistics are then inconsistent, without dividing these geographic and economic areas of China. Nevertheless, Energy Intensity is much lower in urban China than in developed countries. We can see in Table 2.5, overlooking the energy for space heating, the other energy consumption in house sector in China is less than the other regions except cooking. To specify, the per floor area building energy consumption of urban China is approximately 1/2 and 1/3 of that in Asian and American developed countries, respectively, and somehow close to the average European levels. Particularly, the per capita BEC (Building Energy Consumption) of China is only 1/10 of that of the USA. Explanations of such a surprising result are given, covering both the flexibility in energy supply and the different internal conditions to be respected.

Table 2.5 Energy consumption for residential building (kWh/m^2.a)

Region	Total	cook	Hot water	Lighting	Appliance	AC
China	27	9.5	3-5	6.7	5-15	1.5
US	97	7.2	24.5	14.8	36.7	13.8
Japan	41	3.5	15.6	20.4		1.3
EU	82	3	11	22	30	2.5

Source: Building energy data book, US department of energy; Thullner K, 2010; China engineering research center for human settlement,2010.

Fig. 2.9 shows energy use in residential buildings in different countries. It could be consequently concluded that residential energy use, in both per capita and unit area value, of China is much lower than that of developed countries. The unit area residential energy use in urban China is only half of that in western countries, while the per capita value is 1/3 of developed countries in Asia, 1/6 in Europe and 1/10 in America.

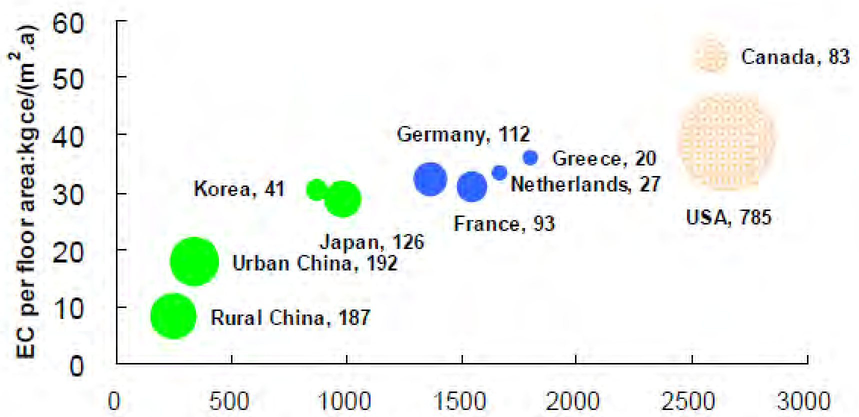


Fig. 2.9 Primary energy use in residential buildings, 2005

The number after the country name in the figure is total energy use of the corresponding country in the unit of Mtce.

Energy consumed in homes for heating water is much lower in China than in developed countries. Less than 70% of urban households in China own a water heater, and many of those that do so rely on solar power. The average urban Chinese household uses only 80 to 130 kilowatt-hours (kWh) for heating water per year, compared to an average of 1,404 kWh (ten times the Chinese figure) per year in Japan. This is a powerful reflection of the difference in lifestyles and living standards between the two countries.

Energy consumed by residential air-conditioning in China (including by thermodynamic heating systems in the south) is far lower than in the US. The majority of Chinese families will turn on the air conditioning only after they come home from work, or when they are at home at the weekends. When no one is at home, the air conditioning will be switched off, and when the outside temperature is within a comfortable range, people will open windows to provide natural ventilation, so energy consumption is very low. According to a survey, the average household in Beijing only uses air conditioning for less than 200 hours per year, consuming an average of five kilowatt-hours per meter (kWh/m^2) per year. In contrast, most American households have air conditioning switched on 24 hours a day for the whole year, maintaining temperatures between 18º to 26º. In order to maintain a high level of air quality, fixed ventilation systems are used, which at any time throughout the year can replace half the air in a room every hour. Simulations have shown that these differences in the way air conditioning is operated could increase residential energy consumption by close to three times.

There are also differences between China and developed countries in the use of domestic lighting and electrical appliances. There is not much difference between the density of lighting in Chinese homes and those in developed countries, but the length of time for which lights are switched on varies hugely. This variance in patterns of usage is the main reason for differences in this kind of energy consumption. And the energy consumption for cooking in China is more than other regions, that's because the different cooking habits. Usually, Chinese cooking takes long time and procedures than the others.

The same as the CO_2 reduction in industry need more updated technologies and police support from governments, energy efficiency technology application in residential building also need support from government. Especially the energy processing and conversion industry, like electricity production, should transfer to a sustainable way by using renewable energy such as falling water, wind power and solar radiation. Scheer (2008) discussed the possibility reconnecting city energy generation and use by the logic of solar energy. In his opinion, renewable energies is an energetic imperative and the only choice of the future society, but making the changeover is more than a matter of simply switching energy source. It was the industrial revolution, with its possibilities of concentrated energy supply and improving transport possibilities, which first created the basis for the growth in high density urban areas and hence the shift of human settlements from the countryside to the towns and cities. It is no possible change within the conventional energy system, and the cities must create new infrastructure to adapt the future energy supply. In his design as Fig. 2.10 shown, the cities should change from parasite to power station and walk on a Self-reliance way.

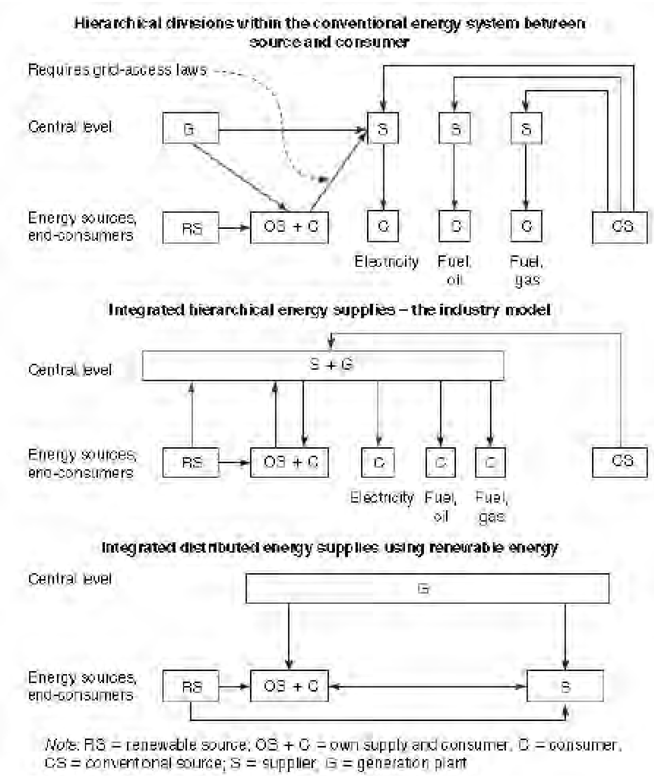


Fig 2.10 The Transformation of Energy Supplies Models (Scheer, 2008)

Energy efficiency technology and policy relevance should be considered the primary tools in the process of implementing sustainable residential building and low carbon urban. The development of more efficient building designs suitable for Chinese conditions, and more energy-efficient windows, building materials, envelope insulation and ventilation options create large opportunities to save energy in the near future and over a long term since buildings can last over 40 years. Heating in the northern urban areas in China is the most important energy consumer in the building sector. Despite significant reduction of building energy consumption achieved after the implementation of 1995 Energy Efficiency Standard for New Residential Buildings in 1995, the average energy consumption for heating in China's northern provinces is about 90–100 kWh/m^2 a, which is still almost twice of that in Sweden, Denmark, The Netherlands and Finland (40–50kWh/m^2 a) (Li,2008). Furthermore, the low efficient heating system leads to enormous energy loss and causes a serious problem of environmental pollution during winter time.

In the same time, industrial development of efficient alternative materials of extreme importance is another strong support for energy conservation refurbishment in existing residential buildings.

Thus, we summarized the reasons for implementing refurbishment of existing residential buildings into three aspects which are closed related with energy consumption of residential building. Since there is sufficient reason and demand-supply relation in this topic, there is significant for this research.

2.3 Regulation and standards for Energy-Saving and Energy Utilization of residential building in China

To make the research about the residential building in China, we have to know the existing regulations and standards in this aspect in China. In this section, the review and analysis of existing regulations and standards for energy-saving and energy utilization of residential building in China in the last years will be summarized.

2.3.1 General analysis of existing regulations and standards

China has a centralized Ministry of Construction (MOC that is named Housing and Urban-Rural Development of People Republic of China since 2009), which is responsible for regulating its massive building industry. Under the MOC, a network of Construction Commissions in the major cities and provinces oversees building construction, including the granting of building permits and the enforcement of building codes. MOC also has a parallel network of building research institutes to provide technical expertise and support for its own activities and for the building industry.

Energy-efficiency efforts began in the early 1980s in China. With supports of the State Economic and State Planning Commissions, the Ministry of Construction (MOC) approved projects to investigate the amount of energy consumed by space heating and to develop an energy-efficiency design standard for residential buildings in the very cold and cold zones of the country (i.e. in Northern China) where very large amounts of energy were being consumed for heating. More than half the country's total floor area (all types of buildings) is located in Northern China where the heating season is between 3 and 6 months long. Statistics show that, by the end of the 1980s, heating energy consumption was 130 million tons standard coal equivalent or about 11.5% of total energy use in China and more than 20% of total use in Northern China (and about 50% of total energy use in some cities in the very cold zone of the country). (Lang, 2004)

China adopted building energy standards in stages, starting with an energy design standard for residential buildings in the Heating Zone of north China in 1986. This was followed by a standard for tourist hotels in 1993; for residential buildings in the Hot-Summer Cold-Winter Region of central China in 2001; and for Hot-Summer Warm-Winter Region of south China in 2003. A national energy efficient design standard for public buildings (the term used in China to refer to commercial buildings) was adopted and implemented in 2005. Earlier standards for residential buildings set targets to reduce building energy consumption compared to pre-existing construction by 30% in 1986 and by 50% in 1995. The 2005 standard for public buildings set the target at 50% energy reduction compared to pre-existing buildings.

In recent years, 1.6–2.0 billion m^2 of new buildings were built each year in China. Another 30 billion m^2 are projected to be added by 2020, in which 13 billion m^2 will be built in cities. Given this, combined with that buildings already became the main consumed sector of the total national energy consumption as we discussed before, China has to enforce the energy efficiency design standard more strictly. For residential buildings, since 2000, MOC has moved to develop energy-efficiency design standards for residential buildings in Central and Southern China as well. The Ministry of Construction issued the GB/T 50378-2006 “Evaluation Standard for Green Building” in 2006 in order to conduct the idea of sustainable development in the building design and construction field. Aimed at the rigorous situation of increasing energy consumption by civil buildings, the China government decreed the “Regulation of Energy Saving in Civil Buildings” in 2008, which promotes the utilization of thermal isolation materials in new buildings. In order to promote the building design integrated with solar energy technique, the China government launched a policy to subsidize the BiPV (Building integrated Photovoltaic) projects in design and construction period with total amount of 100MW, which would acquire 50% of investment costs for the photovoltaic addition.

We can collect these existing regulation and standards which are proposed specially for energy-saving and energy utilization for residential building in different levels. The main contents of the research cover laws and regulations, national standards and codes, industry standards and codes and typical local standards and codes in housing sector of China related to environment and energy, with research on their operation effect and current bottlenecks, and analysis on its development trends and existing potential.

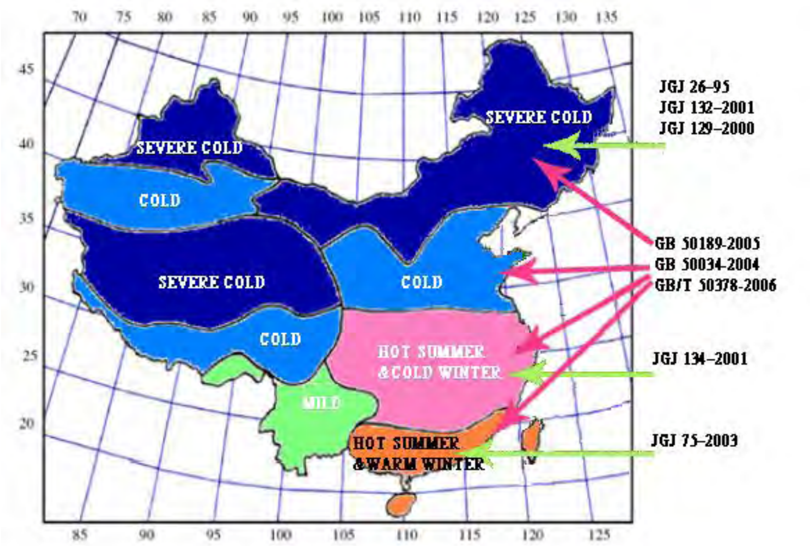


Fig. 2.11 Main standards for residential building energy efficiency in China

China covers a vast geographical area, and the temperature difference from the north to south is very large, especially in winter. In general, the average monthly temperature in China in January is 10–18 °C lower than that of other areas of the world at the same latitude; in July, the average monthly temperature is 1.3–2.5 degrees higher than those other areas. According to the national "*Standard of Climatic Regionalization for Architecture*" GB 50178–93, China is divided into the following zones based on climate characteristics: severe cold, cold, hot summer and cold winter, hot summer and warm winter, and mild zone (Fig. 2.11).

In general, Air conditioning and heating requirements for different zones are different.

- In the severe cold zone, the major requirement is heating, and few residential buildings are equipped with air conditioning.
    - Energy conservation design standard for new heating in residential buildings JGJ 26–95 includes indices of building heat loss and coal consumption for heating along with sections on thermally efficient building and heating design.
    - Standard for energy-efficiency inspection of heating in residential buildings JGJ 132–2001 specifies inspection and testing methods for heating-system energy efficiency, was approved by MOC in February 2001 and took effect on 1 June 2001. The standard stipulates nine items to be inspected to assess the energy savings in residential buildings with central heating systems, located in very cold and cold zones in China.

  - Technical specification for energy conservation renovation of existing heating in residential buildings JGJ 129–2000 is approved in October 2000 covers retrofitting of existing buildings that central heating systems and are located in very cold and cold zones in China.

- In the cold zone, the primary requirement is heating, followed by air conditioning;

  - Design standard for energy efficiency of residential buildings in hot summer and cold winter zones JGJ 134–2001 is approved on 5 July 2001, The standard covers energy-efficient design for new construction as well as retrofits and renovations in the hot summer/ cold winter zone. Designers can use the standard to determine building envelope thermal performance and the energy-efficiency ratio of heating and air conditioning equipment required to produce a 50% reduction in heating and air-conditioning energy consumption compared with that of a base building under the same indoor thermal conditions.

- In the hot summer and cold winter zone, both air conditioning and heating are needed;

  - Design standard for energy efficiency of residential buildings in hot summer and warm winter zone JGJ 75–2003 is approved in July 2003, The standard targets a reduction in energy consumed for air conditioning and heating (mainly air conditioning in this zone).

- In the hot summer and warm winter zone, the major requirement is air conditioning, and few residential buildings require heating;

- In some parts of the mild zone, heating is needed; in other parts, both heating and air conditioning are needed; The availability of heating and air conditioning depends on several factors, including the degree of economic development in an area, the availability of energy supplies, and requirements for environmental protection.

In addition, there are GB 50189-2005 Design Standard for Energy Efficiency of Public Buildings, GB 50034-2004 Standard for lighting design of buildings and GB/T 50378-2006 Evaluation standard for green building, they are relevant standards which are fit for all climate zones of China.

We have listed the related laws and codes in the following tables. Then they are divided into different aspects emphasis on the key point of residential building design. We can analysis the laws and codes on their operation effect and current bottlenecks, and analysis on its development trends and existing potential.

Table 2.6 relevant legislation and standards for residential building energy consumption in China

No.	**Laws and Regulations**	
1	The Law on Environmental Impact Assessment of The People's Republic of China	Adopted at the 3rd Meeting of the Standing Committee of the Tenth National People's Congress on June 28, 2003
2	Environmental Noise Prevention and Control Law of The People's Republic of China	Adopted at the 22nd Meeting of the Standing Committee of the Eighth National People's Congress on October 29,1997
3	Regulations on the Administration of Construction Project Environmental Protection	Promulgated by Decree No. 253 of the State Council of the People's Republic of China on November 29, 1998
4	Notice on Strengthening the Supervision and Management Work of Environmental Impact Assessment of Construction Projects,	Document of the General Office of the Ministry of Environmental Protection, Huanban(2008)No. 70
5	Location Planning Management Methods of Construction Projects, the Stte Planning Commission of the Ministry of Construction,	Jiangui(1991 No.583 [Issuance time: August 1991; Effective time: August 1991]
6	Six Policies on the Regulation and Control of Real Estate Market Issued by Nine	Ministries and Commissions of the State Council in 2006
7	Notice of the State Council on Promoting the Economical and Intensive Utilization of Land	Guofa (2008) No. 3
8	State Regulations for the Supply and Consumption of Electric Power	On August 25, 1983 the State Economic Commission approved and transmitted it and the Ministry of Water Co-servancy and Electric Power issued it on September 1, 1983
	Green Codes	
1	Evaluation Standard for Green Building GB/T50378-2006	
2	Evaluation Standard for Green Building of Beijing	

	DBT01-101-2005	
3	Management Specification of Green Construction DB11/513-2008	
4	Green Construction Guide (Jianzhi [2007] No. 223)	
	Environment and Energy Sources	
1	Design Standard for Energy Efficiency of Civil Buildings (Heating Residential Buildings) JGJ26-95	
2	Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone JGJ134-2001	
3	Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone JGJ75-2003	
4	Code for Design of Thermal Engineering of Civil Buildings GB50176-93	
5	Standard for Design of Building Lighting GB/T50033-2001	
6	Code for Design of Sound Insulation of Civil Buildings GBJ118-88	
7	Standard of Environmental Noise of Urban Area GB3096-1993	
8	Environmental Quality Standard for Noise GB3096-2008 Code for Indoor Environmental Pollution Control of Civil Buildings Engineering GB50325-2001	
9	Standard for Land-saving of Urban Construction of Beijing (Trial Implementation)	
10	Evaluation Standard for Energy Efficiency Building (Opinion Soliciting Draft)	
11	Design Standard for Energy Efficiency of Public Buildings GB 50189	
	Residential Buildings	
1	Code of Urban Residential Areas Planning & Design (2002 Version) GB50180-93	
2	Design Code for Residential Buildings (2003 Version) GB50096-1999	
3	Residential Building Code GB50368-2005	
4	Technical Standard for Performance Assessment of Residential Buildings GB/T 50362-2005	
5	Code for Design of Buildings for Elderly Persons JGJ122-99 Configuration and Technical Specifications for Intelligent System in Residential Areas CJ/T 174-2003	
6	Standard for Design of Residential Buildings for the Aged GB/T50340-2003	
7	Temporary Provisions for Space between Residential Buildings of Beijing (Opinion Soliciting Draft)	
8	Code for Design of Green Space in Residential Areas in	

	Beijing (Opinion Soliciting Draft)	
Specialty Code		
	Architecture:	
1	Code for Design of Civil Buildings GB50352-2005	
2	Technical Specification for External Insulation on Walls JGJ144-2004	
3	Code for Vertical Planning on Urban Field CJJ83-99	
4	Code for Design of Transport Planning on Urban Road GB50220-95	
5	Technical Code for Engineering of Security and Protection System GB 50348	
	Structure	
1	Code for Design of Steel Structures GB50017-2003	
2	Code for Design of Masonry Structures GB50003-2001	
3	Code for Design of Concrete Structures GB50010-2002	
4	Code for Seismic Design of Buildings GB50011-2001	
5	Technical Specification for Steel Structure of Tall Buildings JGJ 99-98	
6	Technical Specification for Concrete Structure of Tall Buildings JGJ 3-2002	
7	Code for Design of Timber Structures GBJ5-88	
8	Technical Specification for Concrete Structures Prestressed with Unbounded Tedons JGJ/T 92-93	
9	Technical Specification for Steel Reinforced Concrete Structures JGJ 138-2001	
10	Technical Specification for Seismic Strengthening of Buildings JGJ116-98	
11	Technical Specification for Application of Anchorage, Grip and Coupler for Prstressing Tendons JGJ 85-92	
12	Specification for Design and Construction of Fabricated Board Civil Building Structure JGJ 1-91	
13	Unified Standard for Reliability Design of Building Structures GB50068-2001	
14	Technical Specification for High-Strength Concrete Structure CECS 104:99	
15	Technical Specification for Cast-in-Situ Concrete Hollow Floor 2Structure CECS 175:2004	
	Water Supply and Drainage:	
1	Engineering Technical Code for Rain Utilization in Building and Sub-district GB 50400-2006	
2	Code for Design of Building Reclaimed Water System GB	

	50336-2002	
3	Technical Code for Solar Water Heating System of Civil Buildings GB50364-2005	
4	Technical Specification for Water-saving Irrigation Engineering GB/T 50363-2006	
5	Code for Design of Wastewater Reclamation and Reuse GB 50335-2002	
6	Technical Conditions for Water Saving Products and General Regulation for Management GB/T 18870-2002	
7	Domestic Water Saving Devices CJ164-2002	
8	Standard for Water Saving Design of Civil Buildings (Opinion Soliciting Draft)	
	Heating, Ventilation and Air-conditioning	
1	Code for Design of Heating Ventilation and Air Conditioning GB50019-2003	
2	Technical Code for Ground-source Heat Pump System GB50366-2005	
3	Guide for Design of Thermal Insulation of Equipments and Pipes GB 8175	
	Electrical	
1	Standard for Lighting Design of Buildings GB50034-2004	
2	Code for Design of Electric Power Supply Systems GB 50052-95	
3	Code for Design of Installation of Shunt Capacitors GB 50227-95	
4	Standard for Design of Intelligent Buildings GB/T 50314-2006	
5	The Minimum Allowable Values of Energy Efficiency and the Evaluating Values of Energy Conservation for Three-Phase Distribution Transformers GB 20052-2006	
6	Code for Electrical Design of Civil Buildings JGJ/T 16-2008	
7	Technical Specification of Urban Nightscop Lighting of Beijing Part 3: Light Pollution Limit DB11/T 388.3-2006	
8	Code for Electrical Design of Residential Buildings (Opinion Soliciting Draft)	

As we know, residential building plays an important role in the civil building especially in China which is country with huge population and whose emergency target is solving the problem for basic life. In recent years, with the increasing need of residential building, the regards for residential building is rising that some special laws and codes for residential buildings are issued after 1990s. But construction is such a complex issue that has relations with many industries and techniques so there are also many other rules which are not only laws and codes but also architecture and structural standards, provision that we should consider of.

We refined these provisions into five aspects which can reflect the key points for residential building design. In this section, effects and bottlenecks are been summarized by the research of these existing provisions.

2.3.2 Thermal design of architecture

- **Fixing orientation**

Although the provision for the residential building orientation is not compulsory, the provision play a good role in guiding the residential building to adopt the north-south direction. In China, to adopt the layout of north-south direction can avoid the western direct sunlight in summer and the western strong cold wind in winter, at the same time can be conducive to the natural ventilation in summer.

The following problems still exist in the code and the execution process:

1) In the northern areas there are still a large number of buildings adopting the layout of east-west direction; in winter, the western rooms are very cold and the heating energy consumption is very large.

2) The orientation is not paid much attention in the southern areas, the direct sunlight of western residential buildings is serious, the rooms are very hot in summer, and the air-conditioning energy consumption is large.

- **Shape Coefficient**

The requirements for shape coefficient can effectively reduce the surface area of external building envelope and the heat loss, which plays a good role in effects for energy efficiency of chilly and cold areas.

The following problems still exist in the code and the execution process:

1) The requirements for shape coefficient shall be higher in the north and looser in the south, but the hot summer and cold winter areas have the hard provisions, on the contrary the heating areas have not the hard requirements.

2) The shape coefficient of bar type and high-rise buildings is less and easy to reach the requirements, but the low-rise, multi-storey and tower type buildings are comparatively difficult to reach the requirements; especially, at present, as the dwelling area prescribed by the Six Policies on the Regulation and Control of Real Estate Market Issued by Nine Ministries and Commissions of the State Council in

2006 is less, the high-rise and tower type buildings of small dwelling size are more difficult to reach the requirements.

3) In recent years, some buildings of heating areas in the north excessively pursue the complex shape and space effect, and the excessively complex shape causes the heating energy consumption is excessively large.

- **Area Ratio of Window to Wall**

The external window is a weak link of heat insulation of external building envelope, the requirements of area ratio of window to wall effectively reduce the overlarge window area, and especially the large-area use of glass curtain walls is effectively controlled.

The following problems still exist in the code and the execution process:

1) The hot summer and cold winter areas have no definite requirements for the area ratio of window to wall.
2) The solar radiation heat of the roof is very large in summer, which shall be controlled in residential buildings; the area ratio of skylight to roof isn't stipulated in the heating areas and hot summer and cold winter areas.
3) With a large number of the use of glass curtain walls for public buildings, more and more residential buildings also use glass curtain walls, which results in that the heating air-conditioning energy consumption is greatly increased.

- **Thermal Performance of Building Envelope**

The thermal performance of the building envelope is the key of energy efficiency of buildings. The regulations for energy efficiency in each district have been specified in detail. Recently, the requirement of thermal performance of the building envelope has been enhanced with the social and economic development, greatly putting forward energy efficiency of buildings.

The following problems exist in the code and in the execution process:

1) The ways to regulate the thermal performance are not uniform: the heat transfer coefficients of key parts are required, but the indexes of thermal inertia and shading coefficients are not required in some districts.
2) The ways to calculate the heat transfer coefficients are not uniform, so the same practice can work out different heat transfer coefficients.
3) The product quality of heat insulating materials is greatly different: the heat insulating property of the same heat insulating materials from different manufacturers are greatly different, and the market is still stuffed with many disqualified products.

4) The thermal insulation design of the building envelope of many buildings reaches the regulated requirements, but it pays no attention to the actual results, such as waterproofing, crack of thermal insulation layer and thermal bridge of connectors, etc., thus drastically weaken the actual results of thermal insulation.
5) For instance, the buildings having the conditions want to improve the thermal performance of the building envelope, but energy efficiency rate of the buildings does not have definite calculation methods approved by the state and the calculation methods of various softwares are different, thus leads to great difference of calculation results.

- **Air Permeability Performance of Windows**

The requirement on air permeability performance of windows effectively reduces the lost heat due to air permeability of windows, and especially has certain effect on decreasing the heating load in winter in heating areas.

The following problems still exist in the code and the execution process:

1) The air permeability performance of windows and glass curtain walls is regulated in different regulations, thus it is inconvenient to operate. Different districts have varied requirement ways on the air permeability performance.
2) The air permeability performance will propose requirements during building design, but when selecting the windows and glass curtain walls, little attention is always paid to the performance without examination.
3) Due to certain contradiction between the air permeability performance and fresh air volume; when selecting windows with better air permeability performance, the effects of fresh makeup air volume shall be considered in design.
4) During using, some residents open the windows to change air for a long time during heating period, resulting in large amount of hot air loss.

- **Thermal Insulation Measures**

The code has regulated the treatment of the weak links such as the thermal bridges of external wall, roof and window and recommends several thermal insulation measures, which have good effect on controlling the thermal loss of the thermal bridge and leading the buildings to optimize the thermal insulation practice.

The following problems still exist in the code and the execution process:

1) The thermal insulation measures in each code are not systematic and the names of the same practice are confused.
2) Put no stress on the effects of thermal bridge on the thermal performance of the

external building envelope in the processes of design and construction. In particular, after the heat-insulating property of the external building envelope is improved, the negative effects of the thermal bridge become obvious.

3) The thermal bridge parts such as balcony and other overhanging components, surroundings of windows, fixed connectors of outer wall are not treated properly, leading to great reduction of thermal performance of the external building envelope and internal dewing effect.
4) The recommended practice of thermal insulation lacks collective drawings; new practices and materials are short of effective extension ways; the relaxed examination on new products and insufficient experimental demonstration always cause new problems.

In recent years, the new practices and materials of thermal insulation have sprung up constantly, so supervision on their entry into the market shall be strengthened, requirements on their test and examination shall be strictly executed. In addition, the extension process shall be speeded up after maturity and the incorrect practices shall be promptly amended.

- **Sunshade**

In the code, lead the windows of the buildings to set external sunshade, in particular, the east-oriented and west-oriented windows shall set external sunshade to effectively reduce the effect of the solar radiation piercing the rooms in summer on the air conditioning load in summer and increase the indoor comfort level.

The following problems still exist in the code and the execution process:

1) The internal sunshade in the residence is used commonly, but the utilization rate of the external sunshade is very low, which is mainly because in the districts with poor air quality, there is a lot of dust on the external sunshade which is inconvenient to be washed and maintained; the external sunshade does not enjoy the integrated design with the building, affecting the elevation effect outside the building; compared with the internal sunshade, the price of the external sunshade is higher.
2) The adjustable external sunshade can effectively select the sunshade angle and avoid impact on the indoor sunlight acquired in winter, which but has relatively higher price; what’s more, the adjusting parts are easily damaged, restricting the extension of the adjustable external sunshade.

With more and more use of external sunshade, more and more architects and owners begin to stress the integrated design of sunshade and buildings. The sunshade products also pay more attention to the organic combination with the buildings and bringing no damage to the performance of the buildings.

2.3.3 Energy saving of HVAC

- **Energy-Saving of Cold and Heat Sources**

The above regulations of cold and heat resources of Heating Ventilation and Air-conditioning (HVAC) in the standards can be classified into mandatory clauses and general clauses. As for the contents regulated in the mandatory clauses, for example, it is generally not allowed to adopt direct electrothermal heating, most design units and designers can consciously execute the contents and can implement them through the examination and approval of the third party of the construction drawing. Meanwhile, because the clauses have the direct interest relationship with the residence owners or users, the use fees of direct electrothermal heating are far higher than the heating in other heat source forms.

But in some other non-mandatory clauses, as for the heat source forms which can get the conclusion through comprehensive technical and economic analysis and comparison, different persons can get different conclusions by adopting different analytical and comparative approaches targeting the same residence project by reason of lack of uniform comprehensive technical and economic comparison and analysis forms and approaches and formal actual practice. Some designers even determine the heat source forms to be adopted by use of their own experience and knowledge without elaborate technical and economic analysis and comparison.

- **Energy-Saving of HVAC Equipment**

In the above codes, requirements of efficiency of the boilers serving as central heating sources and performance and efficiency of the split air conditioners which are widely and largely used in the residential buildings have been put forward, so the designers can follow the requirements in the code to put forward corresponding requirements of the heat source equipment and split air conditioners in the residential buildings in the design document. However, in the residential design, purchase of the above equipments is not restricted, so the design can not be well fulfilled and is just a form. The investors decide which energy-saving equipment to be adopted.

For large number of split air conditioners used in the residential buildings, most investors are the users, and they decide the purchased the energy efficiency equipment based on their own understandings and economic conditions. Generally, no one will decide to purchase equipment with what kind of energy efficiency ratio based on comprehensive analysis of one-time equipment cost and the operating electricity charges saved by the equipment. Even though this professional analysis is conducted, it may be difficult to reclaim the overpaid cost due to purchase of equipments with high energy efficiency ratio by using the saved operating cost within the service life of the equipment.

At the present stage, we can not ensure that the equipment with high energy efficiency ratio are more economical than those with low energy efficiency ratio regarding the sum of the one-time equipment cost and the operation cost, so improvement of the industry standard or market access standard of the cold and heat source equipment makes people can't buy the cheap equipment with low energy efficiency ratio at all in the market, thus achieve the goal of energy saving of HVAC cold and heat source equipment.

2.3.4 Energy-Saving of Water Supply and Drainage

At present, in the present national regulations, there are no specific requirements in connection with energy conservation during selecting the pressure water supply equipment. In the practice, the adopted pressure water supply modes and energy consumption generally are:

Therefore, compared with other water supply modes, network pressure-superposed water supply and water tower are the measures which can save most energy, but the following problems exist during the actual use of the two water supply modes:

1) Water tower is the pressure mode featuring low investment and high efficiency, but because of its management problems, the secondary pollution of water tank serves as the reason why people abandon this kind of water supply mode.
2) The network pressure-superposed water supply equipment take full advantage of the water supply surplus pressure of the municipal pipe network, thus reduce the design head of the water pump and achieve energy efficiency. However, this kind of water supply mode is restricted by the municipal water supply conditions, and within the range of municipal water supply, when the domestic water supply system adopts network pressure-superposed water supply, it shall be approved by local water supply administration management department and water supply department.

2.3.5 Energy-Saving of Electric

- **Energy-Saving of Power Supply and Distribution**

The energy-saving design approaches of the residential power distribution system are generally reduction of the distribution line loss and selection of energy-saving products, but as for reduction of the distribution line loss, besides that the substations shall be erected in the load center and in the distribution rooms on each layer while the distribution boxes on each layer be erected in the load center to minimize the line length, the voltage level and power factor shall be upgraded as possible to lower the current and reduce the line loss. The requirements of reactive power compensation are put forward in such standards and specifications as Code for Design of Installation of Shunt Capacitors GB50227-95, Code for Design of Electric Power Supply Systems GB 50052-95 and Code for Electrical Design of Residential Buildings (Opinion Soliciting Draft), thus restrict the distribution line loss to some extent.

In the meantime, in Code for Electrical Design of Residential Buildings (Opinion Soliciting Draft), Residential Building Code GB50368-2005 and Code for Electrical Design of Civil Buildings JGJ16-2008, it requires that the elevators, transformers, fans and water pumps in the residential buildings shall adopt energy conservation measures, so it has achieved certain energy conservation effects. However, the following bottlenecks still exist in the design of electric power supply systems:

1) Because no regulations of minimum allowable values of distribution line loss are made in the codes, measurement and evaluation cannot be conducted.
2) At present, the information publishing of transformers in home market is in a nice pickle. The data of the energy saving transformers with the same model but from different manufacturers are always greatly different and even the situation that the new-model transformers from manufacturer A have more loss than the old-model transformers of the same series from manufacturer B arises.
3) The energy saving elevators lack formal definition and relevant standards of energy efficiency.
4) The energy conservation of electric motors and transformers only enjoys product standard and has not been specifically regulated in the codes for design.

- **Design of Green Lightings**

In the above code, some specific measures and design methods for lighting energy conservation are regulated, such as lighting energy conservation control in the public areas of the residential buildings, automatic time/brightness controller control of outdoor lighting, etc., and they have had good energy conservation effects. However, the following bottlenecks still exist:

1) Generally, because the lighting design at the fine fitment stage can be constructed without being examined by related departments, the lighting design and the luminaires at the fine fitment stage fail to meet the regulations.

2) Lighting design is not closely combined with the day lighting environment and fails to have optimal energy conservation effect.

3) Lighting calculation is complicate and tedious, but most of the lighting calculation software used in the industry is developed by the luminaries manufacturer and lack standards and uniformity.

- **Lighting Sources, Lamps and Energy Efficiency Control Measures**

In the above code, requirements of selection of lighting sources, luminaries and attachments have been put forward, up to now, it has had good energy conservation effect. However, the following bottlenecks still exist:

1) In the design, it only puts forward requirements of lighting sources but fails to have relevant requirements of lighting luminaries, so that the owners fail to compare and screen the energy conservation effects of lighting luminaries when purchasing the equipment.
2) No specific parameter requirements of luminary attachments are put forward in the design thus result in that some luminary attachments are not matched with the light sources or luminaries so as not to meet the design requirement and achieve energy conservation effect.

2.3.6 Renewable Energy

- **Solar Water Heating**

Presently, the utilization of solar water heating system in national standards is only confined in a range of recommended use. Due to the increasingly exhausted traditional energy sources, the hard-and-fast rules shall be implemented on the utilization of the renewable energy according to the resources distribution areas so as to facilitate the utilization and promotion of the renewable energy.

- **Ground Source Heat Pump**

The underground water source heat pump system has been rapidly developed in China in previous years. Abundant and stable groundwater resources are necessary, and the economic efficiency of this system has a lot to do with the depth of underground water table. So far, the groundwater recharge technology in China has not been fully developed. Under many geological conditions, the recharging speed is dramatically lower than the pumping speed. It is very difficult for the water pumped from the underground after heat exchange to be fully recharged into the aquifer, which thus results in the loss of groundwater resources.

In Technical Code for Ground-source Heat Pump System GB50366-2005 issued and implemented by the Ministry of Construction in 2005, it is specified that there must be detailed data of hydrogeological exploration as the basis of the design.

- **Solar Energy Generation and Wind Power Generation**

The Chinese government has attached much importance and support on the development and utilization of solar energy and wind power generation, and successively issued a series of relevant policies as well as laws and regulations in recent years to promote the vigorous development of the new energy resources nationwide. However, there are still some existing bottlenecks as follows:

1) The Chinese government has already formulated some local specifications in Shanghai, Jiangsu Province and Guangdong Province, etc., where the construction of "photovoltaic roofing" has been first launched on a large scale as a pilot "roofing plan" being implemented. However, it is of much difficulty for the photovoltaic roofing plan to be specifically implemented, among which the most prominent issue is the much higher construction cost. The current price of solar photovoltaic power generation is still higher and the generating cost is about 10 times higher than that by the conventional source of energy, so solar photovoltaic power generation is promoted slowly in China.

2) The shortage of wind power generation and solar energy generation for the buildings is one of the obstacles for developing the solar energy generation and wind power generation.

Facing the serious situation of energy shortage globally, the governments of many countries and energy sources workers actively develop and utilize the renewable energy like the solar energy and wind energy. In addition, the integrated design of solar energy generation and wind power generation as well as the buildings shall be positively promoted to realize the reasonable, harmonious and perfect combination with the buildings and make it implemented in the specific on-off design and construction.

Along with the development of solar energy and wind power generation of the buildings, it is believed that the problems like the energy shortage, environmental pollution and "greenhouse effect" will be fundamentally resolved in the future. Specific for residential building refurbishment, it is one of best available technologies that could be adopted.

2.4 Chapter summary

In present chapter, we made a review of relevant literature related the energy conservation for existing residential building in China.

We started with building energy consumption analysis. The conflict between worldwide energy crisis and improvement of urbanization and industrialization caused the dilemma for building energy consumption. And in China, building energy consumption is increased rapidly with the world trend. As the basic and essential type of building, energy conservation for existing residential building refurbishment in urban area of China is our topic. We must guarantee there is enough energy for keeping operation of residential building in urban area of China because economic development needs, sustainable growth of requirement of residential building in urban and popularization of energy efficiency conception at home. In the meanwhile, building energy efficiency regulation is developed a lot in China in recent years, relevant policy support would improve possibility for implementing energy efficiency in existing residential buildings through refurbishment. We studied all relevant regulations and analyzed them through different aspects of energy efficiency and made a summary. Through the process of summarizing the energy-saving and Energy utilization of residential building in China, possible problems that caused by these regulations had been found and that would help us to find proper feasibility for residential building refurbishment in next step.

Chapter 3

Feasibility for improving energy efficiency in existing residential building in urban area of China

- WHAT ARE THE DIFFICULTIES AND TARGET OF RESIDENTIAL BUILDING IN CHINA?
- WHY AND HOW EUROPE DEVELOPS IN A LOW CARBON EMISSION WAY?
- WHAT ARE THE VALUABLE EXPERIENCES THAT COULD BE LEARNT FROM EXCELLENT RESIDENTIAL BUILDING REFURBISHMENT EXAMPLES?

3 Feasibility for improving energy efficiency in existing residential building in urban area of China

Since utilization of energy directly affects in our life and work, especially in urban area, energy is motivation for urban industry, transportation, commercial and daily life. As Blair, the pre-Primary Minister of UK, pointed out, ‘Energy is vital to a modern economy. We need energy to heat and light our homes, to help us travel and to power our businesses. Our economy has also benefited hugely from the resources of fossil fuels -coal, oil and gas’ (SSTI, 2003).

Residential energy consumption has attracted much attention, particular in relation to efficient use of energy and its benefit for climate change (Carraro and Braun, 2011). Using less energy and in a more efficient way contributes not only to limiting carbon emissions and air pollutants, but is also important in terms of energy security and equity issues. The potential for energy conservation in the residential sector is large and can often be achieved at low costs. Recognizing this, energy conservation is ranking high on the energy policy agenda of many governments. The EU, for instance, has endorsed the objective of cutting EU energy consumption by 20% by 2020 – equivalent to 780 million tonnes of carbon dioxide (CO_2) – and has given energy efficiency in buildings high priority (EC, 2009a).

Even the developed countries are being disturbed by so many issues to tackle climate change and energy crisis, how about China, the biggest developing countries during modernization and urbanization process? The benefits of energy conservation are largely undisputed, nonetheless the diffusion energy efficient technologies and behavior appears to be too low, a phenomenon coined as the “energy efficiency gap” (Stavins et al., 2004). Much is still to be learned on energy consumption in residential building and how to adopt variously energy efficiency technology across households.

Thus, it is necessary to carry out the feasibility study before implementing energy efficiency strategy in existing residential building in urban area of China. Therefore, this chapter intends to demonstrate the basis for energy conservation strategy for existing residential building in China, through the and statement of implementation of low carbon strategy in China and EU and successful EU case study, we prove the huge impetus of Chinese cities to reducing energy consumption in existing residential building, even though China still has a lot of difficulties.

3.1 Clean energy strategy for architecture in China

In order to control China's fossil-based energy consumption in the process of rapid urban development, both the government and researcher are attempting to establish a set of procedures for low carbon sustainable planning accompanying with various appropriate methods. Clean energy is being implemented in China. Clean energy is the similar of sustainable energy that is the provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often regarded as including all renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, bioenergy, and tidal power. It usually also includes technologies that improve energy efficiency.

China has reduced its energy intensity (amount of energy used per dollar of GDP) dramatically since 1980. Between 1980 and 2000, China's GDP quadrupled but energy use only doubled. This is good news. Of course, absolute emissions levels have raised dramatically over that period, but the CO_2 savings over what would have happened are remarkable. Thanks to the 20% energy intensity goal, China will save 1 billion metric tons of CO_2 in 5 years. For comparisons sake, the EU's commitment under Kyoto will save 300 million metric tons (Geoff, 2008). So, China has taken action, but it's important to note that the EU's commitment is an absolute reduction of CO_2 emissions, while China's reduction is only relative to otherwise massive growth in CO_2 emissions.

Far from being synonymous with reduced social welfare, lower energy use and carbon emissions associated with modern consumption models based on Chinese traditions can go together with high levels of satisfaction regarding the way people meet their building and transportation needs. This provides strong factual evidence those policies to “control urban-life energy” use can, simultaneously, promote patterns of urban-life energy consumption and related GHGs emissions that are sustainable and meet the needs and aspirations of the majority of the urban population.

If accompanied with the right policies and the provision of appropriate services and infrastructure, lower energy use does not mean lower welfare and lower quality of life; on the contrary, it implies the opposite. The policy recommendations should put forward hereafter address the pre-requisites and present the measures needed to implement such a policy to control urban-life energy consumption and related GHGs emissions.

3.1.1 Changing the energy consumption structure

Clean energy is determined as the main direction of energy consumption for architecture in China is the result by both internal and external causes.

- **External causes**

(1) The global sustainable development is in the step of substantive cooperation between the different regions and countries.

<Our Common Future>, also known as the < Brundtland Report >, from the United Nations World Commission on Environment and Development (WCED) was published in 1987. Its targets were multilateralism and interdependence of nations in the search for a sustainable development path. The report sought to recapture the spirit of the United Nations Conference on the Human Environment - the Stockholm Conference - which had introduced environmental concerns to the formal political development sphere. Our Common Future placed environmental issues firmly on the political agenda; it aimed to discuss the environment and development as one single issue.

The United Nations Conference on Environment and Development (UNCED), also known as the ***Rio Summit***, Rio Conference, Earth Summit (Portuguese: Eco '92) was a major United Nations conference held in Rio de Janeiro from 3 June to 14 June 1992. The Earth Summit resulted in the following documents:

- Rio Declaration on Environment and Development;
- Agenda 21;
- Convention on Biological Diversity;
- Forest Principles;
- Framework Convention on Climate Change.

The publishing of these documents marked the cooperation of global sustainable development entered a substantial phase.

In 1997, the <***Kyoto Protocol*** > was passed. It's a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at fighting global warming. The UNFCCC is an international environmental treaty with the goal of achieving the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. (UN, 1992)

In 2002, the World Summit on Sustainable Development, WSSD or Earth Summit 2002 took place in Johannesburg, South Africa. It was convened to discuss sustainable development by the United Nations. WSSD gathered a number of leaders from business and non-governmental organizations, 10 years after the first Earth Summit in Rio de Janeiro. The ***Johannesburg Declaration*** was the main outcome of the Summit. (http://en.wikipedia.org/wiki/Earth_Summit_2002) The states leaders from all the partners solemnly declared again the commitment for sustainable development.

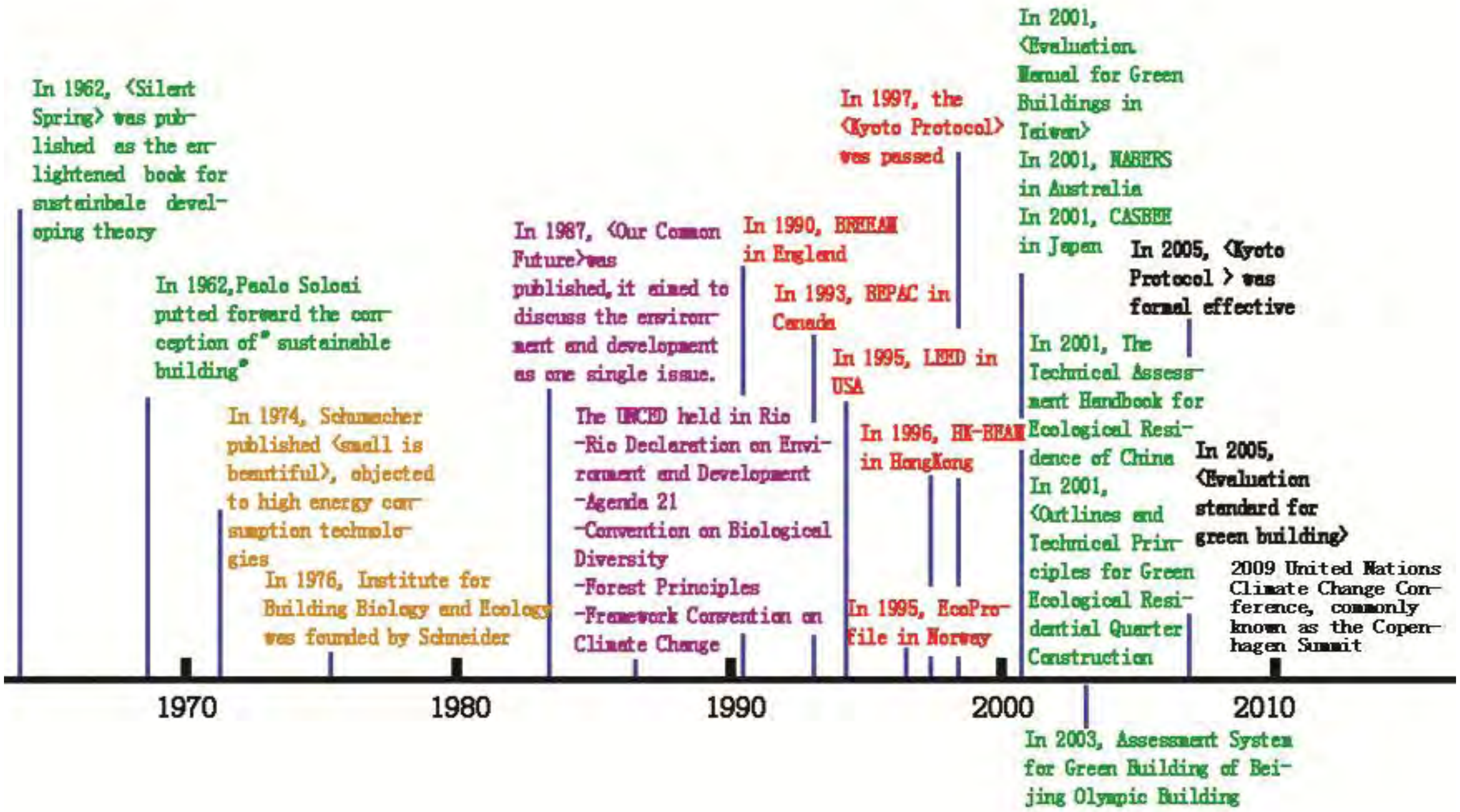
In February 2005, the <Kyoto Protocol > was formal effective.

The 2009 United Nations Climate Change Conference, commonly known as the Copenhagen Summit, was held at the Bella Center in Copenhagen, Denmark. The conference included the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change and the 5th Meeting of the Parties (MOP 5) to the ***Kyoto Protocol***. According to the ***Bali Road Map***, a framework for climate change mitigation beyond 2012 was to be agreed there. China promised to undertake reducing 40%-45% carbon emission compared with that of 2005 by 2020.

All of these actions showed that sustainable development is a worldwide cooperation of which all the partner states must implement as the international obligation. We summarized the progress in Fig. 3.1.

In China, until the end of 2000, total energy consumption for building sector is 376 million tons which takes about 27.6% of the total energy consumption while the GHG emission from building sector rose to 25%. Since the high energy consumption in building sector, only heating for north China consumes about 18 million tons that cause direct economic lose is 7,000million RMB and the GHG emission is 520,000 tons (Tao, 2005). The environment pollution caused by energy consumption for buildings is becoming an important problem in nowadays society and needed to be solved.

Fig. 3.1 Route Chart of World Green Building development



(2) Energy is becoming the bottleneck for economic and society development in China

There are four main problems of energy consumption in China. The first is per capita of energy consumption and reserve stock is low; the second is energy consumption in China is mainly rely on the fossil fuel especially coal of which takes 75% and annual coal consumption is over 1,300 million tons. We know that the energy efficiency of coal is low and pollution is serious. It's the direct reason for acid rain. The third problem is that the energy distribution is not balance in China. There is serious energy crisis in economic developed regions and shortage of commercial energy in rural, they cause the policies of coal transition from north to south, gas transition from west to east, electricity transition. The last problem is inefficiency of energy usage. The terminal energy usage is only 33% in China which is about 10% lower than that of developed countries.

Since 2003, in China there are some electricity limitation policy in some provinces while force the high-energy consumption industries stop working during the daytime. In the same time, with the development of urban construction and improvement of society, energy consumption for building sector rose a lot and becoming the main energy consumer in China. Now building energy consumption takes 45% of the total energy consumption of China (including direct energy consumption and indirect materials and transition). It is predicted that by 2020, total construction area is 70 billion m^2. In the beginning of 2003, shown in the report of energy convey by developing center of the State Council, now there are over 40 billion m^2 exiting buildings are high energy consumption buildings. For new buildings, over 95% are high energy consumption buildings.

We should know that buildings without any energy efficiency measures are everywhere in China not only in rural but also in urban. If energy consumption would develop in this way, by 2020, energy consumption in China would be 108.9 billion m^2 which is 3 times of that of 2000. So solving the energy problem in building sector should be put in the first place. Energy consumption structure is urgently needed to be promoted in the future.

- **Internal causes**

(1) Real estate development is in the step of transition

In 2005, the state council published <Notice of stabilizing the house price> which is called ***National Eight Policies*** in China. It is a special result under the administration system of Chinese characteristics. This national document raised the house price to the national level and with enhancing of macroscopic control; real estate competition will be changed to presume high-quality and brand-strategies from maximize short-time economic benefit, huge scale and construction speed.

In this period, real estate companies are facing the pressure not only from internal re-construction but also the demand of improvement of quality which is result of the market competition and policies that leaded by government. Uses of clean energy, conception of sustainable buildings are the key words of building development in the future. 'Technology real estate' is becoming the fresh troops in this turning stage. Especially the publishing of <Green building assessment>, <Guideline of green building technology > pushed the use of clean energy becoming the most important solution during the real estate turning stage from capital- external to technology- countermeasures in China.

(2) Improving the quality of building is the requirement of all the consumers

After solving the problem of basic living, how to improving comfortableness, building environment are inherent requirements. In the recent 20 years, living condition has been improved a lot in China, but the problems of high energy consumption, low comfortableness, thermal bridge, air leak, moisture condensation are also obvious. Along with the continuous economic improvement, buildings quality is one of the important psychological indicators for living level.

In 2001, China Product Quality Association organized "***House Assessment by Million Resident***" in 20 cities including Beijing, Shanghai, Tianjin, Harbin, Xi'an, Guangzhou etc. And the result showed that the degree of satisfaction is 45.5%.

Of course, the awareness for building quality must been undergoing a process from shallow to deep, from over decoration to green building. People will find that only coordinate environment, healthy and efficiency building can offer high quality which is the essence of the residential buildings. Clean energy offers the solution for sustainable building.

In addition, there is huge market perspective for technology support in energy efficiency for residential building in China. Due to great economic success and huge potential demand, businesses are delivering hundreds of existing and emerging green technology solutions to China markets. These technologies will provide significant positive impact on the Chinese environment. To understand well the current situation of green technology development in China, CGTI (2009) outlined the market map to describe the various field of technologies. The map is comprised of nine broadly-defined market sectors and 40 focused segments across three broad categories: energy supply, resource use and other markets, as shown in Table 3.1.

Table 3.1 The China Green Technology Market Map (CGTI, 2009)

	Energy supply			Resource use			Other markets		
sectors	Cleaner Conventional energy	Renewable Energy	Electric Energy Infrastructure	Green Building	Cleaner Transportation	Cleaner Industry	Clean water	Waste management	Sustainable forestry and Agriculture
	Cleaner coal	Solar energy	Transmission	Optimized Design	Cleaner road	Optimized Design	Water extraction	Waste collection	Sustainable forest management
	Cleaner oil	Wind power	Distribution	Sustainable materials	Cleaner rail	Sustainable materials	Eater treatment	Waste recycling	Sustainable Land management
	Cleaner gas	Bioenergy	Energy storage	Energy efficiency	Cleaner air	Efficient processing	Water distribution	Energy from waste recovery	Sustainable farming communities
segments	Nuclear power	Hydropower	Demand Management	Wave efficiency	Cleaner waterway		Water use	Waste treatment	Optimize crops
		Wave Power	Supply Flexibility				Waste water treatment	Sustainable waste disposal	
		Geothermal Energy							

3.1.2 Low carbon emission target for building sector in China

Clean energy has been widely accepted as the best energy sources to substitute current fossil based energy, the ultimate reason is that reduce carbon emission. Since the beginning of 21st century, low carbon emission had been fixed as the main indicator for measuring the energy efficiency effect. Building, as one of the most important sectors of energy consumption in China, attracted extensive attention in the low carbon emission trend.

It's obviously shown that along with the technology improvement, the dream of extricating from conventional energy system with high dependence on fossil energy can be achieved in not so far future. In many sustainable planning practices, an integration of renewable energy with fossil energy has been implemented. For some projects with more advanced ideas, 100% dependence on renewable energy is also designed to as the final goal. Therefore, for low carbon sustainable planning, it is important and necessary to execute potential assessment on renewable energy sources for the cities before formulating carbon reduction actions, because potential assessment clearly gives an idea of the maximum possible locally reachable targets.

- **Using Renewable Energy**

Qualifying the various renewable energy supplies for measuring their degree of sustainability is an unsolved issue and categorizing is a necessary step for avoiding errors caused by the uniform treatment of different cases (Verbruggen et al., 2010). In order to assess the potentials of renewable energy, defining the practical renewable energy supplier is the first step. The Dictionary of Energy edited by Cleveland and Morris (2006) defines renewable energy is "any energy source that is naturally regenerated over a short time scale and either derived directly from solar energy (solar thermal, photochemical, and photo-electric), indirectly from the sun (wind, hydropower, and photosynthetic energy stored in biomass), or from other natural energy flows (geothermal, tidal, wave, and current energy

Renewable energy can be summarized as the following categories which are coming from directly from the sun, indirectly from the sun and other natural energy. Actually all these renewable energies had been implemented for energy system more and more in recent years. With the improvement of the technologies, the cost for these kinds of burgeoning energies is becoming acceptable for big scale application.

In general, producing significant shares of heat, power and biofuels from locally available resources, including solar, wind, ocean, geothermal, energy crops and biomass from wastes, could be a future option for a municipality. Therefore, as the above introductions, six categories of renewable energy are the main renewable energy sources and are widely implemented at municipal level now. Table 3.2 proposes a conclusion for these renewable energy sources and their applications, available energy for residential building refurbishment process are outlined by gray color in background.

Table 3.2 Principal renewable energy application at municipal level

Category		**Municipal source**	**Approach**	**Outcome**
Directly from sun	Solar	concentrating solar plants	smart grid	Electricity
		solar PV in urban community	smart grid	Electricity
Indirectly from sun	Wind	off-shore wind power	hydrogen/desalination station	Hydrogen
		community wind farm	smart grid	Electricity
	Hydropower	hydropower plant	smart grid	Electricity
	Bioenergy	forest biomass	wood process plant/bioenergy CHP plant/smart grid	Electricity
		animal manure	biogas plant	Gas
		municipal solid wastes	recycling plant/biogas plant	Gas
		municipal sewage	biogas plant	Gas
		short rotation energy forest	incinerator	Heat
		energy crops	biomass refinery	Bio-diesel/ethanol
Other natural power	Tide and wave	wave power	hydrogen desalination station	Hydrogen
	Geothermal	geothermal CHP	smart grid	Electricity
		ground source heat pump	end users	Heat

- **Improving energy saving measures**

In the other hand, China is a developing country which needs huge amount of energy import to support the enormous energy consumption. The current situation is that although China owns abundant energy resources within its broad territory, the per capita possession is very low after divided by the huge population. Particularly the per capita amount of oil and natural gas in China are only 7.7% and 7.1% of the world average respectively (NDRC, 2007). An unprecedented need for resources is now rising in China. Twenty years ago, China was still largest oil exporter in East Asia, while now it is the world's second-largest importer. Table 3.3 shows the variation of energy import and the trade reliance of China's energy. Since 1995, China became a net oil importer. China's oil imports have increased rapidly; from 37 million tonnes in 1995 to 98 million tonnes in 2000 and 195 million tonnes in 2006. Exports have been table at approximate 25 million tonnes since 1995. The share of imports of oil was only 7.6% in 1995, but increased to 33.8% in 2000, and is now almost 50% since then. China still remains a net exporter of coal, but to meet the domestic demand for special types of coal, China imports some coal. Since 2000, this has been increasing in volume of coal import to reach nearly 40 million tonnes standard coal equivalence in 2006.

Table3.3 Export and import and trade reliance of China's energy (million toonnes and %)

Year	Aggregate trade and reliance				Coal trade and reliance				Petroleum trade and reliance			
	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance
1980	2.6	30.6	28	4.6	2	6.3	4.3	0.7	0.8	18.1	17.2	19.7
1985	3.4	57.7	54.3	7.1	2.3	7.8	5.5	0.7	0.9	36.3	35.4	38.6
1990	13.1	58.8	45.7	4.6	2	17.3	15.3	1.4	7.6	31.1	23.5	20.5
1995	54.6	67.8	13.2	1	16	28.6	27	2	36.7	24.5	12.2	7.6
1996	68.4	75.3	6.9	0.5	3.2	36.5	33.3	2.3	45.4	27	18.4	10.6
1997	99.6	76.6	23	1.7	2	30.7	28.7	2.1	67.9	28.2	39.7	20.2
2000	143.3	90.3	53.1	3.8	2.2	55.1	52.9	4	97.5	21.7	75.8	33.8
2004	265.9	116.5	149.5	7.4	18.6	86.7	68.1	3.5	172.9	22.4	150.5	47.5
2005	269.5	114.5	155.1	6.9	26.2	71.7	45.6	2.1	171.6	28.9	142.8	43.9
2006	310.6	109.3	201.3	8.2	38.3	63.3	25	1	194.5	26.3	168.3	48.2
Growth rate annually												
1980-1990	17.6	6.7	-	-	0	10.6	-	-	25.2	5.6	-	-
1990-2000	27	4.4	-	-	1	12.3	-	-	29.1	3.5	-	-
2000-2006	13.8	3.2	24.9	13.7	61	2.3	11.7	20.6	12.2	3.3	14.2	6.1
1997-2006	15.6	4.4	27.3	19.3	38.7	8.4	1.5	7.7	14.6	0.1	17.4	10.2

Note: Aggregate energy is measured in million tonne standard coal and reliance is the percentage of net import in total domestic consumption.
Data source: China Statistical Yearbooks, 1991-2007

If China wants to keep its rapid development in the future, the researchers must find proper measures for improving energy saving. All the energy consumption countries especially China could not solve the energy problem without the energy saving measures. And the clean energy strategy is a powerful driving force for improving energy saving measures in China.

- **Reducing Primary energy consumption**

Improving using of clean energy, the most important target is reducing primary energy consumption. As we showed in the first chapter, the primary energy consumption since the industrial revolution has created serious energy crisis in 21st century. In China, energy use per-capita of city residents is slightly lower than the national average in the USA and the countries of EU. By contrast, the cities in China own significantly higher energy intensive per-capita than the national average (Table 3.4), due to higher incomes and better availability of energy services compared with rural areas. The recent growth in Chinese national per-capita energy consumption — 8.5% per year between 2000 and 2006 — has been driven partly by urbanization (IEA, 2008). The UN projections predicate the current rate of urbanization in China — around 40% — will reach 60% by 2030. In addition, accompanying with the continuing urbanization in China, there will be further 355 million inhabitants immigrating into the city areas.

Table 3.4 Overview of city energy use and urbanization rate in regions and countries, 2006

Region	Share of city primary energy demand in regional total	Ratio of city per-capita primary energy demand to regional average	Urbanization rate
USA	80%	99%	81%
EU-27	69%	94%	73%
CHINA	75%	182%	41%
Data source: IEA,2008			

Hence, it is scarcely in doubt that China's energy needs will continue growing to fuel its economic development. However, the rate of increase and how those needs are met are far from certain, as it depends on just how quickly the economy expanding, also depends on the economic and energy-policy landscape worldwide. The expansion of China's share of world energy demand will or has already posed a threat to the balance of world's energy system, and will challenge the world's energy security. The existing global energy market could not bear China consuming energy in the American way. Till now, the per-capita energy consumption in China is still much lower than the Western countries, and the major energy is consumed in the producing process in industrial sector, not for daily life use by all city inhabitants. So, China still has chance to switch its patter of city energy consumption to low carbon and low fossil-dependence more comfortably and quickly than developed countries. Low carbon sustainable development is the only way for Chinese cities in future.

3.1.3 Residential building energy targets and initial performances

The increasing of households in China is associated with the national macro-policy. With the speed of urbanization, there are much more persons living in urban areas and this brings some problems such as employment, residents, education etc. China is in the step of high-speed of urbanization which the European countries and USA had experienced 30-50 years before.

China is still during the industrialization period, and most of energy is consumed in Industrial sector. Table 3.5 compared the ratios of sectorial energy consumption to total energy consumption among the USA, European Union and China. As the above section analyzed, nearly all Chinese cities have industrial factories and most of them dominated the city economic development, which creates the high ratio of industrial energy consumption in China more than 70% in 2006. Different from China, the industrial energy consumption of USA and EU-27 are much lower, neither was more than 1/3. Both of them spent very high proportion of energy in residential and transportation sectors, which indicates their daily lives highly relying on the fossil energy now, especially their cities, because they all have reached very high urbanization rate. Energy use per-capita of city residents is slightly lower than the national average in the USA and the countries of EU.

Table 3.5 Ratios of Sectorial Energy Consumption to Total Energy Consumption in Regions and Countries, 2006

Region	Residential	Commercial	Industrial	Transportation
USA	20.8%	17.8%	32.5%	28.9%
EU-27	25.9%	11.4%	27.6%	31.5%
CHINA	10.3%	6.1%	72.6%	7.5%
Data sources: EIA, 2010; EEA, 2009; CESY, 2007				

Growth in residential energy consumption is driven both by an increase in total floor space devoted to these uses and by the increase in appliance, lighting, and heating and cooling usage in these areas. As urbanization increases, growing from the current 40% to 56% in 2020, and household wealth continues to rise, demand in households for refrigerators, air conditioners, lighting products, clothes washers, consumer electronics, space heating, water heating and other functions will increase substantially. For example, the average efficiency of an “efficient” split-type room air conditioner in urban households is expected to improve by nearly 40% by 2020 over the 2004 level, but owing to continued high rates of sales, total electricity consumption by "efficient" room air conditioners is expected to more than triple, from 12 TWh in 2004 to 38 TWh in 2020. (Zhou et al. 2009)

China's government plan calls for efficiency improvement through a tightening of standards, incentives and subsidies as well as moderate measures to accelerate the adoption of higher-efficiency technologies (RNECSPC, 2005). Fig. 3.2 illustrates an example of the efficiency change of space heating technology. For instance, the average efficiency of district heating will increase by 23 percent, whereas a heat pump shows 80 percent efficiency-improvement potential.

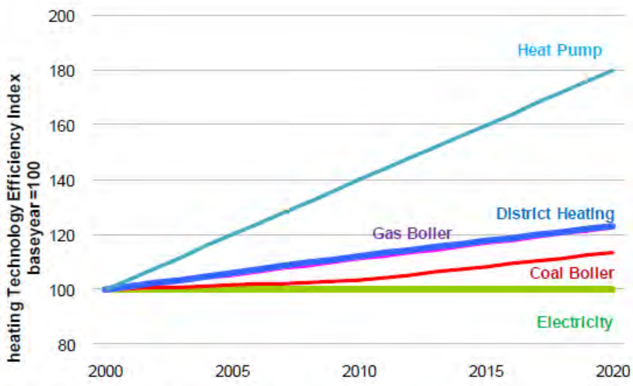


Fig. 3.2 Efficiency of the Space Heating Technologies (Zhou et.al. 2009)

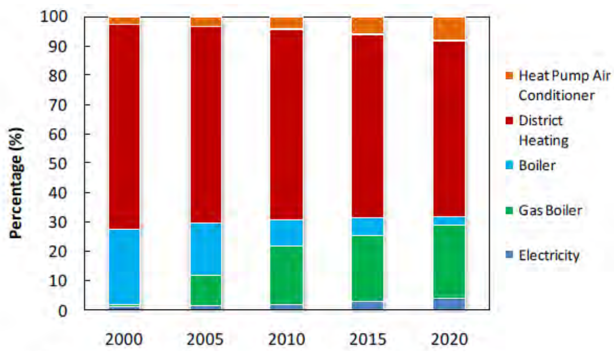


Fig. 3.3 Space Heating Technology Shift in Residential Building (Zhou et.al. 2009)

At the same time, the market share of efficient and cleaner technology also rises according to the current government policy (Fig. 3.3). Technologies such as conventional coal boilers and district heating will gradually shift to cleaner gas boilers and more efficient heat pumps. The projection is based on assumption that both the efficiency and market shares of the different technologies used in the Chinese residential sector will converge to their current level in Japan by 2020.

3.2 Emission reduction issues in Europe

Global concern of climate change has led to the development of a variety of solutions to monitor and reduce carbon emissions on both local and global scales (D'Avignon, et al, 2009). As well as the sources of GHGs, the opportunities for controlling their emissions exist at the local level (Wilbanks and Kates, 1999). Cities should assume the most responsibility for CO_2 emission reduction to mitigate the effect of global climate change. To achieve this goal, quantifying the amount of CO_2 emitted due to the energy consumption, i.e. CO_2 emission inventory, in the territory of the local authority should be a priority. As a first step to addressing climate change many cities have established inventories of GHG emissions, often using the simple pragmatic approach of the International Council for Local Environmental Initiatives (ICLEI, 2008). Low carbon emission policy provides a basis for action on energy crisis and climate change. In particular, issues on residential building sector would be an important part of sustainable urban development.

3.2.1 Low carbon urban strategy

Global warming has already caused disturbances to our climate, with extremely serious repercussions for humankind, and the future looks even bleaker. To limit these repercussions and guarantee the sustainable development of our societies, it is now generally agreed that world greenhouse gas emissions must be halved by 2050, with reference to the 1990 level.

The European Union (EU) is tackling the challenge through a policy whose target is nothing less than the transformation of the entire energy system, with far-reaching implications on how we source and produce our energy, how we transport and trade it, and how we use it. In short, we must make low-carbon technologies affordable and competitive – a market choice. This is the core idea behind the European Strategic Energy Technology Plan.

Although urban policy is not formally an EU competence there has been a focus on urban matters within the EU institutions since at least 1990 when, at the request of the European Parliament, the European Commission published its Green Paper on the Urban Environment. The Council of Ministers subsequently called for the establishment of an Expert Group on the Urban Environment, active between 1991 and 2005, which produced an influential report on European Sustainable Cities and, with the European Commission and several city networks, launched the European Sustainable Cities and Towns Campaign which local authorities joined by signing the Local authorities active in this Campaign produced integrated strategies for local sustainability/Local Agenda 21 in which energy issues featured strongly.

In December 2008, the EU adopted an integrated energy and climate change policy, including ambitious targets for 2020: by 2020, the “20-20-20 policy” aims at cutting Greenhouse gas emissions by 20%, at reducing energy consumption by 20% and at reaching a 20% share of energy from renewable sources. They set 20/20/20 targets to be met by 2020:

- 20%reduction of GHG emissions by 2020 compared to 1990.
- 20%share of renewable energy in final energy consumption by 2020.
- 20%reductionin EU primary energy consumption by 2020, compared with projected levels, to be achieved by improving energy efficiency.

Energy efficiency is a key element of the energy policy at the EU level. It contributes to all main goals: energy security, reduction of carbon/GHG emissions, economic competitiveness as well as energy equity and lowering of energy costs to consumers. The EU is a strong driving force in this policy field. Many countries lack a systematic energy efficiency framework and the EU guidelines therefore play a crucial role in facilitating this.(Carraro and Braun, 2011) The EU is prepared to move to a reduction target of 30% by 2020 if certain conditions are met, but no decision has yet been taken on this.

Buildings are seen as the largest cost effective saving potential and individual goals are set by Member States:

- UK: 0 carbon homes by 2016 (heating and lighting).
- Hungary: 0 emission buildings by 2020 (Climate Change Strategy).
- NL: energy neutral buildings by 2020.
- France: energy positive buildings by 2020.

Council Directive 93/76/ EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE) indicated implementing actions in the fields:

- Energy certification of buildings,
- The billing of heating, air-conditioning and hot water costs on the basis of actual consumption,
- Third-party financing for energy efficiency investments in the public sector,

- Thermal insulation of new buildings,
- Regular inspection of boilers,
- Energy audits of undertakings with high energy consumption.

The new "**Directive on the promotion of the use of energy from renewable sources**" (April 2009) sets mandatory national targets, improves the legal framework for promoting renewable electricity, requires National Renewable Action Plans that establish pathways for the development of renewable energy sources including bioenergy, creates cooperation mechanisms to help achieve the targets cost effectively and establishes the sustainability criteria for biofuels. This new Directive must be implemented by Member States by December 2010. If important technical problems still have to be resolved for the development of renewable electricity, the unanimous adoption of this new directive by the 27 Member States shows their strong determination to fight against Climate Change.

EU support a project named "Smart city" of which the aim is to demonstrate the feasibility of rapidly progressing towards our energy and climate objectives at a local level while proving to citizens that their quality of life and local economies can be improved through investments in energy efficiency and reduction of carbon emissions. This Initiative will foster the dissemination throughout Europe of the most efficient models and strategies to progress towards a low carbon future.

3.2.2 Building Energy Performance Directive in EU

With the spread of using clean energy, EU is paying more attention to building energy efficiency. It's a comprehensive issue which is not only has relationship with architecture and urban plan but also with many other majors like material, engineering and transportation. In Europe thousands of buildings are built or renovated every year. The construction sector is one of the largest employers with 16.4 million jobs, contributing to about 10.4% of the Gross Domestic Product (GDP). Buildings are responsible for 40% of energy consumption and 36% of EU CO_2 emissions. Improving the energy performance of buildings is a cost effective way of fighting against climate change and improving energy security, while also creating job opportunities, particularly in the building sector.

EU has fixed a serious of building energy consumption target. New buildings and major renovation in the European Union will be "Nearly zero energy" by 2021, though the phrase's definition will vary significantly by country. Regulatory support has begun, and will increase with the 2011 and 2014 updates of National Energy Efficiency Action Plans. Less than 1% of existing space is nearly zero energy at present, primarily Passive Houses. Of the 30 billion square meters of floor space in Western and Eastern Europe, 74% is residential, and 2% is affected annually by new construction or major renovation. Certified green building space will increase from less than 1% in 2010, to more than 2% in 2016, and is already 2% in France.

Reducing these emissions is a big challenge but can also be seen as a fantastic opportunity. The construction sector can make a significant contribution to reducing the impacts of climate change and to decreasing fossil fuel dependence. The difficult question is how to reach the 165 Mote (23.6%) reductions from the existing buildings (in 2005) and the contribution of 50 Mote from renewable energies during the period from now until 2020 (E2BA, 2009).

European Commission has published a serious of legislation in building energy efficiency in buildings. On 18 May 2010 a recast of ***The Directive on energy performance of buildings (2002/91/EC)*** was adopted in order to strengthen the energy performance requirements and to clarify and streamline some of its provisions. The Directive on energy performance of buildings is the main legislative instrument at EU level to achieve energy performance in buildings. Under this Directive, the Member States must apply minimum requirements as regards the energy performance of new and existing buildings, ensure the certification of their energy performance and require the regular inspection of boilers and air conditioning systems in buildings.

There was the Energy Intelligent Europe (EIE) Program, was approved in June 2003. The EIE has SAVE as a sub-program within it.

The EU is also involved in technology development through the 6th Framework program, which covers all EU-funded research between 2002 and 2006. Energy efficiency is funded through one of the priority areas of sustainable development, global change and ecosystems.

Most recent Policy instruments to help speed up energy efficiency and achievement of EU goals by 2020 are listed:

- Directive on energy performance of buildings (EPBD) (2002/91/EC);
- Directive on the promotion of cogeneration (2004/8/EC);
- Directive on the taxation of energy products and electricity (2003/96/EC);

- Directives on efficiency requirements for boilers, refrigerators and ballasts for fluorescent lighting;
- Directives on the labeling of electric ovens, air conditioners, refrigerators and other appliances;
- Directive on eco-design requirements for energy-using products (2205/32/EC and recast 2009/125/EC);
- Directive on energy end-use efficiency and energy services (2006/32/EC);
- Regulation on Energy Star labelling for office equipment (2422/2001/EC);

Several Directives are directly related to energy efficiency of buildings:

- Directive on energy performance of buildings (EPBD) (2002/91/EC);
- Directive on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels (1992/42/EEC);
- Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market (2004/8/EC) and amending Directive 92/42/EEC;
- Directive on energy end-use efficiency and energy services (2006/32/EC) and repealing Council Directive 93/76/EEC.

Of course, there is much legislation (policy, code, standard etc.) which constitute a complex system of building energy efficiency legislation. In fact, there are different levels from EU to single country even to the cities in a top-down mode. (Fig. 3.4)

There is also strict certification system. Energy performance certificates an important instrument to communicate energy efficiency of the building to the general public. It should include the energy performance of a building calculated according to a methodology. A series of standards aimed at European harmonization of the methodology for the calculation of the energy performance of buildings in order to help the Member States to implement Directive 2002/91/EC in a consistent way.

Initially planned approaches and procedures for implementing EPBD in the Member States were very different from each other which were due to different interpretations of the Directive. This has however changed during the development process thanks to the cooperation among countries.

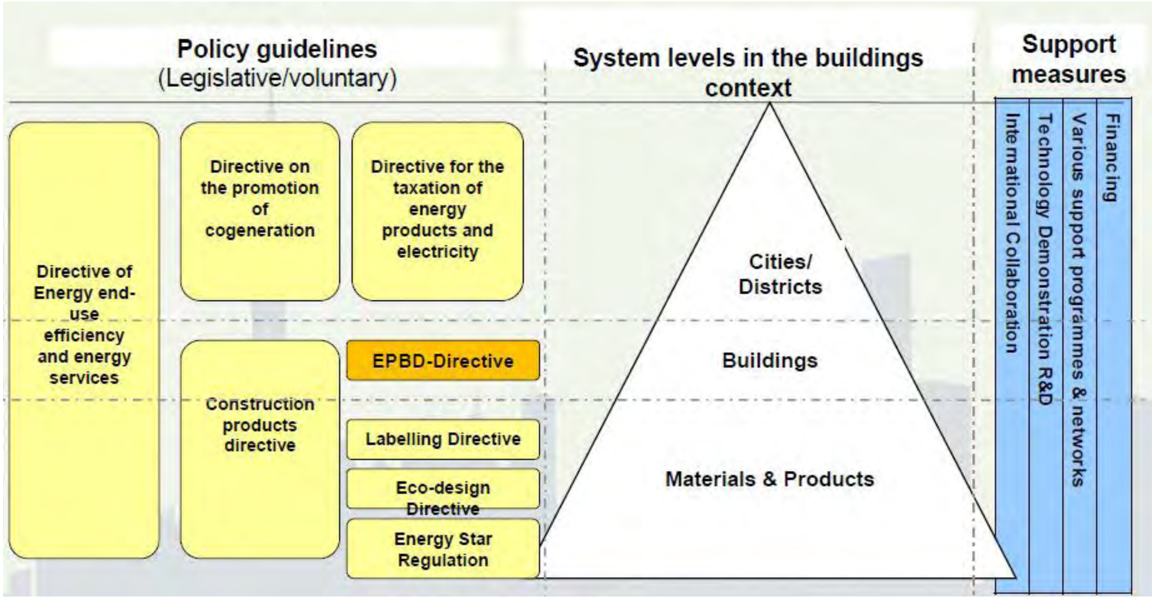


Fig. 3.4 Structure of building energy efficiency legislation (Iverfeldt, 2011)

Italy:

We now turn to some stylized facts and data about residential energy use and policy frameworks in Italy.

In 2003 Italy was responsible for 11.2% of total final energy consumption of the EU-27 and its per capita CO_2 emissions were about eight tonnes. The final energy demand experienced an increase of 21.63% during the period 1990 to 2003 – much stronger than the EU average of 9.19% in the EU-27. This trend, according to some baseline scenario projections, is expected to continue in the near future (EC, 2008). The final energy consumption by households has been increasing by 13.8% in the period 1990–2003, less than the EU-27 average of 15.15%. The residential sector accounted for almost 23% of TFC in Italy in 2003. It was the third largest sector in terms of TFC after transport (33.3%) and industry (38.5%) (Eurostat, 2010).

At the very beginning of implementation, Italy therefore tried to intervene in this field with different instruments in order to reverse the trend. The efforts of the Italian policy on energy conservation and efficiency at the level of the final consumer date back to Law 373/76 from 1976, which introduced the obligation for dwellings built after 1977 to meet certain parameters of insulation. However this law, which had the merit of raising the interest towards these issues, is characterized by several limitations. Law 373/76 has been subsequently almost entirely repelled by Law 10/91 from 1991, which was already planning the introduction of the energy certification of buildings. Unfortunately, Law

10/91 has not been fully enforced due to the lack of certain enforcement provisions that could have helped Italy taking the lead of energy sustainability policies in the residential sector (Anglani and Ricciardi, 2007).

The "***Directive on the energy performance of buildings***" (EC, 2002) has been transposed into national law with Legislative Decree 192/2005 and subsequent integrations and arrangements. It obliges the provision of the energy certification (or labeling) of nearly all ***existing buildings***. When buildings are constructed, sold or rented out, an energy performance certificate is made available to the prospective buyer or tenant. The main aim of the energy certificate is to increase awareness and knowledge of final consumers on energy efficiency and energy savings issues. Once the scheme gains ground, in fact, it is expected the certificate to be part of the economic evaluation of consumers when they reach a decision on buying or renting an apartment or house.

The most relevant domestic cross-sectorial initiative in Italy is the ***White Certificates Scheme*** (D.M. 20/07/2004), aimed at promoting energy efficiency and delivering emissions reductions across all energy end-use sectors. The majority, over 63%, of the white certificates are focused on the residential sector (IEA, 2009a). At the same time a tax credit scheme has been introduced in 2007 (and extended up to 2010) aiming to offer a fiscal incentive for the use of energy efficiency equipment or renewable energy technologies. These incentives are mainly tax breaks – between 36% to 55% depending on the type of building and measure implemented – recognized in the case of energy modernization of buildings, installation of photovoltaic cells, solar thermal panels, energy efficient devices, etc.

By the studying of EU energy legislations for building sector especially detailed analysis of energy use and policy frameworks in Italy, we can get the conclusion that the legislation system in EU is more complete compared with that of China. By the strong implementation of energy efficiency in residential building sector, there was some successful energy conservation refurbishment projects had been done in past years. In next section, we will introduce on residential building refurbishment project in EU----ENPIRE and we hope the successful experiences could be good lessons for this kind of projects.

3.3 European case study (ENPIRE)

ENPIRE (Energy and Urban Planning in Restructuring Area) is a European Union project. It was started since January 2008 and the partners including university research groups, Housing association, municipality, architects from seven EU countries. Italy is one of these seven countries and residential building refurbishment project is finished in city Casale.

The project is focused on the specific view of energy efficiency policy and technology for residential building refurbishment. All over Europe local governments are involved in projects to improve the quality of houses in the urban environment. This involves not only the development of new urban areas but increasingly also the restructuring of existing urban areas. Although improvement of the overall quality of the dwellings and of social conditions in the neighborhood will be the primary aim of such projects, there are also very good opportunities for improving the energy efficiency of the dwellings. Improvement of energy efficiency will not only contribute to the mitigation of climate change but can also help to stabilize energy costs for inhabitants. However, it is very important that the issue of energy efficiency is already considered at the most early stages of the urban planning processes so that optimal choices can be made with regard to energy infrastructure, energy efficiency measures and renewable energy generation.

3.3.1 Introduction of the Project ENPIRE

The project ENPIRE was lasted two years from beginning of 2008 to the end of 2009. During the project, seven local projects of residential building refurbishment had been done with appropriate technologies, a serious of workshop had been organized and a serious of documents and papers were published.

General documents:

- ENPIRE Final Report
- ENPIRE Guidelines on Process
- ENPIRE Guideline on Ambitions and legislation
- ENPIRE Guideline on Embedding Agreements
- ENPIRE Evaluation Report of Local Projects
- ENPIRE factsheet
- ENPIRE State-of-the-art report

These different Guideline documents have been prepared by the ENPIRE project, covering the following subjects:

- Process: how should the process of energy planning and preparation of an energy vision study be organized in order to achieve good results;
- Legislation and Ambitions: which efficiency requirements are required by existing legislation in different countries and in what way can one set a ambition level that exceeds the legal requirements;
- Embedding Agreements: in what way can a certain ambition level for energy efficiency or CO_2 reduction be agreed between stakeholders and laid down in a joint agreement.

Local authorities have a specific and very influential role in promoting and facilitating the process of energy efficiency in urban planning, and are often in the best position to take the lead in CO_2 reduction initiatives. In order to provide the different parties in the planning and decision making process with good information and best practice examples. Within this project general guidelines have been developed and practical experiences documented with regard to energy planning in urban renewal projects. Apart from these Guideline documents a number of **local projects** involving urban planning and energy visions studies have been implemented in:

- Albertslund, Denmark
- Ávila, Spain
- Breda, Netherlands
- Casale, Italy
- Dublin, Ireland
- Havířov, Czech Republic

From the progress of ENPIRE project, we find that it is more difficult to deal with existing residential building refurbishment comparing with new constructions. If European and national regulations are supposed to drive the constant development of energy efficient projects in new and existing buildings, it is noticed that the levels of ambitions expected have not yet been reached in many member countries. The lack of control in the implementation of regulation and, moreover, the lack of financial or technical resources make it difficult to ensure the final performance of efficient urban projects.

The following figure shows the importance of the alleviation risk at early design stage of a new or refurbishment project.

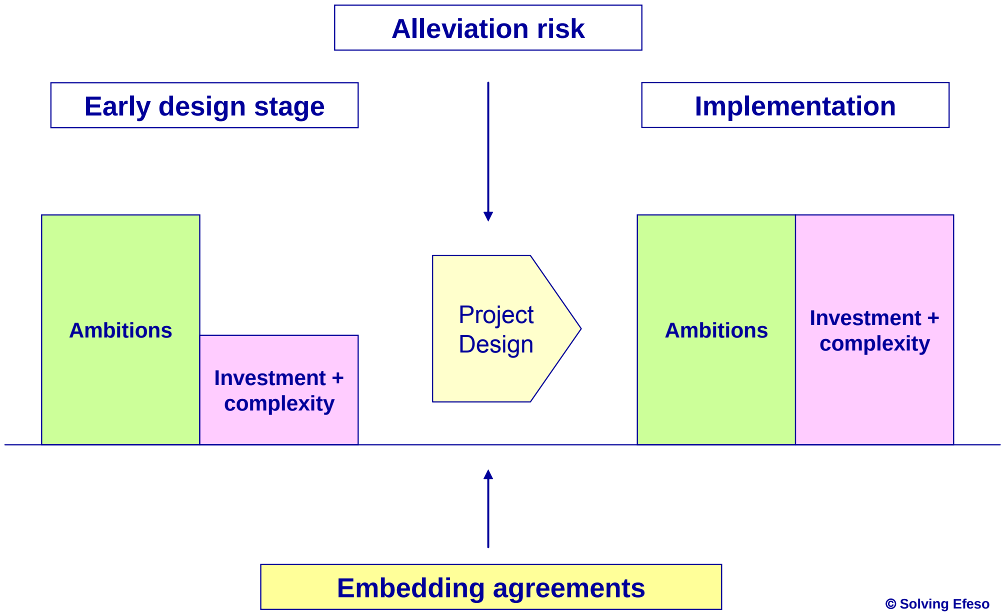


Fig. 3.5 Alleviation risk at early design stage of a new or refurbishment project (ENPIRE, 2009)

ENPIRE will evaluate the state of the art on energy and urban planning in participating countries to gain and share experience on "Energy and Urban Planning" and policy benchmarking. This project leads to recommendations and guidelines for local policy process. ENPIRE has an active dissemination policy and focuses on local target groups in all EU 27 Member States.

The outcome of local case studies lead to conclusions and recommendations for future projects and the dissemination task within ENPIRE. At an international symposium the work has been presented. Each participant disseminated the conclusions and recommendations nationally. An evaluation of the state of the art, local experience and existing knowledge in the participating countries on energy and urban planning had been used to set-up guidelines which will be applied in 6 case studies in restructuring areas.

Since large scale urbanization in Europe has been finished in last twenty to thirty years, the quantity of new constructions of residential buildings is lasted in a steady speed. Europe has solved the problem of residential building refurbishment during the effects in the last twenty years. So far, no comprehensive strategies have been developed in the countries to start energy efficient, sustainable multi-storey housing refurbishment. Especially effective legal and administrative structures need to be developed, energy efficient refurbishment measures chosen, sustainable housing refurbishment implemented.

The main benefit of buildings refurbishment is usually considered as saving of energy. It is obvious, however, that most energy saving measures allows not only to save energy, but also to improve the building's condition and in turn to increase the value of a building. All these tasks should be managed as a complex system in order to achieve refurbishment sustainability effect.

3.3.2 Local projects

The local case studies provided an indispensable source of information and practical lessons for the guidelines developed within the ENPIRE project. An energy study was carried out for each of these projects and can be found in the project reports on the ENPIRE website, together with other documentation material.

Fig. 3.6 The local projects of ENPIRE are located in Albertslund (Denmark), Ávila (Spain), Breda (Netherlands), Casale (Italy), Dublin (Ireland), Le Grand Chalon (France) and Havírov (Czech Republic).

The existing situation at each of the sites of the local projects was quite different. It varied from areas with dwellings that needed to be renovated or demolished (Albertslund, Breda, Havířov) to agricultural lands with agricultural buildings (Ávila) to an industrial area with cement industry that will be demolished completely (Casale). Only one project involved strictly new buildings and is being realized on a 'green field' site (Dublin). The prefabricated row houses of the period 1965-1970 in Albertslund and the masonry blocks of flats of the 1950's in Havířov will be refurbished. The dwellings in Breda will be partly refurbished and partly demolished and rebuilt anew.

Case study:

Albertslund, Denmark

The Danish Housing company, BO-VEST, is responsible for the largest and most costly renovation plan for social housing in Denmark. Approximately 2.200 industrialized concrete housing units from the 1960's in the municipality of Albertslund, will go through a costly urban renewal renovation at an estimated cost of not less than 180.000 Euro per unit. Around € 360 million will be invested, of which € 200 million is available for retrofitting the social housing dwellings. In the plan the partnership between the housing association, the municipality and the tenants organisation is very important. A central council manages the communication among partners and has to approve every decision.

Fig. 3.7 Photo of project in Albertslund before refurbishment

Ávila, Spain

The project in Avila is an urban development project in the rural area of Sanchidrian, which was previously mainly used for agricultural activities.

The project will transform the agricultural area into an urban area with more than 200 houses, annexed buildings and a golf course. This is one of the most common changes of use in Spain, so is of potential interest for many other projects.

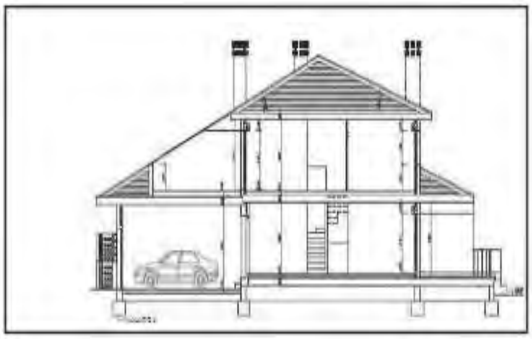


Fig 3.8 Section of project in Avila before refurbishment

Breda, Netherlands

The Heuvel refurbishment project in Breda comp rises of a residential area with 3.200 dwellings, built in 1945–1960, with a great variety of housing blocks an d local facilities. Of these dwellings, 2.500 are owned by housing associations and 700 have private owners.

Fig. 3.9 Photo of project in Breda before refurbishment

The energy is supplied by natural gas and electricity. The restructuring process (2005 – 2015) comprises of the demolition of 650 houses, the renovation of 650 houses and the construction of 950 new dwellings. In addition a new retail centre and a new school will be built and an old monumental church will be changed into a multifunctional center.

Casale, Italy

The Ronzone district used to accommodate a cement-asbestos production facility and other cement industries of the Piedmont region. The area has been decontaminated and reclaimed for reuse.

After the demolition of the abandoned factories, an eco-village will be built, integrating eco technologies like bioclimatic design, passive solar, PV modules, biomass heating systems on the village scale and using recycled materials for basements. All this is necessary to meet the high standards of an eco-settlement. Presently the main energy carriers are natural gas and electricity.

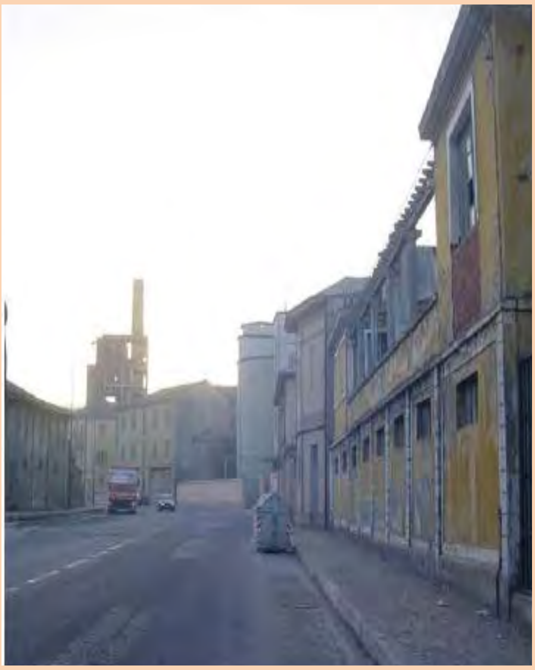


Fig. 3.10 Photo of Project in Casale before refurbishment

Dublin, Ireland

Tyrrelstown Housing is a new development of Social Rented, Shared Equity and Affordable Purchase family dwellings by the National Association of Building Co-operatives (NABCo) Society Ltd, a Government approved Housing Body.

The project comprises of the construction of 234 new family homes including both houses and apartments in 2 and 3 story blocks together with 3 communal welfare facilities including a crèche, community center and estate management offices and a public park.

Fig 3.11 Photo of Project in Dublin before refurbishment

The site is located to the northwest of Dublin city. The Fingal County

Development Plan 2005-2011 sets out the Local Authority's policies and objectives for the development of the County for a six year period from 2005 to 2011. The Plan seeks to develop and improve in a sustainable manner the environmental, social, economic and cultural assets of the County and includes specific policies for the improvement of qualitative standards for sustainable building design.

The dwellings will generally be heated by individual high efficiency condensing gas boilers and a percentage of hot water will be provided using solar thermal technology.

Havířov, Czech Republic

The buildings in the local project are owned by the city of Havířov and managed by its housing company MRA. The dwellings are of masonry construction and were built in the 1950's. They presently have a low energy efficiency and are in an unsatisfactory technical state.

From an economical point of view that 85% of the apartments administered by MRA have regulated rentals (fixed low rent) which provide insufficient financial resources for technical renewal of the buildings. In the period 2007-2010 this will be solved by deregulating rents, so that they can be increased from 0,73 to

Fig. 3.12 Photo of Project in Havířov before refurbishment

1,60 €/m^2.

The site is a protected landmark and is named "Sorela" after the building style that was applied. A specific requirement is that the original appearance must be preserved after renovation, including frescos, colors and decoration. The challenge is how to insulate the external walls without losing these frescos and decorations. This will be done in collaboration with the Monument Protection Office.

In the following table, a comparison of the process and result of each local project are listed. In each local project, there are groups of stakeholders and stakeholders would set ambitions for this specific project after a serious of discussion. Final report like kind of agreement would be published and the aim of these agreements is to improve the embedding of the energy efficiency for residential buildings.

Table 3.6 Comparison of the process and result of each local project ENPIRE

Country	Setting the ambitions	Kind of agreement	Improving the embedding
Denmark, Alberstlund	- Discussions with design team, municipality and housing association - Negotiation with suppliers	- Voluntary commitment - Shared vision on the energy performance definition and requirements	- Formalise a common vision on ambitions
Holland, Breda	- Strong commitment of the municipality and the local housing association - Discussions with the inhabitants	- Signed voluntary agreement (Covenant Heuvel Breda) - Use of Energy Performance indicators	- Systematic use of preliminary energy studies to enter negotiation with stakeholders
Czech Republic, Havířov	- Integration of national targets at local level - Negotiation with design team and local District Heating supplier	- NA	- Identify local stakeholders providing energy services and taking action in historical buildings

			- Formalise a shared vision on energy ambitions
Italy, Casale	- Involvement of inhabitants through workshops - Commitment of local authority - Negotiation with design team	- Position paper - Integration of energy and sustainable issues into early design stages	- Secure negotiation among all stakeholders
Spain, Avila	- Meetings with the different stakeholders - Role of the local Energy Agency to coordinate the definition of ambitions	- Signed voluntary agreement among main stakeholders : Energy Agency, constructor, municipality, associations of engineers and architects	- Integrate stakeholders at very early design stages - Develop win-win approaches
France, Le Grand Chalon	- Preliminary energy studies - Meetings with the local authority and stakeholders	- NA	- Anticipate possible difficulties in political commitment - Dissociate project development stages from political deadlines
Ireland, Dublin	- Local strategy documents addressing sustainable issues - Negotiation with housing association	- Contracting documents	- Anticipate as much as possible the evolution of the regulation - Integrate energy issues as early as possible

3.3.3 Instruction for residential building refurbishment project

Realization of a high level of energy efficiency in building projects starts by giving this subject its own place within the overall urban planning process. In this document we have described a number of key steps in which the energy planning process may be broken down and discussed methods to manage the process. These recommendations are based on practical experiences in local projects in 6 European countries. Some key lessons that we have learned from these local projects were:

- Local authorities are in a good position to initiate the process of preparing an energy vision.
- A wide range of participants should be involved in initial discussions about ambitions. These discussions may cover more aspects than only energy or CO2 reduction but can also address energy costs and comfort levels for inhabitants, technical building improvement, etc. In this way a common set of interests can be identified with regard to improvement of existing buildings or the requirements for new buildings.
- A broad consensus among stakeholders on the desired ambition level is crucial for success in the implementation phase.
- The enhancement of market value of dwellings should be sought by improvement in technical quality, comfort levels and reduced energy costs in parallel with energy saving measures.
- Technical analyses should be used to support and guide this ambition setting process, but parties themselves will have to decide on the ambition they want to commit themselves to.
- An energy vision study should consider also the options for the project area as a whole and not be restricted to measures on a building level.
- Technical solutions should preferably have a high degree of flexibility to accommodate future changes in energy infrastructure, energy demand and energy pricing.
- Regulations that place an upper limit on the cold rent can create a serious bottleneck for the economic feasibility of investments in energy saving measures. Consideration of total housing costs (i.e. rent plus energy costs) and guarantees by property owners on the maximum level of these total housing costs in the future will help to overcome this problem.

- Good communication, a clear route plan and perseverance are essential ingredients to keep the high ambitions alive in the fi nal step of project implementation.

The main steps in the scheme described above may or may not be applicable for each specific project but overall, the steps described above give a good idea on how the energy planning should be organized.

Process steps in the energy planning process:

Discussing Ambitions: In this first step ambition level of the project will be discussed between stakeholders. Themes in this discussion can extend to more than just the reduction of energy consumption and/or CO_2 emissions, but also related to the quality of the buildings with respect to its technical state, indoor climate, comfort levels and energy costs for inhabitants. CO_2/energy ambitions will be regarded in relation to national and local regulations, climate policy targets and the overall project context (type of buildings, area, prospective users). A first agreement on the overall ambitions may be laid down in joint agreement document between local authorities, investors and prospective users.

Inventory phase: In this step all information is collected to characterize the project area, local resources of renewable energy, present and future energy demand of buildings and building users, existing energy infrastructure, technical characteristics of the buildings, comfort levels, indoor climate requirements, and various social aspects. Also planned developments in adjacent areas may be considered as they may affect the possibilities for new energy infrastructures and certain collective solutions (e.g. activities generating waste heat or expected increases in heating/cooling demand). For this inventory a good input from the stakeholders will be necessary to obtain all relevant information. Based on the inventory a portfolio of potential energy options can be prepared.

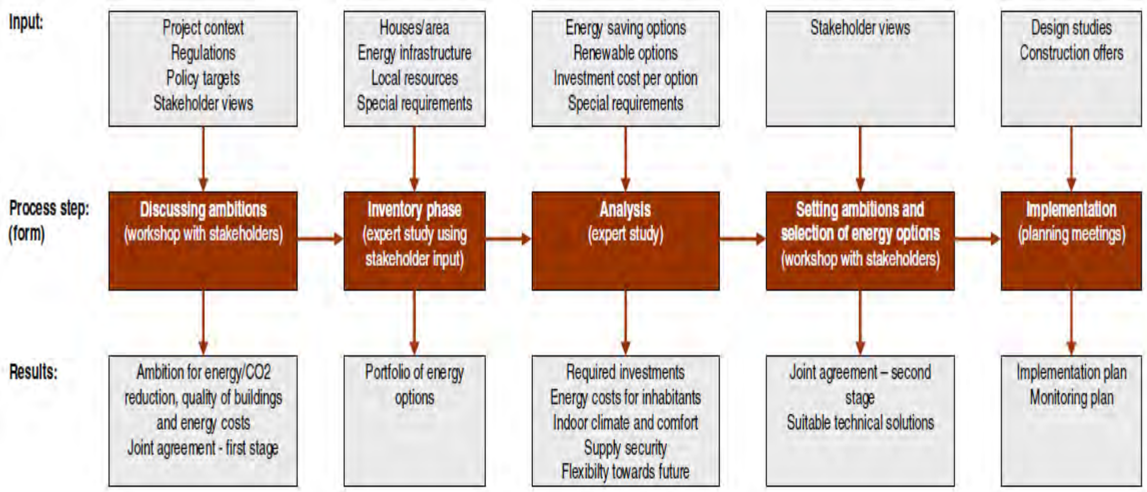


Fig. 3. 13 Scheme for the process of energy planning (Final Guidelines on the Process of ENPIRE, 2009)

Analysis: The analysis step builds further on the inventory phase by analyzing the most promising energy options in terms of expected energy/CO_2–reductions, required investments, and energy costs for inhabitants. Also the analysis study will address issues like security of energy supply and the flexibility of each concept with regard to future changes in the energy context.

Setting ambitions and selection of energy options: Based on the detailed analysis results the original ambitions need to be revisited, leading to either a reconfirmation of the ambition level or a down- or upwards modification of the original ambition. A broad support of the decisions reached in this phase by all stakeholders will be crucial for the further success of the project. Also a decision may be made about the most suitable combination of energy measures that can achieve the agreed ambitions at acceptable costs and that also meets the additional requirements that were formulated in the first two steps. Identification of potential bottlenecks during the following phase of implementation and possible solutions for these bottlenecks should be addressed already at this point.

Implementation: The implementation phase is of course the most important part of the process, and in many cases also one of the most challenging. This phase involves other actors with other interests than previous steps and it has its own dynamics. Several measures can be taken to help in maintaining the ambition level intact and to monitor the (intermediate) achievements.

In the project of ENPIRE, we can summarize the key points of a residential building refurbishment. Starting from the stakeholders, a good project manager and involvement of partners is essential for realizing higher ambitions. After fixed the constitution of stakeholders, a clear process is essential. The manager should make sure everybody in the process has the same focus and ambition and have interest in realizing this ambition. Financing and economic issues define what energy saving options can be seriously considered. What is should be pay attention to is that the building process to avoid mistakes in the realized buildings. In the undergoing project, especially for residential building, architects and engineers should choosing well known techniques improves the chance of realization. Voluntary agreements are acceptable as instrument to realize higher ambitions. Ambitions in the participating countries are hard to compare because of different calculation models and performance indicators. In case of renovating or building rented houses, the problem of split incentive must be solved. It has to be subject in the beginning of the process. Some projects dealt with this problem successfully. Energy studies should be focused on more aspects than energy alone. Aspects like economics (investments, financing, energy costs, raised value (in case of renovation)), indoor air quality, comfort and even social aspects should be made clear for the different partners in the process and for different possible solutions. They are important factors in the decision making process. Introduce aspects on a higher scale than the building itself (local aspects) in the earliest stages of the project. It cán provide other or better solutions for energy saving or CO_2 reduction. In most projects the focus has been on energy saving measures on building level. This means that this aspect needs extra attention.

In the other hand, since residential building is private owned, we should think about long-term effects. Investigate possibilities for different forms of exploiting the energy system. Take future regulation into account when planning new buildings over longer periods of time. Low temperature heating is a measure that makes the heating system suitable for many techniques including techniques that use renewable energy (solar, ground, et cetera).

3.4 Chapter summary

In this chapter, on the base of literature review, the research is focused on proving feasibility for improving energy conservation residential building refurbishment in urban area of China.

First of all, from the side of China, China is implementing clean energy strategy in residential building sector now. Compared with developed countries, residential building in China consumes less energy; but the built environment of residential building is worse than that of developed countries. Thanks to the improvement of technology, it is possible to reduce CO_2 emission in existing residential buildings and there were a tightening of standards, incentives and subsidies as well as moderate measures to accelerate the adoption of higher-efficiency technologies. With the international promise of CO_2 emission reduction, China has to fix the low carbon emission target in building sector which includes Using Renewable Energy, Improving energy saving measures, Reducing Primary energy consumption. Especially in residential building sector, increasing energy demand and serious air pollution urged China to adopt energy conservation technology to slow down the increase of energy consumption by residential building.

In the side of EU, more complete energy efficiency regulations had been set up in recent 20 years. EU is the first to establish low carbon urban sustainable development strategy. A series policy focused on low carbon urban development was proposed. And in building sector, Building Energy Performance Directive has been published in 2009. The complete policy covers the scope includes urban design, district plan, building design and materials productions. In order to understand better, Italy has been chosen as the example to state the policy of residential building energy use. In the meanwhile, practice of residential building energy conservation refurbishment has been taken action in EU. A successful project ----ENPIRE is introduced as good case study, there is a comprehensive the working procedure and organized well in all local projects. With the brief introduction of project ENPIRE, the comprehensive refurbishment framework is summarized and feasibility for implementing energy conservation residential building refurbishment in China had been proved.

The residential building refurbishment which aims at specific energy conservation is an emerging working method in China. Through the study of literature review, there are sufficient reasons to improve energy efficiency of residential building in China; with the technology and social development requires low carbon sustainable strategy in China; in the meanwhile, following advanced European experience, there is a mature condition to establish a comprehensive strategy and design methodology in China.

In next chapter, we will discuss about the available methodology for establishing comprehensive framework of energy conservation residential building refurbishment in urban area of China.

Chapter 4 Methodology

- WHAT ARE THE FACTORS WHICH INFLUENCE RESIDENTIAL BUILDING ENERGY CONSERVATION REFURBISHMENT?
- HOW TO CONSIDER THESE COMPLEX FACTORS IN A SYSTEMATICS WAY?
- WHAT ARE AVAILABLE ENERGY EFFICIENCY TECHNOLOGIES FOR RESIDENTIAL BUILDING REFURBISHMENT?

4 Methodology

For the conception of energy efficiency which is to be understood in relation to how to meet the specific building comfort requirements with low energy expenditure and different energy sources. Currently several different methods are used to characterize energy efficiency in the field of architecture. In Europe, the calculation of primary is very commonly used in energy consumption (Korjenic and Bednar, 2011). To calculate the primary energy need, conversion factors must exist for the conversion of a measured or calculate the energy demand into primary energy. In fact, there is multilayer factors influence building energy consumption. Building is one constitution of located city. The local climate condition, geography condition, economic budget and available technology, all of them directly impact on energy consumption of the building.

Compared with new constructions, refurbishment projects is much more complex. There are many related factors which can impact on it. When we talk about energy consumption of a building, we should think not only about city characteristic, natural and artificial conditions and the function and property of this building but also the owner and utilization status of existing building. With the help of proper analysis method and available technology, refurbishment plan could be fixed finally.

In this chapter, available methodologies would be analyzed in three aspects: data collation for existing target building which is specific characteristic of refurbishment project; analysis methodology which is helpful in fixing plan process; proper energy efficiency technology which are suitable for residential building refurbishment.

4.1 Data Collection

Data survey has crucial significance for existing building refurbishment project. Generally speaking, data of climate condition and geography condition of the city is the basic material for architecture design. For residential building, the surrounding building and transportation condition of the location should be taken into consideration during plan. And for residential building refurbishment, the data also includes energy consumption in existing building and even the inhabitants' information of the building should be investigated at the very beginning of the project. The data will be material for judging whether the existing building needs to be refurbished or not and what should be improved of existing building.

When we make refurbishment plan for an existing building, there are must be many factors which influencing the past performance of this building. Especially for an energy-efficiency refurbishment project, past energy consumption condition is the condition-prerequisite for setting energy consumption ambitions. Energy data collection should not only be concentrated in energy consumption in the building, but also thought about the urban environment for the target building.

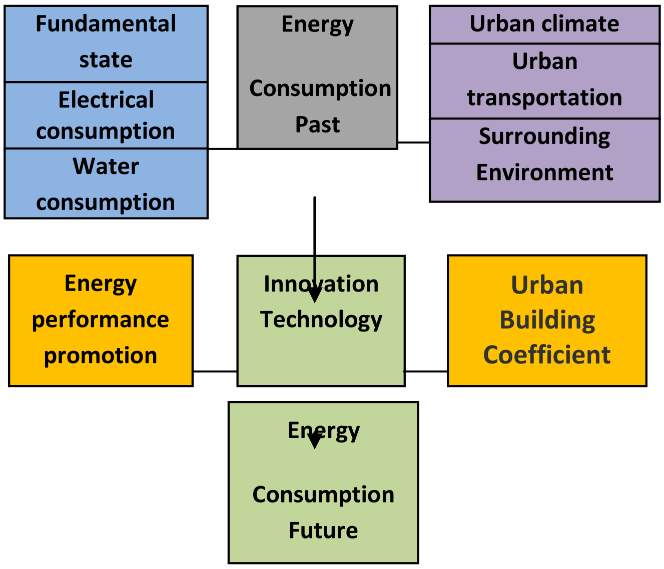


Fig. 4.1 Schematic diagram of data and refurbishment content

4.1.1 Architecture climate zones in China

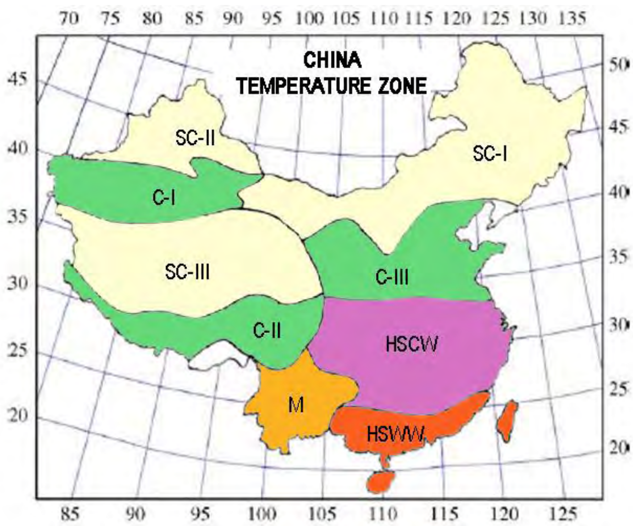


Fig. 4.2 Geographical layout of the thermal and solar climates across China (SC = severe cold, C = cold, HSCW= hot summer and cold winter, M=mild, HSWW= hot summer and warm winter)

China is the third largest country in the world while the first one is Russia and the second one is Canada. But different with Russia and Canada in which most area is scarcely populated and the bulk of population is concentrated in several zones, the distribution of Chinese population spreads extensively in the mass of China. If we compare the area of Europe and China, we can find that the area of Europe which is 10,160,000m^2 including 45 countries is similar with the area of China which is about 9,600,000m^2.

Table 4.1 Mean temperature in Architecture climate zones

Climate Zone	Mean temperature in			
	Coldest month	Hottest month	HDD ^{o} 18	CDD ^{o} 18
Sever cold	≤ -10 ^{o}C	-	3800-8000	-
Cold	-10-0 ^{o}C	-	2000-3800	100-200
HSCW	0-10 ^{o}C	25-30 ^{o}C	600-1000	50-300
HSWW	> 10^{o}C	25-29 ^{o}C	≤ 600	> 200
Mild	0-13^{o}C	18-25 ^{o}C	600-2000	≤50
Source: Lin, 2008; Huang and Deringer, 2007.				

China has an area of about 9.6 million km^2. Approximately 98% of the land area stretches between a latitude of 20^{o}N and 50^{o}N. In China, a major climate classification is for the thermal design of buildings. According to the national "*Standard of Climatic Regionalization for Architecture*" GB 50178–93 (MoC, 1994). China is divided into the following zones based on climate characteristics: Severe Cold Zone, Cold Zone, Hot Summer and Cold Winter Zone, Mild Zone and Hot Summer and Warm Winter Zone (MoC, 1993), these three climate zones takes almost 70.5% area of China. (Fig. 4.2) In the meanwhile, there is also special Paramus zone like Tibetan Plateau.

China covers a vast geographical area, and the temperature difference from the north to south is very large, especially in winter. In general, the average monthly temperature in China in January is 10–18 ˚C lower than that of other areas of the world at the same latitude; in July, the average monthly temperature is 1.3–2.5 degrees higher than those other areas.

Air conditioning and heating requirements for different zones are as follows: in the very cold zone, the major requirement is heating, and few residential buildings are equipped with air conditioning. In the cold zone, the primary requirement is heating, followed by air conditioning. In the hot summer and cold winter zone, both air conditioning and heating are needed. In the hot summer and warm winter zone, the major requirement is air conditioning, and few residential buildings require heating. In some parts of the moderate zone, heating is needed; in other parts, both heating and air conditioning are needed. The availability of heating and air conditioning depends on several factors, including the degree of economic development in an area, the availability of energy supplies, and requirements for environmental protection.

Currently, the main renewable energy resources utilized in China are wind power, solar power, hydropower and biomass. It is noticed that no matter what kind of renewable energy, its reserves distribution are geographically unbalanced. Fig. 4.3 shows the wind energy resources distribution in China, from which it can be judged that the wind energy sources of China are mainly located in the north west provinces, the plain sand deserts of Inner Mongolia, the southwest and northeast mountain areas and a few coastal regions. The Northeast, North China and Northwest are the richest wind energy areas with flat terrains for the wind farms, convenient transportation and no destructive wind velocity. It is the largest tract of land with wind energy sources which is suitable for building large scale wind farms (Wang and Yuan, et al., 2010).

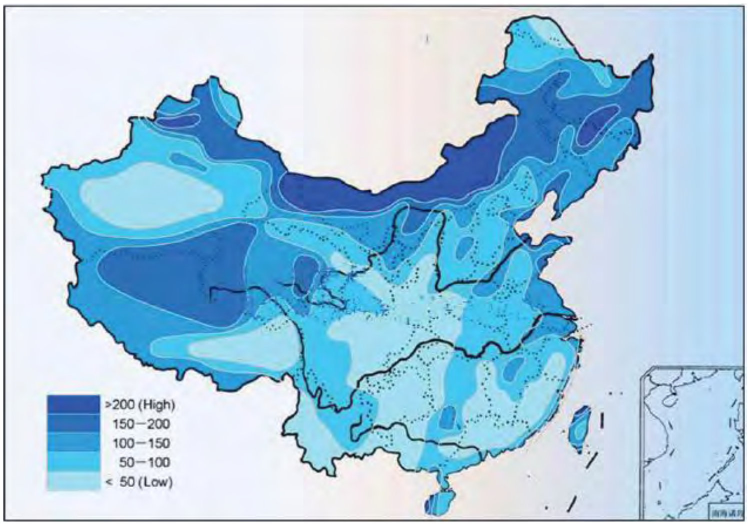


Fig. 4.3 Distribution of Effective Wind Power Density in China. (Unit: W/m^2) (CWSERA, 2010)

The maximum solar altitudes vary considerably and there is a large diversity in climates, especially the temperature distribution during winter. China also has a complex topography ranging from mountainous regions to flat plains. These diversities and complexities have led to many different climates with distinct climatic features. In south China, like Leizhou Peninsula, Hainan, Taiwan and south part of Yunnan, the weather is rainy and with high temperature all over the year without winter. In zones along Changjiang river and Huanghe river, the weather is good and with four distinctive seasons. But in the north of China, like Heilongjiang, the weather is cold and snowy. Most of north-west of China, the weather is dry and with cold winter and hot summer. In the gorges area in south-west, there are several different climates from hot-humidly to high-cold.

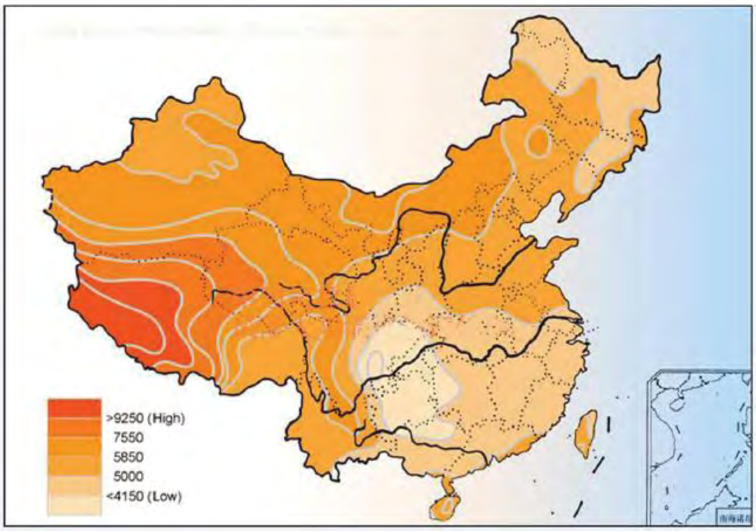


Fig. 4.4 Distribution of Effective Solar Power Density in China. (Unit: W/m^2) (CWSERA, 2010)

Fig 4.4 displays the solar energy resources distribution in China. Generally speaking, the solar resource is abundant in China, but greatly diverse in various areas. The regions that have the richest solar energy resource are Tibet, Qinghai, Xinjiang, the South of Ningxia, Gansu and Inner Mongolia, while the southeast part of China is poor in solar energy. The direct normal solar radiation ranges from less than 2 kWh/ (m^2•day) in part of the southeast to more than 9 kWh/ (m^2•day) in part of the west (Qu et al., 2008). The total amount of potential hydropower in China is abundant; however, the distribution is uneven and not matched with economic development.

We can summarize three characters of China climate:

- The annual and daily temperature difference is obvious, the temperature different of winter and summer;
- Uneven precipitation is too serious that is reducing from southeast to northwest and the cooperation is 40:1, precipitation in winter is quite less than summer;

- Alternation of wind direction by seasons is obviously. In winter north cold wind comes from high latitude zones landmass is frigid and dry while south wind comes from ocean is warm and wet in summer.

4.1.2 Urban Building Coefficients

There are various ways to classify climate types or zones according to different criteria using different climatic variables and indices. This depends largely on the purpose of establishing such classification. Olgyay, in his work on the influence of climate on building design principles and the architectural similarities around the world, had suggested four main climate types, namely cool, temperate, hot and arid, and hot and humid in the early 1960s (Olgyay, 1992). Later also on a worldwide basis, Givoni specified four major climates—hot, warm-temperate, cool-temperate and cold with 11 sub-climate types. The emphasis was on the influences of climatic characteristics onhumancomfort as well as the thermal response of buildings (Givoni, 1976). Recently, there had also been attempts to develop human bioclimatic atlas/zones for Mexico (Morillón-Gálvez et al., 2004) and India (Singjh et al., 2007).

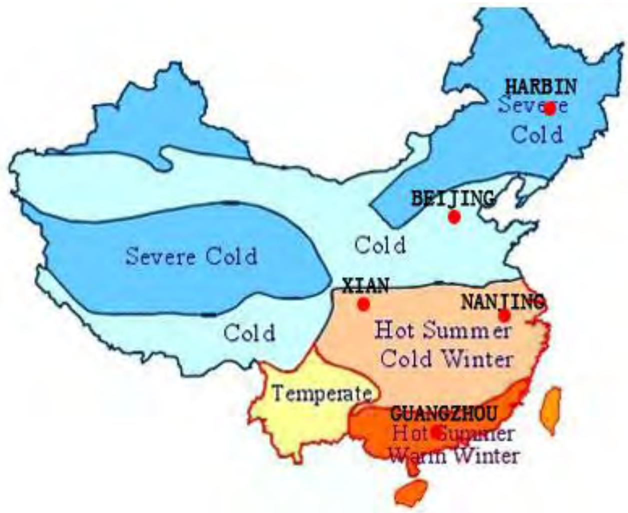


Fig. 4.5 Selected cities in China

Fig. 4.5 shows the geographical distribution of the five major climates. Five corresponding cities, ***Harbin, Beijing, Nanjing, Xi'an*** and ***Guangzhou***, are represented the five climate zones respectively. The five cities were chosen to represent China's three main climate zones, which range from a northern temperate zone to a southern subtropical zone. The two northern cities of Harbin and Beijing experience long, cold winters, typically coldest from November to February. Summers are short but hot. Winter in the

Yangzi Valley cities like Nanjing of central China is milder and shorter, coldest in December and January, but summers are hot and humid. Xi'an is located in the center of China and has clear four seasons. Although Xi'an and Nanjing are both in the hot summer and cold winter zone, the temperature in Xi'an is much colder than coastal cities like Nanjing. Guangzhou's location on the Tropic of Cancer provides for almost no winter, and an extremely long, hot, and humid summertime (Table 4.2). Climatic differences are reflected in air-conditioner ownership and usage patterns and in the use of wall and window insulation.

Table 4.2 Relevant climate information of five cities in China

	Beijing				Harbin				Xi'an				Nanjing				Guangzhou			
Month	Avg. High °C	Avg. Low °C	Avg. Precip mm	Humidity	Avg. High °C	Avg. Low °C	Avg. Precip mm	Humidity	Avg. High °C	Avg. Low °C	Avg. Precip mm	Humidity	Avg. High °C	Avg. Low °C	Avg. Precip mm	Humidity	Avg. High °C	Avg. Low °C	Avg. Precip mm	Humidity
Jan	1.8	-8.4	2.7	44	-12.3	-23.9	3.4	72	4.8	-3.8	6.9	66	7.0	-1.1	37.4	74	18.3	10.3	40.9	72
Feb	5.0	-5.6	4.9	44	-7.1	-19.8	5.3	68	8.3	-1.1	9.6	63	8.8	0.6	47.1	77	18.5	11.7	69.4	68
Mar	11.6	-0.4	8.3	46	2.5	-9.5	9.7	56	13.9	3.6	28.6	66	13.4	4.8	81.8	70	21.6	15.2	84.7	56
Apr	20.3	7.9	21.2	46	13.6	0.5	18.4	49	21.0	9.5	43.0	68	20.3	10.6	73.4	72	25.7	19.5	201.2	49
May	26.0	13.6	34.2	53	21.2	7.9	40.4	51	26.1	14.2	60.2	68	25.6	15.9	102.1	74	29.3	22.7	283.7	51
June	30.2	18.8	78.1	61	26.0	14.6	84.4	65	31.2	19.2	54.4	62	28.8	20.7	193.4	76	31.5	24.8	276.2	65
July	30.9	22.0	185.2	75	28.0	18.3	142.7	77	32.1	21.9	98.6	71	31.9	24.6	185.5	80	32.8	25.5	232.5	77
Aug	29.7	20.8	159.7	77	26.3	16.2	121.2	78	30.6	20.9	70.8	75	31.7	24.2	129.2	79	32.7	25.4	227	78
Sep	25.8	14.8	45.5	68	20.7	8.7	57.6	70	25.3	15.9	91.6	79	27.3	19.2	72.1	78	31.5	24.0	166.2	70
Oct	19.1	7.9	21.8	61	11.7	0.1	25.9	63	19.5	9.9	59.9	77	22.2	12.9	65.1	71	28.8	20.8	87.3	63
Nov	10.1	0.0	7.4	57	-0.1	-10.1	9.6	65	12.2	2.9	23.9	74	15.9	6.1	50.8	71	24.5	15.9	35.4	65
Dec	3.7	-5.8	2.8	49	-9.4	-19.8	5.8	71	6.4	-2.5	5.8	69	10.0	0.4	24.4	76	20.6	11.5	31.6	71

Beijing, Nanjing, and Guangzhou are China's leading metropolises. Beijing is China's capital, home to top government and educational organizations, and is generally regarded as somewhat culturally and politically conservative. Nanjing which is similar with Shanghai has traditionally been China's most outward-looking city and has a long history of international trade and commerce. It is in the economic center of the "Golden Delta" region of the Lower Yangzi river. Guangzhou, near Hong Kong, is South China's commercial and financial center and capital of Guangdong province, from which the majority of overseas Chinese derive. These ties strengthen Guangzhou's traditional focus on business over politics. Harbin is in the heart of Northeast China's declining industrial belt, where first the Russian, then Japanese, then later the Chinese with Soviet assistance, built an extensive array of heavy industries reliant on the plentiful raw materials in the Northeast. Xi'an is famous and historic city which was set as capital cities six times in the past thousand years. It's one of the cradle of Chinese culture and even in the nowadays Xi'an is the most important city in west China.

As shown in Table 4.2, here is the general information of these five cities. We can see that the climate of these five cities is different from each other. From north to south, the warm period lasts longer and longer while the precipitation is more and more. In China, most cities concentrated in east half because west part is unsuited for human living and the geography condition is complex. When we make a building design project, we should learn about the basic condition of this city.

Table 4.3 relevant climate information of selected Chinese cities and European cities

	Copenhagen Denmark	Turin Italy	Berlin Germany	Paris France	Madrid Spain	Beijing China	Harbin China	Xi'an China	Nanjing China	Guangzhou China
Latitude	55°40'N	45°04' N	52°27'N	48°49'N	40°23'N	39°54'N	45°04'N	32°16'N	32°03'N	23°08'N
Avg. High °C	**11.1**	**16.8**	**13.4**	**15.5**	**19.4**	**17.9**	**10.1**	**19.3**	**20.2**	**26.3**
Avg. Low °C	**5.0**	**6.5**	**9.6**	**8.5**	**9.7**	**7.2**	**-1.4**	**9.2**	**11.6**	**18.9**
Precipitation mm	**613**	**914.4**	**571**	**649.6**	**43.6**	**571.8**	**524.4**	**513.3**	**1062.3**	**1736.1**
Avg. humidity %	**79**	**74.8**	**80.8**	**78.1**	**61.8**	**56.8**	**65.6**	**69.8**	**76.4**	**77.5**
Sunshine hours	**1,539**	**1.990.4**	**1,625.6**	**1,630**	**2,769**	**2670.8**	**2,571.2**	**1646**	**1,982.8**	**1628**

If we make a comparison with European city, it would more clearly for us to understand the complex geography condition in China. (Table 4.3) The country area of China is close to area of Europe, but the geography condition of China is more complex than that of Europe. Consider about the latitude and climate characteristics, it's very similar that of these five Chinese cities and some European cities. From the information of Table 4.4, it's easier for us to understand the climate condition of selected cities in China.

But when we talk about the city scale, usually, cities in China are much bigger than cities in other parts of the world. It's determined by the huge population of China. In Table 4.4, we can find living condition characteristics of these five cities in China. Because of supervision of national information is more strictly in China, we can't get complete information recent years, but it is sure that the urban development in Chinese cities is quite fast after 2000, the current status of residence in cities is even worse than that in Table 4.4. In this stage, the development of Chinese cities is quite unbalance. As we know, in mainland of China, there are 23 provinces and five municipality directly under the Central Government (Beijing, Tianjin, Shanghai, Chongqing and Shenzhen) and five municipalities (Guangxi Zhuang Autonomous Region, Inter-Mongolia, Tibet, the Ningxia Hui Autonomous Region, the Xinjiang Uygur Autonomous Region). Beijing and

Shanghai are two mega cities and there are around 80 big cities which the population is around 500,000 and 1,000,000. On the side, there are also more than 200 middle cities which population is more than 200.000 and less than 500,000 and more than 300 small cities which population is between 50,000 and 200,000. Most of these middle and small cities are new settled cities since 1980s. So in this paper, we focus our attention to the big cities and mega cities which have a lot of buildings which are needed to be refurbished but not these new settled cities.

Table 4.4 Characteristics of living condition

	Beijing	Harbin	Guangzhou	Xian	Nanjing
City area (sq.km)	16,410	4,187	3,843	3,782	4,730
Urban area(sq.km)	1,454	458	670	600	782
Urban population(thousand)	14918	4775	10350	8434	5412
Temp Annual Avg°C(°F)	13.1	3.3	22.8	14.1	15.7
Density(persons/mi2)	1171	183.5	1459.2	826.6	929
Per capita GDP(yuan)	63,029	24,700	81,233	21,300	50,327
Avg Living Space per person(m^2)	19.4	19.5	20.8	28.51	22.7
Average People per Household	2.94	3.01	3.04	2.71	2.68
Average Age of Residents	38	40	37	39	37
Average of Income	30673	17448	32681	17751	28278
Average Year Moved In	1986	1988	1991	1987	1989
Average Number of Rooms	2.86	3.01	3.08	3.11	3.01
Average Floor Space(m^2)	56.9	58.4	63.2	68.5	57.8
Average wind speed(m/s)	2.36	3.5	1.7	1.6	3.1
Source: China Statistical Yearbook; Web of local statistical bureau. Data valid time: 2000-2004					

4.1.3 Energy Consumption of Residential Building

Building energy consumption data cover numerous end uses, including air conditioning, heating, lighting, appliances, cooking, domestic hot water, and others. However, heating and air conditioning account for the largest share of residential energy consumption. Along with China's economic development, energy consumption has increased rapidly. The energy efficiency goal for residential buildings in China is to reduce the energy consumed for air conditioning and heating while maintaining comfortable indoor thermal environments.

In residential building, energy use composition depends on climate of the local city and living mode of the inhabitants. Generally speaking, the energy can be categorized by typology: electricity, water, coal, gas, sometimes there are few buildings even use wood for cooking.

4.1.3.1 Energy use composition

When the building energy data is expressed, the corresponding boundary of building energy consumption should be pointed out.

There could be four boundaries of building energy consumption considering energy flow in buildings when it is being used. The four boundaries are:

ED---- Energy delivered to the energy exchange system outside the building, it refers to the energy delivered to the energy exchange system and transport system outside the building (such as all kinds of generating systems, central heating systems, central cooling systems etc.) that serves the building, for instance, coal, oil, gas, biomass, wind, solar, waste heat and so on.

ET---- Energy transferred into building for technical system, it refers to the energy that is transferred into building and used for technical systems (like coal, oil, gas and electricity, hot water, steam, cold water etc.).

ER---- Energy provided by the renewable energy system integrated in the building for the technical system, It refers to the energy used for the building energy system that is provided by renewable energy usage and exchange systems (for example solar photovoltaic, solar thermal, wind power equipment and so on) which are combined with the building itself.

EB---- Energy for building end use**,** it refers to the energy supplied to cover the actual needs and input into the building by all kinds of terminal equipment. The energy for building end use boundary is used to express all the kinds of activities' actually getting energy in the building. The energy loss during energy exchange and transfer is not considered when types of energy in the building are measured on the energy for building end use boundary.

For building heating, cooling and hot water, the expressed energy consumption on the energy for building end use boundary refers to the actual heat or cold used for the building area or human activities that is provided by heating, cooling and hot water systems. The type of building energy has nothing to do with the system form. For cooking, lighting, life/working equipment, elevator, fans, building service, sub room and other special functional equipment, the energy consumption is expressed on the energy transferred into building for technical system and energy provided by the renewable energy system integrated in the building for the technical system boundary, not the EB boundary.

4.1.3.2 Building energy end-use

But when we think the energy efficiency in the architecture view, usually the energy for building end use is the key point. For residential buildings, the energy usages can be categorized as the following types:

- **Heating energy delivered into the building space,** it refers to the actual heat input into the building to maintain thermal comfort by all kinds of terminal equipment of the heating system.
- **Cooling energy delivered into the building space**, it refers to the actual cooling energy input into the building to maintain thermal comfort by all kinds of terminal equipment of cooling system.
- **Heating energy delivered to domestic hot water**, it refers to the actual heat needed to raise the water temperature from the tap water temperature to provide domestic hot water by all kinds of terminal equipment of the heating system.
- **Energy for fans**, it refers to the energy consumed by all the mechanical ventilation fans inside the building which includes electricity consumed by all the blowers, back fans, exhaust fans and kitchen exhausts, toilet exhausts, garage ventilation fans inside of air handling units, fresh air handling units, fan coil units and other equipment. In residential building, it refers to air conditioner, kitchen and toilet exhausts.
- **Energy for cooking**, it refers to the energy provided to the lighting system inside the building in order to meet indoor people’s demands for food processing.
- **Energy for lighting**, it refers to the electricity that is consumed by lighting fixtures and accessories (including ballast) in order to meet human requirements for illumination, including indoor lighting and facade lighting.
    - **Energy for indoor lighting,** the electricity consumed to keep the inside building lighting requirements which includes normal lighting, emergency lighting and duty lighting etc.
    - **Energy for public space,** landscape lighting is the electricity that is consumed by landscape lighting for outdoor public areas if there is an exterior surface lighting system.

- **Energy for household**, it refers to the electricity and energy consumed by functional equipment in the building which includes all kinds of equipment that gets power from adapters like PC, printers, drinking fountains, fridge, TV, table lamps and other home appliances and working equipment.
- **Energy for elevators**, it refers to the electricity that is consumed by the elevators and their supporting equipment (like elevator ACs, fans in the elevator sub rooms and ACs in the building). In China, elevators only exist in new buildings more than 7 stories.
- **Energy for devices in the information station**, it refers to all kinds of service equipment and systems in the building, such as electricity of water pressure pumps, sewage pumps, water pumps etc. and electricity of distribution transformers.
- **Energy for building auxiliary equipment**, it refers to all kinds of service equipment and systems in the building, such as electricity of water pressure pumps, sewage pumps, water pumps etc. and electricity of distribution transformers.
- **Energy for other special functional equipment**, it refers to the energy that is consumed by building medical equipment, laundry room, swimming pool and other special function equipment.

Table 4.5 Residential building energy consumption by End-use

Heating	Heating system supply	kWh/m^2 kWh/ annual
	Energy transferred into building	
Cooling	Cooling system supply	kWh/m^2 kWh/ annual
	Energy transferred into building	
Lighting	Public space	kWh/ annual
	Indoor	
Cooking		MJ /annual household
Domestic water heating		Mj/annual household
Household appliances	TV	kWh/ annual household
	Fridge	
	Washing machine	
	PC	
	Other	
AC		kWh/ annual
Building equipment		kWh/ annual
Other use		kWh/ annual

For a refurbishment project, we have to survey the energy consumption in this building before refurbished. Table 4.5 showed the general residential building energy consumption by end-use. For each building, the description of the existing condition, is based on information about the location, surrounding environment, envelope, shading devices, systems for space and domestic water heating, heating and electrical consumption as well as prevailing indoor thermal comfort conditions. Information about location, surrounding environment, envelope, shading devices, systems for space and domestic water heating, are based on the observations made by the investigation in the preparing step. Information about energy consumption result from the energy bills during a whole year, for fuel consumption, electricity consumption in apartments and electricity consumption in common used spaces of the building. The indoor thermal conditions are grouped in three qualitative categories acceptable, average and not acceptable, resulting from the occupants' response to the questionnaire or their interaction with the researchers. More specific, typical heating energy consumption for residential buildings is 20.1W/m^2 in north China. Typical electrical energy consumption for residential buildings is 30kWh/m^2 for all regions. (Jiao and Wang, 2007) The energy behavior of the building (heating and electrical) is characterized as good, average and bad, for low, average and high consumption, respectively, based on the typical consumption of residential buildings in the corresponding climatic zone. The feeling of inhabitants for energy performance is an important requirement for refurbishment.

4.1.3.3 Calculation Mode

Residential energy demand is shaped by a variety of factors, including location (in both geographic location and urban vs. rural) and climate. In developing countries such as China, it is important to divide households into rural and urban locales due to the different energy consumption patterns found in these locations. Within the locales, end uses were broken out into space heating, air conditioning, appliances, cooking and water heating, lighting, and a residual category.

The Ernest Orlando Lawrence Berkeley National Laboratory made a lot of effort on research of building energy consumption in China. In the publication of <Current Status and Future Scenarios of Residential Building Energy Consumption in China >, the equation for energy consumption in residential buildings can be summarized as follows:

$$E_{RB} = \sum_{i}^{OPTION} \sum_{m}^{OPTION} \frac{P_{m,i}}{F_{m,i}} \times \left[\left(H_{m,i} \times \left(SH_{m,i}\right)\right) + \left(\sum_{j} p_{i,j,m} \times UEC_{i,j,m} \right) + C_{m,i} + W_{m,i} + L_m + R_m \right]$$

In addition to the variables listed above:

m = locale type (urban, rural)

$P_{m,i}$ *= population in locale m in region i*

$F_{m,i}$ *= number of persons per household (family) in locale m in region i,*

$H_{m,i}$ *= average floor area per household in locale type m in region i in* m^2

SH_i *= space heating energy intensity in residential buildings in region i in kWh/*m^2*-year,*

j = type of appliance or end-use device,

$p_{i,j}$ *= penetration of appliance or device j in region i in percent of households owning appliance*

(values in excess of 100% would indicate more than one device per household on average),

$UEC_{i,j}$ *= energy intensity of appliance j in region i in MJ or kWh/year,*

C_i *= cooking energy use per household in region i in MJ /household-year,*

W_i *= water heating energy use per household in region i in MJ /household-year,*

L_m *= average lighting energy use per square meter in locale type i in kWh /square meter-year*

R_m *= residual household energy use in locale type i in MJ /household-year.*

Here we list this equation just to help to understand energy consumption calculation in data collection progress. From the table 4.5, we know that the energy consumption of target existing building is related with not only single building or household, but also the energy supply and consume system of the building and residential community. With the data collection result, architects can analyze energy consumption condition of target building and select proper energy options for energy efficiency.

4.2 Analyzing method

Obviously, there are sufficient impetus and basis to refurbish energy performance of existing residential building in China, no matter from the viewpoints of culture, economy, politics, society and resource reserves. While there is still a huge gap need to be bridged between governmental politic ambitions and economic limit of populace. Human-imposed threat to residential building environment has two fundamental dimensions: population growth and the ever-increasing per capita demand for goods and services, particularly material needs and energy. Today, 75% of the population in industrialized countries lives in urbanized area, which is the goal of all developing countries, especially China, in not so far future. Cities are centers of high living standards supported by huge consumption of fossil-based energy. Being the principal contributors of GHG emission and root causes of the global sustainability problem, cities should take the foremost responsibility of relieving climate change threat through carbon reduction and energy efficiency increase. Hence, residential building, which is the basic contained space for human living, should be the “protagonist” of the urban plan and building design in the development of the city rather than “supporting role”.

Since the specifics of residential building, refurbishment should be a balanced result by influence of the constraint. Thus, the factors which could influence the residential refurbishment design, comprehensive evaluation system for residential building refurbishment in China could be help in energy plan decision process. In this section, we will analyze complex situation of residential building refurbishment in China and introduce some methodologies which could be implemented in analysis in decision-making period.

4.2.1 Traditional respect to energy conservation for residential building

The complexity of residential building refurbishment in China is related to urban plan progress and local architectural design development. Modern urban development is started in Europe and expanded in China in recent 30 years. The irrational development caused a serious problem. Compared with the gradually residential refurbishment in European cities, the residential building refurbishment in Chinese cities is urgent issue which should be solved in short time. Residential building in Chinese cities has responsibility to improve energy efficiency and developed in sustainable way.

As cultural heritages, Chinese traditions are generally believed by many scholars as conducive to ecologically sensitive behaviors which suggest a relationship between people and nature resonant of contemporary environmental ideals (Jenkins, 1998). In contrast with the modern environmentally destructive tendencies in science, economics and public policy which have deeply historical roots in Western religious and philosophical traditions, Chinese traditions offer conceptual resources for ecological thinking by placing economics within a wider socio-ecological fabric, emphasizing soft technologies and encouraging systemic wisdom (Jenkins, 2002).

Three ancient Chinese traditional c*hiao*: Confucianism, Daoism and Buddhism commonly emphasize respect for others, social harmony, interconnectedness with nature and the Earth (Liu and Constable, 2010). While *chiao* can refer to bodies of doctrine and is sometimes translated as ‘religion’, it is better rendered as ‘moral teaching’ (Bodde, 1957) since it is also used secularly for systems of ethical social behaviors (Hu, 1934; Bodde, 1991). Confucianism emphasizes companionship with the world, compassion towards people and living things. Although principally confined to human social questions rather than related to an analysis of nature or specific statements of environmental awareness, Confucianism yields resources for ecological thinking by recognizing ‘continuity of being’ (Tu, 1998) and nature as a background moral force which could be regarded as a primitive think about sustainable development. *Tao* is often translated as ‘way’, understating the complex philosophical and spiritual nature of Taoism’s quest for nature’s order and the universe’s immanent power. The core principle of Taoist is *wu-wei*, often translated as ‘non-action’, but better seen as ‘action which does not go against the grain of nature’ (Needham, 1956). For Taoism, the natural world is not an external utilitarian resource to be controlled and exploited, but a dynamic process within which harmonization is a liberating abstraction from the competitive striving of everyday human existence (*tian ren he yi*). According to Daoism, humans should attach great importance to the environment and live with the Earth’s rhythms. Chinese Buddhism was enriched by Chinese indigenous culture, integrating the ideas of Confucianism, Daoism and other philosophical systems. Chinese Buddhism emphasizes the value of all life and the interconnectedness of people and the natural environment, which teaches its adherents to cultivate a way of life that is in harmony with the natural world (Yu, 2011).

The enlightenment by the traditional religions still influence the attitudes and actions of current Chinese populations in many aspects, such as building design, energy use and traffic choice. In most area of China, the direction of main façade of residential buildings is suggested towards South by national legislation and local regulations not only because the sunlight but also deeply influenced by *fengshui*. The good direction brings sufficient sunshine to buildings especially in winter time, by which the requirement of heating will be largely lessened in daytime. Natural ventilation of buildings is also required by the national legislation. Till now, most of Chinese families are accustomed to drying the wet clothes by sunshine and natural ventilation, different from using drying machine in many developed countries that is one of the main reasons that electricity energy consumption in Chinese cities is much lower than that of developed countries. Although there are absent of exact parameters about comparison of residential energy use habitats between China and other countries, we can still judge Chinese habitats through the research on countries with similar culture background, like Japan. Wilhite, Nakagami and their colleagues had made a deep interview on the comparison of residential energy use between Japan and Norway (Wilhite et. al, 1996). They found Japanese space heat and light habits are more disciplined and less culturally than the Norwegian home. An important background is that the two investigated cities have similar infrastructures and their living standards are compatible.

The concepts of energy conservation and environment protection are generally recognized in China nowadays. But with the development of economic and society and influenced by globalization, the differences of lifestyle between Chinese inhabitants in city, especially young people, and that of developed countries is becoming less. There are some new demands for residential building in urban area. Such like more utilization of artificial facilities at home; higher demand for indoor environment comfort level like temperature, humidity, light and sound etc.; more attention of outdoor environment of residential community etc. Energy efficiency is an issue attracted more and more attention in Chinese family. When we make a judgment of energy performance of existing residential buildings in urban area, the criterions are different from that of before. With the improvement of humanization demand, energy performance of existing residential buildings should be refurbished to direction of sustainable development.

4.2.2 Comprehensive analysis system for residential building refurbishment project

Energy conservation plan for residential building refurbishment is a nature – society balance combination artificial system with multi-level and multi-factors. The factors like economic, society, and environment are intrinsically connected and complementary effects. For residential building refurbishment, operation of existing buildings, surrounding environment and inhabitants are also influence factors should be considered of. When making feasibility study and fixing refurbishment measures, all of these complex factors should be analyzed from different aspects. Comprehensive analysis system should be used to evaluate and balance benefit and cost of the whole project for achieving energy conservation effect.

Factors affecting residential building refurbishment could be summarized as:

- **Economic factor**: economic has direct relation with building design especially with residential building. Energy consumption cost and family income will play important role in decision.
    - *Energy price:* energy price for heating, cooling, electricity, water and gas would be an important reference indicator for energy consumption structure in household. In urban are of China, most family would like use gas for cooking because the cost is lower than electricity. The cost for winter heating in northern China of residential building is kept increasing because of increase of coal price. In this background, people pay more attention on energy price than before.
    - *Family income:* in a certain context, residential building is the mirror of family's income in the city. Usually, people who live in existing buildings built 30 years ago are low or middle income group in the city. For these groups, it's impossible to buy new apartment in the city, economic cost and benefit of refurbishment is an important factor for refurbishment project.

- **Built environment**: compared with public buildings, built environment for residential building is more important because it is related with everybody's normal life. For existing residential building, the built environment is not good enough because of obsolescence of the building envelope and not humanized design.
    - *Indoor temperature:* temperature is the most direct indicator for evaluating built environment of residential building. In northern China, the minimal indoor temperature in heating period is 18^{o}C, but human ideal temperature is over 20 ^{o}C. In summer, indoor temperature should be convenient for human living. However, if thermal insulation performance of existing residential building could not meet the requirement of inhabitants, such like low or high

temperature, thermal bridge, the existing building is needed to be refurbished.

- *Indoor humidity:* similar with temperature, humidity could influence comfort level of built environment. Cold or hot wind infliction and rain penetration caused would decrease indoor comfort level. Refurbishment should be made in building envelope.
- *Noise:* noise pollution is a serious disturbance in residential building. Effective retrofit measure would decrease outdoor noise and indoor noise interaction.
- *Light:* for residential building, natural light is the first choice since health and economic reason. Artificial light would be the addition for creating convenient indoor light environment.
- *Functional continent:* original building design is fixed on the requirement decades years ago, not only structure but also internal space organization could not meet the requirement which is improved with society improvement and change of family members. So in some cases, functional space should be improved in refurbishment.
- *Outdoor green leisure spaces:* this is a key-point in new residential building design but neglected in existing residential buildings. Outdoor green leisure space could be used with inhabitants' communication and sport. A good outdoor green leisure space is a strong guarantee for improving residential building built environment.

- **Transportation:** transportation accessibility representatives the connection of residential building with local surrounding environment. In refurbishment plan, transportation is a factor which should be considered of. Nowadays, the ownership of private car in China is increasing and car and public transportation have been replaced the role of bicycle in China. Traffic plan in residential community and parking area location are new demand for refurbishment plan.
- **Low carbon emission**: It is evident that urbanization is both an outcome and driver of global and environmental change through the interaction of cities with the Earth System. Around 80% of the GHG emissions that affect the climate are related to urban activity (MunichRe, 2004). Reducing carbon emission is a main aim of energy conservation refurbishment for existing residential building in China.
    - *Clean energy:* renewable energy is encouraged to use in residential building. For example, solar energy is a free and useful energy could be implemented in residential building in many countries.

- *Energy efficiency:* improvement of energy efficiency is the best way to get economic and energy benefit. With innovation technology, the requirement of energy efficiency retrofit is improved in many existing residential buildings.

- **House property:** the operation of maintenance for residential building and investment for refurbishment is depended on ownership of house property. Different stakeholders such like inhabitants, public institutions would consider the refurbishment in different views.
- **Policy support:** national and local policy support for energy efficiency measures, for low carbon emission development and for clean energy utilization would strongly improve the implementation of residential refurbishment.
- **Local humanity and culture:** existing building is located in developed urban district, the influence of local humanity and culture would be considered in refurbishment.

So, these facts taken together, comprehensive analysis system for residential building refurbishment project should be established at the very beginning of the project. The analysis is needed in preliminary feasibility study, discussion energy conservation ambitions, refurbishment plan selection step. We have to summarize these complex influence factors into several aspects and the judgment should be taken by different stakeholders who are involved in this project. In general, the influence factor for an existing residential building refurbishment project could be considered from three aspects:

- **Environment:** includes indoor and outdoor built environment. It is mainly refers the built environment in where the people live and feel directly. In modern cities, there are regulations and standards for ruling the lower limit of living environment criteria. For professionals, we should try to create a comfort living environment for inhabitants.
- **Energy:** includes ED, ET, ER, EB we mentioned in section 4.1.3.1. In a refurbishment project, we should try to reducing energy consumption while keeping or improving comfort of environment.
- **Economic:** includes two parts: cost for energy consumption in residential building (long-term) and cost for refurbish construction (one-off). Financial mode of a refurbishment project is an important factor and all stakeholders are presuming low cost and much saving.

4.2.3 Integrating AHP and ANP analytic network process

There are two possible ways to learn about anything – an object, a feeling or an idea. The first is to examine and study it in itself to the extent that it has various properties, synthesize the findings and draw conclusions from such observations about it. The second is to study that entity relative to other similar entities and relate it to them by making comparisons (Saaty, 2008). We need to explicit the idea that we can judge the benefit and lose and find the balance for supporting decision.

Systematic analysis methodology could be used in analysis process to help to fix a proper plan. AHP (Analytic Hierarchy Process) and ANP (Analytic Network Process) are two feasible analysis methodologies could be used for residential building refurbishment project. These analysis methodologies are used in building evaluation field in China, but in refurbishment projects, they are not yet been used well. Since our topic is setting up innovation energy conservation, rather than deep research about analysis methodology, we will make general introduce of feasible methodology analyze how to use them for residential building refurbishment.

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The basic principle of AHP is separating one complex problem into single factors and groups these factors in government, forcing them forming step by step structure in order. Comparison is made between each two factors to fix importance of each factor and judging the weight of each factor. (Fig 4.6)

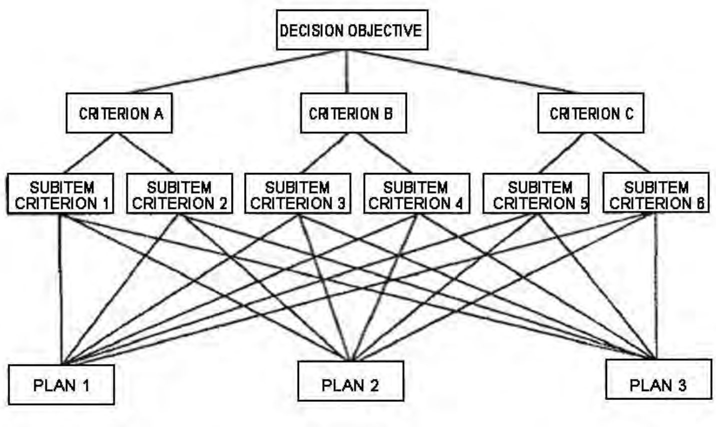


Fig. 4.6 Hierarchy analysis structure of AHP

To make comparisons, we can set a series of numbers that represents how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. (Table 4.6) The judgment should be made by selected representatives of related stakeholders. The result number reflects the weight of each plan, by comparing the weight, complex influence factors could be coordinated to make the decision.

Table 4.6 The fundamental scale of absolute numbers (Saaty, 2008)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

We fix the evaluation of issue which needed to be analyzed in a residential building refurbishment as the final aim ---- A level, the influence factors could be divided into four aspects: economic, built environment, Energy efficiency and Territoriality, these four constitute second level ----B level. Thus, there are several sub-factors in each aspect which represents factors in details----C level. Of course, there could be D or E level divided in hierarchy. The lower hierarchy in the system reflects factors more detailed. (Table 4.7)

Table 4.7 Core factor sets by AHP method for residential building refurbishment

A	B	C	D
EXISTING RESIDENCIAL BUILDING REFURBISHMENT	Economic	Total cost in utilization period of the building after refurbishment	Cost for refurbishment
			Cost for monitoring and maintenance
			Cost reduction by energy-saving
		Investment resource	Household income
			Property structure
		Technical support	Cost of technical measures
			Policy support for cost reduction
	Built environment	Outdoor environment	Green space
			Parking positions
			Transportation accessibility
		Indoor environment	Physical comfort
			Function organization
			Municipal facility modernization
	Energy efficiency	Low carbon emission	CO_2 reduction by energy efficiency measures
			CO_2 emission by refurbishment construction
			Clean energy utilization
		Material consumption	Consumption for building retrofitting
			Consumption for energy efficiency measures
	Territoriality	Architecture context	Architecture identifiability
			Harmoniousness with district and city
		City plan	Active improvement of urban function
			Coordinating multi participation

The ANP (Analytic Network Process) is an innovative technique, widely experimented in the United States in several contexts, from the company one to the military one, not so well known in China and not yet used.

Such a technique, elaborated by the mathematician Thomas L. Saaty, is able to consider a multiplicity of quantitative-qualitative criteria according to a network model and it is particularly indicated when it is in presence of problems and complex systems, characterized by dependencies and interactions.

The application of a methodology of this type has been demonstrated to be very useful for the evaluation of the pre-feasibility of scenarios of urban and territorial transformation, thanks to its capacity to consider all the interactions between the elements constituting the decisional problem. (Girdano, 2010) The theoretical essential requirement on which the ANP departs is based on the consideration that many decisional problems may not be structured in a hierarchic manner because they provide interactions and dependencies between the decisional elements. It can be affirmed that in a determined situation there is not only the importance of the criteria determining the importance of the alternatives, as in a hierarchy, but that the importance of the alternatives influence and determine the importance of the criteria.

Series of pairwise comparisons are made to establish the relative importance of the different elements with respect to a certain component of the network. Comparative or relative judgments are made on pairs of elements to ensure accuracy. In paired comparisons, the smaller or lesser element is used as the unit, and the larger or greater element becomes a multiple of that unit with respect to the common property or criterion for which the comparisons are made. In Fig 4.7, is a simple example of ANP network structure. In the case of interdependencies, components with the same level are viewed as controlling components for each other. In pairwise comparisons, a ratio scale of 1-9 is used to compare any two elements (Table 4.8).

Table 4.8 Saaty's fundamental scale (Saaty, 1986)

Value	Definition	Explanation
1	Equally important	Two decision elements equally influence the parent decision element
3	Moderately more important	One decision element is moderately more influential than the other
5	Much more important	One decision element has more influence than the other
7	Very much more important	One decision element has significantly more influence over the other
9	Extremely more important	The difference between the influence of the two decision elements is extremely significant
2, 4, 6, 8	Intermediate judgment values	Judgment values between equally, moderately, much, very much and extremely

The numerical judgments established at each level of the network make up pair matrices. The weighted priority vector is calculated through pairwise comparisons between the applicable elements. This vector corresponds to the main eigenvector of the comparison matrix (Saaty, 1986).

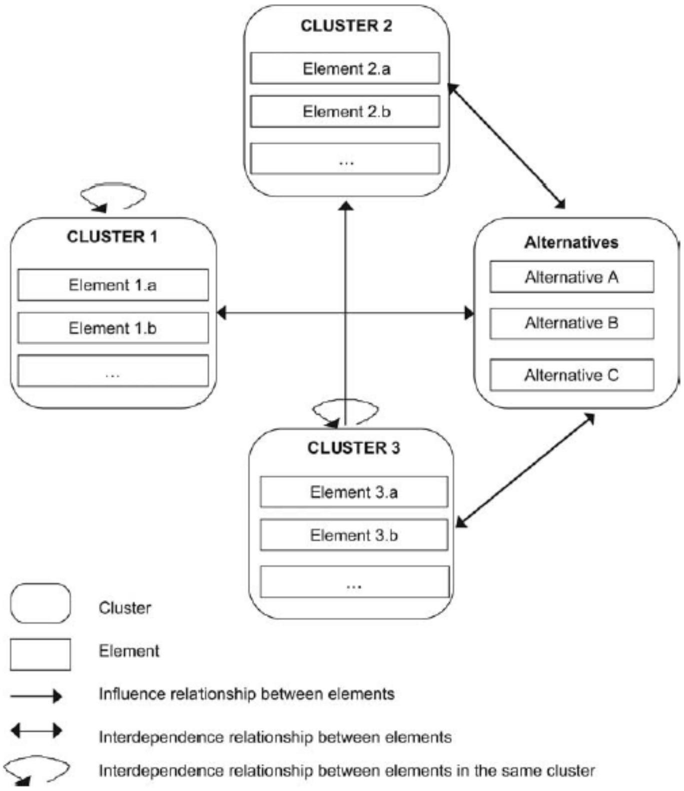


Fig 4.7 ANP network structure (Bottero and Ferretti ,2010)

In short, ANP is designed to help decision-makers to integrate different options that reflect the opinions of the actors involved in a prospective or retrospective framework. The participation of the decision-makers in the process is a central part of the approach. The ANP is characterized as a generalized development of the AHP (Saaty, 1980; Saaty et al., 1990). The main difference between the two analyses is represented by the structural approach with which the decisional problem is modeled. The AHP uses a hierarchical linear structure in which the relationships of dependence between the elements of the different decisional levels are unidirectional along the hierarchy and where dependencies do not exist either between the elements of a same cluster, or between elements belonging to different clusters. The clusters are groups of homogenous elements that are hubs, according to the decisional problem are broken down.

In real practice, the implementation of AHP is more than ANP. In some cases, these methodologies could be used in different step of the whole project. Although ANP is not yet used for refurbishment project, both of AHP and ANP should be implemented in residential refurbishment plan making process in China.

4.3 Energy efficiency Technology

The world development trend of building energy efficiency technology is that each country strengthens the research of the technology, and develops new technology. The relevant technologies include high efficient insulation for complex walls, roof and ground; infrared thermal reflection technology; high efficient insulated glazing; solar energy technology; thermal energy recovery technology; test for new buildings and computer aid technology, etc. Meanwhile, demonstration and spread of pilot project is also important. Last, the relevant standard and affiliated policy are continuously revised to meet the new requirement.

A broad array of technical measures can be used to reduce energy consumption and related CO_2 emission with co-benefits (U¨ rge-Vorsatz et al., 2007). Besides enhanced building envelope insulation, urban and architectural design also plays a fundamental role in reducing energy consumption in buildings. Various techniques allow energy consumption reduction in buildings, such as: sustainable urban planning; optimized site planning and design, including natural ventilation and suitable orientation; solar, geothermal and other renewable energy integration; bioclimatic architecture design; and enhanced mechanical ventilation with optimized heat recovery system. All these design and operating improvements can lead to substantial reduction in building energy consumption, all while providing much superior thermal comfort for residents (Harvey, 2006).

4.3.1 Passive Renewable Energy

Concerns about a range of environmental problems and health risks from burning fossil fuels and steeply rising oil consumption have sparked China's plans to pursue alternative energy sources to meet the country's increasing energy needs. Thanks to by these green technologies; China drafted its ambitious plan to develop renewable energy to satisfy its growing demand. Table 4.9 makes a summary on medium plans on various renewable energy sources.

Renewable energy consists of solar energy, biomass, wind energy, and geothermal energy, etc. Solar energy is the most mature renewable energy used in buildings in China.

Table 4.9 China Renewable Energy Capacity Target

Resource Type	2005 Actual	2010 Target	2020 Target
Energy from renewable sources	7%	10%	20% (15%)
Hydropower	117 GW	190 GW	300 GW
Wind power	1.3 GW	5 GW	150 GW
Solar PV	0.07 GW	0.3 GW	20 GW
Solar water heating capacity	80 million m^2	150 million m^2	300 million m^2
Biomass power (agriculture/forestry)	2 GW	5.5 GW	30 GW
Bioethanol	1 million tons	3 million tons	10 million tons
Biodiesel	0.05 million tons	0.2 million tons	2 million tons
Data Resources: (NDRC, 2007)			

Solar energy

Buildings can serve as collectors and transformers of solar energy, meeting a large fraction of their energy needs on a sustainable basis with minimal reliance on connection to energy grids, although for some climates this may only apply during the summer (IPCC, 2007).

In general, the deployment of renewable energy in buildings has been driven by incentives, such as subsidies for installation of RE equipment, tax credits and low-interest loans, as well as regulations (e.g. in the case of solar water heating). Many developed countries have been promoting small-scale electricity generation in residential and commercial buildings based on incentives, such as feed-in tariffs, [1] in some cases backed up by targets.[2]

[1] A Feed-in Tariff (FiT) is an incentive structured to encourage the deployment of renewable energy technologies for the generation of electricity. The system is implemented through government legislation that obliges electricity utilities to buy electricity generated from renewable sources at above-market rates set by the government. For example, a FiT may provide households with an incentive to install renewable energy systems, such as a residential PV panel, as the electricity thus generated can be sold at an above-market price to the utility. The difference is spread over all of the customers of the utility, resulting in a small increase in the price of electricity per customer. The system normally works well as long as electricity from renewable sources accounts for only a relatively small portion of total electricity generated by the utility. A FiT is

Solar energy becomes the center attention of with the nature of being clean, safe and permanent. It is calculated that the total solar radiant energy accepted by the China inland territory surface becomes 335–837 kJ/(cm^2 a) (Goswami et al., 2004), and more important, it can be easily utilized in buildings. Solar energy is often used to directly heat a house or the building. Heating a building requires much more energy and larger panels than heating a building's water system.

Table 4.10 Solar energy resource distribution and energy equivalent per m^2 annually in China (Li et al. 2007)

No.	Annual shinning hours (h)	Solar energy radiation (MJ/m^2 a)	Energy cumulation (kg CE/m^2 a)	CO_2 reduction (kg/m^2)
I	3200–3300	6670–8370	225–285	306
II	3000–3200	5860–6670	200–225	252
III	2200–3000	5020–5860	160–200	216
IV	1400–2200	4190–5020	140–170	180
V	1000–1400	3350–4190	115–140	144

Notes: CE in table means coal equivalent.

Most solar energy technologies have been in existence in one form or another for centuries in building industry in developed countries (Muneer et al.,2006). There are many applications for the direct and indirect utilization of solar energy, and the most extensive utilization is in building industry and related fields. In China, the main solar energy uses in building industry involve solar water heat heater, solar heating buildings, solar refrigeration, air conditioners and photovoltaic system. Especially, with the rapid rise of the energy price, solar energy application in building industry is accelerating. In China, extensive solar energy utilization in building industry brings great environmental and economic benefits (Li et al., 2005).

Solar heating, hot water supply, and electricity generation is the main range to use solar energy. Due to the economical level in China, hot water supply by solar water heating system is the main usage of solar energy in Chinese residential buildings. Solar water heating system consists of centralized system and distributed system. The common resident use distributed system, i.e. one home has one solar water heater. This mode could

normally phased out over time. In Germany, for example, the FiT is reduced annually by a fixed percentage as an incentive to stimulate technological progress and reduce costs. See, for example, Government of South Australia (2007) for a discussion.

[2] The National Energy Efficiency Action Plan: Portugal Efficiency 2015 seeks to stimulate smalls cale electricity production so as to turn 75 thousand homes into electricity producers by 2015. The Plan also includes a target to have one in every fifteen buildings equipped with solar hot-water heaters (IEA, Addressing Climate Change. Policies and Measures Database)

save water, easy to manage, no conflict, and suitable for families with less residents. However, for the whole residential building, compared with centralized system, distributed system has its disadvantages, such as higher total cost, lower energy efficiency, inconvenient maintenance, bad visual effect, etc. With the performance development of solar water heating system, centralized (unit) solar water heating system and solar combined other energy sources to supply hot water have become the new research emphasis.

Most buildings in China face the south that always receives the strongest sunlight, therefore, the buildings designed for solar heating usually have the large southoriented glass windows or trombe wall or simple solar heated ventilation. When sunlight passes through glass or other glazing, it warms the buildings, and stores solar energy in floors or walls. Proper ventilation allows the heat to circulate within the building.

Fig. 4.8 Typical solar heat water system on roof in China

Photovoltaic cells convert solar radiation to electricity power by semiconductor (such as silicon) materials. Photovoltaic cells (PV) have too high equipment cost to popularize in building construction. This situation can only be improved by reducing the electricity generation cost of PV system. The typical design and integration of photovoltaic cells into the building concerns the wall, rooftop and balcony layout, which replaces conventional building craftwork (Wang and Gao 2004). This integration may be in vertical facades replacing view glass windows, spandrel glass or other facade material replacing semitransparent skylight. It is commonly found that a photovoltaic roofing system replaces the traditional roofing materials or shading'eyebrows' in the windows, or other building envelope systems (as shown in Fig. 4.9).

Fig. 4.9 A typical building integration photovoltaic system with shading materials.

Utilization of solar air-conditioning is the most ideal harmonious state between human and nature, which can create both favorable indoor and outdoor environment temperatures. Therefore, the effect of 'warm-island' in the big cities will be cut down. The absorption chiller driven by solar energy demands no Freon refrigerants, so it does not damage the ozone layer, and is hence named 'green air-conditioning'.

Biomass

The use of biomass is centralized in rural area of China. The advantage of biomass usage in rural area is high integrated usage efficiency and complete recycle. Therefore, good economic benefit can be achieved. For example, waste from rural area can be converted into biogas, so the sanitation condition is improved and traditional energy is supplemented. A study case in Zhejiang Province: To solve the river pollution by waste leavening from a solvent production factory (called Jinhua Yong Kang), a solution was given: the waste leavening from factory can be processed to be the feedstuff for pig, manure from big is fermented to produce biogas, and biogas is for living energy, liquid produced from fermentation process can be used to plant and breed. Green vegetable can be inversely used for feeding pig. A biologic cycle is well formed and good social, economic effect is achieved.

Utilization of geothermal energy resource

Geothermal energy is a clean energy resource. Its characteristics are high thermal flow density, easy to collect and transport, stable quality (flow and temperature), easy to use, etc. It is not only a mine resource but valuable tour resource and water resource. It has become an exploitation hotspot. China has abundant geothermal energy resources. More than 2500 places with geothermal energy have been exploited. The annual geothermal energy quantity is 1.04×1017 kJ, which is equal to 3.56 billion ton coal equivalent. Exploitation and usage of geothermal energy resource have important meaning to the regulation of national energy structure and improvement of recycling economy.

In buildings, geothermal energy can be used for heating, cooling, hot water supply and entertainment & health care, which has been widely applied in Iceland, Turkey, Japan, U.S., Italy and Philippine, etc.

China is now promoting ground source heat pump technology, which uses thermal resources from aquifer (including underground water, soil and surface water, etc.) to supply heating or cooling sources for high efficient air conditioning system. Aquifer energy comes from solar energy, restoring in soil, sandstone and groundwater, which has characteristics in wide distribution, huge storage, quick renewable speed, constant quality and easy to collect, etc. The indoor required temperature in China is 18℃ in winter and 27℃ in summer. Slightly upgrading from geothermal energy, the energy will fit the indoor temperature requirement and it can completely replace traditional energy resources. Because geothermal energy has higher efficiency in heating and cooling, ground source heat pump can save 60% energy compared with ordinary air conditioning system. *Nanjing Feng Shang* Residential Block project (2009, Nanjing) uses the ground source heat pump system in multi-story buildings.

4.3.2 Small Scale Hydro Power

Hydropower on a small-scale is one of the most cost-effective energy technologies to be considered for rural electrification in less developed countries. It is also the main prospect for future hydro developments in Europe, where the large-scale opportunities have either been exploited already, or would now be considered environmentally unacceptable. Small hydro technology is extremely robust (systems can last for 50 years or more with little maintenance) and is also one of the most environmentally benign energy technologies available.

Small hydro is in most cases 'run-of-river'; in other words any dam or barrage is quite small, usually just a weir, and generally little or no water is stored. The civil works purely serve the function of regulating the level of the water at the intake to the hydro-plant. Therefore run-of-river installations do not have the same kinds of adverse effect on the local environment as large hydro.

Renewable energy sources such as wind and solar are being scaled up from residential to electric utility size. In contrast, hydro power is being scaled down to residential size. The small machines are similar in most ways to the large ones except for their scale.

In China, the resource of waterpower is abundant. There are hydropower stations in big scale locating in most area of China which from Tibet in west to eastern coastal cities and form Guangzhou in south China to Heilong river in north China. For example, among them, there are the '***Three Gorges Project***' and '***South-to-North Water Diversion Project***' which were finished in recent years. Otherwise, in many cities which have abundant waterpower, we can also utilize small scale hydro power for residential settlement.

Although the potential for a mass market is clear, residential customers are conservative in respect of adopting new technology and take-up for micro-CHP in general may be slow (Carbon Trust, 2002). On the other hand fuel cells may have some advantages over alternative technologies. As they are based on an electrochemical reaction, rather than an 'engine' technology that involves moving parts, noise, and vibration, they may be more acceptable to the residential market. In addition, they have a lower heat to power ratio than the alternatives, and this could be very important to the new build residential market, which is likely to have reduced demand for heat, as a result of improved insulation. More importantly, fuel cells are the most attractive option from the point of view of reducing CO_2 emissions, and they can operate at very high efficiency. With hydrogen as the fuel feedstock, they have zero CO_2 emissions, but in the absence of a hydrogen infrastructure most fuel cells currently under development use reformed natural gas (Wallmark and Alvfors, 2002).

Despite the careful design needed to produce the best performance, a micro hydro system isn't complicated. The system is not difficult to operate and maintain. Its lifespan is measured in decades. Micro hydro power is almost always more cost-effective than any other form of renewable power.

4.3.3 Combined Heat and Power (CHP)

Current structures of electricity production are mainly based on large thermal plants; existing large-scale plants for power generation are usually located far away from centers of population. This prevents the efficient utilization of the waste heat produced. Moreover, current technology limits these power stations to a maximum efficiency of about 40%, which, after the transportation of electricity through the grid, is reduced to about 30%. This means that vast quantities of fossil fuels are burnt releasing unwanted pollutants (CO_2, NO_x) into the atmosphere. The new scheme of energy generation and supply is developed.

CHP stands for Combined Heat and Power. This means in a CHP system heat and power are generated at the same time. Therefore CHP systems are also called "cogeneration plants". In CHP systems large engines are attached to an alternator to produce electricity. The combined production of heating, cooling and power in small- scale systems in the residential and tertiary sectors has a great saving potential. The potential application of similar strategies in small-scale systems as residential or commercial HVAC (heating, ventilation and air conditioning) has only gained interest in recent years, mainly as a result of the policies of promotion of efficient and distributed energy generation (Chicco and Mancarella, 2008). Some countries have implemented legislation that offers economic bonuses to efficient energy generation systems, which makes it more profitable for companies to invest in decentralized CHP systems in buildings selling electricity to the grid and thermal energy to the users (Streckiene et al. 2009).

Additionally to the cogeneration of power and heating, in warm climates such as the Spanish one, where CHP viability is affected by the low thermal demand during a part of the year, the use of absorption chillers to generate cooling from waste heat allows increasing the system utilization factor. The so-called CHCP (combined heat, cooling and power) or regeneration plants tend to show in these cases better global efficiency and profitability than systems without cooling (Piacentino et al. 2008).

It is widely recognized that large-scale district heating networks powered by high efficiency combined heat and power (CHP) plants present one of the best solutions for meeting the heating needs of urban buildings in northern China. CHP systems offer the potential for additional energy savings of 30% to 50%, compared to current energy consumption levels.

After all, there is a broad prospect for implementing energy efficiency technology in residential building to improve energy performance and living environment of residential building in China. Specific for existing residential building, applying innovation technology is not the aim of refurbishment, architects should choose proper energy options on the base of real condition and the energy saving target. Although innovation technology has been implementing in new constructions in China more and more, it is need to set up a framework of energy conservation strategy for existing residential building refurbishment which is suitable for urban areas of China.

Chapter 5
Scheme stage for urban residential building refurbishment project in China

- WHAT FACTORS DIRECTLY INFLUENCE THE REFURBISHMENT PLAN?
- FOR EXISTING RESIDENTIAL BUILDING, WHAT SHOULD BE IMPROVED BY REFURBISHMENT?
- HOW TO IMPROVE IDENTIFICATION OF RESIDENTIAL BUILDING ENERGY EFFICIENCY IN CHINA?
- HOW DOES THE INTERNAL OPERATION MODEL OF RESIDENTIAL BUILDING IMPROVE THE ENERGY CONSERVATION REFURBISHMENT IN EXISTING BUILDINGS?

5 Scheme Stage for Urban Residential Building Refurbishment project in China

Under the spectacular development of urban residential building in China, rational definition and analyzing should be summarized, otherwise it's impossible to make any research about building and urban topic and guidelines for it. In this chapter, we will begin to focus our attention specific on design strategy and methodology of residential building refurbishment in China.

Analysis of essential problems of residential building in urban area in China is made in order to grab the key points for innovation researches for residential building refurbishment in China. Through the analysis of existing problems and developing trend of residential building in urban area of China, we can fix the goal of refurbishment. An investigation would be made to the professional architects who are the main force working in architecture and urban design field in representative cities in China. On the base of investigation result, possible professional solutions would be shown clearly. In the discussion of internal operation, the construction system, administration mode and financial structure of residential building refurbishment in China would be analyzed as management support for refurbishment project.

5.1 Analysis of residential buildings in urban areas

At the beginning, this section will start from the development and status of residential building in urban area of China, it would help us to find the direction of residential building refurbishment. Economic development and a desire for improved living standards have spurred rapid construction and development in China during the past 20 years. During the early 1980s, new construction floor area totaled 700–800 million m^2 per year. By the early 1990s, the yearly total was 1000 million m^2, and the annual total in recent years has been 1600–1700 million m^2, of which 400–500 million m^2 are urban residential buildings, 400–500 million m^2 are public and industrial buildings (mainly in cities), and 700–800 million m^2 are residential buildings outside cities. (Lang, 2004) This rapid rate of construction has implications for energy consumption; in particular, the energy consumption per meter square for heating in traditional residential buildings in China is twice that of residential buildings in developed countries under the same weather conditions. In China, most of the residential buildings are multi-stories or high-rises of predominantly heavy-mass structures with solid brick or concrete walls. From the analysis of category and characteristic of existing residential building in urban area of China, general problems will be summarized. Combining with the development trend of residential building in China, what should be improved in existing buildings could be summarized clearly.

5.1.1 Category and characteristic of existing residential building

The construction of residential building in urban area of China after 1949 closely follows the urbanization process in China and is a result of strictly control by government. The development of residential building in urban area in China was developed in three stages.

- **First stage**: Univocal growing of quantity. In the beginning of foundation of PRC, refurbishment for existing residential building was emphasized due to there were many cities needed to be regenerated after a long period of civil war. Then until middle of the 1950s, new constructed buildings were influenced by design concept came from Russia and China begun the exploration of unit residential building design which was organized the single rooms connected by corridor without living room. In the 1970s, the design for residential building was not humanizing that there was not living room so the activities such as meeting, eating and even sleeping were concentered into the mixed-function space.

- 1950s, in Shanghai
- 1990s, in Shijiazhuang
- 2000s in Shenzhen
- 2005 in Beijing

Fig. 5.1 Typical residential building in China

- **Second stage**: Growth both of quantity and quality. It begun from end of 1980s and with the development of economic and improving of living level, the design conception of residential building changed into big living room and small rooms in the unit. This style divided the space by functions and brought out the division of activate and quiet.

- **Third stage**: Quality improvement. This period begun from end of 1990s until now. During this period, the residential building in urban areas of China was improved a lot as the result of urbanization and privacy inform. The residential building industry was changed into real estate industry and the essential of design conception is matching the demand of residence. In recent years, there are many new demands such like comfort improvement, multi-functions, natural ventilation and lighting etc. In addition, the surrounding living environment and municipal facilities also became the factors for judging the quality of a residential building.

5.1.1.1 Category

The category of residential building can be summarized by many methods. In general, we always categorize residential building as single house, villa, apartment, townhouse, etc. Basically, according to the living style, single house and apartment are two main categories of house in urban areas. Because the huge population and limit of landscape, most of residential building in China are apartment which is different from Europe and US that villa takes a fairly large number.

Category by height: Low storied dwelling; Multi-storied dwelling; Mid-high-rise-storied dwelling; High-rise dwelling; Super-tall residential.

- Low storied dwelling: refers to one detached house (one family), townhouse (two families) and row house (multi families). Compared with multi-storied apartment and high rise residence, low storied dwelling is more natural and agreeable (there are single yield) and fit for old people and children. It meets people with great favor because there are good living environment and less interaction by others but the restriction by land price and utilization efficiency limited quantity of low storied dwelling.

- Multi-storied dwelling: is the most common residential style in all cities in China. All the spaces organized by vertical public transportation.

It's developed so broad in China cause its advantages:

a) In the economic aspect, the investment for public infrastructure like elevator, water aspirator and etc. is more efficient.
b) In the design aspect, inter space combination is simple.
c) In the structure aspect, masonry—concrete structure which is used broadly is low cost.

But there are also disadvantages:

a) The living environment such like natural lighting, ventilation, thermal insulation and water repellency for ground floor and top floor is undesirability.
b) Building façade and space combination are similar and there are no opportunities for innovation.

- Mid-high-rise-storied dwelling: refers buildings which have 7-10 stories. This type of building's height is more than 24 meters, so it's high-rise building but has many similarities with multi-stories buildings so we call this kind of residential building as mid-tall- storied dwelling. So the characteristics of this kind of building is obviously:

  a) Building plot ratio is higher than multi-storied building so it's more efficient for land use.
  b) From the view of inter space design, the concrete structure which is broadly adopted in this kind of building makes it's more flexible for space combination.
  c) Cause of the height limit, the insulation of elevator makes it's more comfortable.

- High-rise dwelling: is the result of urbanization and industrialization and usually there are two categories which are point style and board style. The advantages of high-rise residential building are: high efficiency of land use; thorough infrastructures and public external space etc. It's attractive to house owners. But the disadvantages are also evident: insufficiency of natural lighting, ventilation and high cost because of elevator and high pressure water pump etc. The transportation resolved the inter space combination.

- Super-tall residential: refers to high-rise building which are more than 30 stories or over 100 meters height. This kind of building are constructed in big cities in China but the price for it keeps high level compared because of addition part for investment. On the other hand, the huge construction leaves floor for architecture innovation such as application of materials, façade and even civil engineer.

Category by structure : Wood and brick structure; Masonry—concrete structure; Steel frame structure; The steel scissors wall structure; The steel scissors wall structure; steel structure etc.

Of course, there are also other typologies for dividing residential building. In urban area of China, the most common type of residential building is unit apartment. Different from that of EU, as we talked in chapter 4, the city scale of Chinese cities is much bigger compared with European cities since the huge population and urbanization, the living environment of residential building in urban area of China is limited by space and natural resource. There is few single dwelling or townhouse in urban area. In urban area, Chinese people used to live in apartment building with several units in each floor. According to REICO data base (State Statistics Bureau China), until 2009, in all existing residential building in urban area of China, unit apartment takes 93.4% which is 0.7% more than that of 2008. And two-bed-room unit is the most common unit in existing buildings. But for new constructions, the area of unit is kept improving in recent years.

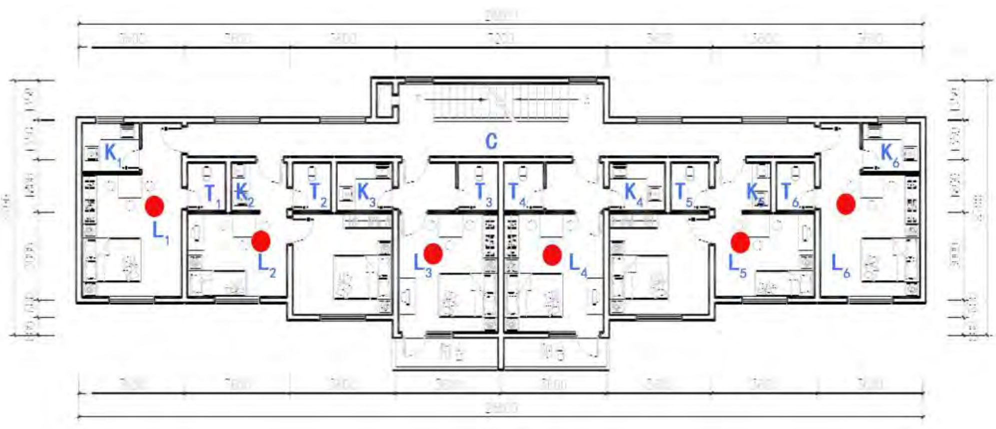
5.1.1.2 Space combination characteristics

The suit model is influenced by social productivity, science development, living level and level of civilization and the internal space combination is improved with the rise of living environment. In China, as we mentioned in last title, most residential building which are worth to be refurbished are built in 1970s to 1990s last century are built with bricks and concrete structure and are changed a lot.

Different with the dwelling and apartment in Europe and US, residential building in China is usually smaller and designed in simpler style. It's decided by the low living requirement and low economic condition.

There were three kinds of space combination methods will be introduced.

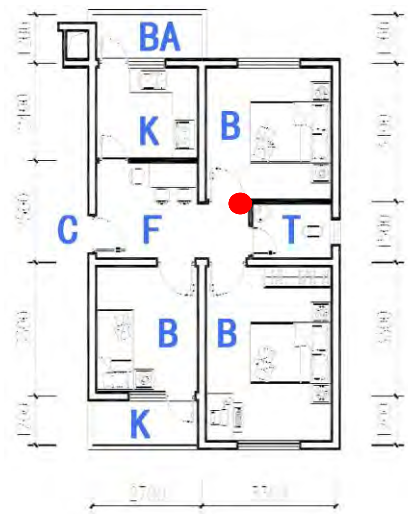
- **Bedroom-centered combination**: those buildings which were built at the beginning of 80s, because of the economic limit they were designed in the aim that solving the basic requirement for a family. In the plan of this kind apartment, architect only divided space into living area, cooking area and washing area. All the activities excluding toileting, washing and cooking are all acted inside the central space ---- living area. So the extents of functional spaces are so low and complex that only could meet with the basic living requirement. Fig. 5.2 is a plan of standard floor in a typical "Bedroom-centered combination" apartment. We can see that there are six units located symmetrically by the stair and in each unit there are only bedroom as living area, toilet as washing area and kitchen as cooking area.



K-kitchen; L-living room; T-toilet; C-corridor

Fig. 5.2 Plan of Bedroom-centered combination unit in residential building

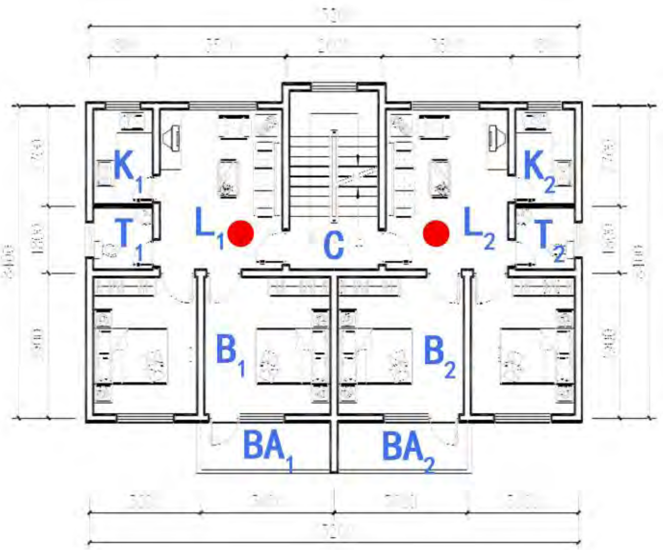
- **Foyer-centered combination:** That kind of building was built from middle of 80s to middle of 90s. The characteristic of plan design is that bedroom and dining room were separated and all the functional spaces like bedrooms, kitchen, toilet and dining room are combined by foyer. Sometimes, in the small unit, foyer is used as dining room and living room. The disadvantage of this kind of unit is lack of natural ventilation and visual contact among different rooms, and there would be interaction by different family members. Fig. 5.3 shows the plan of a typical "Foyer-centered combination" apartment. We can see that all the functional spaces are combined by foyer. Just because of this, the boundary of foyer is split by four doors so efficiency of foyer is reduced.



K-kitchen; B-bedroom; T-toilet; C-corridor; F-foyer; BA-balcony

Fig. 5.3 Foyer-centered combination unit in residential building

- **Living room-centered combination**: this kind of building was built from end of 80s to 90s. It was developed from "foyer- centered combination" model. Different from the former one, the unit is larger and there were living room what could be the main communication space for family members. And the conception of "movement and quiet division" was used in the plan. We can see from Fig. 5.4, there are only two families in each floor and natural ventilation and lighting environment were promoted a lot because of the north-south direction. But with the improving of society and changing of living style, the problems of this kind of apartment such as toilet is too small and lack of thinking for guests, residential building are needed to be refurbished.



K-kitchen; B-bedroom; T-toilet; C-corridor; F-foyer; BA-balcony

Fig. 5.4 Living room-centered combination unit in residential building

5.1.2 General problems of existing residential building in urban areas

Although with the huge development of economic and urbanization in China, the great demand of residential building in urban China came out, but limited by territory new construction can match with the demand while there are many problems with existing residential building which built 20 years ago. To catch up with the living improvement in modern cities, existing problems needed to be refurbished by residential building retrofit process. So we have to summery the problems of existing residential building in urban areas in China. Generally speaking, the economic development started since the beginning of *Reform and Open-up* to the world policy. In 1979, the beginning of reform and open to the outside world, the occupancy area per head in cities and towns is 3.6 m^2. After 20 years endeavor, the occupancy area per head has reached 8.7 m^2 in 1997 and in 2009 the number raised to 30m^2. However, compared with developed countries, Chinese residential area per head is still on low level and seriously imbalance, far below the requirement from habitants. Sharply improvement also resulted in mass of low quality residential building. Chinese government has put the residential construction to be the new increasing point of national economy.

Obviously, with the economic improvement, there are two aspects conceded that improving of residential condition: in one hand, living area was raised rapid in the last twenty years, we can get the data that in 2006 the average living area was double as that of 1991 and family unit got smaller (we will talk about family unit development in 5.1.3.1) while the living area per household was raised a lot (Table 5.1). In the other hand, both house price and income were raised but we can see that ratio of house price and income was raised, too. That means residential building became more important in urban area.

Table 5.1 Table of Household living area and income 1991-2006

Year	Average Living area per capita	Average person number per household	Average living area per household	Price per M^2	Price of one house	Average income per person per year	Total family income	House price / income
	M^2/ person	Person /household	M^2/ household	Yuan/ M^2	Yuan/ household	Yuan/ person	Yuan/ household	
1991	14.2	3.43	48.7	756.23	36832.92	1713.00	5875.59	6.27
1995	16.3	3.23	52.6	1508.86	79440.18	4288.00	13850.24	5.74
2000	20.3	3.13	63.5	1948.00	123773.97	6296.00	19706.48	6.28
2001	20.8	3.10	64.5	2017.00	130056.16	6869.00	21293.90	6.11
2002	22.8	3.04	69.3	2092.00	145000.70	8177.00	24858.08	5.83
2003	23.7	3.01	71.3	2197.00	156727.39	9061.00	27273.61	5.75
2004	25	2.98	74.5	2608	194296	10129	30184	6.44
2005	26.1	2.96	77.3	2937	226901	11321	33509	6.77
2006	27.3	2.95	80.5	3119	251209	12719	37522	6.76

Source: <China statistical yearbook>
House price / income= total house cost per family/ total family income
Total house cost = average living area per person * average person number per family* Price per M^2
Total family income= average person number per family * Average income per person per year

With the improvement of living level since reform and open to the world, residents' requirements became diversified. Architects attempted some innovations in new constructions design. Contemporary, problems with existing residential building were paid much more attention. Outdated design resulted in functional inefficiency;

improvement of urbanization resulted in energy shortage; economic limitation resulted in severe human living environment, etc.

5.1.2.1 Functional inefficiency

Many existing residential building were built in 80s and 90s last century while the beginning of urbanization. But as we mentioned about the residential building category, by the influenced by former society structure, these residential buildings designed with similar façade and plan but cannot meet the new requirements of modern lives.

- Seriously inefficiency of the improvement of internal functions which is result of life changing and urbanization process in urban China. This is quite easy to understand that demand of residential buildings in cities is changed a lot by the economic and society improvement in urban China, people would need larger house and diversified functions inside the house.
- In public space, like corridor, stair space, the environment is dirty because of the stack of stuffs and long-time lack of clean. Many of these residential buildings are apartment with three or five units per story and the inhabitant lived there for twenty or thirty years, limit internal space resulted in that inhabitant would stack much stuff in public space so that there is not enough space in public space. This is not only the problem about public health and environment, but also the narrow public space would obstruct fire disaster seriously and would lead to grave consequences.

Fig. 5.5 Photo of common exsiting resdiential building in urban area of China

- Lack of thermal insulation solutions would cause the waste of energy consumption and uncomfortable internal environment. Because techniques limitation and ageing of the insulation materials, thermal insulation and impermeability are not good enough to meet the internal living requirement.

- The problem of worn circuit, lacking moisture proof and waterproof measure, circuit that doesn't comply with national safe requirements are common in these buildings. With the widely using of domestic appliances, electricity demand is kept rising but carrying capacity of the electricity and water lines are far less than the demand. There are even clogging and water seepage existing in some buildings.

- Without plan of air-conditioner water pipe and the condensate water drop on the façade of buildings. This phenomenon would damage the wall materials and surrounding environment.

- There are too many attachments hugging in the wall out of order and this would affect the building façade. These attachments like Metal shelves, air-conditioner shelves and plaques.

In addition, in some old residential settlement, young couples moved out after got married and only the old people remained in these old buildings or who with low income and don’t have ability to move to new houses. So these problems are difficult to be solved not matter for the technology nor economic.

5.1.2.2 Energy shortage

The speeding up urbanization and residential building demand is the obviously result of a miracle of keeping high economic development by decades which was made by China. The economy is measured by the GDP (Gross Domestic Product). However, GDP can be used, along with other variables like infant mortality rate, freedom and literacy, to give a reasonable picture of national wealth and progress. We can get the conclusion that energy consumption per capita in economic developed regions in China is higher than less developed regions. The energy demand is in directly proportion with GDP per capita.

Table 5.2 Residential energy consumption and GDP in China by province in 2009

City/Province	GDP (1000rmb) per capita [A]	Residential Energy (kgce) per capita [B]	B/A	City/Province	GDP (1000rmb) per capita [A]	Residential Energy (kgce) per capita [B]	B/A
Beijing	58,204	568	0.0096	**Hubei**	16.206	174	0.0107
Tianjing	46,122	451	0.0097	**Hunan**	14,492	188	0.0129
Hebei	19,877	297	0.0149	**Guangdong**	33,151	264	0.0079
Shanxi	16.945	303	0.0178	**Guangxi**	12.555	119	0.0094
Inner Mongolia	25,393	407	0.0160	**Hainan**	14,555	107	0.0073
Liaoning	25,729	349	0.0136	**Chongqing**	14,660	188	0.0128
Jilin	19,383	275	0.0141	**Sichuan**	12,893	176	0.0137
Heilongjiang	18.487	260	0.0140	**Guizhou**	6,915	277	0.0400
Shanghai	66,367	418	0.0063	**Yunan**	10,540	160	0.0152
Jiangsu	33,928	177	0.0052	**Tibet**	12,109	404	0.0336
Zhejiang	37,411	244	0.0065	**Shanxi**	14,607	206	0.0141
Anhui	12,045	160	0.0132	**Gansu**	10,346	214	0.0207
Fujian	25,908	241	0.0093	**Qinghai**	14,257	429	0.0301
Jiangxi	12,633	145	0.0115	**Ningxia**	14,649	268	0.0183
Shandong	27,807	214	0.0077	**Xinjiang**	16,999	337	0.01982
Henan	16,012	185	0.0115				

Source: REICO data base (State Statistics Bureau China), 2009
B/A= Residential Energy/GDP

We can get information in this table, data of GDP (representative as A) and data of residential energy consumption (representative as B) in each province. Then we got the number of ratio by energy consumption and GDP (B/A) which reflects energy consume cost benefit ratio. Though evident that economic developed zones such like Beijing, Shanghai, Jingsu etc. consumed much more energy than less developed zones such like Tibet, Qinghai etc., the ratio also proved that energy consumption efficiency is higher in economic developed zones than less developed zones.

Although the total energy consumption of China is the second in the world, the per capita or per square meter residential energy consumption is much less than that of the developed countries for different life styles or customs, residential policies(Long, 2007). We can get another point that China's relatively low building energy consumption is not the result of advanced energy efficiency technologies, nor a widespread awareness of the need for energy efficiency in buildings. Rather, it is related to China's current level of economic development and the standard of living of its people. Considering economic factors, energy price in China is higher than developed countries if compared with the ratio in income. Most Chinese people especially people above 30 years old have the traditional habit low energy demand and consciousness of energy saving. It is easily to find by the data of Fig. 5.6, it's the comparison of energy consumption (kgce/m^{2}a) excluding energy consumption for space heating for residential of China, US and Japan. Energy consumption in residential of China is much less than that of US. Although both of Japan and China are eastern countries with similar traditional culture and life style, energy consumption of China is less than that of Japan because low quality of living environment.

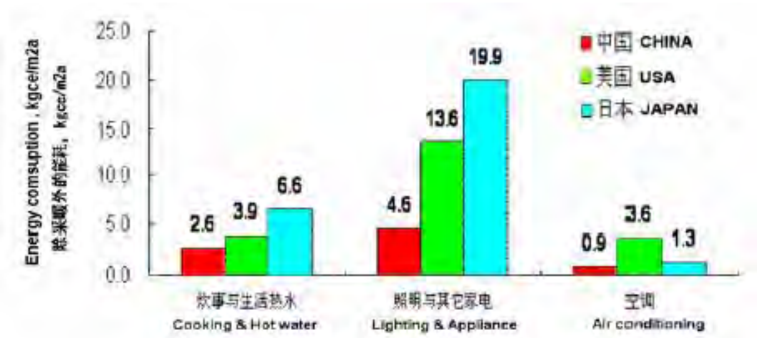


Fig. 5.6 Energy consumption excluding space heating for residential of China, US and Japan 2004 (THUBRC,2008)

Although energy consumption in China still remains in low level compared with developed countries, energy shortage is spread all over China. Many factories in the country's export-oriented eastern provinces are already losing electricity from the grid during the daytime for one to three days a week. That forces them to operate at night, run on costly diesel generators or reduce output. The national grid has given priority to maintaining electricity supplies for residential customers, particularly in cities. But in small towns and rural areas, many homes are also losing power needed to use the more than 100 million air-conditioners, washing machines, refrigerators and other appliances sold since the start of 2009. Those purchases were aided by government subsidies aimed at narrowing the gap in the standard of living between city residents and the rest of the country.

5.1.2.3 Severe human living environment

In the last few years, however, while urban construction booms, the new residential communities under construction make the old the residential environment of residential communities look more outdated, with notably backward supporting facilities. Residential communities that were extensively developed in the early stage of housing reform are mostly less than 20 years old. While there are many years before the durable period of these structures is up, the development of new residential communities and the people's increased awareness of dwelling, the old residential communities are now close or exceed their durable period in terms of dwelling functionality. It has not been many years since the construction of residential communities developed in the early stage of housing reform, and thus reconstruction is unlikely in the near future. As for the abounding old residential communities in the cities, they present the key issues of urban development, including how to improve their dwelling functionality, how to govern the residential environment in such communities, and how to make them reassuring, safe, and comfortable.

Human living environment refers to indoor environment and outdoor environment. Outdoor human living environment was ignored in the past decades in China. But in fact, outdoor living environment is an important factor for residents. A good living environment would supply comfortable physical and psychology environment to inhabitants. It's an indispensable element for modeling comfortable house and sense of belonging which are attraction of home.

There are several universal problems as follows existing in a great deal of existing residential buildings:

- Existing residential areas water environment design only pays attention to sight impact unilaterally. Actually, even few which has water environment design, design skills of these water environment are all disadvantageous in the formation of geomancy (Fengshui).
- There are several universal limitations as follows existing in vegetation environment design of existing residential buildings: a great deal of existing residential buildings outside, vegetation environment was not designed; on the other hand, there are just lawn but no attention to arranging in pairs or groups in existing residential buildings having vegetation environment design; traditional vegetation environment keep to programming pattern which public greenbelt, building greenbelt and path greenbelt three parts fit together.
- Ignoring of public space for outdoor activities. Such as the childish games location, grown-up and the senior citizen rests, the fitness location and trash storage and transportation station and so on, all of them are imperative functions for residential buildings;

- There are many illegal structures which were built by residents during past years and the ground floor of some residential buildings which is located along the street are changed into shops with signs in different styles. These illegal structures destroyed the human living environment seriously.

5.1.3 Develop trend of urban residential building in China

"Energy revolution as a paradigm of urban development"

----Peter Droege

As we indicated in Chapter 3, with the progress of urbanization in China, cities in China were developed a lot in the field of scale and population. But energy will be the decisive factor for urban development. Now, China is attempting to fulfill the CO_2 emission reduction target and also Europe and US, energy problem is becoming the most important global issue. In this background, there are some new develop trend of urban residential building in China.

5.1.3.1 Changes of family structure

Energy consumption is determined by the occupants' lifestyles and the increase of energy efficiency. Many of our investigations show that the user's lifestyle and their behaviors can have an enormous impact on real energy consumption. In practice, energy-related improvements are only useful if they are accepted by the users. Therefore, for residential buildings, mainly passive or user-friendly active measures are meaningful.

In recent years, procedures considered in the standardized assessment are based upon an assumption of a very outdated lifestyle standard that often does not reflect practice. So much so that the standardized assessment which is usually considered of is really lag compared with European countries and US wide range of lifestyles and their dynamic characteristics caused the changes of family structure and directly and indirectly influence energy flows and energy consumption.

The impact of lifestyle and user behavior on energy consumption patterns became an important common point in the analysis topics in recent years. The impact of user behavior on energy consumption is reflected by the choice of indoor temperature, occupied time, ventilation habits, temperature adjustment, use of different equipment and other behavioral parameters. The impact of consumer lifestyle in the US has been studied by Bin and Dowlatabadi (2005). They proposed an alternative hypothesis, called the Consumer Lifestyle Approach (CLA), to explore the relationship between consumer activities and environmental impacts in the US.

Family unit----Becoming smaller

In China, family unit is becoming smaller. This change is mainly caused by two factors. Affected by "One-child" policy which was implemented in China since 1980, most Chinese family only have one child instead of 3 or 4 children as before. In the same time, affected by economic improvement and education background, more and more young-couples choose to live independent, especially in the cities.

Historically, the average household size has been declining in most of the developing countries. China adopted one child policy in 1979 which accelerated this decrease. Average household size declined from 5 persons in 1980 to 3.7 persons in 2004, and in urban China it has almost reached the level of developed countries. Change in household size is important because per capita energy use rises as household size decreases, since a small household have many of the same appliances as a large household and use same amount of energy for heating and cooling (Schipper et al.1992). In 2006, average Chinese urban family size is 3.17 persons per family, decreased 1.64 persons compared with 4.81 persons in 1973. (State Statistics Bureau, 2010) Smaller size of household unit and larger population in urban area, it's clear that there would be much more households in China urban and the directly result is growth of household energy consumption. There is statistics of household size of China in 1982, 1990, 2000 and 2010 in Fig. 5.7, and also there is predication of household size development trend until 2050. We can see that the household size will keep steady around 3persons in the next 4 decades.

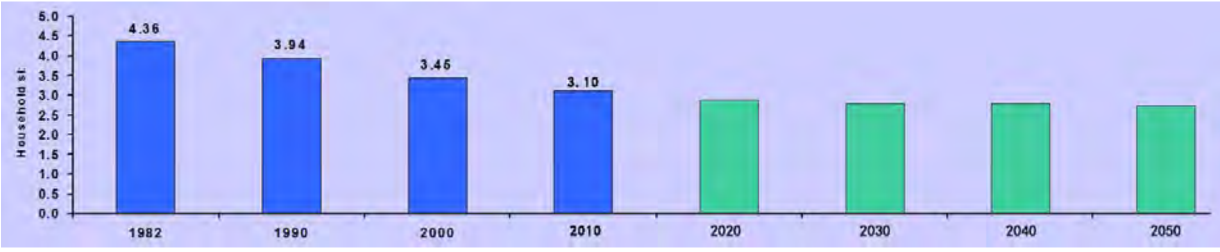


Fig 5.7 Average family household size, 1982-2050
Source: 1982-2010, NBSC data base
2020-2050 predict, Zeng Y et al.

Life custom---- Humanization

At its core, urban-life energy consumption is strongly influenced by lifestyles and related consumption patterns. To further reduce urban-life energy in cities, greater emphasis will be placed on dominating social culture and values (for instance, one would feel, for those newly-built high-rise double skin commercial buildings, glorified due to their fashion, or humiliated due to their high energy cost and uncomfortable environment, etc.), individual choices and behaviors. Of course, income levels matter, but they do not solely define consumption patterns: these are largely defined by the type of urban environment, amenities and physical organization of space in which people live, service price and availability, and the nature of value-driven criteria used for making personal decisions and choices.

Chinese people, especially urban citizens, are changing their life custom from traditions to modern mode during the urbanization process. There are monotonous cities full of skyscrapers and glass-façade buildings all over China. The life-style in Chinese cities is developing toward to western mode. People are paying more attention to comfort level of the building, not only indoor environment but also outdoor environment of the building. Air and noise pollution lead to reduction of natural ventilation and lighting.

5.1.3.2 Function requirements

Widespread use of household electrical appliances is another typical characteristic of Chinese city development. High-speed urbanization and high-consumption financial policy simulated rising of household electrical appliances. In fact, sustained rises in appliance ownership have already corresponded to growing residential electricity use at an annual average rate of 13.9% between 1980 and 2007 (Fig. 5.8) (NBS various years).

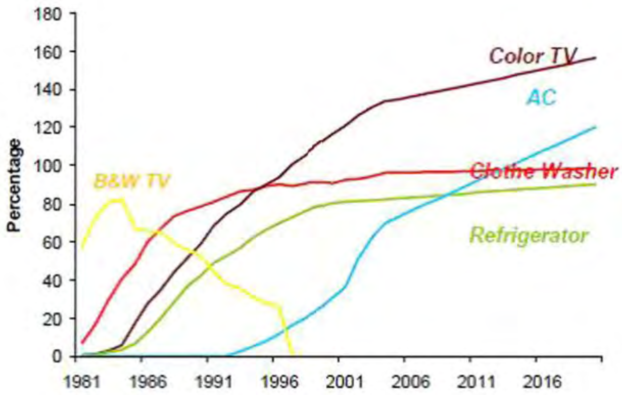


Fig. 5.8 Urban appliances ownership

Energy consumption is rose by ownership and saturation rate of appliances. With the society development, comfort demand is also rose in urban areas. Home appliances can be divided into two categories: traditional big household appliances and emerging small household appliances. Big household appliance, like TV, air conditioner, clothe washer and refrigerator, are general used at home and guarantee basic living in nowadays urban area. Small household appliance, like humidifier, sound equipment, security system, PC and etc., are being used more and more and improve the comfort level at home.

Although ownership of household appliance is rising sharply these years, it’s still much lower than developed countries and will be kept growing in the future. Because there were less household appliance in China before, energy consumption by household appliances is much lower than the developed countries. Comfortableness is much lower in China as a result. In Fig. 5.9, there is the information of China’s annual production of air conditioner from 1978 to 2009, we can find that the production of AC is raised a lot during the period between 2000 and 2008, that’s the result of improving functional requires.

Urban Chinese households are now well equipped with appliances. According to the State Statistical Bureau (SSB, 2004), by 2002 each urban household had more than one color TV set, and the ownership of refrigerators and room air-conditioners stood at 89% and 62%, respectively.

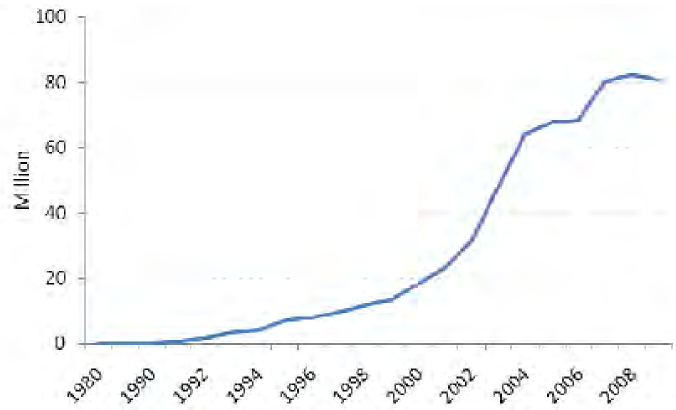


Fig. 5.9 China's annual production of AC (air conditioner) 1978-2009

Source: NBSC ,various years

In March 2006, one group (Richard Bradley and Ming Yang) undertook an on-site auditing survey of the appliances in a typical middle class family in Beijing, with most of the appliances made in China in 2005. The survey results generally support the technical data given above (Table 5.3). When all the appliances are plugged in but not switched on, the total power consumption amounts to about 24W. While these appliances are switched on but not in full operation, i.e. in standby mode, the total standby power consumption reaches about 40W. The total energy consumption by both standby mode and plugged-in mode is over 0.5 kWh per day.

Table 5.3 Auditing results of standby power in a typical middle family in Beijing (Cromptonand Wu, 2005)

Appliances	Plugged in (W)	Plugged in time (hrs/day)	Standby power (W)	Standby time (hrs/day)	Energy use by standby (kWh/day)	Energy use by plugged-in (kWh/day)
Audio system (made in Korea)	2.0	24	2.0	10	0.02	0.03
Cooking fan (made in China)	0.0	24	0.0	5	0.00	0.00
Digital video disk (DVD) (made in China)	11.6	2	11.6	2	0.02	0.00
Washing machine (made in China)	1.0	24	2.0	24	0.05	0.00
Microwave oven (made in China)	2.2	24	2.2	24	0.05	0.00
Refrigerator (made in China)	2.0	24	2.0	24	0.05	0.00
Television 1 (made in China)	0.0	24	5.5	8	0.04	0.00
Television 2 (made in UK)	0.0	24	1.1	8	0.01	0.00
Battery charger (made in China)	1.0	12	1.0	10	0.01	0.00
Gas water heater (made in France)	0.0	24	4.5	24	0.11	0.00
Desktop computer machine (made in China)	2.1	24	2.5	8	0.02	0.03
Desktop computer screen (made in China)	1.2	24	2.9	8	0.02	0.02
Laptop computer (made in Ireland)	0.8	24	2.6	8	0.02	0.01
Sum	23.9		39.9		0.43	0.10

5.1.3.3 Renewed attention of executing energy efficiency standard

The building sector is one of the highest energy consumers in China. The potential to save energy in existing buildings is very high. Currently, there is not system of policy incentives encourage home owners to renovate buildings to meet the energy efficiency requirements, reduce energy consumption, and reduce CO_2 emissions. Nevertheless, there are often discrepancies between the measured and calculated energy consumption results despite efforts to take parameters into account such as the exact geometry and thermal properties of the building, energy demand for hot water, heating, cooling, ventilation systems, and lighting in the planning phase for selecting the best reconstruction option.

In the past decades, the attention of energy efficiency for buildings felled behind in China by government and residents.

- *Knowledge of the co-benefits of building energy efficiency*: There is far-reaching agreement among experts that consumers are not aware of the fact that they can reduce their energy costs and improve their living comfort by living in an energy efficient building and using energy efficient appliances. We found that residents living in energy efficient retrofitted homes in North China attach most importance to the improvement of the room temperature and better conditions for their health. The emphasis on enhanced living comfort instead of reducing energy costs is due to the fact that heating is still not billed according to consumption. In addition, we noticed that even though in China it is a common practice to frequently replace the windows, people primarily do so in order to make their homes prettier as well as reducing dust and therefore do not necessarily install more efficient double-glazed windows.

- Technical measures and options to enhance building energy efficiency: Residents need knowledge about technical measures and options to make purchasing decisions and to use appliances efficiently. We found that one major obstacle for investments in EEB is that people face great difficulties when attempting to evaluate the quality of energy efficient buildings as well as appliances. EEB often is invisible. Wall insulation, for example, cannot be seen and its benefits can only be experienced by residents over time. Therefore, households are not willing to purchase them. Furthermore, residents lack the technical know-how when it comes to evaluating the quality of building energy efficiency products (e.g. double-glazed windows) and they do not trust in the market: in the past, the term "green building" has been used as a marketing tool in an inflationary way. Often, it referred to buildings which in fact were not energy efficient. In addition, simple technical measures to enhance energy efficiency such as shading are not commonly known in China.

- Breaking the misunderstanding that building energy efficiency is too expensive: The costs for energy efficient buildings are often overestimated. Not only households, but key players in real estate and construction as well misjudge the costs and benefits of energy efficient buildings. In fact, by improvement of technologies, cost for energy efficiency technologies are much lower than before and benefits of low energy consumption and higher comfort level are accepted by residents. Most of the key actors in China estimated the additional cost of green buildings more than four to five times higher than the true cost. On the household level, this perception is due to the fact that many developers also use the term "green building" as a marketing tool for high-end developments. Consequently, many interviewed residents perceived energy efficient buildings as a luxury good and did not even consider buying an energy efficient apartment for themselves.

5.2 Identification of residential building refurbishment design strategy

5.2.1 Improvement of importance for residential building refurbishment by professionals *(Investigation to the architects in China)*

In order to comprehend the necessity of improving residential building refurbishment research, an investigation was made in 2011 to professionals in China. In the previous part we have already expanded feasibilities and importance for improving building refurbishment technologies and standards in China especially for residential building in urban area, furthermore, this investigation was aimed at surveying the real comprehension for those professionals who are the implementers and playing the most important role in the whole process of refurbishment project. But in the other previous studies, researchers used to emphasizing technologies in details or society effects in macro level. We must grab the key points that are neglected in previous works. By this investigation, we will analysis the problems intuitionistic by all the feedbacks.

<u>Investigation to the architects in China</u>

Aim area

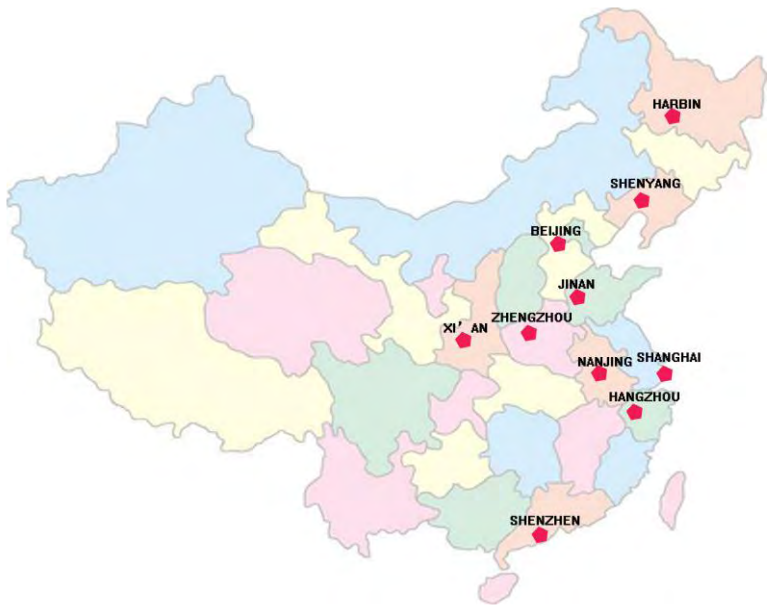


Fig. 5. 10 Location of 10 selected cities in this investigation

In this investigation, we focus attention on the professional architects who are working in the big cities in China. We selected 10 cities which are all first level cities (Fig. 5.10).

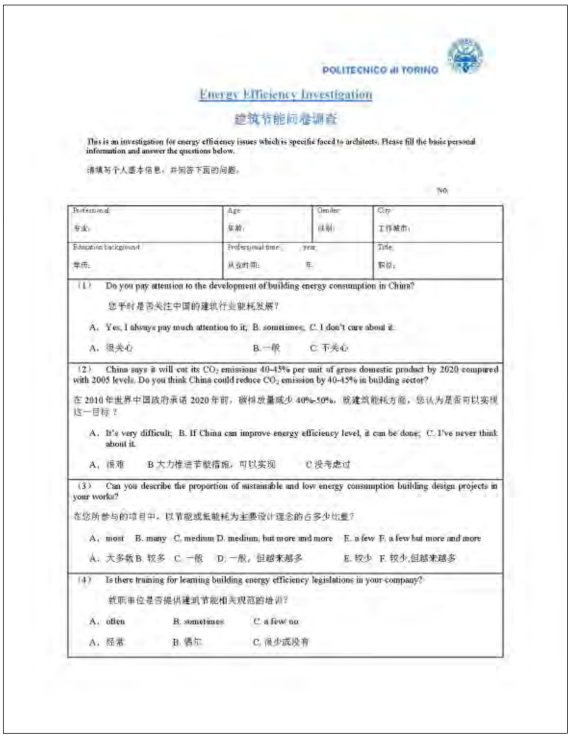
They are Beijing, Shanghai, Harbin, Shenyang, Hangzhou, Nanjing, Xi'an, Zhengzhou, Jinan, and Shenzhen. As we know, majority Chinese are living in east part of China and most Chinese cities are located in east part of China. We chose those 10 cities which are representative cities in developed area in China. Also as we mentioned in Chapter 4, these cities are distributed in different climate zones. All of those cities are facing the building refurbishment problem.

Aim group

Then we delivered questionnaires to architects those are working in the top level building design institution.

We delivered 276 copies of investigations and got 186 effective replies. To make the analysis, we made the questions in 3 aspects:

- General opinion about building energy efficiency technology and CO_2 emission reduction issues.
- Importance of exiting energy efficiency regulations in building design process.
- Development of residential building refurbishment project.



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Energy Efficiency Investigation

建筑节能问卷调查

This is an investigation for energy efficiency issues which is specific faced to architects. Please fill the basic personal information and answer the questions below.

请填写个人基本信息，并回答下面的问题。

NO.

Professional 专业：	Age 年龄：	Gender 性别：	City 工作城市：
Education background 学历：	Professional time year 从业时间： 年		Title 职位：

(1) Do you pay attention to the development of building energy consumption in China?

您平时是否关注中国的建筑行业能耗发展？

A. Yes, I always pay much attention to it; B. sometimes; C. I don't care about it

A. 很关心 B. 一般 C. 不关心

(2) China says it will cut its CO_2 emissions 40-45% per unit of gross domestic product by 2020 compared with 2005 levels. Do you think China could reduce CO_2 emission by 40-45% in building sector?

在 2010 年世界中国政府承诺 2020 年前，碳排放量减少 40%-50%，就建筑能耗方面，您认为是否可以实现这一目标？

A. It's very difficult; B. If China can improve energy efficiency level, it can be done; C. I've never think about it.

A. 很难 B 大力推进节能措施，可以实现 C 没考虑过

(3) Can you describe the proportion of sustainable and low energy consumption building design projects in your works?

在您所参与的项目中，以节能或低能耗为主要设计理念的占多少比重？

A. most B. many C. medium D. medium, but more and more E. a few F. a few but more and more

A. 大多数 B. 较多 C. 一般 D. 一般，但越来越多 E. 较少 F. 较少,但越来越多

(4) Is there training for learning building energy efficiency legislations in your company?

就职单位是否提供建筑节能相关规范的培训？

A. often B. sometimes C. a few no

A. 经常 B. 偶尔 C. 很少或没有

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(5) When you work for a project, would you think about of using renewable energy (solar, wind, etc.) initiatively?

在设计过程中，是否会主动考虑使用可再生能源？（如太阳能，风能等）

A. Yes, I'd think about it initiatively; B. Just to meet the demand of related legislation; C. No, I wouldn't

A. 主动考虑 B. 达到相关要求即可 C.不考虑

(6) In your opinion, what should architect do for reducing building energy consumption?

您认为建筑师在建筑节能减排工作中应该起怎样的作用？

A. Just follow the basic legislation; B. enhancing concern of using energy efficiency technologies; C. cooperating with other relevant partners initiatively to improve building energy performance

A. 被动执行相关规范即可 B. 在设计过程中加强节能技术应用的意识 C. 主动协调相关专业及业主，提高节能水平

(7) Do you think applying energy efficiency measures is an important procedure in design process?

您是否认为，节能设计是住宅设计中的重要环节？

A. Yes, it's really important; B. moderate; C. It's not important at all

A. 是的，很重要； B. 一般； C.不重要

(8) What do you think about the possibility of implementing energy efficiency standards for residential building in China

目前中国住宅建筑能耗标准在实际项目中的执行性？

A. Easy; B. medium; C difficult

A. 易 B. 中 C. 难

(9) Do you think it's possible to improve the energy efficiency criterions for residential building in China?

您认为，现有住宅建筑的节能标准是否有可提高的空间？

A. Because the current standards have already been used for several years, With the technology improvement, it's possible to improve the standards for building energy efficiency

B. I've never think about it, I just follow the current standards passively.

C. It's already difficult to implement the current standards, I don't think it should be improved.

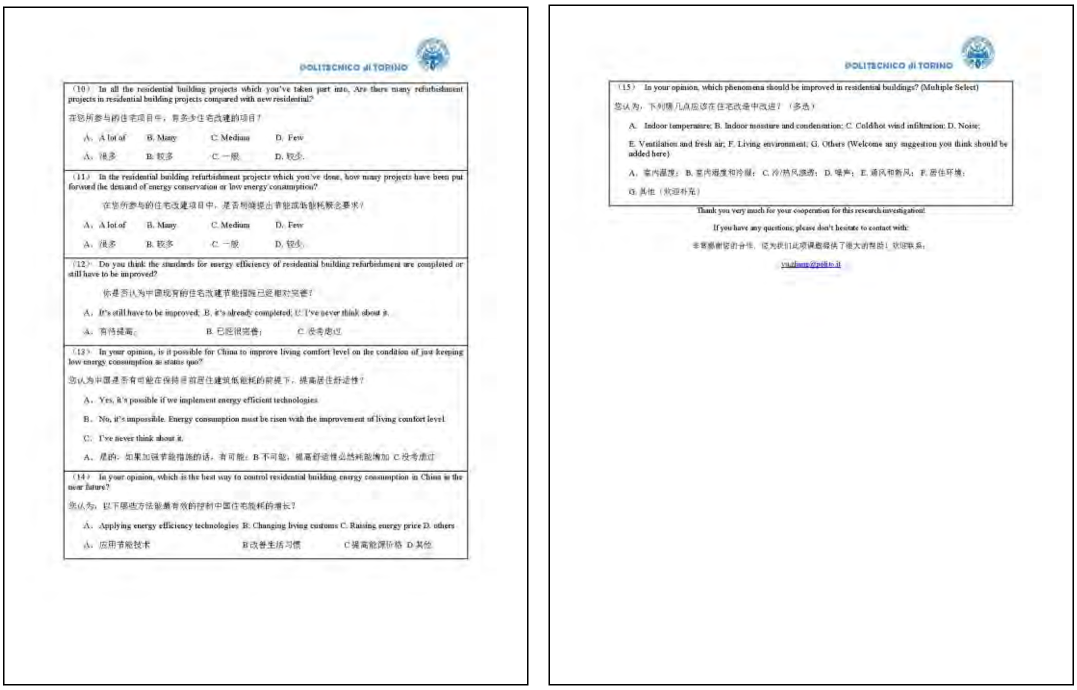
A. 现有规范制定时间较长，目前随着科技进步，在节能标准上有很大提升空间，

B. 没有考虑过，被动执行标准；

C. 现有规范执行起来难度已经很大，不需要改进

Fig 5. 11a Investigation sample

There are 14 questions in total (Fig. 5.11a and b). We supplied several answers for each question and they can analysis these relevant questions defectively.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(10) In all the residential building projects which you've taken part into, Are there many refurbishment projects in residential building projects compared with new residential?

在您所参与的住宅项目中，有多少住宅改建的项目？

A、A lot of B. Many C. Medium D. Few

A、很多 B. 较多 C. 一般 D. 较少.

(11) In the residential building refurbishment projects which you've done, how many projects have been put forward the demand of energy conservation or low energy consumption?

在您所参与的住宅改建项目中，是否明确提出节能或低能耗概念要求？

A、A lot of B. Many C. Medium D. Few

A、很多 B. 较多 C. 一般 D. 较少.

(12) Do you think the standards for energy efficiency of residential building refurbishment are completed or still have to be improved?

你是否认为中国现有的住宅改建节能措施已经相对完善？

A、It's still have to be improved; B. it's already completed; C. I've never think about it.

A、有待提高； B. 已经很完善； C. 没考虑过

(13) In your opinion, is it possible for China to improve living comfort level on the condition of just keeping low energy consumption as status quo?

您认为中国是否有可能在保持目前居住建筑低能耗的前提下，提高居住舒适性？

A、Yes, it's possible if we implement energy efficient technologies.

B、No, it's impossible. Energy consumption must be risen with the improvement of living comfort level.

C、I've never think about it.

A、是的，如果加强节能措施的话，有可能；B 不可能，提高舒适性必然耗能增加 C 没考虑过

(14) In your opinion, which is the best way to control residential building energy consumption in China in the near future?

您认为，以下哪些方法能最有效的控制中国住宅能耗的增长？

A、Applying energy efficiency technologies B. Changing living customs C. Raising energy price D. others

A、应用节能技术 B 改善生活习惯 C 提高能源价格 D 其他

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(15) In your opinion, which phenomena should be improved in residential buildings? (Multiple Select)

您认为，下列哪几点应该在住宅改造中改进？（多选）

A. Indoor temperature; B. Indoor moisture and condensation; C. Cold/hot wind infiltration; D. Noise;

E. Ventilation and fresh air; F. Living environment; G. Others (Welcome any suggestion you think should be added here)

A、室内温度； B. 室内湿度和冷凝； C. 冷/热风渗透； D. 噪声； E. 通风和新风； F. 居住环境；

G. 其他（欢迎补充）

Thank you very much for your cooperation for this research investigation!

If you have any questions, please don't hesitate to contact with:

非常感谢您的合作，您为我们此项课题提供了很大的帮助！欢迎联系：

yu.zhang@polito.it

Fig. 5.11b Investigation sample

As statistics, male architects are more than female architects and the graduation background for Chinese architects is improving steadily these years. The main force of architects who are working in the front line are bachelor degree graduated or master degree graduated and even there are a few architects are doctor degree graduated.

If we compared the statistics with different cities, we would find that in more developed cities like Beijing, Shanghai and Shenzhen, the graduated background of architects is higher than the inland cities which are less developed like Jinan, Xi'an.

If we compared the statistics with people of different graduated background, we would find that architects with higher graduated background used to pay more attention to energy efficiency issues that architects with lower graduated background. The reason could be different information collection related with knowledge stratification.

If we conclude the professional time, we would get summary that the main forces of professionals are young and middle age who have worked less than 20 years. That's the result of fast urbanization in China in recent decades so there was large demand of profession architects.

On the base of this investigation, a large amount of value information was gathered and demand of development of energy efficiency for residential building could be summarized straightforward.

==

（1） Do you pay attention to the development of building energy consumption in China?

In our statistics, the percent of people who chose option *B sometimes* takes 58.1% in the total. In the meanwhile, the percent for other two choices *A Yes, I always pay much attention to it* and *C. I don't care about it* were taken the account of 37.6% and 4.3%. So we can get the conclusion that there are few people don't care about building energy consumption but the majority architects don't pay much attention on energy consumption issues. Although building energy consumption is an issue which has been paid attention by social concern, most professionals don't used to think about it in real projects.

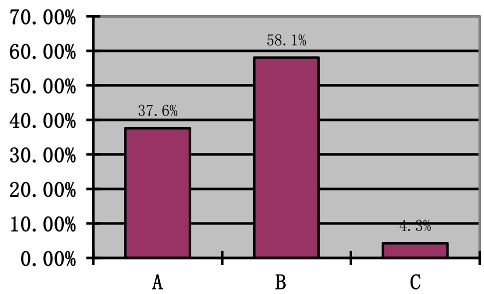

Fig. 5.12 Statistics of question 1

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（2） China says it will cut its CO_2 emissions 40-45% per unit of gross domestic product by 2020 compared with 2005 levels. Do you think China could reduce CO_2 emission by 40-45% in building sector?

In our statistics, the percent of people who chose option *A It's very difficult* takes 48.4% in the total. In the meanwhile, the percent for choices *B.If China can improve energy efficiency level, it can be done* takes 36.6% but for choice *C. I've never think about it* takes the account of 15%. At least, for Chinese people, it's very pessimistic for the promise which had been done by government to the world.

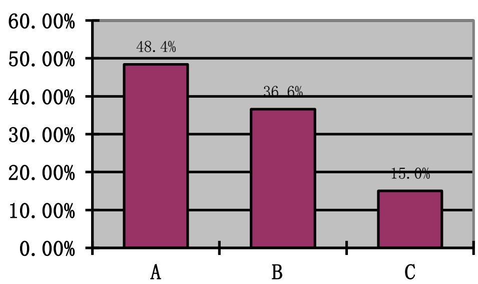

Fig. 5.13 Statistics of question 2

It's known all over the world that CO_2 emission reduction issue is the compelling obligation for all the countries in a certain period. As the second energy consumed country----China is highly expected to meet the aim by 2020 and the cost for failure is inconceivable. CO_2 emission reduction issue should be paid attention by each person. Especially for the architecture and urban plan related professionals, since the building sector takes 40% energy consumption in China, they should implement the energy efficiency method and technologies consciously. Compared with the other energy consumption sectors, like industry and agriculture, they are prerequisite living conditions and economic driven force. If China wants to keep economic improvement, we must improve the conscious of architecture professionals.

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（3） Can you describe the proportion of sustainable and low energy consumption building design projects in your works?

In our statistics, the percent of people who chose option *D Medium, more and more* which is the most takes 45.8% in the total. In the meanwhile, the percent for choices *C Medium and B Many* take 22.9% and 11.5% while the choice *A Most, E A few* and *F a few but more and more* take 9.4%, 6.2% and 4.2%. So we can get the information that there are more and more sustainable and low energy consumption buildings would be constructed in China that means all sectors the society have got the consensus that sustainable and low energy consumption is the developing trend in the future.

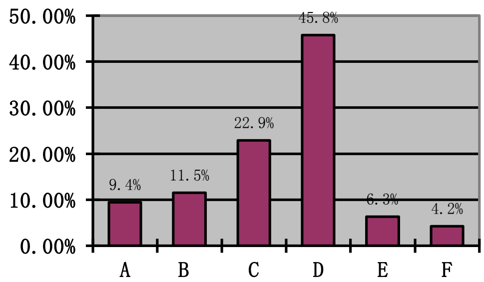

Fig. 5.14 Statistics of question 3

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（4） Is there training for learning building energy efficiency legislations in your company?

As we know, the energy efficiency techniques and standards are updated fast with technology development. In Europe,

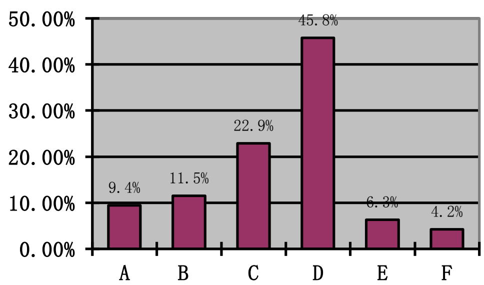

Fig 5.15 Statistics of question 4

professionals have many opportunities to get training and take participant into research in society and universities and the company or social institute also have cooperation with research institute.

But in this survey, 45.8% people chose choice _B sometimes_ but people who chose choice _C a few/ no_ take 22.6% even more than choice _A often_ which is 14%. That means most people don't have enough opportunities to update energy efficiency knowledge. Although there are test of building legislations in registered architect exam, it's still lack of training for advanced energy efficiency technologies and legislations in China.

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（5） When you work for a project, would you think about of using renewable energy (solar, wind, etc.) initiatively?

This question is aimed at investigating the consciousness of professionals during their profession work adopting clean energy or renewable energy. In the replies, 62.4% people chose option _B Just to meet the demand of related legislation_ while the proportion of option _A Yes, I'd think about it initiatively_ and _C No, I wouldn't_ are 19.4% and 18.3%. In my opinion, it's the result of lacking of training nor support for improving energy efficiency legislations. It means most of the professionals would not consider using renewable initiatively. The reasons could be summarized as high cost and immaturity of renewable energy technologies and lack of administrative support.

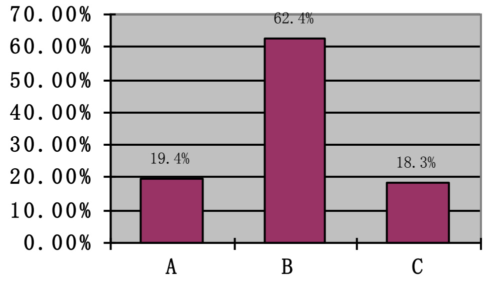

Fig. 5.16 Statistics of question 5

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（6） In your opinion, what should architect do for reducing building energy consumption?

In this question, the proportion of option _B enhancing concern of using energy efficiency technologies_ and _C cooperating with other relevant partners initiatively to improve building energy performance_ are the same is 46.2% while the proportion of

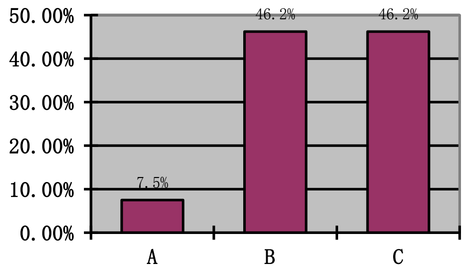

Fig. 5.17 Statistics of question 6

option *A Just follow the basic legislation* is only 7.5%. Just compared with the last question, we'll find that architects including urban planner have the instinctive responsibilities to improve building energy consumption reduction.

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（7） Do you think applying energy efficiency measures is an important procedure in design process?

Just for affirming correctly, this question proved that development of adopting of energy efficiency measure in design process will be completed successfully in the future.

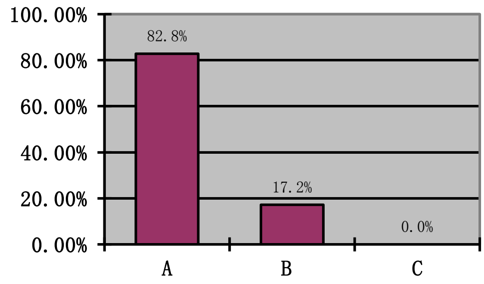

Fig. 5.18Statistics of question 7

Overwhelming majority chose the option *A Yes, it's really important* and option *B. moderate* takes only 17.2% while nobody chose option *C. It's not important at all*. Since everyone has realized the importance of applying energy efficiency measures and even very important.

It's an important procedure not only for residential building but also for all kinds of building. Architects should chose proper energy efficiency measures and apply these measures in all possible sectors.

（8） What do you think about the possibility of implementing energy efficiency standards for residential building in China?

For residential building which is the main force for real estate improvement in China, in fact, energy efficiency is only paid attention by these recent years. In the previous projects, energy efficiency criterions were neglected because of lack of related standards. In this question, 63% people chose option *B medium* and 26.1% chose option *C difficult*, 10.9% chose option *A Easy*. That means although majority has got the consciousness the importance there still a lot of obstructions for implementing

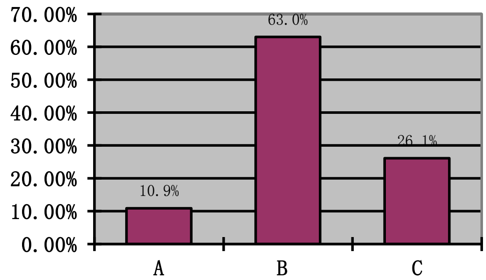

Fig. 5.19 Statistics of question 8

energy efficiency standards for residential buildings. That's because there are really much more difficulties in China for implementing than EU countries.

==

(9) Do you think it's possible to improve the energy efficiency criterions for residential building in China?

If we consider about possibility to improve the energy efficiency criterions for residential building in China, 60.9% respondents chose option *A Because the current standards have already been used for several years, With the technology improvement, it's possible to improve the standards for building energy efficiency*.

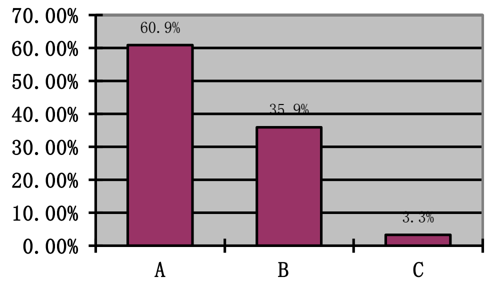

Fig. 5.20 Statistics of question 9

While only few respondents (3.3%) chose option *C It's already difficult to implement the current standards. I don't think it should be improved.* And 35.9% respondents chose option *B I've never think about it, I just follow the current standards passively.*

It's shown through this result that most respondents have enough confidence and willing to improve energy efficiency criterions. Compared with the last question, insufficient implement and low level energy conservation standards lead to enormous gap to improving exiting criterions.

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(10) In all the residential building projects which you've taken part into, Are there many refurbishment projects in residential building projects compared with new residential?

In this question, 86.9% people chose option *D few* while proportion of the other options are *C medium* 8.7% , *A lot of* 2.2% and *B many* 2.2%.

In China, people used to construct new residential buildings than refurbish exiting buildings. On the one hand, that's because the disparity between urbanization and building construction. On the other hand, low benefits and complex cooperation system also led to ignorance of residential building refurbishment.

So different from the situation in EU, although the lifespan of residential buildings in EU is much longer, in China, most residential buildings are needed to be refurbished after 15-20years. Refurbishment is a research topic which would be attaching importance to from now on.

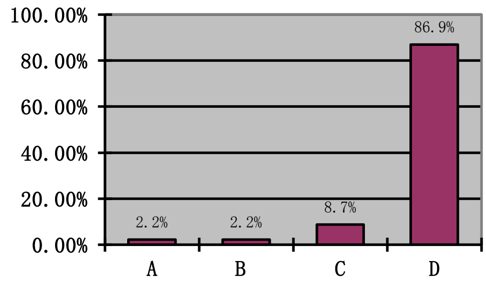

Fig. 5.21 Statistics of question 10

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（11） <u>In the residential building refurbishment projects which you've done, how many projects have been put forward the demand of energy conservation or low energy consumption?</u>

Among those residential building refurbishment projects, about half respondents (52.2%) chose option <u>*D few*</u> and 29.3% respondents chose option <u>*C medium*</u>. But there were only 7.6% and 10.9% respondents chose option <u>*A A lot*</u> of and <u>*B Many*</u>.

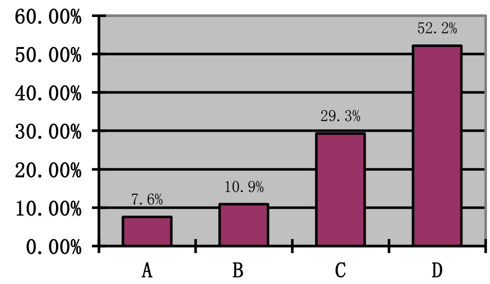

Fig. 5.22 Statistics of question 11

So many architects have emphasized on improving enthusiasm of government (strategy planner) and developer (performer).

Energy efficiency technologies must be implemented in every steps in the design process and a complete framework and methods for urban residential building refurbishment project should be set up as soon as possible.

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（12） Do you think the standards for energy efficiency of residential building refurbishment are completed or still have to be improved?

For feasibility of improvement of energy efficiency standards for residential refurbishment, 84.8% respondents chose option *A It's still have to be improved* and proportion of option *B it's already completed* and *C I've never think about it* are 2.2% and 13%.

Compared with question 9, although most architects don't know exactly how to improve energy efficiency criterions for residential building in China, it's shown in this question that overwhelming majority architects have conscious that energy efficiency standards for residential building refurbishment in China are outdated and needed to be improved.

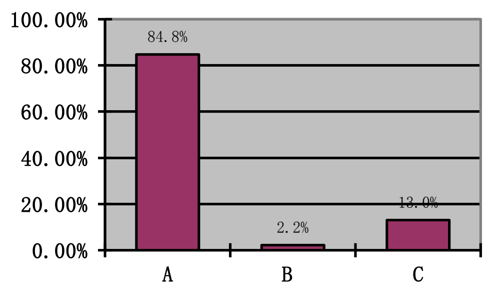

Fig. 5.23 Statistics of question 12

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（13） In your opinion, is it possible for China to improve living comfort level on the condition of just keeping low energy consumption as status quo?

In this question, we find that 81.3% respondents chose option *A Yes, it's possible if we implement energy efficient technologies* while 6.2% respondents chose option *B No, it's impossible. Energy consumption must be risen with the improvement of living comfort level* while 12.5% respondents chose option *C I've never think about it*.

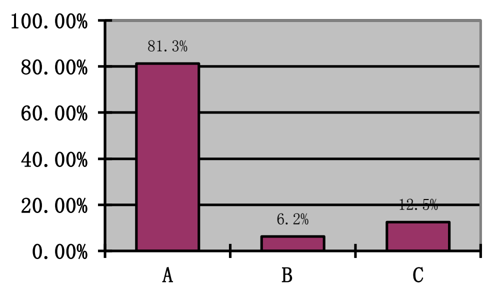

Fig. 5.24 Statistics of question 13

There was a certain common view that China should keep low energy consumption in residential building sector as current level but don't need any energy efficiency measures. But as we know, low energy consumption in China in current is result of internal low comfortable level. It's impossible for China to keep this situation because the explosion of demand and society development. In the result of this question, we find that there is already got agreement that China should improve comfortable level with energy efficiency strategy.

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（14） <u>In your opinion, which is the best way to control residential building energy consumption in China in the near future?</u>

We offered four options for this question and they are:

<u>A. Applying energy efficiency technologies</u>

<u>B. Changing living customs</u>

<u>C. Raising energy price</u>

<u>D. others</u>

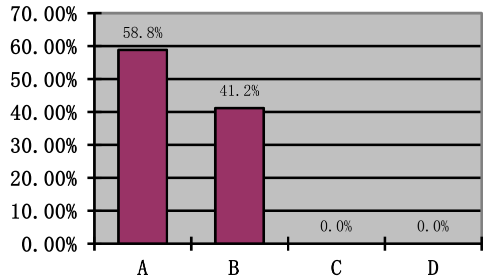

Fig. 5.25 Statistics of question 14

As our statistic, the answers are focused on option A and B. This result coincided with this research we made in previous chapters. We have analyzed the changing of living customs in section 5.1.3 and next part we will find solution of how to apply energy technologies into residential building refurbishment project in China.

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（15） <u>Phenomena should be improved in residential buildings.</u>

A. Indoor temperature;
B. Indoor moisture and condensation;
C. Cold/hot wind infiltration;
D. D. Noise;
E. Ventilation and fresh air;
F. F. Living environment;

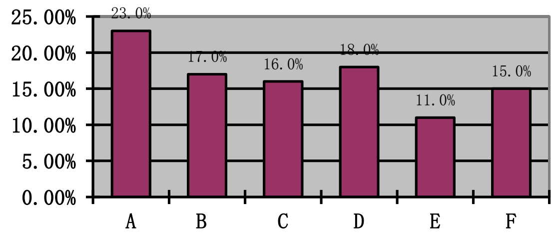


Fig 5.26 Statistics of question 15

We want to investigate the main problems in of residential building in this question. The result supplies a strong guide support for choosing energy options. We will talk it in section 6.4.

5.2.2 Improvement of importance for residential building refurbishment by professionals

Besides the answers to questions in this survey, many professionals also gave us many suggestions for energy efficiency development for residential buildings in China. We are happy to see that energy efficiency issues had been improved to higher level than before, but we have to face the fact that there are not enough energy efficiency techniques and related standards in China while building energy efficiency is already an urgent issue for China. Feasible and mature techniques should be improved immediately.

When we talk about energy efficiency, we start from group consciousness (low-end maintain) and advanced techniques (high-end solution) these two aspects. Each sector in the society should try to implement proper energy efficiency measures. Improvement of innovation technologies not only could be used to limit energy consumption but also to improve living environment which is especially important for residential buildings. In the other hand, implementing energy efficiency technologies also could help keeping society improvement and CO_2 emission reduction.

Several aspects of which energy efficiency for residential building have been presented:

- *Popularizing energy efficiency idea.* Energy efficiency measures should be started from the design period and implemented by all the steps including constructing, using and refurbishing. So except the professional architects and governors, the energy efficiency idea should be popularized to real estate, constructor and inhabitants. Professionals have the duty to popularize benefit of energy efficiency to all the sectors in society.

- *Enhancing governance and offering more concessions to energy efficiency building projects.* In the case of residential building, local government could offer concessions by tax and land using. In China, residential building using age is 70 years. It's different from EU and US, the house owner could only have proprietorship of the house for 70 years which is timed since land use approval. The using age of residential building in China is much less than other countries. This limitation caused low cost strategy in previous projects. So in China, forcing from government is the indispensable reason for improving energy efficiency.

- *Completing related legislation.* A complete and feasible framework of sustainable residential building design should be set up in China. Compared with EU and US, overtime legislation should be updated and local techniques should be explored.

- *Improving fissures such like technology and clean energy.* As we mentioned in Chapter 3, in China, using of clean energy such like solar and wind is improving fast and also innovated energy-saving material has been transferred in.

- *Inspecting previous projects.* Researchers should get experiences from reviewing previous projects and taking advanced experiences from EU and US cities which have similar conditions.

5.3 Internal operation model

Actually, it's impossible for China to complete the working framework for existing residential building refurbishment by internal research although this is really an urgent research issue which Europe started earlier and already achieved remarkable results. But compared with European cities and residential building refurbishment projects, the step which is conspicuous is the internal operation model of Chinese residential building administration system. We can talk about this topic in two aspects: research ability in China and residential building governance.

China's research and development expenditure as a percentage of GDP is about 3.15% (Ministry of Finance PRC) which is very low compared with developed countries and even some other developing countries. The country has low levels of educational attainment, which does not augur well in an increasingly knowledge based economy. Elsewhere, China has been granted very few patents, which shows that the country lacks the culture of innovation. The country has failed to carry out proper impact assessments before giving permission for tourist infrastructure in some ecologically sensitive areas.

In the meanwhile, residential building construction system in China is different from that of EU neither US. From the governing level to the design process and construction step and even the proprietorships are operated in Chinese model.

5.3.1 Residential building construction system in China

The administrative structure of China is different from that of most western countries' and administrative control divisions are different either. It's shown in Fig. 5.27 that the division of administrative level was organized as central government, province level, prefecture level, country level, township level and village level. In the figure, we can see that there are also several categories for each level but it is a clearly hierarchical structure based on China's actual conditions. We can divide the structure into part for urban area and part for rural area these two parts.

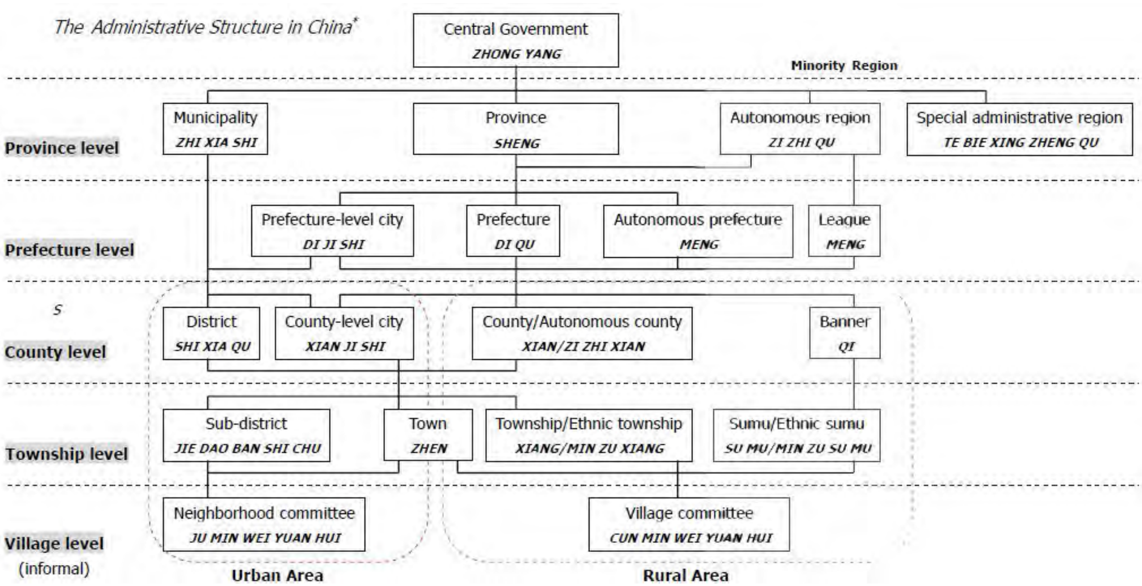


Fig. 5.27 The administrative structure in China

5.3.1.1 Top-down promotion

In fact, in China, all administrative control implement are operated in the Top-down mode. Also the residential building construction is controlled by government strictly. From the land-use approval to construction process and even real estate market prices, all should be done under the guidance of government. So the most efficient method for implementing energy efficiency of residential building is promoting real actions by top-down mode.

Refurbishment of residential building is one of the main parts of energy efficiency promotion. The policies and related regulations issued by central governments have been the legal basement of residential building energy efficiency procedure in Chinese cities. In addition, the residential building energy efficiency procedure will become obliged ordinances after integrated with Master Plan and Regulatory Plan of the cities which will strengthen the feasibility of sustainable development. As the Fig. 5.27 shown, the Chinese government is hierarchically organized from the central to prefecture level and the promotion or appointment of officials only decided by their achievements at local levels and the appraisals by their higher-level governments. The transition of the criteria of measuring their achievement from GDPism to green GDP is an important turning point of city development in China. After the highest administration exposing the stable determination to alter GDPism to sustainable development, the municipal governments all take the initiative to change their original development pattern. Some Chinese cities have begun to establish low carbon planning and more cities have formulated incentive polices for renewable energy application. By this hierarchically top-down transfer mode, a general ambition could be progressively decomposed to a group of specific projects. All the transformations happened and happening in China all proved the strong effects of this politically top-down promotion.

Table 5.4 2008-2010 Energy–saving Retrofit plan on existing residential building in 15 provinces in northern China (Zeng, 2011)

Province (Unit: million square meters)	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia	Liaoning	Jilin	Heilongjiang
Retrofitting Area	2500	1300	1300	460	600	2400	1100	1500
Province (Unit:million square meters)	Shandong	Henan	Shaanxi	Gansu	Qinghai	Ningxia Hui Autonomous Region	Xinjiang Uygur Autonomous Region	Total
Retrofitting Area	1900	360	200	350	30	200	800	15000

In 2008, China started energy-saving retrofitting on existing residential buildings in northern 15 provinces (municipalities and autonomous regions) and planned to transform 150 million square meters of existing residential buildings in three years, with retrofitting tasks of various provinces (municipalities and autonomous regions) as shown in following Table 5.4. Energy-saving retrofitting includes the following three elements:

1) Retrofitting of indoor heating system measurement and temperature adjustment and control of buildings;

2) Heating and pipe network heat balance retrofitting, including heat resources, thermal stations, pipe network installation metering devices and water balance, climate compensation, frequency and other adjustment and control devices;

3) Energy-saving retrofitting of building envelope retrofitting, including exterior walls, windows and doors, roof, floors and staircases, etc. The central government provides subsidies for energy-saving retrofitting of existing buildings in the form of award replacing subsidy with subsidy fund accounting for 20% of the retrofitting fund and other 80% fund will rely on local finance, enterprises and individuals.

As of the end of 2009, northern 15 provinces and municipalities have completed 110 million square meters of energy-saving retrofitting. According to calculation of relevant departments, the transformed energy-saving projects could form the capacity of saving 750000 tons of standard coal annually and reducing emission of 2 million tons of carbon dioxide. The left projects will be finished before the heating season of 2010. The retrofitting pilot projects have benefited residents in northern cold areas and residential housing insulation and heating situation have been fundamentally improved leading to remarkable improvement of living conditions.

After nearly three years of practice and exploration, the retrofitting model of guidance by government, support by policy, market-oriented operation, risks sharing of state, enterprise and individual and benefit sharing have been brought to the front in energy-saving retrofitting on existing residential buildings in North China, which has laid solid foundation for further promotion of this work in the Twelfth Five-year Period.

5.3.1.2 Bottom-up implement

Of course China is still under authoritarian regime, but the amount of civil organizations is increasing and the capacity and impact of them are strengthening recently during the transition from planned economy to market. Even as biased policies and corruption due to concentrated political power and wealth contribute to greater conflict and potential instability which will threaten China's economic future, China's society is still developing in positive ways. Energy service is disaggregated into corresponding end-use to represent the whole energy use picture in residential and commercial building sectors. GDP and population growth are the key drivers of increase in floor space; while increase in household income is taken as a proxy of living standards to give people more aspiration to better services in buildings, translated into accrued demand for energy services, in particular space heating and home appliance in residential buildings.

The CCP (China Communist Party) mistrusts any independent civil society, and state interference prevents civil society organizations from developing fully. Notwithstanding, in the past decade, Chinese have joined civic organizations in droves. These include chambers of commerce, neighborhood property-owner committees, sports and recreation clubs, animal and environmental protection societies, art and culture clubs, and philanthropic organizations (Gilboy and Heginbotham, 2010). According to the statistical bulletins of Ministry of Civil Affairs of the People's Republic of China (MCAPPC, 2010), between 2000 and 2009 the number of civil society organizations has increased from 130,000 to 425,000, which suggests China's society is changing and Chinese citizen consciousness is awakening.

These grassroots organizations have played important roles in city development and social affairs, which are also affecting a lot of government decision-makings by their own capabilities. Especially the implementation of low carbon planning will depend on the whole society, not only the powerful government. The scholars of think tanks can assist the governments to formulate of residential building energy efficiency scheme. With market forces, many ideas and schemes of energy efficiency residential building projects could be easily realized. Private capitals will play an important role in the commercialization of all energy efficiency technologies which is essential for the implementation of the projects. And private capitals could have more essential motive to implement existing residential building energy efficiency refurbishment.

5.3.1.3 Integrated-model projections

Jiang and Hu (Jiang and Hu, 2006) specified China's building sector energy-demand development trend and emission scenario by the IPAC model, and the implication of different policy options in building sector has been analyzed. Their model predicts that coal use will be replaced progressively by gas and electricity in the Chinese building sector, electricity would represent 42% and 48% of the final consumption in 2020 and 2030, respectively, in the baseline scenario. They projected that energy demand in buildings would increase steadily to reach 417 mtoe in 2020 and 666 mtoe in 2030 in the baseline scenario. On the other hand, by implementing vigorously the efficiency improvement policies in both new construction and existing buildings as well as upgrading appliance efficiency, energy demand could be reduced by 17% in 2020 and by 28% in 2030, respectively, under the policy scenario. Building energy performance improvement and other measures such as distributed heating and cooling, heat pump promotion and appliance efficiency improvement (cooking, office, air conditioner, lighting appliance, etc.) are considered in the 'policy scenario'. They also pointed out that there is still room for further energy savings if more advanced technologies could be fully diffused. Buildings would account for around 28% of the final energy consumption in 2030 under the reference scenario, and 26.7% under the policy scenario (IEA, 2006), EIA's reference case projected that China's buildings energy consumption would reach 282 mtoe in 2015, 312 mtoe in 2020 and 401 mtoe in 2030.

Residential energy demand would increase dramatically given the improvement of the standard of living and household structure evolution. The improvement of residential condition and development of the urbanization process will stimulate energy services demand such as heating and cooling in the building sector in the cities.

Furthermore, low-income people and rural residents will gradually switch to modern energy such as natural gas or electricity to replace conventional biomass energy (mostly straw and stalk), which is now widely used in rural areas for cooking and heating use. The pursuit of Western life style will inevitably accelerate this process. The tension between energy supply and demand could be sustained if no energy efficiency policies are implemented effectively in the building sector.

5.3.2 Instinctive motives of residential building refurbishment in urban area of China

Compare with EU experiences, in China, residential building refurbish projects should be thought about in a higher macro level. Since the development of cities in EU and China are quite different which are the result of general-purpose effect such as different society structure, different culture context, different economic conditions etc.

Fig. 5.28 Images of cities in Italy and China[1]

For example, Italy and China both are countries with long history and rich culture heritage. Although been started development in different time, cities in these two countries are entranced into post industry period. But when we go to visit Chinese cities, we would find that most of cities are looked like similar with each other. There is distinct shortage of identity among most of the cities. Actually, this phenomenon is odd because that there were many kinds of historic architecture styles handed down and there were specific

[1] Source: http://www.h2it.org/2008/regions/piemonte/piemonte-progetti/progetto-why
http://upload.wikimedia.org/wikipedia/commons/6/66/Valentino_castle.jpg
http://biz.cn.yahoo.com/ypen/20101030/67212.html

architecture styles in different areas in China. However, in China, especially in urban areas, the phenomenon tending towards the assimilation has appeared in the more and more cities.

We listed four photos in Fig. 5.28, the two photos above are overhead view of city of *Turin* and photo of architecture faculty of university of *Politecnico di Torino*. And we also put two photos of *Beijing* and architecture faculty of university of *Harbin Institute of Technology* to make a comparison. Turin is the third city in Italy which is famous as "automobile-city" and other industrial enterprises. Although Turin is an industrial city, we can find that the city architecture style and texture are remained well as traditional local style while the modern transportation and industry are integrated into this traditional city for meeting modernism development. In comparison, Beijing as the capital of China is the cultural and political center but it's difficult to find traditional texture even in center of the city, almost all the historic buildings even the historic blocks are submerged by skyscrapers surrounding. In the meanwhile, transportation system is organized disordered in the joint between historic district and new planned urban area.

We can easily get the summary that the different city-refurbishment mode is the direct cause for this result. As we know, even with long history, European cities were started industrialization earlier than Chinese cities, but European cities were obeyed the guidance that would refurbishing the exiting districts on the base of thinking more holistically rather than just enlarging the urban area by constructing new buildings. For China, the situation is just contrary, as we talked about in last section, GDPism leaded huge reconstruction areas in cities in China.

Fig. 5.29 Foggy weather in Beijing

At present buildings, energy consumption in China contributes to 25% of GHG emissions (Long, 2005). Housing construction in China consumes 20% of total steel output and 17.6% of cement production each year. Average steel and cement consumption in housing construction in China is 55 kg/m^2 and 222 kg/m^2, respectively, 10–25% higher than in developed countries. [1]

Table 5.5 PM 2.5 particles information of Beijing

Beijing	Beyond index 500
PM 2.5 particles	522
Data: live feed from US embassy Chaoyang district, Beijing. 04-12-2011	

What's more, it's not only waste of materials and energy in the process of constructing cities in China, but also result in a serious of environment problems. Since this autumn, air quality in Beijing became exacerbate and even disturbed normal life in Beijing and could be defined as toxic. The term fine particles, or particulate matter 2.5 ($PM_{2.5}$), refers to tiny particles or droplets in the air that are two and one half microns or less in width.[2]

So we must pay much attention on energy efficiency issues for the target of CO_2 emission reduction. There is prime importance of significations for residential building energy efficiency. When we talk about the topic of exiting residential building energy efficiency, we must reorganize that is an issue which is related with dual core that are city and building development. In the top-down level, the refurbishment can be researched from three levels: city refurbishment, district refurbishment and building refurbishment.

5.3.2.1 City renewal

If we take a view to city level, we would find the cities are developed rapidly all over China, not only numbers of the cities was increasing a lot (there were 132 cities before 1949 and 462 cities until 2007) but also scale of the cities was enlarged a lot. Huge scale urban development brings about not only appearance of emerging cities but also existing city refurbishment. Many cities in China are currently impacted by rapid urbanization which leaded to changes of land use, urban form and municipal environment. The importance to incorporate the city regeneration and expansion is urgent to be solved. But in China, city renewal is not considered by society until recent year after a serious of problems which are caused by the out of sequenced development of the city. However, the issues of planning and design of the city is a complex topic related with many factors.

[1] Centre for Housing Industrialization, Ministry of Construction, 2007. http://www.chinahouse.gov.cn/cyfz16/160002.htm

[2] http://www.health.ny.gov/environmental/indoors/air/pmq_a.htm

Link supply and demand energy consumption together via technologies

The discussion of how to develop the cities in a sustainable way has been an enduring topic on the urban planner and architect's table from long time ago. Because of the huge energy demand and CO_2 emission, researches on the topic of Low carbon city had been brought in China in recent years. Approximately half of the global population lives in urban area, which serve as centers of culture, entertainment, innovation, education, knowledge and political power. Although they account for less than one percent of the Earth's surface (Eilperin, 2007), urban areas are responsible for roughly 67 percent of the world's energy demand (IEA, 2008). Roughly three-quarters of all carbon emissions from fossil fuel combustion, cement manufacturing and wood use occur in these fuel urban areas (Mitra et al., 2003).

Energy demand and urbanization development of the city result in a serious problems with existing residential building. New demand and supply mode compelled improvement of self-regeneration pressure in the existing residential community. Innovation technology supplies possibility for solving the problems. Demand-side Energy Technology is the technologies which control the energy demand and promote energy efficiency of buildings and facilitates. In residential building sector, demand-side technologies is tried to reduce energy consumption in heating and cooling, lighting, construction material and ventilation of the buildings and preserve fossil recourse for reducing CO_2 emission. In other hand, supply-side energy technologies is tried to reform traditional energy consumption system by exploring clean energy application and lead buildings on the way more efficiency, more "smart".

Only demand and supply energy consumption together via technologies that existing building could be refurbished in a sustainable way. An energy efficiency building is a diversifying system developed synchronously. In the process of regeneration, new constructions built with energy efficiency technologies would drive refurbishment of existing area. Refurbishment of the city would cause regeneration of residential building in existing area.

Symbiotic relationship for economic and lifestyle

It is scarcely in doubt that China's energy needs will continue growing to fuel its economic development. However, the rate of increase and how those needs are met are far from certain, as it depends on just how quickly the economy expanding, also depends on the economic and energy-policy landscape worldwide. The expansion of China's share of world energy demand will or has already posed a threat to the balance of world's energy system, and will challenge the world's energy security. In a manner of speaking, energy demand and supply condition determines the economic.

China, from its own perspective cannot afford to and, from an international perspective, is not allowed to continue on the conventional path of encouraging economic growth at the expense of the environment (Zhang, 2010a). Although China achieved a quadrupling of its GDP with only a doubling of energy consumption between 1980 and 2000, China has also experienced faster energy consumption than economic growth since 2001 (Zhang, 2010b). The benefits of energy efficiency and the shift to clean energy is identified on economic saving on energy conservation and living environment improvement by healthy lifestyle. In China, the hierarchical bureaucracy of China with planned economic management model is used to divide a general goal to explicit targets down the administrative hierarchy. In Chinese, this is known as dividing the task to the lower layer of government (cengceng fenjie or, literally, dividing the overall growth target and disaggregating the divided targets along the tier) (Wu and Zhang, 2010). Benefiting from the existing multi-level urban planning system dominated by the municipal administrative, this hierarchical scheme could be easily realized in Chinese cities.

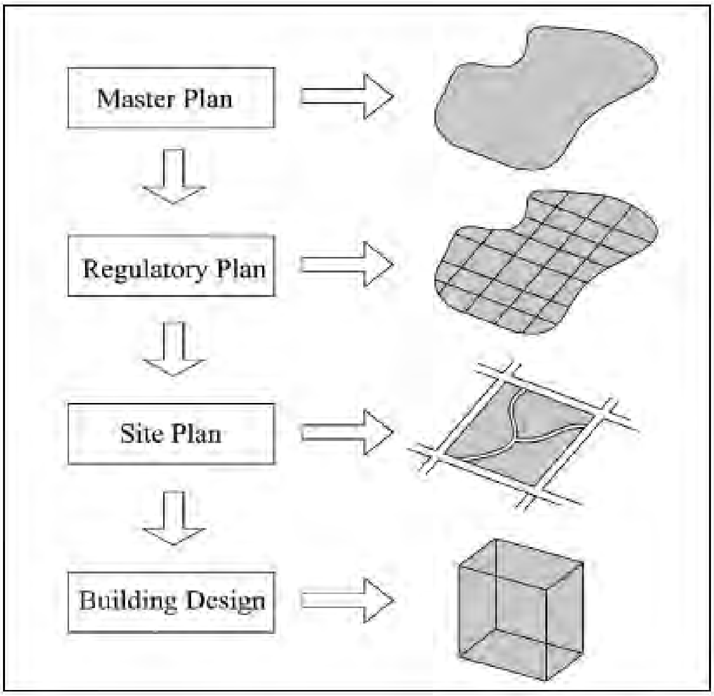


Fig. 5.30 Multi-level Urban Planning System in China

As Fig 5.30 shows, the general planning and design procedures at city scale in China could be divided into four stages. Each stage has its clearly target and implementation area. (Yu, 2011) Master Plan focuses on policy frame integrated with economic development and city construction from general viewpoint; Regulatory Plan determines the precise instructions for city construction by indicator system; Site Plan concentrates on the city context and physical space design at the block level; Building Design works for special building or construction obeying all requirements drafted by the above planning. Therefore, residential building refurbishment is task fixed in the building design level thus it is a result of top-down planning system.

Integrate optimization across system: *Mono to Smart*

Since the complicacy of sustainable city development, city planning is related by a variety of local factors. Detailed plan should be made in local level. It is now widely recommended that every urban local authority should work in partnership with its local community, businesses and technical specialists on the formulation of a local energy strategy. Such strategies generally need to cover at least (Mills, 2010):

Table 5.6 Local energy strategy in urban level

• Energy use in municipal, residential, industrial and commercial buildings, including the design and operation of energy efficiency retrofit programs
• Public lighting
• Municipal vehicles
• Public transport
• Private, commercial and freight transport
• Waste management
• Waste water management
• Energy generation and distribution (especially local and distributed electricity
• generation using, for example, wind power, hydro-electric power, solar power, combined heat and power and district heating)
• Land use planning and urban design
• Programs to support telecommuting
• Building standards for new development and renovation
• Public procurement standards
• Behavior change on the part of citizens and enterprises

Based on these principles, city development should be developed on the way from “mono” to “smart” by stratified multi-objective programming. The complex topic of sustainable city development plan could be split into related issues on different viewpoints. For city level, plan for smart city could be started from transportation, deployment, industry, infrastructure and building sectors. Under the city level, urban area is constituted by some districts, development of city drive the refurbishment of existing urban area, and plan of city refurbishment is implemented by district refurbishment. In building sector, energy efficiency technologies finally are embodied in building construction process. So we can get the conclusion that building retrofitting make up the district regeneration and city renewal; in the contract, the process is also established in the reverse direction. Because of the instinct relations among urban-building system, urban development gives a great push to building refurbishment. (Fig 5.31) In the meanwhile, as we have discussed about in Chapter 2, that urbanization improvement intensifies need for residential building. Residential building is an important part of city development.

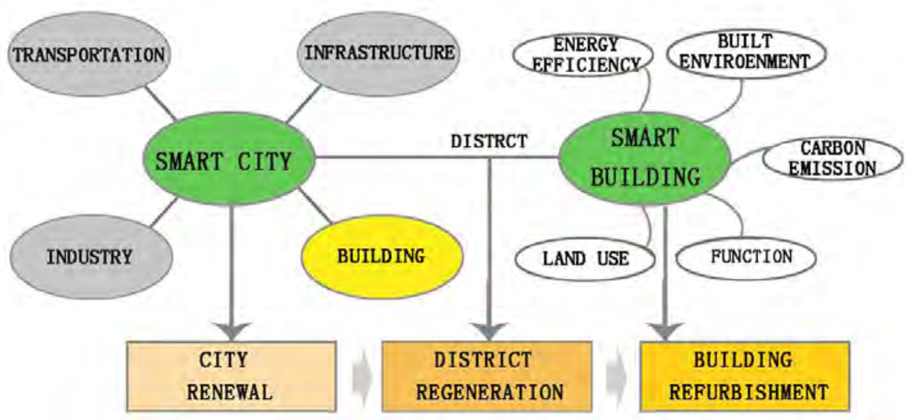


Fig. 5.31 Diagrammatic diagram of smart city and smart building and key points

5.3.2.2 District regeneration

For exiting residential districts, outdoor space refurbishment is a very important part because public space and facility is the container for community and affected a lot on inhabitants' sense of belonging.

A complete and comprehensive improvement for outdoor space in residential districts is part of urban construction and also a part of district refurbishment. The aims of improving of outdoor space are improving living level, living environment, and city sense and improving value of existing residential district. Outdoor space is always neglected because the indeterminate property and lack of investment. And outdoor space of existing residential district is limit with original design and illegal occupant. The common problem of outdoor space of existing residential district includes: dilapidation facilities without thorough repairmen; narrow active recreation area without plan; serious illegal occupant; not convenient living environment and etc. In allusion to these problems, the residential district refurbishment should include the following principles:

Comprehensive improvement of outdoor space

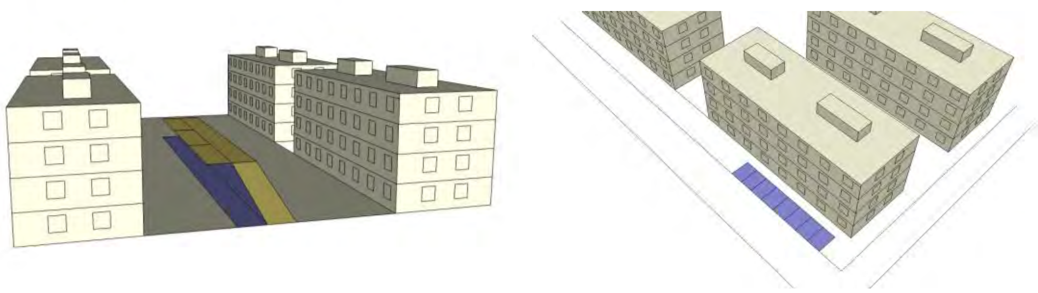
The outdoor space improvement should be made on the base of original status and try to keep traditional feature of the existing residential district. Creating high quality yard for meeting recreation needs, measures like demolishing unnecessary construction like storage shelf or constructing green roof on the residential building should be taken by coordinating with inhabitants and management department.

Fig. 5.32 Photo of Yuanding Residential community (Harbin, China) environment in 2007

Photos in Fig. 5.32 and Fig. 5.33 show residential district environment before and after refurbishment in Yuanding Residential District in Harbin (China). This residential district locates besides Harbin Institute of Technology and refurbishment specific of outdoor environment is made in 2007. Before refurbishment, the operation of residential building built in 2003 was good and didn't need to be refurbished but the outdoor environment of Yuanding residential district was dilapidation with grass back to front and could not meet the improving requirement of parking, sporting and communication etc. Refurbishment is made in two aspects: parking area reconstruction and green area retrofit. By new site plan the green area of this residential district is harmonized with sport stadium of university and park. And public road of residential district is reconstructed by division of traffic area and parking area. By refurbishing, the parking area is increased to 3126m^2 with 119 parking positions while green area reached over 1000m^2.

Fig. 5.33 Photo of Yuanding residential district (Harbin, China) environment after refurbishment 2008

Rational Public transportation system



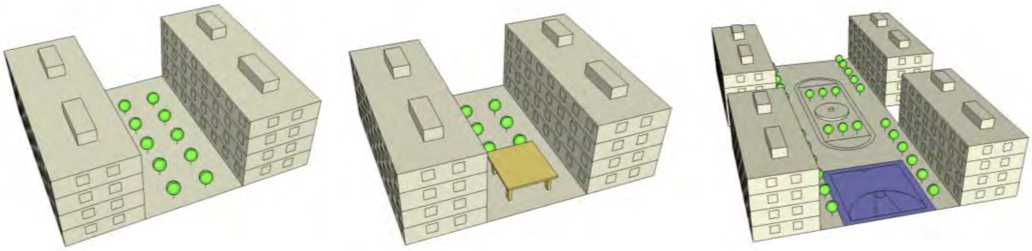
Three-dimensional parking system　　　　Ground parking

Fig. 5.34 Parking area retrofiting in residential district

It is difficult to make transportation retrofit in existing district and it is more difficult in mountainous region with slope landform. So the aim of transportation retrofit in existing district is to retrofit the unreasonable and inconvenient fields on the base of original status. With the improvement of living level, demand of parking areas for private car is increased a lot, so the refurbishment related reconstruction of road, passage for the disabled and site plan of district. Developing underground space or constructing multi-floor constructions for parking could be used in case there is enough space for transpertation is another solusion besides ground parking. (Fig. 5.34) In mountainous region with slope landform, vertical transportation should be considered with slope.

In allusion to shortage of existing residential district built before 2000s which are lack of sustainable conception and utilization of renewable energy, refurbishment should tried to increase green area and solar light.

Improvement of public facilities



Adding trees in yard; Recreational facility with green areas; Sport field and square

Fig. 5.35 Combination mode of outdoor public facilities in residential district

Public facilities include parking area, community center, certain scale of commercial area and municiple facilty. The demand for public activities is increased by improvement of living environment. The mythology of refurbishment is divided into three levels: adding trees in yard between residential buildings; reconstructing recreational facility with green areas; reconstructing sport field and square in district. In Fig. 5.35 shows intention of public facility refurbishment in residential district, in real practice, combination mode of public facilities with residential buildings should be considered with transportation plan and building refurbishment.

5.3.2.3 Building refurbishment

From the analysis of city refurbishment and district refurbishment, we can find that both of them have direct effect that driven the requirement of residential building refurbishment. Plan of sustainable city propose the energy efficiency of residential building and improvement of district environment would lead to improvement of indoor environment, too.

By the influence of instinctive motives from city refurbishment and district refurbishment, residential building refurbishment in urban area in China is started after 2000. Since 2002, the Chinese Government has organized nationwide special inspection on building energy saving each year to conduct investigation, check, evaluation and summarization on implementation of energy-saving work in various provinces (Zeng, 2011). However, the work of building energy saving special inspection is difficult issue that needs governmental support and coordinating so at the beginning the work was only limited within various provinces without systematic summarization on the nationwide energy-saving work implementation. 2009 is an important year for Chinese development as a connecting link between the preceding and the following. Therefore, in order to establish scientific methodology of energy conservation refurbishment in urban area of China, a survey about major problems in the process of promoting existing residential building energy-saving retrofitting had been done in China at the end of 2009. The major respondents of questionnaire are corresponding government departments at various levels, including construction, development and reform and finance departments of provinces, cities and counties, and relevant bodies including financial institutions, energy service companies, and real estate developers, owners of public buildings, energy supply enterprises and residents. In the question of "Reasons for retrofitting of existing residential buildings energy efficiency", 39% households chose the reason due to unified promotion and organization of governments and it is expected that such way could be continued; while 34% inhabitants insisted the motives was came from willing of improvement of indoor comfort; and choices of other reasons took 27% as shown in Fig. 5.36.

Fig. 5.36 Reasons analysis on existing residential buildings energy efficiency retrofitting

Therefore, although there is strong expectation by inhabitants, residential building refurbishment in China is implemented passively in top-down mode. The aim of energy conservation refurbishment is concentrated in energy performance of residential building, comfort level of indoor environment and reasonable function.

Energy Performance

Improvement of energy performance is embodied in energy efficiency for heating and cooling, electricity energy consumption for household appliances and ventilation, water consumption for toilet and kitchen facilities and waste management etc. Retrofitting of building envelope like external wall, window, roof, foundation, basement, stairway, floors and building entrance; retrofitting heating/cooling system and pipe network including heat resources, power station; modernization of heat/ cool meters and water meters are main measures for improvement energy performance in the building. Economic saving by reduction of energy consumption is an obvious effect by improvement of energy performance for the inhabitants and the inhabitants could enjoy benefit of high comfort level without additional payment for energy consumption; while for local municipal government, CO_2 emission reduction could improve development of sustainable city.

Indoor Comfort Level

The indoor comfort level improvement by energy conservation refurbishment is embodied in human feeling. Improvement of control of indoor temperature could be achieved by energy efficiency measurements for reducing energy consumption for heating. The average indoor temperature was 15oC in most existing building previously while it was increased 3-6oC after retrofit. (Ding et al., 2011) Due to retrofitting of building envelope, the phenomenon of thermal bridge and mold could be avoided and cold/hot wind infliction could be solved. What is more, utilization life of existing residential building is extended and value is increased in the meanwhile.

Reasonable Function

By refurbishment, indoor space of existing residential building could be reconstructed to get more reasonable function for meeting living requirement. Since internal plan of most of existing residential building which were built before 2000s are lack of reasonable organization, with the development of society and economy, reasonable function refurbishment are strongly requested.

5.3.3 Financial structure

Energy-saving of building sector has important significations for environment protection, improving living level and constructing sustainable city. Energy conservation refurbishment for residential building is urgent issue need to be paid more attention in China. But there are still serious problems in refurbishment project. Financial organization is a key factor that is the basic for refurbishment project. In China, there is no complete financial operation system for residential refurbishment project.

At the beginning of refurbishment project, primary project budget demand and fund investment supply should be compared with each other and benefit of refurbishment could be analyzed. It is an important consideration for a residential building refurbishment.

5.3.3.1 Economic cost analysis

Residential building refurbishment is a compound of characteristics of residential building construction and refurbishment project. The constitution of factors which influence economic cost of residential building refurbishment is complex, energy price, family income, clean energy policy, house property form, participants in project, energy retrofit plan of the residential building could generate an improvement in the local domestic product. This improvement comes from:

- A decrease in CO_2-related social costs;
- Macro-economic effects of local energy-efficiency investments (Green Investments) in buildings (local added –value and employment);
- Decrease in energy consumption cost by inhabitants.

By this analysis, we can find get the conclusion that three groups could benefit from residential building refurbishment: local authority, inhabitants and energy company.

From the view of local authority: through energy efficiency effect by residential building refurbishment, CO_2 emission could be reduced while living environment could be improved in the same time. The low carbon development will be great benefit to improve working efficiency and management ability of both government organizations and employees. For local authority, they have the responsibility to play the leader role in residential building refurbishment management and coordinate all possible partners in the refurbishment process.

From the view of inhabitants, they get the direct benefit from residential refurbishment project. However, in real practice, they are the main opponent for implementing energy efficiency measures because refurbishment measure needs investment and disturbs their life. As the property owner and direct user of the house, they can get benefit of improvement of living environment, improvement of value of the house and energy consumption reduction by energy conservation. Therefore, only if the benefit of refurbishment such like economic saving by heating energy consumption reduction and electricity consumption by air-condition, improvement of living comfort level, appreciation of assets, increasing of rent rate, utilization time dilation and renewed facade etc. is clearly estimated, they would interest in refurbishment project. Inhabitants should be one of the main parts for funding refurbishment project.

From the view of energy company, energy efficiency effect could mitigate energy supply crisis and improve relationship with local authority and inhabitants. Meanwhile, energy efficiency refurbishment of heating/ cooling system and municipal pipe system (gas, electricity, water, telecom etc.) could reduce energy waste; regeneration of energy meters could accurately monitor energy consumption in household. Energy company could extend energy supply area and get more profit.

5.3.3.2 Establishing multi-level financial support mechanism

Since the investment for refurbishment is one-time action while the withdraw benefit from energy saving and real estate value of house are long-term plan, the conflict between investment and benefit should be solved by establishing a feasible financial mechanism for residential building refurbishment project operation.

In Europe, there is relatively complete financial support mechanism for residential building refurbishment project. Local authority and house association would supply specific fund and get low-rate loan with help of bank. There is clear and detailed contract with all partners involved in the project for division of responsibility and benefit. In China, as we talked before, issue of residential building refurbishment is not paid enough attention until recent years in the cities, there is not explicit work framework for residential building refurbishment and financial organization is an urgent problem in real practice.

In this period, a multi-level financial support mechanism which is leaded by local authority could be a proper way for organizing financial support of residential building refurbishment project in China. Fig. 5.37 shows the main sources of possible financial support. The process of organizing financial support should follow the principle of "financial support should come from who get benefit in the project". The main part of fund source should be local government and inhabitants.

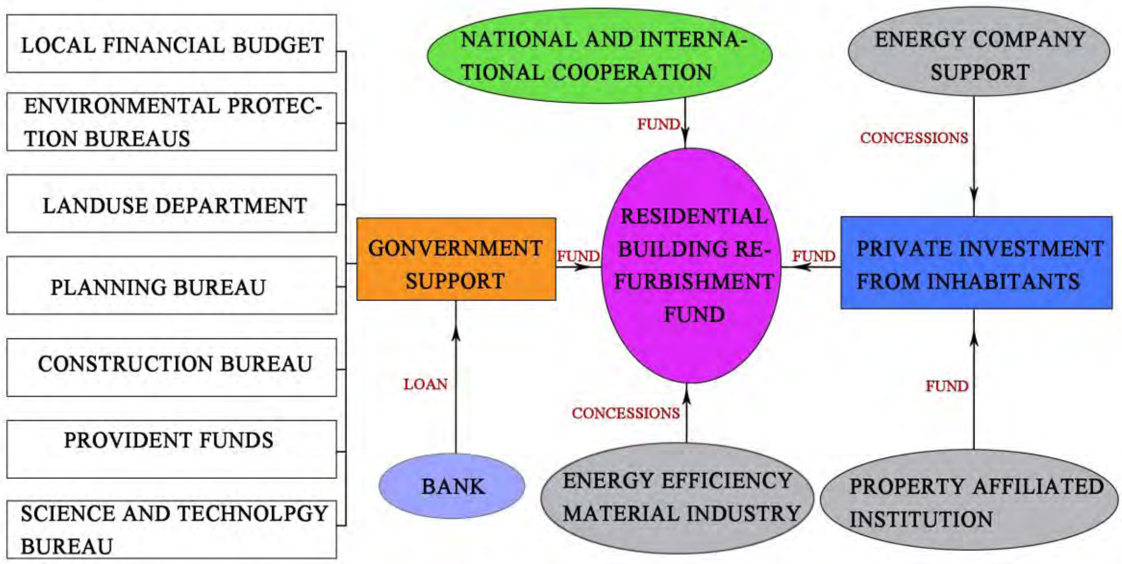


Fig. 5.37 Schematic diagram of constitution of financial support for residential building refurbishment in urban area of China

- *Government support*

Implementation of energy conservation refurbishment needs the economic policy incentive; therefore, besides the national encourage policy and energy efficiency plan for energy conservation residential building by central government, local authority should fix locally policies includes tax preference, bonus encourage etc. to make pilot project with some target typical buildings. These pilot projects would be demonstration for other projects in the same area.

The source of government financial support would come from: specific financial fund for existing residential building refurbishment; environmental protection bureau support for improving CO_2 emission reduction; specific residential building maintenance fund from land-use department; free technical support from planning bureau and construction bureau; specific fund of Central Provident Fund; fund for implementing innovation technology from science and technology bureau and etc. For different projects, the constitution of fund source would depend on real condition. However, specific project, financial support from government would be basic requirement of a residential building refurbishment project in urban area of China.

In the other hand, local authority could try to improve low-rate loan support from bank. In China, bank loan only face to new residential building; it's difficult to get low rate loan by inhabitants for refurbishment project. By the help of local authority, low-rate loan could be made between authority and bank.

- *Private investment from inhabitants*

This part is the other main source of refurbishment fund. Residential building refurbishment is mainly concentrated in building envelope retrofit and heating system reconstruction, inhabitants should afford part of construction materials. Agreement for investment should be made between authority and inhabitants through deep communications. Contract with clear budget estimate for the whole project could be made at the very beginning of refurbishment.

In China, although there is no house association like Europe, because of political system, before 2000s, most of residential buildings in urban area are part-belonged to affiliated institution where the inhabitants work in. In refurbishment project, in case the house is related with affiliated institution, the affiliated institution would afford part of fund with inhabitants.

In the meanwhile, energy company would give some offer to inhabitants for improving energy performance in residential building.

- *Cooperation from energy efficiency material industry*

In the aim of populating innovation energy efficiency materials, energy efficiency industry would supply specific fund or preferential offer by coordinating of local authority.

- *National or international cooperation*

There are some national or international organizations for improving low carbon city and low carbon buildings would supply technical and economic support for improving energy conservation in residential building. For example, according to section 12 of Kyoto Protocol, if developing country implements *Clean Development Mechanism* (CDM) they would get international technical support. That means developed countries would cooperate with developing countries implementing CO_2 emission reduction project. Obviously, residential building energy conservation refurbishment supplies a platform for cooperation. In fact, from the beginning of 2000s there were a few pilot building refurbishment projects had been done with the cooperation of EU countries (Germany, France). In perspective, both China and some EU countries like Italy have abundant culture heritage, there is traditional advantage in cooperation in residential building refurbishment between them.

Of course, the financial support mechanism would be improved with complete of economic system and new support mode would be developed in real practice. Building energy conservation industry investment funds could set building energy conservation as object, collecting fund by floating specific fund and operated by professionals. Financial support for residential building refurbishment is a topic still needed to be explored in the future.

5.4 Chapter Summary

Since the implementation of technical strategy for residential building refurbishment is related with many aspects, this chapter discussed three procedures in the scheme stage of residential building refurbishment in urban area of China. First of all, an analysis of residential building in urban area of China is made for discovering general problems of existing residential building in urban area of China. Combining the development trend of residential building in China, we can find the gap between existing building and new construction and fix the refurbishment context for existing residential building.

In the other hand, initiative motivation by professionals and government could effect and promote energy conservation for existing residential building. Through an investigation faced to Chinese architects and urban planners, we comprehended the real awareness in China for this topic. Analysis of investigation results and internal operation model help us to elaborate energy conservation strategy appropriate status of China.

The third part of this chapter described the relevant management support of residential building refurbishment. By the research on urban residential building, internal operation model of residential building in China is analyzed and Integrated-model projections model suitable for current China is proposed as a result. In addition, identification of the instinctive motives of residential building refurbishment is expounded clearly that is improved from the city renewal to district regeneration level then building refurbishment and also operates in reverse. At last, through the analysis of fanatical factors, multi-level financial support mechanism is summarized as a feasible solution. Following chapter will be emphasized on the working procedure and aims to establish a comprehensive energy conservation methodology for residential building refurbishment in urban area of China.

Chapter 6
Technical framework for urban residential building refurbishment project in China

- WHAT ARE THE GENERAL PRINCIPLES OF RESIDENTIAL BUILDING REFURBISHMENT IN URBAN AREA OF CHINA?
- HOW TO EXECUTE DESIGN PROCEDURE OF RESIDENTIAL BUILDING REFURBISHMENT IN URBAN AREA OF CHINA?
- HOW TO IMPLEMENT ENERGY CONSERVATION STRATEGY FOR URBAN RESIDENTIAL BUILDING REFURBISHMENT PROJECT IN CHINA?
- BY THE LESSONS LEARNT FROM EXISTING CASE STUDIES, HOW TO SET UP A COMPREHENSIVE TECHNICAL FRAMEWORK FOR RESIDENTIAL REFURBISHMENT PROJECT TO SOLVE THE PRESSURE BY URBANIZATION AND TO DEVELOP IN A SUSTAINABLE WAY?

6 Technical framework for urban residential building refurbishment project in China

For China, it is a critical period to establish a framework for residential building refurbishment in urban area. As we talked in the previous chapters, since the building scale and construction material are totally different from residential building in rural China and urban China and the energy consumption structure are quite different, building design process of residential building refurbishment in urban China is a research field which is needed to be completed immediately. There are too many relative researches fields with refurbishment research, but we are focusing our attention on architecture field. The most important point is technical solution in residential building refurbishment process.

In China, after 2000, along with the acceleration of the globalization, sustainable development is became the new guidance for building development. "Sustainable building" which is also called "ecological building" or "green building" is raised as a new research direction in architecture field. Energy efficiency and healthy living environment are two aspects which people paid much attention to. Except the aesthetic aspect, technology aspects relative to energy and environment are concerned for sustainable building in order to consume as less as possible energy and other resources but nature friendly and be healthy to be occupant. Since the energy crisis of 1970s, some developed countries contributed a lot in research, design and construction of energy efficiency for buildings. Quite a lot of attempt was made in the demonstration buildings. The principle technical approach which is used in these demonstrations was a combination of the passive measures by optimal building design and the active measures by efficient mechanical system design to control the indoor climate. Of course, these demonstrations were not only made for new constructions but also for refurbishment including residential building. In Europe, where obliges existing housing to meet the regulations, refurbishment construction for old buildings using thermal insulation for exterior wall are implementing, except for the buildings registered as World Heritage Site. In Japan, the number of existing housing amount about 47 million units, which is overwhelmingly large compared with that of newly constructed housing at about 1.2 million units in recent years (Fujimoto, 2009). As it is generally thought that using time for residential building in urban area is less than 70 years for those existing buildings which were built in 1970s and 1980s, it is clear that drastic strengthening of refurbishment will strongly be required for the existing residential buildings in urban area. However, cheaper refurbishment method without large-scale construction exists even today, refurbishment parts, which enable to exchange only window glass from single-glazed to multi-glazed glass, are still available in the market.

On the other hand, although many of the developed countries have successful experiences in residential building refurbishment research, design and monitoring, it is not suitable for China to copy their experience simply, since most big cities in China have much higher population, building density and much less renewable energy available per square meter floor area. However, the residential buildings in developed countries are usually single dwellings or multi-storied apartment buildings in low building density and more available renewable energy like solar energy and higher green rate. So the household or independent heating system, garbage treatment, water treatment and reusing system are easier to be adopted in those houses instead of the centralized system which is commonly applied in urban areas of China.

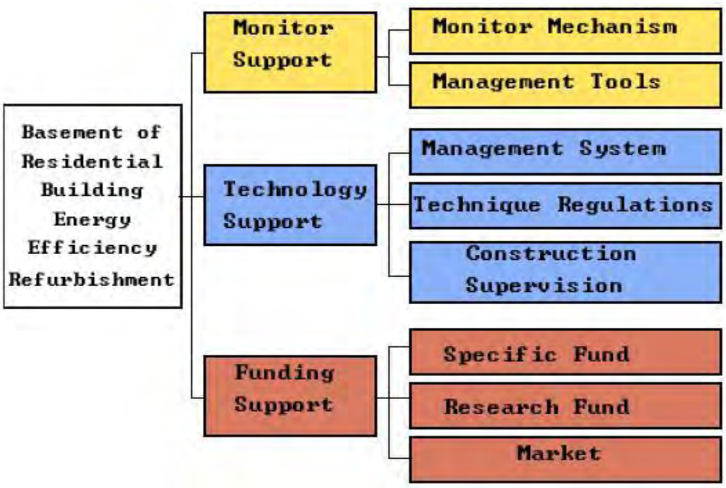


Fig. 6.1 The support means of existing residential building energy efficiency refurbishment

Consequently, instead of applying the advanced technologies directly from developed countries to China, we should find proper solutions by considering various climates, different cultures, conventions, economic development level and social situation of China comprehensively. It's a quite complex and far-reaching research framework. In order to realize efficient refurbishment to current existing housings, new technology development is desired, which realize more suitable technical solutions that means cheaper cost and shorten construction term by establishment of modularization enables quick exchanging parts and components. On the other hand, it is also necessary to consider new refurbishment technology for the future existing housing which will have been constructed in the coming years. Since the residential structures is needed healthy living environment and longer use-life recently, the need is not replacement of new windows and doors updating but higher thermal insulation performance and even low carbon emission after the refurbishment constructed.

To establish the working framework for residential building in urban area in China, support from different fields should be given to. We try to summarize the complex relations into clear structure, in Fig. 6.1 we can see that the support from three fields should be given: monitor given by administrative department; technology support given by professionals like architects, engineers and funding support for demonstrations, projects, researches and marketing. For monitor support, the top-down mode residential building construction system in China had been analyzed in chapter 5 and we will develop monitor tools combined with technical framework which could be used for residential building refurbishment projects in this chapter. For technology support, which has closest relation with architecture field, management system, energy consumption regulations and construction supervision would be discussed. For funding support, the importance and characteristics of financing mode for residential building refurbishment had been discussed in chapter 5.

In present chapter, we will make the research from 5 sections. First of all, working procedure of existing residential building refurbishment projects in China would be proposed and the specific characteristics which are different from Europe would be analyzed to enlighten the significances for existing residential refurbishment. Then the technical framework for residential building refurbishment in urban are in China would be divided into four steps: energy survey phase, discussion and setting ambitions, analysis of energy options and selection of energy options and implementation.

6.1 Working procedure of exiting residential building refurbishment project in China

In the first section of present chapter, we will summarize the general working procedure of exiting residential building refurbishment project in China. The working procedure would be divided into 8 steps. Based on this working procedure, different players who are involved in the project would play different actions to achieve their aims for this project. We would analysis these actions and effects, and then propose the energy consumption process for exiting residential building refurbishment project in China.

6.1.1 Working procedure

Compared with new constructions, the work procedure for refurbishment project is more complicated because of the complex relations of existing buildings. On account of property rights and living needs, for residential building refurbishment, the working procedure is even more complicated than refurbishment of public buildings. In China, most residential building in urban area are apartment in multi-storied buildings, each family should be coordinated separately in the same time, along with the inefficient municipal facilities, these current realities caused interferences in the refurbishment process.

Players: including the house user who has property for the existing residence, professionals for refurbishment project and project executors.

- *Property owner (inhabitants)*: those whom have the property right of the existing residential buildings have decision making right for agree or reject the refurbishment. They always the active supporter for approving a refurbish project but sometimes they are also the main resistance for implementing refurbishment. If the property owner rent the residence to others, the inhabitants and property owner should get some consensus together for setting ambitions and choosing technical methodologies.

- *Architect*: is playing a more and more important role in refurbishment process. In China, architect is the leader in the whole building design process. Architect should involve the project since project approval step and until the final step. They are in charging of building design, drawing blueprints, and choosing proper materials and energy efficient technology with multi professional engineers to meet living environment requirement. Architect is the key point for ensuring the living environment improvement and energy efficiency effect in residential building refurbishment project.

- *Engineer (thermal, ventilation, electricity)*: these professionals should work together with architects and manager to propose suitable energy efficient technology solutions while selecting energy options.

- *Investigator*: they are playing a special role in refurbishment project. For a residential building refurbishment project, solution should be selected on the base of current situations. It is important to coordinate inhabitants and investigate exiting building. So usually the investigator should collect exiting energy consumption data and investigate problems which should be improved in inhabitants' opinion.

- *Manager*: in China, project manager usually is selected by municipal department, manager should control the construction progress and in charging of communicating with administrative department and project executors.

- *Municipal engineering office*: those related municipal engineering office should supply cooperation when they need changing municipal facilities pipes and construction project inspector.

- *Construction company*: is responsibly the construction work in construction stage. They should work with professionals. To guarantee the quality of the construction, the whole process of the construction must take construction control.

Working procedure and actions:

When the refurbishment project is fixed, the general work procedure could be divided into 8 steps.

- *Basic data collection*: when the refurbishment project is started, architect should make detailed survey of target existing building. Architect can collect original blueprint of existing building. Usually, the original blueprint could not be collected completely because of the saving problems, to get enough data for setting refurbishment aim, survey for the building and previous energy consumption should be done in the same time. Then architects should formulate the survey report and analysis the possible equipment and material adoption on the base of these surveys. In the other hand, architect should work together with project manager to make enough communication with inhabitants to make detailed data and coordinate publicizing energy efficiency conception. The first step is the basement for future work, it's very important to publicizing energy efficiency conception with inhabitants, if the house is rented by house owner, house owner must take participant into the communication process, too.

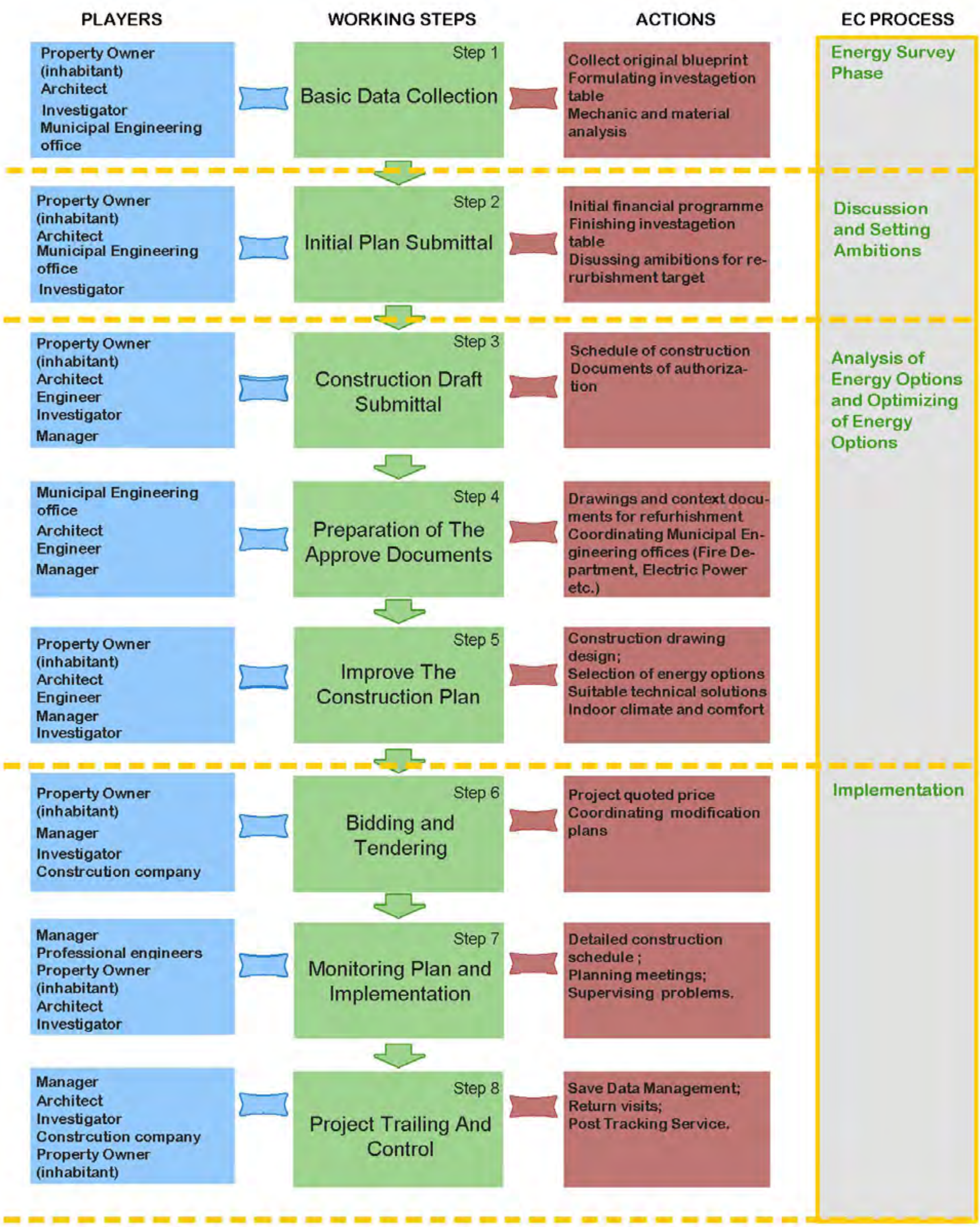


Fig. 6.2 Schematic capture of residential building refurbishment in urban area of China

- *Initial plan submittal*: manager should propose financial plan with investment budget and energy saving benefit. Professionals could calculate bearing ability of each wall and make comparison of different materials. Investigators should make investigation one home by one to ask the information about indoor environment. Initial plan should be submitted by different energy-saving target. Because different stakeholders would set the refurbishment ambitions by their own expectations, the refurbishment target which they set would different.

- *Construction draft submittal*: in this step, based on the initial plan which is discussed with multi-players, architect could begin working for construction draft. In practice, energy saving plan could made in different levels according to ambitions such as low level, medium level and high level. Comparison of different energy saving target on cost, construction difficulty and comfort level improvement aspects would be discussed by multi players. Then the multi-players should get an agreement for refurbishment plan. Usually, refurbishment including energy efficiency renovation and modernization retrofitting. Investigator should collect questions of inhabitants and explain them with professionals together. After they got the agreement, detailed refurbishment plan should be made into a document of authorization which should be signed by related stakeholders.

- *Preparation of the approve document*: in this step, professionals should make drawings and documents to administrative department for applying construction permission. For special work, like close road, municipal facilities pipes rearranging and changing fire hydrant position, they must make special application to related administrative departments.

- *Improve the construction plan*: engineers should make statics calculation and check inspection by professional institute. After energy options selection, inspections should be made to check whether selected technical solutions are suitable and whether indoor comfort level would be qualified. Construction drawings including general drawing, detail drawing and construction drawings could be finished in this step.

- *Bidding and tendering*: in this step, construction Company would be chosen. In China, construction company usually is assigned by administrative department before. In recent years, with the standardization, construction company should be chosen through the process of bidding.

- *Monitoring plan and implementation*: all the refurbishment process should be made followed the fixed schedule in third step and should be monitored regularly. Regular meetings should be organized. Usually the monitoring team including professional engineers for thermal, ventilation and electricity, and investigator who coordinate inhabitants and construction company.

- *Project trailing and control*: With the end of all the refurbishment, all adopted of technology and structural aspects of the renovation should be saved on file. Construction company are required to take on statutory warranty of the project.

Energy consumption process:

Based on the working procedure and actions of residential building refurbishment project in China, energy consumption process for energy efficiency issues of residential building is proposed into 4 steps. This process is fit for general residential building refurbishment in urban area of China. (Fig. 6.3)

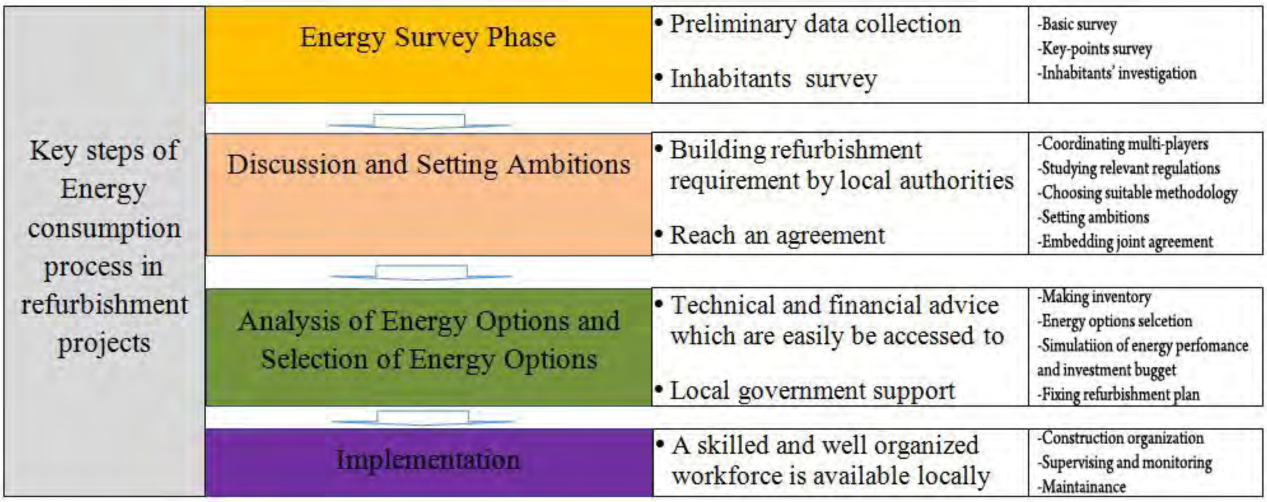


Fig. 6.3 General structure of energy option design process in residential building refurbishment

6.1.2 Enlightening significances of existing residential building refurbishment in China

In China, in order to find solutions that meet the demands of greenhouse gas emissions in the residential sector, the research in last decade was mainly focused on the improvement of new buildings. In literature, a large number of research papers report on building design and urban planning on new low-energy buildings and districts, on energy efficiency analysis of building materials and components and on the optimization of energy related aspects, such as insulation measures, heating systems, photovoltaic and natural ventilation. Also, the combination of indoor environment and energy consumption optimization is used to create new energy-saving residential buildings.

However, a decrease of the greenhouse gas emissions will not occur if no energy is saved through retrofit of the present housing stock (Hens, 2001). In the same time, the impact of the existing residential building energy saving should not be underestimated. The aim of this research is to enlighten significances and fill the gap of existing residential building refurbishment in China.

Characteristics of residential building refurbishment in China:

On the base of scheme stage, we can summarize the special characteristics of residential building refurbishment project in China into five phrases.

Phrase 1 ----House property right is so complicated that multi-players would be coordinated with more difficulties

Different from other countries, management mode of residential building in China is changed since 1980s. With the step of the opening and reform policy implementation, the privatization of residential building in urban area is begun. The property right of residential building is begun to be changed from public owned mode to private owned mode. Table 6.1 showed the comparison of house property of China and several European countries. After decade’s efforts, the proportion of commodity private house in China is still in low level. Although total private house takes over 80%, half of them are privatized by housing reform that means are privatized in the price much lower than commodity house, and part of the property is still belonged to inhabitants’ working organization. During refurbishment process, it is more difficult to coordinate complicated stakeholders.

Table 6.1 House property of China and several European countries

Country	Private		Private rent	Public rent	other
Italy	76%		34%		
Germany	43%		57%		
Denmark	51%		20%	7%	21%
Czech	47%		16%	17%	20%
China	Commodity house	Privatized by housing reform	3.4%	7.1%	1.8%
	46.9%	40.8%			

Source: NBS (China National Bureau of Statistics) REICO database 2009
Nemry and Uihlein,2008 (EUROSTAT 2006)

Phrase 2 ---- Regular communication and meetings with inhabitants should be made by organizer without help of owner's committee

In China, because most residential building is not commodity houses, there is no owner's committee. But for refurbishment project, inhabitants must involve into the process of setting ambitions and existing problems should be investigated at the beginning of refurbishment, so the regular communication and meetings with inhabitants should be made by architect who needs these data for implementing further work.

Phrase 3 ---- Making basic survey of residential buildings, to provide decision-making basis for the transformation of planning.

Basic information of target building should be investigated. For residential building, not only survey of basic construction information should be made, but also the information of located city and surrounding urban plan which could have an effect on building energy consumption and building design should be collected in the meanwhile. The aim of survey is providing decision-making basis for transformation from original plan to refurbishment planning. Compared with new constructions, survey of target building is addition work for existing building refurbishment. Because of the rapid urbanization process, there is no complete building information supervision system in China. There is must be more difficulties on the survey process.

Phrase 4 ---- Cleaning the basement and ancillary buildings and debris back into the original batch in time;

In refurbishment process, a lot of furniture would be moved out for applying enough working space and construction waste had to be deal with. Workers should clean the basement and ancillary buildings for putting furniture and construction waste and batch them in time.

Phrase 5 ---- Improve the dust and noise abatement requirements, cleaning house, and the housing surrounding the stairwell;

While the process of refurbishment project, inhabitants are still living inside the building. The normal life of inhabitants must be kept without disturbance. The workers must improve the dust and noise abatement requirements, cleaning house, and the housing surrounding the stairwell. Working time must be fixed strictly after discussion with inhabitants and followed the work schedule which is made by multi-players before indoor working.

Significance:

Establishing framework for urban residential building refurbishment in China is a research field which has a lot of significances for building energy efficiency in current time. It's a topic has relations with huge social synergistic effect.

- Bringing in comprehensive energy conservation refurbishment concept

The nature of the innovation technical framework discussed here demands a new way of thinking about a strategy for achieving mass-scale, deep-residential-efficiency refurbishment. A successful refurbishment strategy for the future needs to view buildings comprehensive as a critical component of the energy system infrastructure required for low carbon emission development. To this end, the strategy could be designed to evaluate and pursue such improvements, much in the way that other infrastructure upgrade needs (such as urban plan, residential settlement design, gas pipelines, electric grids) are evaluated and pursued: for the long-term benefit of all users. A comprehensive energy conservation refurbishment concept would be brought in architecture field in China. Refurbishment is no longer simply low cost damage repair but an active motivation for energy efficiency strategy for building sector.

- Exploring huge benefits of refurbishment for existing residential building on both economic cost and living environment

By previous studies in recent years, we realized that residential building refurbishment for existing building could bring in benefits both on economic cost and living environment. The multi-participants would bring in comprehensive and multi-faceted conditions. Refurbishment should be addressed the full range of market complexities, including market barriers to efficiency, in an integrated manner. For refurbishment project, what very important is capable of providing consumers both financial incentives and access to attractive financing for the portion of efficiency investments they will make themselves; including addressing the unique needs of low income households. However, improving the building infrastructure on a large scale through efficiency improvements requires engaging the interest and hundreds of individual building owners and mobilizing them to action. A strategy for achieving the potential of residential refurbishment to secure needed economic benefits and living environment improvement must therefore be well-suited to this task.

In addition, the refurbishment of residential building aimed at increasing the energy efficiency can be done not only in old buildings with decade's ages but also in new buildings which needed to be refurbished.

- Providing experiences for establishing related legislation and standards in China

By setting innovation technical framework for residential building refurbishment in China, related building design and energy consumption legislations and standards could be established. For example, in table 6.2, there is the comparison of heating consumption indicators in Beijing (China) and European countries of similar climate conditions. In China, until 2008, MOHURD (ministry of house and urban-rural development of People's Republic of China) published residential building 65% energy saving standards, but only Beijing and Shanghai implemented this standard strictly, for existing residential buildings, most of them consumed more energy compared with this standard in other provinces and cities. So there is extremely essential for providing advanced and suitable European experiences for establishing and implementing related legislation and standards in China by establishing innovative technical framework for residential building refurbishment in urban area of China.

Table 6.2 Heating consumption indicators in China and European countries of similar climate conditions (Jiang et al. 2006)

	Heating consumption indicators (W/m^2)
Normal residential building in Beijing	30.1
Residential building followed 65% energy saving standard	15.0
European countries average	11

6.1.3 Refurbishment principle

By the analysis of scheme stage of strategy of residential building refurbishment in urban area of China, we can find that there was no systematic design principle had been proposed before for residential building refurbishment in China, we present four principles as high-level principles, recognizing that the specific approaches for putting them into practice will need to be tailored to local building conditions and political realities. Below, we discuss each of them in further detail. We predicate our observations and conclusions on the necessity for future initiatives to be both much broader (treating many more buildings per year) and much deeper (achieving much greater average savings per building).

- Architectural aesthetics

When the building envelope is refurbished with additional treatments or reconstructed, architectural aesthetics should be considered as important elements for refurbishment principle. The refurbished building should be harmonized with surrounding districts. Building scale and façade should not be neglected to even for energy conservation project.

- Economic efficiency—finding proper techniques and insisting comfort demands

While buildings and development provide countless benefits to society, they also have significant environmental and health impacts. The multi-players should work cooperated to find proper techniques and insisting the comfort demand. The benefits such like cost saving for energy conservation, improvement of comfort level, extending of building service life, house economic appreciation, offering work opportunity etc. should be presented as simply and clearly as possible to inhabitants (house owners) and other multi-players. In the meanwhile, policy-makers should consider the ‘net cost’ of building energy consumption which takes into account energy consumption of constructing process and operating process as well as the environmental costs associated with energy consumption. Low carbon policies would introduce these environmental costs, altering the results of cost analyses by energy auditors and utilities. In China, especially in less developed areas and traditional cities with a lot of residential building needed to be refurbished, it is impossible to implement high level energy efficiency measures because of economic limit. For different climate conditions, different administrate structure and financial structure, we have to find a balance point by evaluating these influencing factors.

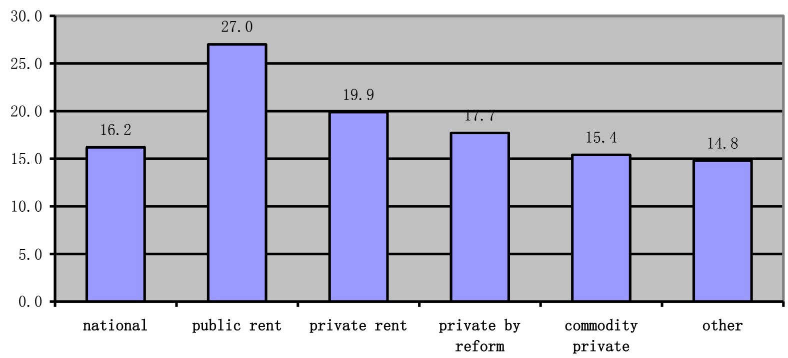


Fig. 6.4 Average duration of service of residential buildings in urban area of China (Year)
Source: NBS (China National Bureau of Statistics) REICO database 2009

If we have a look of service life of residential building, in 2009, average age of national urban residential building is 16.2 years. It is shown in Fig. 6.4, average age of public rent residential building is 27 years that means public rent residential building is older than other types of residential buildings. Average age of private rent residential building is 19.9 years while that of residential building private by reform is 17.7. Average age of commodity private house is 15.4, if we don't consider about the private house before reform, the average age of commodity private house is even smaller which is about 15.4years. In the first level cities, like Beijing, Shanghai, average age of existing residential building is larger. For these existing buildings of different service life, different solution techniques should be fixed in refurbishment.

- Adjust measures to local conditions

Residential building refurbishment is an issue related with local realities. Since influence by local culture context, natural geography condition and materials, refurbishment measures should be adjusted to accommodate local conditions. And local Supported by strong government commitment to the overall strategy, including the level of ambition as well as stable (and sufficient) funding should be given.

- Performance-Based Delivery Framework

Across North America and Europe, a variety of different models for delivery of efficiency initiatives have been tested over the past couple of decades. These include delivery by retail energy suppliers, by distribution utilities, by competitively selected energy efficiency service companies, and by government agencies. While no one model has been clearly demonstrated to be the best or ideal for all circumstances, some important lessons can be drawn from this experience. (Neme et al. 2011)

For China, energy performance for indoor environment is the main indicator for evaluating refurbishment affection. Residential building refurbishment should be followed the mode of performance-based delivery framework that is a performance-based obligation to achieve long-term goals of energy conservation and living environment improvement. To achieve goals, the structure for assigning responsibilities to obligated energy consumption, whether a contract or other form of agreement, needs to support and reinforce its accountability. Usually the affection could be implemented by addition of solid wall insulation, replacement of energy conservation window and door, treatment of thermal bridge, natural ventilation and tightness improvement etc.

From principles to detailed strategy

It is recognized that strategy details will need to vary somewhat between results based on local building conditions and energy considerations. The key is that there should be a well-developed, over-arching strategy that fully encompasses the principles outlined above. In the following sections we provide technical framework and design recommendations in four steps. First we analyses the feasibility study at the very beginning stage. Then we describe the discussion energy conservation stage, based on the result get in the discussion, energy options would be fixed. Finally, we discuss the implementation for energy conservation strategy.

6.2 Energy survey phase

6.2.1 Problems of current residential building refurbishment in China

Compared with EU and US which have begun attempt since 30 years ago, China didn't realized the important of residential building energy-saving until side effect came out. But there is not any research systematic for existing residential building energy efficiency and there is already a serious of problems yet. In this part, we summarized the current problems of residential building refurbishment in urban area of China into five phrases.

- **Lacking of long-term analysis**

Because of the complex situation of refurbished project compared with new constructions, the internal economic connection is related with multi-participations. To coordinate all the stakeholders, the coordinator should make long-term economic analysis to mobilize all the attractions. Although it's recognized by society that residential building refurbishment project would bring sustainable benefit of energy consumption and human living environment, if we focus our attention on the real case, we will find that it's lack of comprehensive analysis in most of exiting residential building refurbishment projects.

- Most of residential buildings which needed to be refurbished are just be pushed over. In the past projects, people used to building new buildings rather than refurbish exiting buildings. The main reason is that short time economic interests for developers and local government but there are also defects such as huge energy waste and CO_2 emission.
- Lack of legislation for culture heritage. It's the fact that many historic districts and buildings which were valued to be protected were demolished because there was no culture heritage legislation to protect them. These buildings and even historic districts are culture heritage of high value and with very important significant for cities and China. It's the loss not only of local culture but also of the world. This kind of demolishing also caused a serious of society problems.
- Incomplete funding estimate. The aim of refurbishment for exiting residential building is improving living condition for residents but there is no profit for developer or manager. For more profit, some cases adopted the method that adding new constructions in the top of exiting building but the result is descending of living quality.

- Resettlement for residents caused a serious of society problems. Inappreciative resettlement and move-back for inhabitants becomes the common social problem which even endangers the national security in urban China.
- Ignoring of suggestion of inhabitants. In many cases, the inhabitants didn't participate in any discussion of the plan. When the coordinator fixed the refurbish plan, they would like only make the meeting with architects, local government and developer but nobody would like to investigate the suggestion of local inhabitants and sometimes there would some misunderstanding among different stakeholders.

- **Indistinct energy efficiency criterion**

Exiting energy efficiency was fixed for new residential constructions and of which the core is meeting thermal digital (such as external wall and roof value K, value D and window sunshade coefficient). But the exiting residential buildings were built in different times and there are enormous differences, it's impossible to reach the current standard that of 50% energy saving; otherwise, energy efficiency technologies which adopted for exiting residential buildings were the same of that for new constructions but not specific for existing buildings. The technologies should be upgraded caused a serious of potential safety hazard. And even the there is no strict definition of safe index. Just because of these reasons, it's difficult to evaluate the quality of residential building refurbishment.

Fig. 6.5 Photos of Shanghai residential building accident 2010 Nov.15th
http://www.flickr.com/photos/cpj/5178106136/

Fig. 6.6 Photos of CCTV building accident(Beijing) 2009 Feb.9th
http://www.flickr.com/photos/drea_genf/3269408450/

For example, there was a serious fire accident in Shanghai 2011 November[1] which caused severe losses not only for Shanghai but also for China. The 2010 Shanghai fire was a fire on 15 November 2010 that destroyed a 28-story high-rise apartment building in the city

[1] http://en.wikipedia.org/wiki/2010_Shanghai_fire

of Shanghai, China, killing at least 58 people and injuring more than 70 others (with at least one source reporting more than 120 others injured)[1]. An investigation under the *PRC State Council* was announced to determine the cause of the blaze. In all, sixteen individuals have been arrested in connection to the fire, including four others accused of being unlicensed welders. The fire may have been caused by the accidental ignition of polyurethane foam insulation used on the building's outer walls. In China, the Foam is commonly used as insulation material without the addition of flame retardants, and the Foam produces toxic gases and carbon monoxide when burned. The Beijing Television Cultural Center was said to have used Polyurethane insulation, which magnified the ferocity of a 2009 fire that consumed the center. In a 24th November press conference, local authorities said that the two apartments next to the destroyed building would be renovated as well, and that Foam cladding on their exteriors would be replaced switched out in favor of fire-resistant materials. Chinese citizens have also questioned the lack of an indoor fire sprinkler system in high rise buildings.

Since it was started late in China, energy efficiency for residential building refurbishment was too focused on design period but neglected supervisor step. In the background of lacking of regulations and supervisor, with the internal complex situation, adopting the energy efficiency design methods which fitted for new constructions would cause a serious of problems. Specific energy efficiency design methods for exiting residential buildings should be set up promptly.

- **Excessively formalized pursuit**

In China, in the field of Architecture, there is a common problem that people used to focus too much attention on pursuing building formulation. Especially for residential building refurbishment project, in a certain period, in many projects the refurbishment was done only for façade re-decoration but not for energy efficiency neither function promotion. These inefficiency projects aroused misunderstanding for refurbishment project and caused large amount of waste. It is result of vanity projects caused by requirement by administration that don't get the real meaning of refurbishment.

[1] http://www.nytimes.com/2010/12/25/world/asia/25shanghai.html

- **Neglecting of built environment**

While constructing new settlements with high quality, improving of living environment of existing residential settlement is compellingly needed for giving same expression to fairness, in the meanwhile, principle of energy performance improvement and can be shown by discovering potential value of existing residential buildings, through retrofit of building, principle of architecture aesthetics and adjust measures to local conditions can be shown, through improvement of municipal facilities, principle economic efficiency can be shown. But in fact, built environment in residential building refurbishment project, like outdoor and indoor public space, municipal facilities, sound and light environment, are usually neglected in China.

When making design for exiting residential building refurbishment project, what we should consider of is not only thermal performance of building envelop, building façade retrofit, roof construction renovation, municipal facilities like electricity line and water supplement refurbishment, but also have to consider of harmonization with built surrounding environment and improvement of built environment. If we just think about the single building, the refurbishment plan is limited with inefficient utilization of existing resources, in the other hand, incomplete refurbishment would cost repeated investment and cause additional burden to urban transportation and inhabitants' lives. A complete, considerate residential building refurbishment framework is needed to be established urgently in China.

- **Lack of knowledge on available technical solutions**

In previous refurbishment project in China, the low quality construction is common problem which caused energy inefficiency after refurbishment. There are two reasons: one is in plan stage, architects are lacking of professional knowledge; the other is in construction stage, workers are lacking of basic techniques knowledge. So it is needed professional guide for residential building refurbishment in China.

In professional aspects, lack of professional knowledge caused a series of problem since design stage. In Fig 6.7, we can find that the problems are presented as inaccurate insulation layer installation; bay window which is adopted a lot in the past years caused increase of radiator area; windowsill without insulation and projecting elements like rain-proof shelter without insulation layer caused thermal bridge; heating system and building envelope are not refurbished synchronously, caused energy waste after refurbished; multifunctional electronic heat meter is high cost and inconvenient for inhabitants.

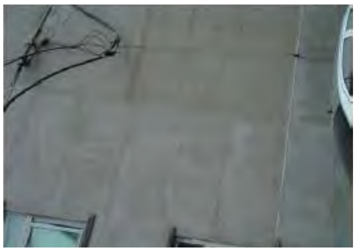
• Inaccurate insulation layer installation	• Bay window increased radiator area	• Windowsill without insulation
		
• Projecting elements like rain-proof shelter without insulation layer	• Heating system and building envelope are not refurbished synchronously	• Multifunctional electronic heat meter is inconvenient for inhabitants
		

Fig. 6.7 Common design problems in residential building refurbishment project in China

Because most of construction workers are lack of basic technique knowledge, there are a lot of problems in construction stage. In Fig 6.8, we can find that the problems are presented as wrong location of control valve which caused complete invalidation of energy conservation measure; coarse treatment of construction details; low quality construction materials caused a lot of damage after refurbishment.

• Wrong location of control valve	• Coarse treatment of construction details	• Low quality construction material
		

Fig 6.8 Common construction problems in residential building refurbishment project in China

All these problems are caused by lack of experiences and neglect of residential building refurbishment, we have to pay more attention in the future projects and solve these problems by setting up innovative technical framework for residential building refurbishment.

6.2.2 Investigative formulation (basic data investigation)

For residential refurbishment project, to find proper technical solution for reaching energy conservation aim, preliminary work which is special existing in refurbishment should be done. The preliminary work including construction characteristics of target building, located city characteristics which have influence on building design, energy consumption status quo of target building and families, inhabitants' desire for refurbishment to fixing refurbishment plan.

Aim of Preliminary investigations

- Understanding local architecture characteristics could help local context continuation

It is necessary to have a thorough understanding of architecture characteristics of residential building in local city. Both the natural factors like climate condition and geography condition and local urban design planning would effect on residential building energy performance. By a thorough understanding of architecture characteristics, architects consider concordance with local architecture context and adopting local materials in refurbishment plan.

- Understanding construction information could help professionals to adopt proper technologies

In the same time, it is necessary to have a thorough understanding of target building which is going to be refurbished. The information of construction structure, total area of the building and each household are needed to be collected. Architects and engineers could find bearing structure of the building. Then a series of structure and thermal tests could be done with target building. With all of these data, architects and engineers could find the possibility for adopting proper technologies.

- Understanding status quo of building energy consumption and damage could help professionals to fix energy conservation target

By household visit and inhabitants' investigation, building damage details and status quo of energy performance could be investigated. And stakeholders can communicate with each other effectively. It is very important to involve all stakeholders in the process of refurbishment. Only got all refurbishment desire of different stakeholders, a compromised agreement could be embedded to fix energy conservation target.

- Estimating refurbishment cost

A flexible financing scheme would help for a better implementation and better energy conservation results. Through the preliminary survey, cost beget could be investigated as the basic for making a financing scheme. And the working process of refurbishment could be valuable experiences for future projects.

Investigative formulation

The preliminary data collection could be divided into three typologies: basic investigation in the view of city level; key point investigation which is focused on target building; inhabitants' investigation which is specific to inhabitants (house owner).

The key point of prophase measurement and assessment content could be summarized as table 6.3. For each aspect, there are key-points in survey process. For different key points, existing assessment could be used as guidance in survey process.

Table 6.3 Prophase measurement and assessment content

Building condition	Statistics content	Method and assessment
Outdoor climate condition	Temperature	• Local meteorological department • JGJ 132-2001
	Air humidity	
	Wind direction	
	Wind speed	
	Solar radiation	
Building structural performance	External wall/ roof structure dimensions	• Original Construction Drawing collection • Site test result • CECS 03-2007
	External wall/ roof structure intensity	
	Carbonation of concrete	
	Concrete compression strength	• Site test result • GBT 50344-2004
	Thickness of protective layer of steel	
Building thermal performance	Air tightness	• Site test result • JGJ 132-2001
	Thermal bridge	

	U value of main envelope elements	
Indoor thermal environment	Damage of indoor Heater and heat meter	• Site test result • JGJ 132-2001
	Indoor temperature	
	Indoor moisture	
	Temperature of wall surface	
Building energy consumption	Heating energy consumption	• Heat meter
	Gas energy consumption	
	Electricity energy consumption	

☐ Basic survey:

Basic investigation should be made in different cities. In each city, beside the environmental factors like climate and geography conditions, residential building is surveyed and categorized by age, construction system, height (floors). This basic investigation is not only done when there is refurbishment project in that area, it can be done as the basic data base for each city.

The content of basic investigation could be summarized as follow:

- Environmental factors :
  i. Climate condition of the city: monthly and annual temperature; amount of precipitation; four seasons wind direction; solar radiation;
  ii. Geography condition
- Existing residential building statistic:
  i. Total number in the city;
  ii. Number of different construction type;
  iii. Age statistics of existing building ;
  iv. Property mode distribution;
- Information about different structures of existing residential building
  i. Heating system;
  ii. Hot water supply ;
- Energy consumption information of existing residential building in the city

Table 6.4 Formulation of basic investigation in urban area

City Basic Survey Table					
Climate condition	Annual temperature	Monthly temperature	Precipitation	Wind direction	Solar radiation
Geography condition	Height above sea level		Area		
Construction	Wood and brick structure	Masonry—concrete structure	Frame structure	Scissors wall structure	

Age of the building	1950s	1960s	1970s	1980s	1990s	After 2000
Height of the building	Low storied	Multi-storied	Mid-high-rise-storied	High-rise	Super-tall	
Building Number	Unit number			Districts number		
Heating system	Central net work		Regional heating boiler plant		Coal	
Domestic hot water supply	Regional hot water supply			No hot water supply		
Energy system	Electricity	Gas	Natural gas	LPG	City network	Renewable energy
Ventilation system	Natural ventilation			Auto-ventilation system		

(LPG-- Liquefied Petroleum Gas)

◻ Key-points survey:

Besides the basic survey, key-points survey faced to target building should be made with more details. As we listed in table 6.5, data about building structural performance, building thermal performance, indoor thermal environment, building energy consumption would be collected by original blue print and professional field test with equipment.

- Residential district information:
  i. General information: location; construction area; construction time;
  ii. Construction information: height (floors); unit number; dwelling number;
  iii. Municipal facilities: heating system; ventilation system

Table 6.5 Survey table for target residential building

Target residential district survey table						
Structure type:	Masonry—concrete		Shear wall	Frame structure		Frame shear
Floors	Low Storied		Multi-Storied	Mid-High-Rise-Storied		High-Rise
Time	1950s	1960s	1970s	1980s	1990s	2000s
Height	**Family Number**		**Unit Number**		**Floor Height**	
Ventilation	Natural ventilation			Auto-ventilation system		
Heating	Central net work		Regional heating boiler plant		Coal	

- Status survey of target building:
    i. Building envelope status quo: damage situation, thermal and static performance of roof, external wall, external window, foundation, balcony, building entrance;
    ii. Indoor structure: stairway internal wall; dwelling door, dwelling plan
    iii. Indoor facilities: Heating system, Ventilation system, kitchen and toilet facilities, electricity system, domestic hot water supply;
- Field test:
    iv. Building envelope U value;
    v. Thermal defect;
    vi. Air tightness;
    vii. Energy consumption and pollution emission.

Table 6.6 Table for Key-Point Investigation

Key-Point Investigation						
Building Envelope	Envelop element		Damage situation (need refurbishment)	Thermal performance (need refurbishment)	Static performance (need refurbishment)	U-value
	Roof (material, layer)	Original design	-	-	-	-
		Status quo	Y/N	Y/N	Y/N	◯
	External wall (material, layer)	Original design	-	-	-	-
		Status quo	Y/N	Y/N	Y/N	◯
	External window (glass thickness, window frame material, open mode)	Original design	-	-	-	
		Status quo	Y/N	Y/N	Y/N	◯
	Foundation (material, layer)	Original design	-	-	-	
		Status quo	Y/N	Y/N	Y/N	◯
	Balcony (close/ semienclosed; interior/ exterior; glass thickness, window frame material, open mode)	Original design	-	-	-	-
		Status quo	Y/N	Y/N	Y/N	◯
	Building entrance (insulated/ no insulated, material)	Original design	-	-	-	-
		Status quo	Y/N	Y/N	Y/N	◯
Indoor structure	Stairway internal wall	Original design	-	-	-	-

		Status quo	Y/N	Y/N	Y/N	
	Dwelling door	Original design	-	-	-	
		Status quo	Y/N	Y/N	-	
Indoor facility	Heating system		Central net work	Regional heating boiler plant	Coal	
	Electric system		-			
	Domestic Hot Water		Regional hot water supply		Not hot water supply	
	Ventilation system		Natural ventilation		Auto-ventilation	
	Energy system		Gas	LPG	Natural gas	
	Kitchen and toilet facilities		Y/N			
Energy consumption (estimated / test)	Heating	Domestic hot water	Household appliance	Gas		
Primary energy consumption and pollution emission estimate						
Indoor living environment	Indoor air temperature	Indoor moisture	Wall surface temperature			

◻ Inhabitants investigation

Inhabitants are the main beneficiaries in refurbishment. They are the direct experience of living environment. So at the beginning of refurbishment, suggestions from inhabitants should be adopted as the main data for refurbishment. Inhabitants' investigation should be done by investigators in each dwelling in target building. Face to face interview also could be done in the same time.

- Family data:
  i. Numbers of Family member, age, healthy status;
  ii. Family income, outcome;
- Comfort level and physical data:
  i. Indoor temperature, humidity,
  ii. Indoor decorations,
  iii. indoor environment satisfaction,
  iv. refurbishment willing and suggestion

Table 6.7 Table of inhabitants' investigation

Inhabitants' investigation table					
Dwelling Property	Private		Public		Rent
Family Member No.	1	2	3	4	5
Inhabitant Age	Over 60		10-60		Less Than 10
Monthly Income	<500	500-1000	1000-1500	1500-2000	>2000
Monthly Outcome	<500	500-1000	1000-1500	1500-2000	>2000

External Wall Tightness		Good	Middle	Bad				
Comfort Level (Winter/Summer)		Hot/Very Hot	Warm/Hot	Middle	Cold/Warm	Very Cold/Cold		
Auxiliary Heater		AC	Electronic Heater	Electric Blanket	No			
Auxiliary Cooler		AC	Electric Fan	No				
Air Quality	**Summer/ Winter**	Good	Middle	Bad				
Ventilation	**Toilet / Kitchen**	Good	No Function	Peculiar Smell	No Peculiar Smell	Demolished	Exhaust Fan	
Water Seepage		Winter Water Seepage	Summer Water Seepage	Moisture Condensation	Mildew			
Decorations		Window	Door	Floor	Wall	Room	Toilet	No
Content Of Refurbishment		Yes, Know Something	No					
Refurbishment Desire		I'd like to	No, I don't want					

6.2.3 Case study— No.1 Building, Heibei residential community, Tangshan,China

Introduction of case study:

This is case study which is finished in 2006 is part of China and Germany cooperation project "existing building refurbishment in China". Three buildings—509,512 and 515 were chosen as the pilot building.

Located city: Tangshan, Hebei Province.

Constructed: 1978-1980, there are 4590 dwellings and five plans in this residential district. The area of each pilot building (509,512,515 building) is 6135m^2, 135 dwellings. For each target buildings, living area is 1535.0 m^2, balcony area is 146.7 m^2 and stairway area is 173.3 m^2.

Fig 6.9 Site plan and building plan of case study 1

(Source: Building energy conservation office of Tangshan city, 2007)

Preliminary survey results:

In this project, comprehensive preliminary data survey had been done at the beginning of the project. On the base of <Basic status survey report of No.1 building Hebei residential community (Tangshan city)>, we make our analysis in the method we proposed in last section.

In city of Tangshan in where there were a serious earthquake in 1979 and causes catastrophic damage to the city. Most of residential buildings were built around 1980 in 5 or 6 floors. After investigation, there are 40,000,000 m^2 existing residential building in Tangshan and half of them are without any energy efficiency measures. Table 6.8 showed the monthly climate parameters in Tangshan before refurbishment.

Table 6.8 2005-2006 monthly climate parameters in Tangshan, Hebei province

	Month	Monthly average temperature (^oc)	Highest temperature in month (^oc)	Lowest temperature in month (^oc)	Average humidity (%)	Average Wind speed (m/s)	Solar radiation (W/m^2)
Coldest month	December	-3.37	5.30	-10.8	44.54	1.6	1383.30
	January	-2.33	7.40	-13.20	55.77	1.23	2615.86
Lowest temperature	February	-1.47	10.90	-13.89	50.58	1.63	2390.81
	March	6.65	21.10	-6.00	41.17	2.12	5953.51
Main wind direction in coldest month				WNW			
Wind speed in coldest month				1.9			

These three buildings are built in cement prefabricated and are typical residential building which been built after earthquake. The u-value of external wall is 2.01W/(m^2•k) which is 2.5 times that of current energy efficiency standard. Energy consumption for heating is 4-5 times that of developed countries. The u-value of roof is 1.7 W/(m^2•k) which is 2 times that of current energy efficiency standard and energy consumption for heating is 3-5 times that of developed countries. In winter, indoor average temperature is only 14^{o}C-15^{o}C. For knowing status quo of building envelop and indoor facilities, since 2005, survey for external wall, roof, external window and toilet and kitchen facilities had been done. After got the information of building elements, a series of field texts also been finished with professional equipment and energy consumption status quo had been summarized.

Table 6.9 Table of key-points investigation of case study 1

Key-point investigation						
Building envelope	Envelop element		Damage situation	Thermal performance	Static performance	U-value
	Roof (material, layer)	Original design	• 110mm reinforced concrete precast slab • 83mm clay • 125mm aerated concrete block • 40mm 1:3 cement plaster • Water proof layer			0.7
		Status quo	Part of waterproof layer invalidation	Low heat insulation ability	Overweight load	1.13-2.23
	External wall (material, layer)	Original design	• 111mm reinforced concrete • 118mm aerated concrete block precast slab • 40mm cement plaster			1.16
		Status quo	There are empty parts in external wall	Low heat insulation ability	Y	1.97-1.99
	External window (glass thickness, window frame material, open mode)	Original design	• 25a single glass steel window			4.0
		Status quo	Most of window are out of shape	Low heat insulation ability	Y	6.4
	Foundation (material, layer)	Original design	• Soil layer • 70mm 75# reinforced concrete • 20mm 1:2:5 cement plaster			-
		Status quo	Serious damage	Low heat insulation ability	N	-
	Balcony (close/ semienclosed; interior/ exterior; glass thickness, window frame material, open mode)	Original design	Open balcony without insulation			-
		Status quo	Refurbished to close balcony by inhabitants	Single glass steel window with low heat insulation ability	-	-
	Building entrance (insulated/ no	Original design	No insulation stairway	-	-	-

	insulated, material)	Status quo	No existing	-	-	-
Indoor structure	Stairway internal wall	Original design	• 140-160mm reinforced concrete • 10mm cement plaster			0.94
		Status quo	• Structure damage	• Low heat insulation ability	-	2.1
	Dwelling door	Original design	• 70mm 75# reinforced concrete • 20mm 1:2:5 cement plaster		-	
		Status quo	• Normal	-	-	
Indoor facility	Heating system		Central net work	Regional heating boiler plant	Coal	
	Electric system		• Precast inside-wall bv plastic copper line			
	Domestic hot water		Regional hot water supply	Not hot water supply		
	Ventilation system		Natural ventilation	Auto-ventilation		
	Energy system		Gas	Lpg	Natural gas	
	Kitchen and toilet facilities		• No drainage in kitchen • Facilities aging			

Energy consumption	Heating (kwh)	Electricity (kwh)	Gas (kwh/m^2)(average)
	219416.7	26175	39.93
	221027.8	26243	39.93
	221472.2	29418	39.93

Primary energy consumption and pollution emission estimate	443.94t

Indoor living environment	Indoor air temperature (^{o}c)	Indoor moisture	Wall surface temperature
	11.3-17.88 (winter)	-	10.36-18.6 (winter)

With the help of local authority, the investigation faced to the inhabitants was made at the very beginning of project. The result is very useful material for next steps of energy option selection.

Table 6.10 Table of inhabitants' investigation of case study 1

Dwelling Property		Private	Public	Rent			
		85.8%	5.4%	9.3%			
Family Member No.		1	2	3	4	5	
		9.1%	33.3%	45.5%	8.3%	3.8%	
Inhabitant Age		Over 60	10-60	Less Than 10			
		32.9%	48.4%	18.7%			
Monthly Income		<500	500-1000	1000-1500	1500-2000	>2000	
		7.8%	23.4%	40.6%	9.4%	18.8%	
Monthly Outcome		9.8%	45.9%	36.0%	8.2%	-	
Envelope Tightness		Good	Middle	Bad			
		Specific to each room					
Comfort Level (Winter/Summer)		Hot/Very Hot	Warm/Hot	Middle	Cold/Warm	Very Cold/Cold	
Auxiliary Heater		AC	Electronic Heater	Electric Blanket	No		
		21.5%	11.5%	47.8%	19.2%		
Auxiliary Cooler		AC	Electric Fan	No			
		26.7%	71.0%	2.3%			
Air Quality		Good	Middle	Bad			
	Summer	6.8%	78.9%	14.3%			
	Winter	5.3%	66.9%	27.8%			
Ventilation		Good	No Function	Peculiar Smell	No Peculiar Smell	Demolished	Exhaust Fan
	Toilet	23.8%	76.2%	29.2%	4.6%	1.5%	4.6%
	Kitchen	28.5%	75.4%	22.3%	5.4%	2.3%	90.8%
Water Seepage		Winter Water Seepage	Summer Water Seepage	Moisture Condensation	Mildew		
Decorations		Window	Door	Floor	Wall	Room	Toilet	No
		61.5%	38.5%	67.7%	13.1%	51.5%	66.2%	10%
Content Of Refurbishment		Yes, Know Something	No				
		43.7%	56.3%				
Refurbishment Desire		I'd like to	No, I don't want				
		96.9%	3.1%				

Lessons learnt:

- Inhabitants should be involved into refurbishment process. They are the main beneficiaries in refurbishment. Since the beginning of refurbishment---- energy survey phase, professionals should communicate with inhabitants and investigate their willing for refurbishment.
- The content of the survey includes not only target building but also the general information of the same type of building in the same city.
- Field tests could be made by professional equipment and by the help of local administrations.
- Energy consumption by sectors (heating, cooling, electricity, domestic hot water, gas, etc.) statistics could be done with professional equipment and got accurate energy consumption data by monitoring; if there is impossible for monitoring with equipment, energy consumption data could be got by estimating.

Fig. 6. 10 Photos of existing building before refurbishment

6.3 Discussion and setting ambitions

As we know, compared to the construction of new buildings, residential building refurbishment is much more complex. We can get this conclusion by last section – complex process of preliminary survey, what is more, after the first step for data advance feasibility study, multi-players should organized to make discussion about their energy efficiency desires and setting energy conservation ambitions together. In China, the process of refurbishment (which is shown in Fig. 6.11) usually begins with an initiative by the local municipal government. The government, which also partly finances refurbishment, contacts households to talk with them about the possibility of their buildings being refurbished. Obtaining the residents' agreement to refurbishment and to financing a part of it usually constitutes a long and complex negotiation process. Here, international cooperation professionals can step in to moderate between the different players and their desires. Furthermore, international cooperation professionals can offer technical advice to both central and local governments, access to advanced technology from abroad and lessons learnt from refurbishment projects in their respective countries.

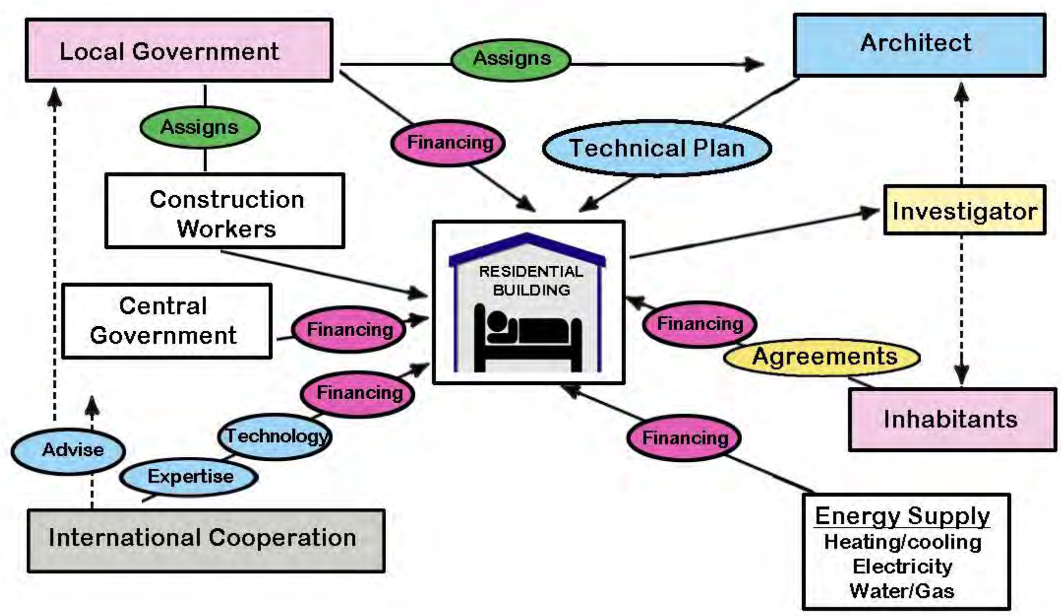


Fig. 6.11 Schematic diagram of Participation of multi-players in residential building refurbishment projects

In this step the ambition level of the project will be discussed between stakeholders. Themes in this discussion can extend to more than just the reduction of energy consumption and CO_2 emissions. The technical quality of the buildings the indoor climate, comfort levels and energy costs for inhabitants all can also be relevant subjects. CO_2

emission reduction aim and energy ambitions will be set in relation to national and local regulations, climate policy targets and the overall project context (type of residential buildings, area, prospective users). A first agreement on the overall ambitions may be set out in a joint agreement document between local government, inhabitants/house owner, professionals and construction company. In later stages of the decision making process, after the analysis of reduction potentials and required investments, a recalibration or reconfirmation of the ambitions may be necessary.

6.3.1 Coordinating multipartite participants

Motivation for making plans will vary between different stakeholders and municipalities depending on different local conditions (economic, society development, urbanization etc.), needs of refurbished buildings, public facilities and surrounding areas, and even their own interests and agenda. It is important to identify and understand the motivations before a plan is made so that the best model may be adapted for each municipality and the best criteria and goals may be identified to help formulate a common decision-making process. The main works in this step are:

6.3.1.1 Arouse initiative of stakeholders

Inhabitants/house owner: They may not always play a direct role within the energy planning process, especially in new construction projects, but it is wise to inform them at the beginning of refurbishment and involve them immediately when it is possible. As we concluded in last section, the main issues on which inhabitants/house owner should be encouraged to express their viewpoints are those relating to the quality and condition of the dwellings and services, the comfort level degree, and about the energy costs necessary to support the work. In China, it is difficult to arouse inhabitants' enthusiasm because they don't know the benefit of refurbishment and they don't want economic cost by themselves. Since there was no widespread successful refurbishment in most cities of China, the benefit spread work should be done as an important work in this step. The benefits of energy conservation, economic cost and improvement of living environment are three points of which inhabitants would interested in.

This is given expression to in ENPIRE project. In the residential district refurbishment project in ***Casale (Italy)***, the municipality played an important role in searching for the best contractors, through the help of the Council of Building Developers of the Alessandria Province. The inhabitants were involved in various meetings from the very beginning of the project. They were first asked how they would like to see their area developed, and then shown the first projects which included a special approach to environmental protection.

Local authorities: At this stage the municipality/local authorities must decide how to develop the urban plan and what the successful integration of energy issues into the urban planning process. There should be a consensus on the energy/CO_2 reduction targets and on the decision making procedures that will be followed by the various stakeholders involved in the energy planning process.

In China, municipality also has the responsibility for supplying low cost rent public house for low income groups (old people, low income family, disabilities, illness people and etc.). In Europe, there are housing associations which are independent nonprofit bodies. But in China this department whose primary objective is to provide low-cost social housing for groups in need is belonged to government. A certain amount of low rent public house are building with long use ages and are needed to be refurbished. Reduction of the total costs of living in these houses (i.e. cold rent plus the energy and general service costs) and improvement of the quality of houses will be the main focus of this participant in the ambition discussion. As a major investing party the local authorizes, should play an important role in the discussion and setting ambition process.

Another example in project ENPIRE, in the residential building refurbishment in ***Breda (Netherlands)***, the government of Breda encourages and supports energy efficiency in new buildings and in restructuring of neighborhoods and also evaluates the overall quality of plans. Inhabitants played a role in the discussions about setting the energy ambitions. A very important issue was the total housing costs, (i.e. the sum of the rent and the energy costs). In the case of projects involving energy efficiency measures it is important to aim at lower or at least equal total housing costs for tenants. In order to cover the costs of the investments, the cold rent for the dwellings has to increase. However, the positive effect is that the resulting energy costs for inhabitants are reduced. In Breda the provision of a guarantee on total housing cost was very important in persuading tenants to agree with the higher ambition on CO_2 emission reduction. The house owner had an active role in formulating the ambitions in the covenant that was drawn up for Breda, but were not involved in the energy study and the choice for energy measures.

Local Energy departments: These related departments are responsible for promoting a reasonable use of energy in the local area and are usually in communication with the municipal authorities or project managers. Energy departments can play a significant role in promoting the relations between the other involved parties and in deciding on different energy related issues. In such cases the infrastructure will need to be restructured.

6.3.1.2 Inspiring creativity of Professionals

Architects: from point of building design, architects are the main force for improving energy conservation and living environment. They should decide adopting energy efficiency technologies in building design step. Especially for residential refurbishment projects, architect should propose detailed plan not only building façade and environment, but also energy conservation measures which are suitable for local condition after preliminary data study and discussion ambitions with all related stakeholders. The energy conservation and CO_2 reduction targets should be set in accordance with or preferably go beyond the level required by national or local regulation or climate policy targets. They should also respect the objectives contained in the overall urban development plan and satisfy other relevant requirements, such as security of supply or economic issues.

Engineer: They are in responsibilities of building structure and related engineering solutions. In preliminary data collection and setting ambition step, they should work coordinately with architects as one group to make field thermal tests of existing building and certain materials, energy estimate calculation, structure static performance calculation and municipal facilities pipe line design. In one professional group for residential building refurbishment project, there should architects, engineers of electricity, thermal, water supply at least.

6.3.1.3 Fixing project developers

Project manager: They are in the responsibility of controlling the whole project operation. If the refurbishment project is organized by local authorities, the project manager is assigned by local authorities while if the refurbishment project is organized initiatively by inhabitants, the project manager would assigned by inhabitants commission. These parties are interested in making an economic profit and building a positive market image. They are also responsible for the actual realization of the project, are concerned with maximizing the value of the dwellings e.g. by increasing the indoor climate conditions and overall dwelling quality, and by decreasing future energy costs. Project developers are directly involved in the process because they are responsible for organizing the financial investments and sometimes also for the economic management of the dwellings.

Investigator: This role is specific needed in residential building refurbishment projects. Because of complex constitution of stakeholders and municipal departments, there is urgent need for a specific role that can coordinate with inhabitants and other stakeholders. The coordinating work is complex and difficult but without high professional knowledge.

Through all the refurbishment process, investigators should make interview and investigations to each family for collection data existing problems and persuade stakeholders to get compromise for embedding agreement. Even when the refurbishment is been done, investigators should make project supervision in a certain period.

6.3.1.4 Communicating with the construction organizations

Construction organization: They may not be involved in the first phases of the process as they are mainly responsible for the technical realization of the buildings. Constructors usually play a more significant role in private property housing especially single houses developments because in that instance they would normally have more freedom to make their own choices with regard to the building construction. The use of labels advocating low energy cost and ecological design can help both parties in marketing their buildings. Usually they are fixed by project manager by submitting a tender.

To achieve the initial energy targets it is necessary to obtain involvement from the various community stakeholders. So local authorities should prepare meetings with such groups not only to make clear what the final goals are, but also to decide how best to cooperate and divide responsibilities. We summarized the characteristics of each player in Table 6.11 and solution strategies are proposed in this table, too. On the whole, for all these barriers, solution strategy could be summarized as technical training, certification for ambitions, refurbish advisor for setting ambitions, direct economic discount, financing budget estimate, market implementing, quality control, building label and monitoring. For each play, there are main strategies which should be promoted and auxiliary strategies.

Table 6.11 Analysis of participants in setting ambition process

Player	Barrier description	Strategies
Inhabitants	• Lack of awareness of refurbishment benefits (energy efficiency, cost saving, living environment improvement) • Difficult to popularize energy efficiency conception • Split incentives and difficult to coordinate • Doubt for energy saving sufficiency (is cost recoverable at sale) • Hassle of transformation	• Certification • Refurbish advisor • Economic discount ○ Financing estimate ○ Quality control
Local authorities	• Lack of technical tools/knowledge • Limit financial budget • CO_2 emission reduction not visible	• Technical training • Certification • Retrofit advisor • Financing estimate ○ Quality control ○ Marketing
Local energy departments	• Lack of enthusiasm • Administration system inefficiency	• Technical training • Certification • Financing estimate ○ Quality control
Professional group	• Limit financial budget • Difficult to popularize energy efficiency conception • Limit of existing refurbishment mode and advanced technology	• Technical training • Certification • Quality control • Building label ○ Financing estimate ○ Quality control ○ Monitoring
Project manager	• Limit coordinate right	• Technical training • Certification • Quality control • Marketing • Monitoring ○ Retrofit advisor
Construction organization	• Lack of enthusiasm • Lack of technical skills/knowledge	• Technical training • Certification • Retrofit advisor ○ Marketing ○ Quality control

• Main strategy ○ Auxiliary strategy

6.3.2 Tools for setting ambitions and embedding agreements

The final ambition level for the project can be established and agreed by comparing the evaluating different energy options and cost. Initial ambitions may need to be adapted in view of realistic energy saving and levels of investment needed. It is very likely that at the beginning of the project the ambition is different for every player. At this point it makes sense to really fix the ambition level. Involvement of all stakeholders is therefore necessary at this stage. They have to agree on the level of energy saving and CO_2 emission reductions they will strive for. Based on the analysis and vision study report the technical solutions that are considered most suitable can be selected.

The common agreement on the ambition level had to be quite good in order to really achieve the project goals. It is good to note that many projects fail to reach energy efficiency goal because they did not fix a reasonable ambition. It is very important to have a firm agreement, not only on the final target, but also on the way to cooperate and communicate in the process.

To better understand the available tools in this process, management structure of urban plan and building construction sector in China is sketched in Fig. 6.12. As we analyzed in Fig. 5.27, for urban area, the administrative structure in China is divided into statement, provincial, municipality and prefecture levels. In building sector, both urban plan and building construction projects and regulations are controlled by relevant departments in these four levels administration. In the same time, the permission and supervision of plans are approved by relevant government. Residential building refurbishment is related with site plan of the residential community and building construction.

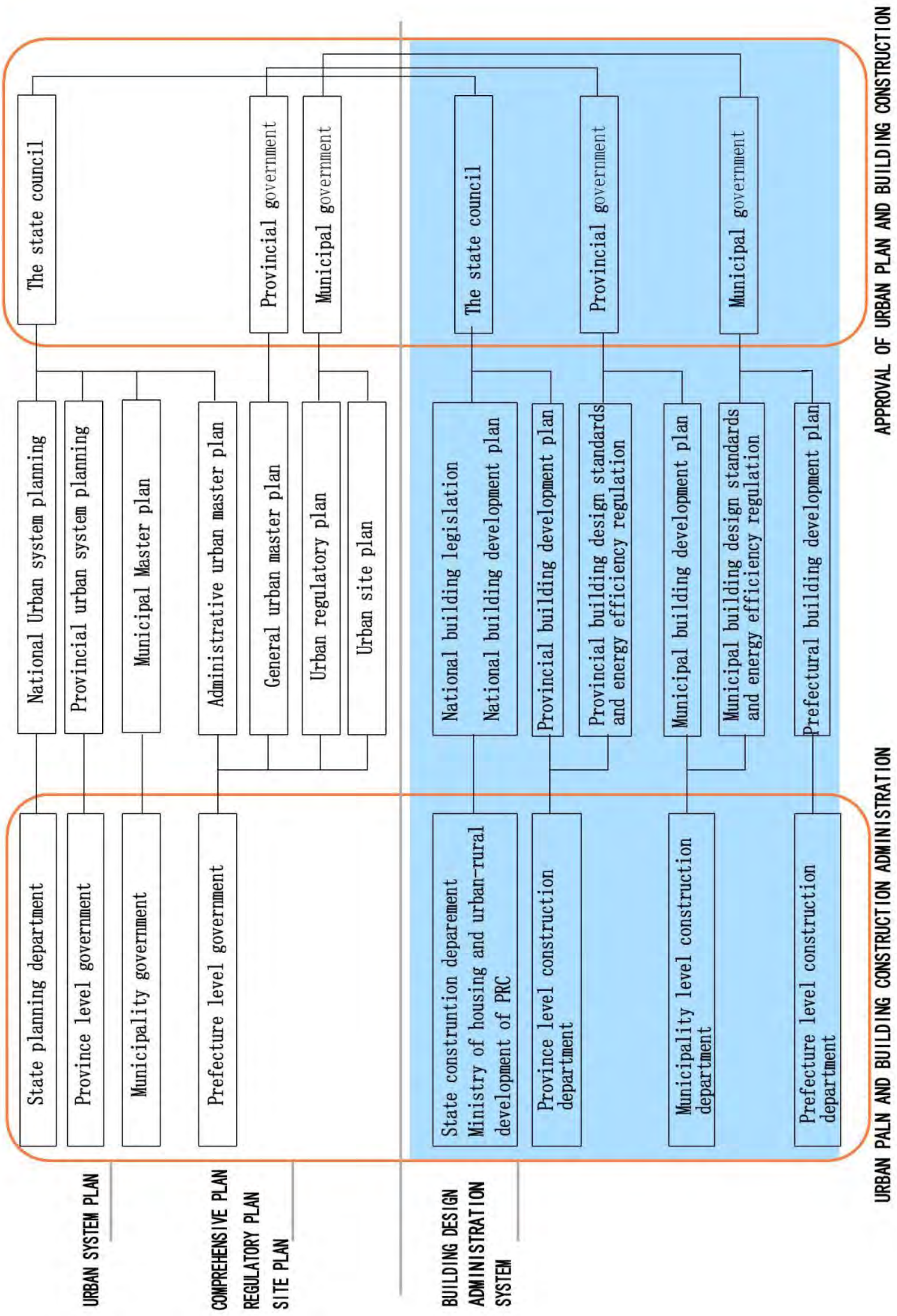


Fig 6.12 Management structure of urban and building sector in China

6.3.2.1 National legislations and local standards

In general, the ambition of refurbishment project is fixed by national legislations and local standards. As the energy crisis is beset with numerous contradictions, there were a series of building energy efficiency legislations and local standards published in European countries and we have talked about it in Chapter 3. In China, the government should learn the European experiences and set up complete building energy efficiency legislation and local standards. Since area of China is huge, there is necessary to publish local standards which are suitable local condition. For policy makers, there are three aspects they have to pay more attention to for existing residential building refurbishment in urban area of China:

- Climate change policy must include provisions to account for the environmental costs of inefficiency in existing residential buildings.
- National policymakers should help state public utility commissions decouple sales volume from profits, in turn providing uniform national promotion of energy efficiency.
- National policymakers should facilitate the implementation of a system of cooperative investment by homeowners and utilities in household retrofits to improve residential energy efficiency.

Legislation System for refurbishment:

Legislation system for building sector is set up by government in recent years. We have talked about it in Chapter 3. Especially for energy consumption in building sector, besides the central government, local administrations published some local regulations and documents for addition. It is shown in Fig. 6.13 that the legislation system for residential building in China.

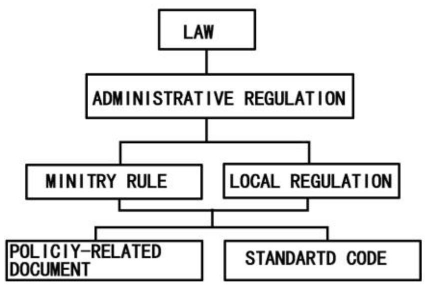


Fig. 6.13 Legislation system structure for residential building in China

- *National law*

Although there are still no existing laws specific for existing building refurbishment, there are some relevant articles which can be used as guidance for building refurbishment in these two national laws.

In ***<Law of the People's Republic of China on Conserving Energy>*** (2007 version), No.37 article ruled "In designing and constructing buildings, energy-conserving building structures, materials, appliances and products shall be employed according to the provisions of relevant laws and administrative rules and regulations in order to improve thermal and insulating performance and reduce energy consumption for heating, cooling and lighting purposes."

<***Renewable Energy Law of the People's Republic of China***> is made for strengthen civil building energy conservation management, reduce energy consumption in the use of civil buildings, and raise energy efficiency, this Regulation is hereby established. It is advocated that low cost renewable energy should be used in building construction especially for residential building refurbishment.

- *Administrative regulations*

In 2005, the <Provisions on the Administration of Energy Conservation for Civil Buildings> (76th order of the Minister of the Ministry of Construction, 2005) made decisive significance for promoting energy-saving work for buildings. Responsibilities of multi-players of construction project and heating department, property department is specified and "building design should be made by guide of energy efficiency standards and regulations. Technical standards are looked as basis for archiving energy efficiency aim.

In 2008, < Regulation on Energy Conservation in Civil Buildings> is published by State Council. By the aim of strengthen civil building energy conservation management, reduce energy consumption in the use of civil buildings, and raise energy efficiency, this Regulation is hereby established. Rules for existing building refurbishment are proposed first time in regulation. Building energy efficiency refurbishment principles are set up; administrative system for building energy efficiency management is completed; standards and financial mode are proposed with more details.

- *Ministry standards and local regulation*

In China, since 2008, a series of local regulation were published by local government (provincial government and municipal governments of some big cities).

In province like Guangdong, Hebei, Hubei, Gansu, Shanxi, Zhejiang, Heilongjiang, Hunan, Jiangsu etc., and cities like Nanjing, Shenyang, Chongqing, Dalian, Hefei, Beijing, Shanghai etc., published provincial <65% residential building energy efficiency design standards> on the base of national standard and proposed rules specific for residential building refurbishment energy efficiency.

- *<u>Guidelines and documents</u>*

Besides the official regulations and standards, provincial administration and municipal administration also published some documents for promoting energy efficiency for residential building and public building refurbishment. Experts from social institutes and universities also worked on guidelines for residential building refurbishment.

Fig. 6.14 Example of local energy design standard for residential building in Shanxi province
Left: DB J04-204-2006 < Design standard for energy conservation renovation of existing heating residential buildings>
Right: DB J 04-243-2006 <Standard for energy inspection of residential building>

For example, in Shanxi province, for promoting residential building refurbishment energy efficiency, the provincial government issued a series measures. *<Shanxi 65% residential building energy efficiency design standards>* and *<Shanxi Civil building project monitoring guidelines>* are published and there are articles for refurbishment proposed. *<Suggestions for improving energy*

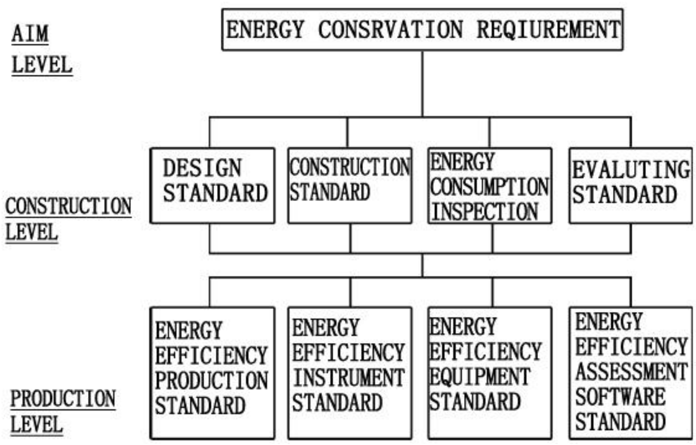


Fig. 6.15 System of energy efficiency standard for residential building refurbishment

efficiency refurbishment for existing building> (Jin [2008] No.10) is published in 2008. “Shanxi province existing residential building heat metering and energy efficiency refurbishment working group” and “Shanxi province building energy conservation monitoring center” were organized. A series of codes like including that are for residential building refurbishment like <Evaluating standard for energy efficiency of residential building >, <Design standard for energy conservation renovation of existing heating residential buildings>, <Standard for energy inspection of residential building >are published. (Fig. 6.14) But the current regulations and standards about residential building are implemented in some regions and is imbalance. In some provinces and cities, there is still gap in energy efficiency regulations for residential buildings.

Energy efficiency for residential building is a systematic mission. If we focus attention on energy efficiency technologies, materials, construction equipment, operation and management of instruments, relevant subjects like cooling, heating, water, lighting and other professional disciplines should be integrated through refurbishment. To achieve the refurbishment goal, we must make full use of various professional disciplines. It is shown that implementation of building energy efficiency standards is an effective way to achieve energy efficiency goals by developed country experiences.

It is necessary to construct an appropriately design institutional framework for residential building refurbishment energy efficiency in order to combine building energy efficiency, administrative regulations and energy infrastructure quality. Building energy efficiency standards play an important role in the promotion and technical support for residential building refurbishment; standards will be completed by the implementation of relevant national policies and development strategies; the overall building energy target demands will be highlighted by professional standards system of relevant subjects. Fig. 6.15 shows the complete energy efficiency standard for residential building refurbishment, the system is divided into 3 levels, relevant standards are proposed from three levels: aim level which represented energy conservation aim; construction level includes standards related with building construction process; production level includes standards related with energy efficiency technologies, materials and equipment. Benefit to need for residential building and economic development will be brought in near future.

6.3.2.2 EPL /ASCOT

In European countries, some tools had been used in refurbishment projects. Some of them can be used as an important addition when setting ambitions for residential building refurbishment projects.

EPL—Energy performance on location, Netherlands

In the Netherlands, some tools for building energy performance evaluating were used for estimate energy consumption before the design process of building projects. When the municipalities develop larger projects with new or existing buildings they often make use of a tool called the Energy Performance of a Location (EPL) to set a certain ambition level.

EPL, which stands for the ***Energy Performance of a Location***, is a government instrument used to set ambitions, monitor and compare the energy performance of districts. It takes multiple new and/or existing buildings into account including the energy supply, transport & generation and the energy consumption of streetlights, drainage and appliances (Vreenegoor et al., 2008). Although it is not legally embedded, the Energy Performance of a Location (EPL) is a Dutch instrument to realize fossil fuel and CO_2 emission reductions in building projects that comprises of several buildings. EPL includes the energy use for heating, cooling, hot water, lighting, ventilation and household purposes in buildings and also a (fixed) value for the energy use for public lighting and water management of the public areas. The EPL-scores scale from 0 to 10, where 10 imply a zero energy CO_2 emission project and 6.6 represents satisfies the building regulations.

Good European Practice: Covenant energy ambition Heuvel, NL (ENPIRE)

In project of regeneration of district "Heuvel", professionals used EPL for setting ambition and with this ambition they strive for a higher level of quality with respect to comfort, healthy indoor climate, future flexibility and the environment.

For the new buildings, guaranteed realization of a minimum EPL =7 for new buildings and aiming for the realization of EPL = 7.4 and the use of low temperature heating systems; For existing buildings, realization of minimum EPL 5.7 was retained, provided that tenants agree and in accordance with the participation rules.

- Advantages
    - New district as well as existing districts can be evaluated;

- It's more directly perceived through the senses that building energy performance is transferred to CO_2 emission;
- Simply calculation methodology is available. Using EPL-scores energy conservation ambition can be monitored during project development and the final EPL-score can be used to check if the ambition had been realized.

➢ Disadvantages
- The energy consumption for appliances depends on the usable floor area which is a rough indication and could differ al lot with the actual situation;
- It is needed to be promoted on the base of 1998 draft since our energy consumption for appliances keeps;
- Incomplete influence indicators.

➢ Lessons learnt for China
- Multifunction tools could be used both for existing and new constructions.
- How to make complicated problem into simple issues
- Municipality should play the "lead role" in the process of discussion and setting ambitions by local regulations and permits.

ASCOT—assessment tool for additional retrofit construction cost, Denmark

ASCOT is a tool that has been developed in Denmark to assist the users in evaluating and optimizing the economic costs of a building renovation project in relation to sustainable development issues.

Financial mode of a residential building refurbishment is an important aspect that needed to be considered of. Only if the investment and cost problem is solved, proper ambitions could be set. Broadly speaking, cost for renovation depends on:

- Whether the measures applied are for energy efficiency only or for refurbishment of the building in general;
- The number of different measures taken;
- The characteristics of the suggested measure (traditional or ones requiring high technologies);
- The standard of living in the local area.

The ASCOT model allows a comparison between a traditional (reference) building renovation and different sustainable concepts for the refurbishment of the building. This comparison will take into account demand reductions during the total lifetime of the building and the frequency of future replacing of building components and systems. The tool is primarily intended for use in the early stage of the design process. It can be used for both new constructions and renovation projects.

The ASCOT calculation tool includes a calculation of the heat consumption for space heating. The calculation covers different climate conditions in Europe and different building categories. The calculation covers different climate conditions in Europe and different building categories. That means the program must handle many different combination of program input. It is the intention that the program must be easy to use by many different users.

The ASCOT tool calculations are based on international standards for energy calculation, such as “Thermal performance of buildings – Calculation of energy use for space heating and cooling” (ISO/DIS 13790), “Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies: Heat generation system, thermal solar systems”.

Good European Practice: Danish example

In Denmark a positive response has been gained with ESCO loans in which there has been a co-operation with local energy saving companies / local energy companies.

The idea is to obtain loans with low interest rates, based on a municipal warranty like the one which is practiced in Denmark for district heating systems. Fig. 6.16 illustrates how one can help to organize energy efficient renovation of social housing projects based on a Danish example. The main results of this are that rather than financing energy savings and solar energy systems by a normal bank loan where the interest rate can easily be 7.5-8% by the end of 2008, instead you can obtain a municipal guaranteed loan at an interest rate of app. 3-4%.

- Advantages:
    - All investment and operation costs over the total lifetime of the building;
    - The savings from the investments with respect to sustainable issues (energy, water, waste) over the total lifespan of the building;
    - Setting up connection between energy saving and cost.
- Disadvantages:
    - Cost for Environmental impact is not included;

- Relaying support of bank.

➢ Lessons learnt for China:

- Pluralist source of investment;
- Municipal support for long time flexible credit and loan mode;
- Specific favorable treatment for energy efficiency technologies.

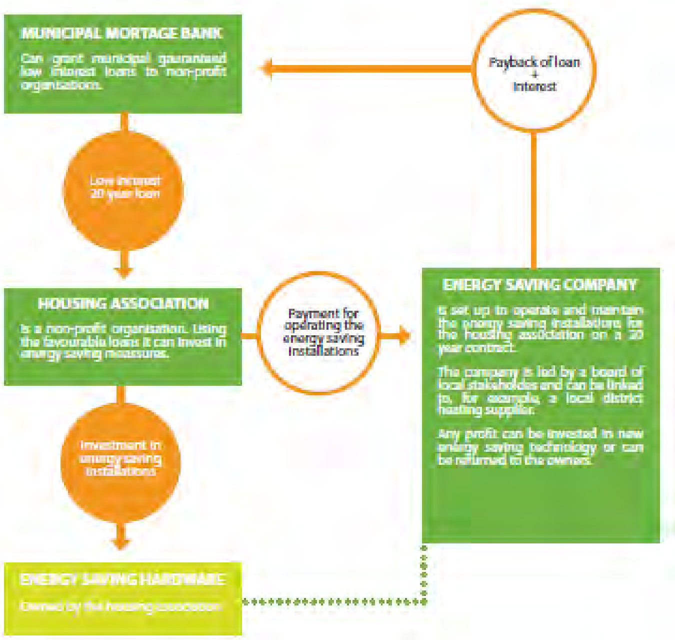


Fig. 6.16 Illustration of the organization of an Innovative Energy Saving Financing System in Danmark (ENPIRE 2009)

From the introduction of EPL and ASCOT, we can find although these methodologies are aimed at EU, highly instructive experience could be recommended to China. CO_2 reduction and financial mode are two problems which are excited broadly interest by society. In future research, proper EPL and ASCOT specific for China will be made as the result of Interdisciplinary Studies.

6.3.3 Joint agreements

All the stakeholders have their own opinion about the result of refurbishment. In this step, they must decide which energy options they are interested in and the financial resources available within the process. By setting the common ambitions they have to make a certain compromise and reach an agreement. In this process, energy efficiency measures may be set at different levels depending on the state of dwellings and actual status of the construction or refurbishment project.

Many of the energy options have very little or no cost implication and a selection of them can be introduced into development plans if they are prioritized. In order to get the best results in relation to the energy saving goals the main drivers for the prioritizing of the options are:

- Political and environmental reasons: reducing energy use and dependence on fossil fuels
- Economic saving reasons - decreasing cost of energy bills by implementing energy efficiency measures and best practices (related with financial resources as well)
- Habitability conditions arguments – increasing comfort and safety within the dwellings, taking advantage of daylight when possible, etc.
- Market arguments - increasing market appeal of the dwellings and improving the public image of the involved parties, by means of the different technical solutions.

In order to ensure considered implementation of the results, a strategy should be detailed and thoroughly described in order to clearly define the responsibilities of each stakeholder and to facilitate effective coordination amongst them. Local authorities might be the leaders of the process, but all participants should contribute actively to achieve good results.

6.3.3.1 Setting ambitions

So far, no comprehensive strategies have been developed in China to start energy efficient, sustainable multi-stored housing refurbishment. Especially effective legal and administrative structures need to be developed, energy efficient refurbishment measures chosen, sustainable housing refurbishment implemented. The main benefit of buildings refurbishment is usually considered as saving of energy. It is obvious, however, that most energy saving measures allows not only to save energy, but also to improve the building's environmental performance.

The ambitions would be fixed on different levels which represent high level or low level of energy saving aims. The level of ambition will depend on the estimated resources, knowledge and the financial support and financial construction that is available to the project team. Financial feasibility is prerequisite of proper technical solution; the energy saving ambition should be fixed on the balance of realistic and ideal. (Fig 6.17)

This step is the second step in energy consumption study for residential building refurbishment. After the preliminary study by local authorities then the refurbishment project would be developed into setting ambitions step. The process of setting ambitions could be divided into 6 steps.

Selection of project: In China, usually the selection is finished by local authority. The department/office which is in responsibility of local residential refurbishment would organize the process of preliminary study and selection. First selection of project should already consider sustainability criteria such as site location and relationship to its environment, possibility to develop or integrate public transportation, existence of energy or heat production facilities in the vicinity, conservation or improvement of the social and economic context.

Identify local stakeholders: once the project has been clearly identified, different stakeholders should be organized in order to make refurbishment ambitions. Stakeholders whom we talked about in section 6.3.1 should be involved in setting and ensuring the level of ambitions.

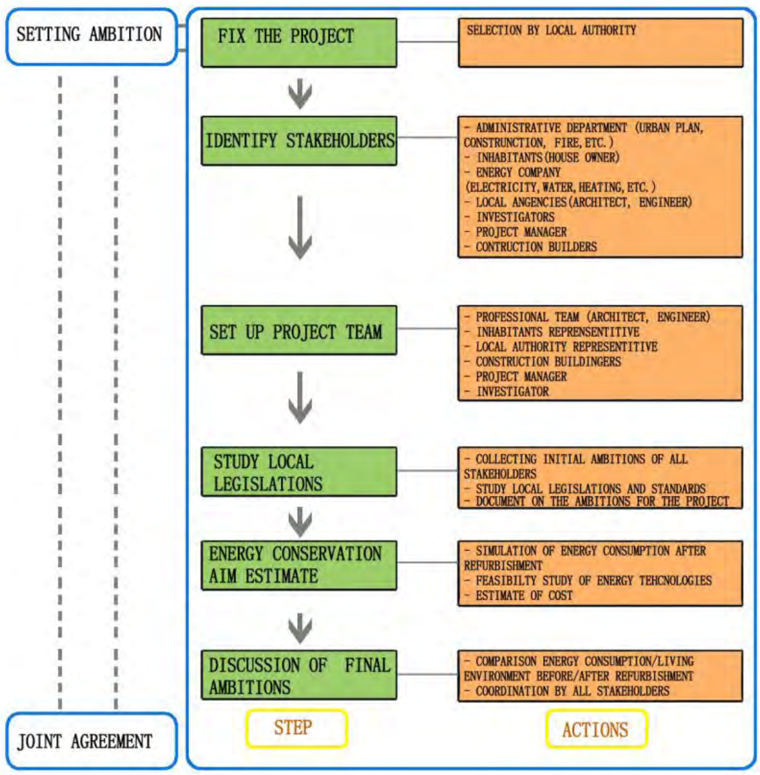


Fig. 6.17 Setting ambition process of residential building refurbishment

Set up a project team: a project team around 10 people (depends on the scale of the project) should be set up at the beginning. Project manager or project office should be fixed by local authorities. Then professionals such like architects, engineers and construction builders should be fixed by project manager. Representatives of inhabitants/house owners should be invited into the team and their suggestions could be the main parameters for setting ambitions. The management procedure of the project team should adopt an integrated design approach and educate the whole team on goals, cost and benefits of the refurbishment.

Study local legislation: National legislations and local regulations are the guidance for setting ambitions. In this step, by discussion, initial ambitions of all stakeholders can be collected and primary document on the ambitions for the project could be formed.

Energy conservation aim estimate: The conventional design process usually introduces energy-efficient technologies during design development. However, the greatest opportunity for cost-effective energy measures occurs earlier in the design process. The pre-design stage is when the team investigates energy-related design concepts that consider the environment, climate, building orientation and other features that will impact performance well into the future. The animation methodology used in this first meeting has to ensure that energy, renewable and climate change ambitions have been addressed. Energy consumption should be estimated in simulation after refurbishment. In the other hand, cost for measures could be estimated. On the basis of the vision document, first technical measures selection and budget orientations could be proposed to all stakeholders.

Discussion of final ambitions: On the basis of the estimate of technical elements and budget plan, meeting with representatives of stakeholders should be organized and they should get agree with the same ambitions. They could make comparison between energy consumption and living environment comfort level before and after refurbishment, some of them should make a certain compromise since consideration of comprehensive factors. The stakeholders share a common vision of the level of ambitions the project is meant to achieve and agree to pursue these ambitions, from conception to construction.

Recommendations:

As mentioned above, the setting of ambitions should at least consider the minimum requirements of national regulation on energy efficiency and the integration of renewable energies. A clear vision should be provided to all stakeholders on the state of the art of official regulation requirements.

To address local specificities, such as the economic context, environment or layout, the setting of ambitions on sustainable urban planning projects will have to integrate local policies or programs.

The ambitions maybe set as different levels such like high level with high quality of living comfort level and low energy consumption; low level with minimum requirements of living comfort level and high energy consumption and middle level is the compromise.

6.3.3.2 Embedding agreements

After the final ambitions are fixed, a joint agreement would be assigned by all stakeholders. A Joint Agreement is made between the local authority, the owner or the developers, on the technical requirements needed for the project to reach the ambitions set into the vision document. The Joint Agreement will be used as a reference for all stakeholders in order to maintain the highest level of ambitions all along the project design and construction phases.

The Joint Agreement can be made under different formats: from a specific document to a full integration in project contracting documents.

The format taken by the embedding of agreements can be different: from a formal document providing precisions of the level of ambitions adopted by all stakeholders to contracting elements. The final format will depend on:

- Local ambitions
- The level of intervention : area planning, new or renewing project …
- The project itself

Table 6.12 Analysis of stakeholders and their attitude on ambitions

	Inhabitant	Authorities	Professionals	Construction	Energy departments	Agreement
Construction time	Very important	Important	-	Very important	Less important	Very important • Fix construction time • Inside household work time
Improvement comfort level	Very important	Important	Important	-	-	Most important
Thermal	Most important	Important	Most important			• Indoor maximum/minimum temperature in winter/summer ; • Natural and artificial luminance; • Ventilation rate • Hot water supply: Y/N • Facility renovation: Y/N
Light	Important	Less important	Important			
Air	Important	Less important	Very important			
Olfactory	Important	Less important	Important			
Facility	Very important	Less important	Important			
Domestic hot water	Important	Less important	Important			
Energy saving	Less important	Important	Very important	Less important	Important	Most important
Heating&cooling		Very important	Most important		Important	• Energy consumption for Heating/cooling (kw) • Energy consumption for artificial ventilation (kw) • Energy consumption for lighting (kw) • Energy consumption for hot water/cooking (kw) • CO2 emission reduction (t)
Lighting		Important	Important		Important	
Ventilation		Very important	Very important		Important	
Water		Important	Important		Important	
CO_2 emission		Very important	Most important		Important	
Economic cost	Very important	Important	-	-	Less important	Very important
Energy bills	Very important	-				• Electricity cost Water cost • Refurbishment invest (material, technologies, employee) • Financial mode
Investment	Very important	Important				
Appreciation	Important	-				
Measures	-	Important	Very important	Important	Less important	Important • Adoptive Technology • Renovation of façade/plan/facility/pipe/envelope: Y/N

6.3.4 Case study

6.3.4.1 Caochangxiang residential community refurbishment , Urumqi, Xinjiang Uygur Autonomous Region, China

Introduction:

This residential building refurbishment project was started in January of 2008. Helped by the motivation of existing building energy conservation, this project was finished as the pilot project in China-German cooperation project.

City of Urumqi is the capital of Xinjiang Uygur Autonomous Region and is a metropolis which has the longest distance from ocean. The population of Urumqi is 300 million. Urumqi locates in cold area and number of heating days is 162 days (162 days for calculation; real heating day is 181 days in 2008).

In this residential district, there are 8 multi-storied (6 or 7 storied) buildings which were built during the period between 1984 and1990. The building area of this residential district is 21,700 m2 and there are 349 dwellings. In the original design, the balcony is open balcony, city district heating. The existing problems are: low indoor temperature in winter and become mildewed seriously.

Fig. 6.18 Photo of case study 2
Top: Before refurbishment
Bottom: After refurbishment

Source:
Lu X et al., 2011, analysis of low carbon energy conservation residential building refurbishment in severe cold zone----case study of Caochangxiang residential community refurbishment.
Ding, 2011, Summary of Urumqi residential building energy conservation refurbishment and heat meter.

Discussion and setting ambitions

- Tools:

In 2005, municipal government published <*Urumqi building efficiency management standards*>; in 2008, <*Urumqi implement plan of building CO_2 emission reduction in building sector* > was published and aim of energy saving was set up.

The financial mode was fixed in the mode of 5:3:2 that mean the prepetition by authority, work agencies and house owner is 50%, 30% and 20%.

- Discussion:

They made a good job on discussion and setting ambitions period. After the authority fixed this project, with the guide from German experts, local authority set up a work group including officers, foreign and Chinese experts. They are in charging of coordinating relevant construction department and inhabitants (Fig. 6.19). In the aim of arousing inhabitants, they made publicity work one by one dwelling and made communication between inhabitants and experts. Since the inhabitants didn't have to pay too much and the work group had solved all the problems with relevant department and energy company, inhabitants are interested in benefits of refurbishment. They signed the agreement successfully. (Fig. 6.20)

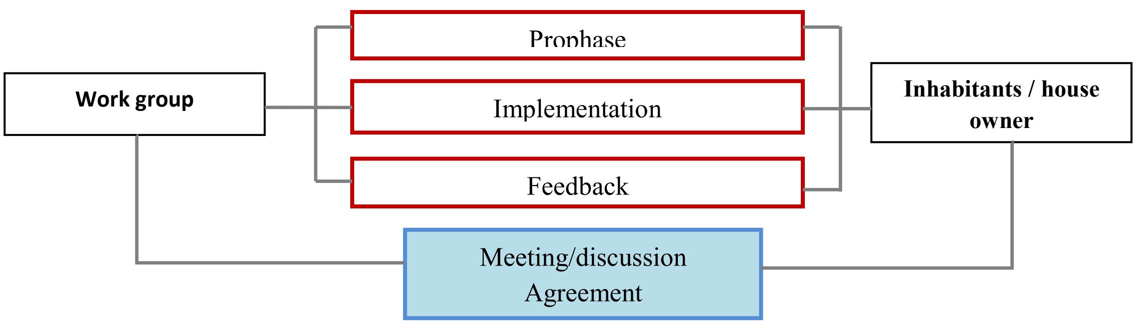


Fig. 6.19 Discussion process of case study 2

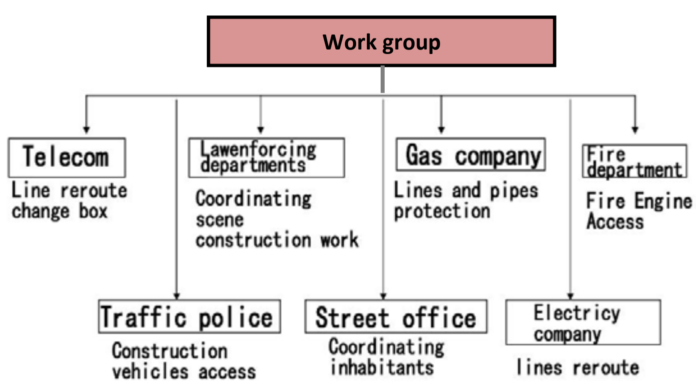


Fig. 6.20 Coordinating work in case study 2

- Agreement

They proposed three refurbishment plans in discussion period; these three plans are made in different energy saving aims which reach energy conservation by 50%, 65% and more than 65%. (Table 6.13)

Table 6.13 Three initial refurbishment plans in setting ambition step for pilot project

		Min. version	Medium version	Max. version
Construction time		Y	Y	Y
Improvement of comfort level		Low (qualified)	Medium	High
Energy saving		Low	Medium	High
Economic cost		Low	Medium	High
Measures	Heating system	Vertical cross single-pipe heating system, thermal-stat valve for every radiator	Vertical cross single-pipe heating system, thermal-stat valve for every radiator	Vertical cross single-pipe heating system, thermal-stat valve for every radiator
	Ventilation system	Natural ventilation	Auto ventilation	Auto ventilation
	External wall	EPS 10cm	EPS 12cm	EPS 14cm
	Window	Thermal-Iso-glass K=2.7 W/(m^2•k)	Heat protecting glass K=1.9 W/(m^2•k)	Heat protecting glass K=1.9 W/(m^2•k)
	Roof	PU 10cm	PU 10cm	PU 10cm
	Basement ceiling	8cm	8cm	8cm
	Balcony floor	EPS 10cm	EPS 12cm	EPS 14cm
	Building entrance	Insulated door with foyer	Insulated door with foyer	Insulated door with foyer
	Basement entrance	Closed door of basement	Closed door of basement with thermal isolation	Closed door of basement, 3 cm thermal isolation for the wall

Lessons learnt

- Fixing plan for organizing multipartite participants and fixing specific person to be responsible for coordinating the whole process. The publicity should be made in residential community level. Regular meeting should be organized and multi-players could communicate with each other and express their ambitions freely.

- Funding constitution could be shared by multi-players. It's better that funding from authority take as much as possible.

- Consideration local condition including natural condition, building condition and especial human conditions. Because difference of inhabitants' age and life mode influence a lot in energy consumption ambitions.

6.3.4.2 No.2 and 7 building, Mishi residential district, Hangzhou, China;

Introduction:

In the end of 2007, Hangzhou government began the "Yard Refurbishment Project" which is aimed at refurbishing existing residential district. The refurbishment includes façade renovation, environment retrofit and energy conservation refurbishment. No.2 and 7 building in Mishi residential community were selected as pilot project for energy conservation refurbishment. Selected building is six-storied masonry—concrete structure building which were constructed in 1986 without any energy conservation measures. There were 54 dwellings in each building and average area of each dwelling is 70m^2 (construction area). 87% of inhabitants are middle or low income citizens in Hangzhou.

Fig. 6.21 Photo of case study 3
Top: Before refurbishment
Bottom: After refurbishment

Source: Tian et al., 2010, Cities in hot summer and cold winter suitability of existing house energy saving measures, Huazhong Architecture, 28(10),pp 51-53.

Discussion and setting ambitions

In discussion and setting ambitions step, data which had been collected was simulated with software. With the simulation different measures had been analyzed with economic cost, energy efficiency and construction difficulty. All these analysis results had been applied to all players.

In this project, AHP (Analytic Hierarchy Process) is used for decision-making. In the analysis process, parameters is set as: A1 represents energy efficiency effect, A2 represents cost, A3 represents construction quality, A4 represents disturbance to life, A5 represents involvement by inhabitants and A6 represents construction time. Five numbers (-2,-1, 0, 1, 2) represents five levels (not important at all, not important, no relation, important, very important). Making analysis on the investigation result by AHP method, the weight of different influence factors is shown in Table 6.14.

Table 6.14 Inhabitants' investigation result about weight of influence factors by AHP

A1 energy efficiency effect	0.212974
A2 cost	0.222250
A3 construction quality	0.096471
A4 disturbance to life	0.141428
A5 involvement by inhabitants	0.112617
A6 construction time	0.214054

- Agreement

From the analysis, we can find that economic cost, energy efficiency effect and construction time are aspects that inhabitants care about most. Then professionals made different available technical measures which could be adopted. At last, all players got an agreement on adoptive measures by considering the factors comprehensively. Compared with energy consumption before refurbishment, after refurbishment, 25.98% energy had been saved.

Table 6.15 Three refurbishment plans in setting ambition step for pilot project

		Min. Version	Middle version	Max. Version
Construction time		Y	Y	Y
Improvement of comfort level		Low (qualified)	Middle	High
Energy saving		Low	Middle	High
Economic cost		Low	Middle	High
Measures	External wall	Insulation layer YNMT 20mm	Insulation layer YNMT 30mm	Insulation layer SPF 30mm
	Window	Heat Shielding Film	Insulated double glazed plastic-steel window	Low E double glazed plastic-steel window

	Roof	Normal pitched roof	Ventilation pitched roof	Insulation layer on flat roof +pitched roof
	Building entrance	Insulated door	Insulated door	Insulated door
Recommend refurbishment measures		West external wall vertical green to improve Thermal insulation performance		
		Adding tall trees		
		Reducing outside cement floor area		
		Reserved space in roof for solar heating		

--Adoptive measure

Lessons learnt:

- Analysis methodology could be used for analyzing complex factors by multi-players in decision-making process. In this case study, AHP (Analytic Hierarchy Process) is used for evaluating weight of different influence factors. Using this kind of accurate measurement, all multi-players involved in discussion process can get agreement easily.
- Besides main technical measures, auxiliary measures could be proposed in discussion period as recommendations. These recommendations are according to local condition and aimed at improving living environment.

6.4 Analysis of energy options and optimizing of energy options

When a residential building refurbishment project is fixed, after preliminary data collection and set ambitions on the base of data, proper measures should be selected for refurbishing existing target residential building. From the point of energy conservation, proper energy options should be selected to achieve the ambitions. In this section, we will discuss the key points for setting an energy version and how it can be communicated to stakeholders.

In fact, setting energy version for a residential building refurbishment is such a complex procedure which related with many considerations that it is hard to achieve energy conservation aim just by one or two measures to part of the building. Because that there are too many influence factors affecting on building energy consumption, the operation system of apartment should be looked as an integrated system. A systems approach to refurbishment recognizes the significant interactive effects among various end-uses and efficiency measures that affect overall savings and carbon reductions. Decisions on energy options also have significant meanings for other issues of concern to stakeholders such as aesthetics, moisture problems, indoor air quality, and comfort level. Programs that improve a systems approach to residential building refurbishment are much more likely to both identify the ideal path for improving energy efficiency and living environment to huge amount of existing buildings.

Implementing energy conservation measures in residential building refurbishment projects in China is an important way for improving residential building living environment and for improving energy efficiency in building sector. But energy conservation was usually ignored in China before; there are obvious benefits by energy conservation refurbishment for residential building:

- *Emphasizing comprehensive energy conservation refurbishment, improving the practical value of the building.*

  In China, especially in urban area of China, with the implementing of privatization reform of residential building, cost for residential building raised a lot. Most Chinese family can afford only one dwelling which takes main part of total asset. Comprehensive energy conservation for residential building refurbishment, especially for low income family, is the best way for improving both the value of existing building and living environment of existing dwelling.

- *Energy conservation refurbishment could save investment.*

  By energy efficiency technology, energy consumption could be reduced while living environment is improved. Comprehensive energy conservation for residential building refurbishment is the best way for saving investment for energy consumption and facilities maintenance.

- *Improving use of renewable energy in residential building.*

  By implementing of innovation energy efficiency technology, renewable energy like solar energy, natural wind energy could be used in existing building if it is possible. Comprehensive energy conservation for residential building refurbishment, use of renewable energy in residential building could be improved and CO_2 emission could be controlled effectively especial in winter and summer.

- *Making pilot building in cities with typical characteristics could set demonstration to other provinces and cities.*

  In recent years, several pilot residential building refurbishment projects which are aimed at energy conservation had been made in China and got great affection for improving energy conservation of residential building. By these successful energy conservation refurbishment projects, benefits of refurbishment could be spread and innovation technologies could be implemented effectively to other projects and other cities.

- *Refurbishing building insulation layer and heating system synchronously*

  The refurbishment should not be made only to buildings, energy efficiency for heating system should also be refurbished to meet energy efficiency standard. Heating energy is transferred from heat power station to residential building by heating system and measured by heat meter and temperature control valve. Old, inefficient heating system would waste a lot of energy in transformation process. Comprehensive refurbishment for residential building should include not only building insulation but also heating system synchronously.

6.4.1 Methods and tools for energy options study

With the spreading of residential building refurbishment benefits, energy conservation would became the main target for residential building refurbishment in China in the near future. For technical framework of residential building refurbishment, after the processes of preliminary data collection and setting ambitions, energy options should be analyzed and selected. An energy vision study may be built up from the following steps:

- *Making an inventory of measures to reduce energy consumption and use renewable energy.* Technical measures which are available for target building should be listed. The measures could be summarized in different levels which we mentioned in section 5.3.2 that are urban building coefficients and layout, district solutions, building components solutions.

- *Screening of this inventory of measures and selection of a number of promising options which seem feasible for the project.* In this step, professionals would choose the proper energy options. A detailed consideration of investment and operating cost of each measure is not yet necessary in this stage. On the base of discussion ambitions step, the stakeholders had made a basic selection, in this step the options with a very high cost and low saving potential may obviously be excluded already at this point.

- *Compilation of measures: suitable combinations of demand and supply side measures which are tailored to the project at hand.* The result of the screening step will be a shortlist of the most promising options to save energy and reduce CO_2 emissions. This shortlist can still comprise of a fair number of technical options, some of which may be mutually exclusive. Also demand reduction options will have an effect on the economic performance of some supply side options. For example higher insulation levels will make investments in district heating less attractive.

- *Detailed evaluation of cost and performance.* A detailed analysis of cost, energy saving and CO_2 reductions can now be performed. As a minimum at least the following criteria should be assessed: investment costs; yearly maintenance cost; yearly energy cost for the inhabitant; consumption of fossil fuel (primary energy); CO_2 emission from energy consumption.

In addition to this, other performance indicators may be calculated, for example the building energy performance indicator, the investment per ton CO_2 reduction or the pay-back time. Comparison between onetime energy consumption for refurbishment measures and CO_2 emission reduction in next decade's years could be made to evaluating benefits of refurbishment plan.

- *Recommendation of the best combination of measures and on practical issues with regard to implementation.* The results of the energy vision study will be laid down in a report and presented to stakeholders in a meeting.

An energy vision study is essential to get a clear picture of the possible energy saving measures, their potential and cost in relation to each other and in relation to choices with regard to (energy) infrastructures. It is important to address issues for all involved stakeholders so that every party gets an informed and balanced view on what is realistically possible and what is not. Based on such information stakeholders may then decide on the right ambition level for their project and, if they want to, also on the best way to achieve this ambition.

Question : Phenomena should be improved in residential buildings

A. Indoor temperature; B. Indoor moisture and condensation;
C. Cold/hot wind infiltration; D. Noise;
E. Ventilation and fresh air; F. Living environment;

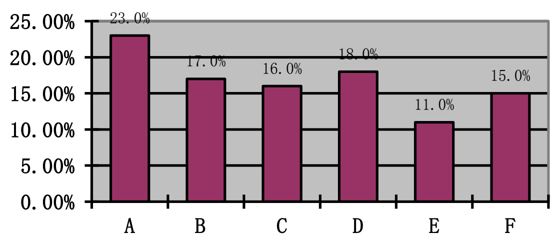


Fig. 6.22 Results of question 15 in investigation

In the investigation we have talked about in Chapter 5, we got the information that which are the phenomena should be improved in residential buildings. Here we only make a summary of main phenomena in residential building in China. The implementation of existing residential building energy conservation refurbishment has resulted in effective improvement of residents living environment, particularly the improvement of indoor temperature and noises comes from outdoor space and surrounding neighbors. Moreover, the phenomenon of indoor moisture and condensation has also been improved and the issue of cold wind infiltration and indoor noise has also been relieved. In addition, choice

F living environment refers to outdoor environment of residential community in this investigation and gets much more resection than expected. The result is shown in Fig. 6.22.

From the northern part of China, energy conservation refurbishment would be concentered in energy efficiency for heating in winter and indoor moisture control. While for southern part of China, the refurbishment would be concentered in cooling in summer and ventilation control.

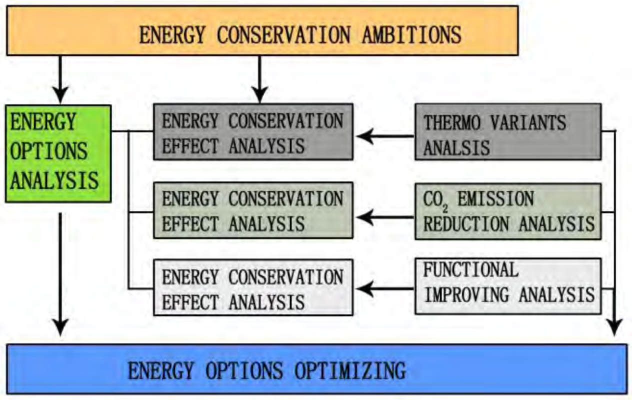


Fig 6.23 Sketch drawing of energy option process

In fact, for certain part of China, both heating and cooling should be considered of in the same time. Anyway, the aim of implementing energy efficiency technology is to spend less energy and get higher comfortable level in target existing residential building. So we would not list a number of technologies which could be used in a certain part of China neither in specific part of the building. For a complete innovation technical framework of residential building refurbishment, we would analysis the energy options in three aspects: building thermo technical; carbon emission reduction effectiveness and functional improvement. (Fig. 6.23)

6.4.2 Building thermo technical and related properties measurement

In China, the most important part of residential building energy conservation work is reducing heating energy in northern China urban area. Although building energy efficiency standards had been enforced to implement since 1999, the energy efficiency of existing residential building in urban China is unsatisfactory. In 2000, MOC (ministry of construction) inspected the implementation of energy efficiency standards, the results showed that buildings which reached standards took only 64%.

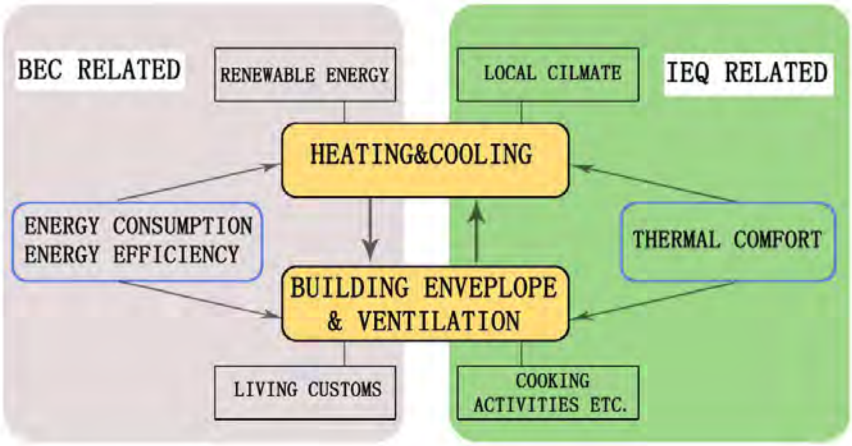


Fig. 6.24 Interaction between BEC (Building energy consumption) and ITE (indoor thermal environment)

In the view of energy consumption, thermal performance of residential building is decided by two aspects: heating and cooling system, building envelope. Heating and cooling system apply energy for keep indoor environment in a certain comfort level while building envelope keep balance between outdoor and indoor thermal environment and ventilation. For each aspect, there are multi influence factors. We also list main factors which influence thermal performance factors. In Fig. 6.20, there are two groups: BEC (building energy consumption) and ITE (indoor thermal environment). The goals for ITE-related issues are to improve indoor thermal comforts, while the objectives for BEC-related issues are to improve energy efficiency and further minimize the energy consumption.

Table 6.16 Analysis of variables for energy efficiency refurbishment measures

Varieties	Influence to EC	Calculate feasibility	Refurbish feasibility	Adoption suggestion
Master plan	High	Low	Low	No
Orientation	High	High	Low	No
Shape coefficient	High	High	low	No
Stair way (open/close)	High	High	Medium	yes
External wall area ration of window and wall	High	Low	Low	No
External wall K value	High	High	Medium	Yes
External window SC value	High	High	High	Yes
External window airtightness	High	Low	High	No
Roof K and D value	High	High	Medium	Yes

External wall K and D value	High	High	Medium	Yes
Internal wall K value	Low	High	Medium	No
External door K value	Low	High	High	No
Floor K value	Low	High	Medium	No
Ground floor K value	Low	High	Medium	No
Roof and external wall solar radiation absorbility factor	High	High	Medium	Yes
External wall and roof greening	High	Low	Medium	No

Almost all the previous studies on residential building only focused on one aspect, either building energy consumption or indoor thermal environment in China. For refurbishment project, most previous studies are made on constructions of building elements such like balcony, external wall and etc. there were not a methodology for overall comprehensive refurbishment project. In this part, we will focus our research on two aspects: heating and cooling; building envelope.

The energy efficiency refurbishment measures are variable. For existing residential building refurbishment, some measures are difficult to implement although energy saving ambitions can be achieved by these measures since limit of existing building and economic budget. In Table 6.16, implementation possibility of various measures for residential building refurbishment had been analyzed. Stair way, external wall K value, external window SC value, external window airtightness, external wall K and D value, roof and external wall solar radiation absorbility factor are elements recommended to adopt in residential building refurbishment.

Energy conservation benefits equation

Energy saving benefits is mainly divided into two parts: target building envelop refurbishment benefits and thermal insulation system (pipe network, power station improvement and circulating water pump frequency equipment) benefits.

- Benefits when only building envelop refurbishment is considered;
- Benefits when only thermal insulation system improvement;
- Integrated benefits.

Some indicators should be collected in energy options analysis process. With these indicators, energy conservation benefits could be estimated for choosing energy options. Some of these indicators are thermal related indicators of the city (heating days, coal price, etc.), districts (heating system, index, etc.) and residence community (construction area).

Table 6.17 Indicators related to energy conservation benefits

ITEM	UNIT	SYMBOL
Numbers of heating days	Day	HD
Average heating index after refurbishment	W/m^2	HI_3
Lower heating value	Kj/kg	H
Standard coal	Kj/kg	Hb
Coal price	RMB/ton	P
Power price	RMB/degree	Kwh
Coefficiency of primary energy conversation before refurbishment	-	Eff
Heated area	M^2	A_4
Dynamic investment payback period	Year	N
Average heating index	w/m^2	HI_1
Heating index of energy saving standard	w/m^2	
Construction area of the residential building	M^2	A_1
Construction area of one heat production plant for this area.	M^2	A_2
Construction area of residential community	M^2	A_3
coefficient of Primary energy conversion after retrofit	-	New Eff

$$Q = \frac{(HI_1 - HI_3)\times 24\times 3600\times \mathrm{HD}\times A_1}{Eff} + \left(\frac{HI_1}{Eff} - \frac{HI_1}{New\ Eff}\right)\times 24\times 3600\times HD\times A_3 \qquad (1)$$

We can understand the energy saving effect better with this Equation (1) which we summarized according to relevant research in China. Q (KJ) represents the total energy saving and includes two parts: the benefits by building envelope retrofit and pipe network and power resource improvement. And other symbols can be found above in Table 6.17. In real practice, the current data could be got by survey phase, and the index after refurbishment could be tested after construction. In the same time, it could be used in design process for estimating energy saving and selecting energy options.

6.4.2.1 Heating system

In China, energy use of district heating is dominant in total residential energy use in north China. Usually district heating runs continuously for 24h every day no matter whether the residents are at home or not. In the same building, the heating energy is supplied to the whole building from one control valve and heating energy is transferred from floor to floor. The inhabitants can't control indoor temperature in accordance with real demand. Since the lack of maintenance of obsolete valve and household valve, inhabitants are lack of subjective consciousness of the occupants to adjust the valves. Consequently, there is great waste and large energy conservation potential in district heating in north China. There are nearly no space heating meters installed to record the actual use in the residential buildings before the early 2000s, and the space heating use is charged by floor area for many years in north China. (Chen et al., 2011) Only after the heat metering reform is being executed in recent few years, heat meters began to be installed, but the popularization rate of heat metering is still very low in north China right now.

When we make heating insulation system refurbishment for existing residential building, we should make the refurbishment on the base of original pipe system and make moderate refurbishment to meet requirement of thermal control and heat metering.

- It's better to make *indoor heating insulation system* refurbishment with building *envelope retrofit* synchronously;
- Try to make heating insulation system *household control* and use matching heat metering mode;
- Heat radiator should not be covered.

According to the economic and social development, in China, there are three heating pipe system that commonly used.

- **Pipe circuit heating system**

System configuration: there is a single pipe parallel connect heat radiators so that the hot water can be controlled on the circuit. Local adjustment of heat radiator can be achieved.

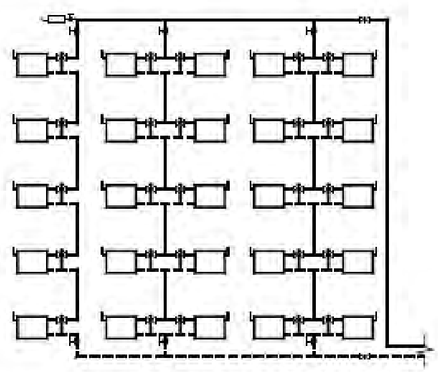


Fig. 6.25 Sketch drawing of operation of pipe circuit heating system

Heat metering mode: there is ultrasonic heat meter installed for metering building heat energy consumption and heat distribution meter is installed in each heat radiator to record heat energy consumption of single heat radiator.

System control mode: a self-operated flow control valve is installed in building heat entrance, tee thermal control valve is installed in each heat radiator. By the adjustment of tee thermal control valve, the total hot water flow is not influenced by terminal thermal control valve.

Vertical double pipe circuit heating system

System configuration: in building heat entrance, hot water is divided to go to each floor, after hot water is transferred to terminal heat radiator, it could be returned to recycle pipe back. Heat radiators in each floor are separated and local adjustment of heat radiator can be achieved.

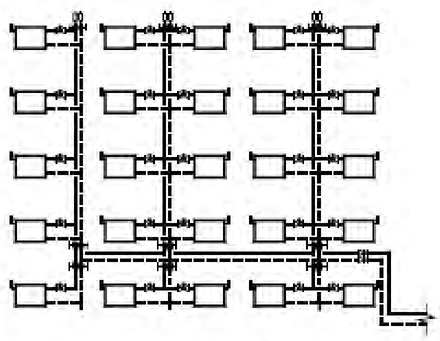


Fig. 6.26 Sketch drawing of operation of vertical double pipe circuit heating system

Heat metering mode: there is ultrasonic heat meter installed for metering building heat energy consumption and heat distribution meter is installed in each heat radiator to record heat energy consumption of single heat radiator.

System control mode: a self-operated differential pressure controlling valve is installed in unit heat entrance; binary thermal control valve is installed in each heat radiator. By the adjustment of binary thermal control valve, the total hot water flow is not influenced by terminal thermal control valve.

Horizontal household circuit system:

System configuration: it's double-pipe parallel connection system in which the heating energy is circulated in horizontal direction inside each dwelling. Hot water is applied to horizontal pipe to each dwelling in all floors, after hot water passed through each dwelling; it is returned to main cycling pipe back to heating

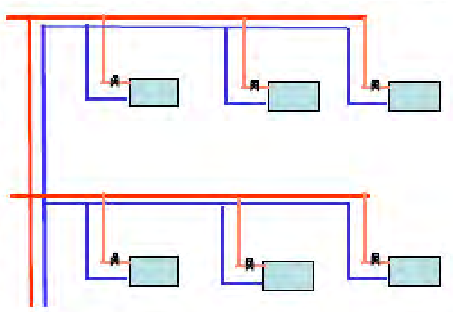


Fig. 6.27 Sketch drawing of operation of horizontal household circuit system

system.

Heat metering mode: there is ultrasonic heat meter installed for metering unit heat energy consumption and heat distribution meter is installed in each dwelling entrance to record heat energy consumption of each family.

System control mode: a self-operated differential pressure controlling valve is installed in unit heat entrance; binary thermal control valve is installed in each dwelling. The total hot water flow is influenced by terminal thermal control valve.

These three heating insulation systems are that suitable for residential building refurbishment in China. For each mode, there are advantage and disadvantage in real projects. We made a comparison of these three modes in Table 6.17.

Table 6.18 Comparison of three heating insulation mode

	Pipe circuit heating system	Vertical double pipe circuit heating system	Horizontal household circuit system
Material supply	Least	Medium	Most
Construction	Least	Medium	Most
Investment(RMB)	Least	Medium	Most
Construction Difficulty	Most	Medium	Least
Controllability	Worst	Normal	Best
Indoor damage	Least	Medium	Most
System complexity	Least	Partly damage	Most

Recommendation:

- When the original heating insulation system is *vertical single pipe system*, it is suggested to add *crossover pipe* between each heat radiator and install low-resistance binary thermostatic valve in branch hot water supply pipe. Manual control valve should be installed in return branch pipe of radiator;

- When the original heating insulation system is *vertical double pipe circuit heating system*, it is suggested to remain heating insulation system and *install high-resistance binary thermostatic valve* in branch hot water supply pipe. Manual control valve should be installed in return branch pipe of radiator;

- When the original heating insulation system *is single and double combined pipe heating insulation system*, it is suggested to refurbish to *vertical double pipe circuit heating system* and install *high-resistance binary thermostatic valve* in branch hot water supply pipe. Manual control valve should be installed in return branch pipe of radiator;

- When the indoor pipe is refurbished, all of original mode above could be refurbished to household independent heating insulation system.

- When heating insulation system of target residential building is refurbished to vertical double pipe circuit heating system or vertical crossover pipe circuit heating insulation, temperature control valve or heat distribution meter should be installed. There are total heat meter in each or several heating entrance.

6.4.2.2 Building envelope

In the case of existing residential building, energy efficiency can be improved by refurbishing insulation performance of envelope components. Energy efficiency retrofit technology for building envelope is quite different based on the climatic region, structure system and type. Before retrofit, the average heat transfer coefficient of exterior walls, the thickness of thermal insulation material and relevant construction measures and joint construction modes should be analyzed and evaluated, and then the most important site and measures for retrofit can be ascertained (Zhao J, 2009). Generally speaking, building envelope components which have direct relation with energy consumption refer to roof, external wall, window and building entrance and ground floor or basement. In view of energy efficiency, the most significant improvement energy options are:

- Changing or applying additional insulation layer to the roof;
- Changing or applying additional insulation layer to the external wall/basement;
- Window/ building entrance door replacement;
- Envelope tightness test and joint sealing replacement.

The implementation of insulation refurbishment on building roof, external wall and basement, and tightness improvement made on existing building will reduce energy consumption for heating. Together with heating insulation system refurbishment, indoor thermo environment would be improved obviously.

Table 6.19 Energy efficiency measures for residential building refurbishment

Envelope component	**Measures**	**Construction Key points**
Roof	Retrofitting : • Adding insulation material on top of original roof +concrete protection layer • Clearing away original insulation material + insulation layer + water proof layer Reconstructing : • Reconstructing roof with insulation layer +water proof layer • Retrofitting original flat roof to slope roof with insulation layer +water proof layer	• Avoiding constructing in rain time; • Choosing Insulation material with low water absorption (e.g. XPS, PU) not EPS; • For retrofitting, vents should be made on original roof ; • For flat to slope roof reconstructing, insulation layer should be made on flat roof;
External wall	• Insulation plaster • External thermal insulation composite system (ETICS) • Interior Insulation	• Fixing energy conservation measures according the request of current standards; • Avoiding thermal bridge in connection of external wall and other components (window, balcony, etc.)
Window	Retrofitting: • Add insulation paster to original window glass Replacement: • Replace original window by new energy conservation window (e.g. double glazed window with plastic-steel frame, etc.)	• Windows should meet airtightness requirement; • Not adopting bay window in north external wall; • Adopting casement window.
Basement	Not insulated: • Adding insulation layer + water proof layer to ceiling of basement • Installing insulated door in entrance to ground floor Insulated: • Adding insulation layer + water proof layer to wall and floor of basement	• Good thermal insulation moisture proofness
Building entrance/ balcony	• Replacing original door to insulated door • Constructing insulated anteroom • Adding canopy • Considering heating insulation system in insulated balcony.	• Door/window in balcony should meet airtightness requirement; • Insulation and water proof measures as external wall; • Avoiding thermal bridge.

Roof

Energy options should be chosen according to current energy efficiency standards. Based on preliminary survey and energy conservation ambitions, energy conservation measures could be adopted for either retrofitting original roof or reconstructing new roof.

Roof insulation and ventilation measures could reduce transmission losses and the energy demand by simultaneously increasing the thermal comfort of the inhabitants of the highest floor in the building.

Retrofitting:

- Adding insulation material on top of original roof and concrete protection layer. When roof of existing building is not constructed for a long time and moisture content is low (<20%), original roof is suggested to be remained and refurbishment measures could be made on top of original roof which had been cleaned up.
- Clearing away original insulation material + insulation layer + water proof layer. When roof of existing building is constructed for a long time and moisture content is high (≥20%), it is suggested to reconstruct insulation layer and water proof layer.

Reconstructing:

- Reconstructing roof with insulation layer+water proof layer. New insulated roof could be constructed when the original roof could not reach energy conservation requirements after refurbishment.
- Retrofitting original flat roof to slope roof with insulation layer +water proof layer. In China, there are many residential building with flat roof built in last decades. Reconstructing these buildings to slope roof could solve the problem of thermal lose and drainage system. Insulation layer should be made on flat roof.

External wall

- Insulation plaster. Insulation plaster could be used when the refurbishment budget is limited or the existing wall could not bear additional load.
- External thermal insulation composite system (ETICS). (Helmut, 2006) It is commonly used in EU and US utilizes polystyrene or recycled material e.g. wool

etc.

- Interior Insulation. If the external wall of existing building could not be refurbished (e.g. heritage building), interior insulation could be adopted. But it is not suggested to be used in normal situation because of various problems with thermal bridges and load-bearing.

Window:

The aim of external window refurbishment is to improve tightness and reduce thermal lose by windows. It should be pay attention for avoiding thermal bridge and cold/hot wind infiltration.

Retrofitting:

- Add insulation paster to original window glass. When the refurbishment budget is limited or thermal performance of original window is almost reach requirements, insulation paster could be added on the glass of original window. It's the cheapest way and waste least construction time.

Replacement:

- Replace original window by new energy conservation window (e.g. double glazed window with plastic-steel frame, etc.). When the thermal performance of original window is too bad, new conservation widow should be installed to replace original one. Different energy conservation window such like double glazed window, three glazed window or window with low-E (low- emissivity) layer and etc. would be chosen depending on local climate condition.

Basement:

If there is basement in target building, basement should be refurbished with other building components as well. The aim of basement refurbishment is reducing thermal energy lose and moisture erosion between ground floor and basement and improving ground floor comfort level in the meanwhile. There are insulated basement and not insulated basement.

Not insulated:

- Adding insulation layer and water proof layer to ceiling of basement.
- Installing insulated door in entrance to ground floor.

Insulated:

- Adding insulation layer and water proof layer to wall and floor of basement.

Building entrance door/ balcony:

- Constructing insulated anteroom. If it is need, anteroom could be constructed and wall and roof of anteroom could be treated as external wall and roof.
- Replacing original door to insulated door. Usually, in refurbishment project, building entrance door could be replaced to insulated door to reduce thermal lose between indoor and outdoor.
- Adding canopy. Canopy should be added in case there is no canopy in existing building. Attention should be pay to water proof and thermal bridge of canopy.
- Balcony refurbishment should follow standard as external wall and window. Considering heating insulation system in insulated balcony.

As we talked in section 6.3, there are national, provincial or municipal levels energy efficiency standards, energy conservation aim of each building envelope components could be fixed according to local standards. In Table 6.20, the reference K-value of building envelope after refurbishment is listed. These parameters in this table is summarized the experience of residential building refurbishment projects in Tangshan city. And it could be also used as reference parameter to other Chinese cities.

Table 6.20 Reference K-value of building envelope after refurbishment in China

Building envelope		**Heat transfer coefficient boundary value $W/(m^2 \cdot k)$**
Roof	Less than or 3 stories	0.40
	More than 3 stories	0.45
External wall	Less than or 3 stories	0.45
	More than 3 stories	0.55
Gable		0.45
External window(door)		2.20
Internal wall in public space without heating		0.98
Floor	Outdoor	0.40
	Indoor	0.50

Source: <Work Manual of Existing Residential Building Retrofitting > (Energy conservation office of Tangshan municipal, 2008)

6.4.2.3 Case study— No.1 Building, Heibei residential district, Tangshan, China

The existing residential building energy efficiency retrofit demonstration project in Tangshan was carried out by GTZ (German Tech-Cooperation Company) and MOC (Ministry of Construction) in2005. This project involved 3 apartment buildings (509,512,515) whose total building area was 6319m^2 and 135 households.

Table 6.21 Indicators related to energy conservation benefits of case study 4

ITEM	UNIT	SYMBOL	Project
Numbers of heating days	Day	HD	133(Tangshan)
Average heating index after refurbishment	W/m^2	HI_3	24.63
Lower heating value	Kj/kg	H	-
Standard coal	Kj/kg	Hb	-
Coal price	RMB/ton	P	-
Power price	RMB/degree	Kwh	-
Coefficiency of primary energy conversion before refurbishment	-	Eff	0.55
Heated area	M^2	A_4	2025
Dynamic investment payback period	Year	N	
Average heating index	w/m^2	HI_1	34.33
Construction area of the residential area	M^2	A_1	2169
Construction area of this kind of building in this residential area	M^2	A_2	6135
Construction area of one heat production plant for this area.	M^2	A_3	-
coefficient of Primary energy conversion after retrofit	-	New eff	0.68

Before refurbishment, all of these three buildings were heated by district central heating with single vertical contacted system which is commonly used in existing residential building in China. In single vertical contacted system, hot water is forced to flow in top-down mode. Since there was no temperature controlled equipment, heat energy is not supplied to each floor uniformly. In the point of thermo performance, the problems of existing building can be summarized as follow:

- Thermal performance of building envelope was poor and heat consumption was too high.
- Hot water is not controlled well in existing heating system.
- Obsolete heat radiator which was forbidden to be used now.

- There was no heat meter for each dwelling.
- Obsolete window and façade.

In the aim of energy conservation, wall retrofit, windows replacement, roof retrofit, facade retrofit and heating system retrofit were implemented in this demonstration project and the technological method in details as follows:

<u>Heating system refurbishment:</u>

- Heating system retrofit technology adopted vertical double-pipe system, household cycle horizontal parallel double-pipe system and vertical single pipe with crossover pipe system, respectively, in three apartment buildings. The metering mode adopted the ultrasonic heat flow meter combined with heat distribution meter.

<u>Envelope retrofitting:</u>

- Roof retrofit technology adopted 2-layers water proofing in the upper and lower side of insulation layer on the basis of removing existing insulation and water- proofing layer.
- Wall retrofit technology adopted exterior wall external insulation WDVS system. EPS insulation of 100mm was applied in the main insulation layer. According to the calculation result, the heat transfer coefficient was 0.43W/m^2 •K

1. Heat radiator before refurbishment
2. Heat radiator after refurbishment
3. Electronic heat distribution meter
4. Ultrasonic heat meter
5. Binary thermal control valve
6. Self-operated differential pressure controlling valve
7. Roof before refurbishment without insulation
8. Roof after refurbishment added insulation layer (14cm PU or XPS)
9. Building entrance before refurbishment
10. Building entrance after refurbishment

Fig 6.28 Status photo of case study 4

which could meet the energy efficiency design standard.

- Windows transformation technology adopted insulating glass square cavity ordinary reinforced plastic windows which could improve the airtightness and insulation performance of windows more effectively.
- Facade retrofit included balcony strengthening and new facade effect design.

Table 6.22 Energy conservation plan of case study 4

	509 Building	512 Building	515 Building
Heating insulation system	• Vertical double pipe heating system, each heater with Temperature control equipment and Heat distribution equipment ; • Ultrasonic heat flow meter, Total electric meter and gas meter;	• Indoor horizontal cycle, each heater is installed with temperature control equipment and heat distribution equipment • Heat meter per family • Ultrasonic heat flow meter, total electric meter and gas meter;	• Vertical single pipe system, each heater is installed with temperature control • Heat meter per family • Ultrasonic heat flow meter, total electric meter and gas meter;
Roof	• 14cm PU roof insulation	• 14cm XPS roof insulation	• 14cm PU roof insulation
External wall	• 10 cm EPS external insulation system	• 10 cm EPS external insulation system	• 10 cm EPS external insulation system
Window	• Double-layer glasses window with Low-E glass	• Double-layer glasses steel window	• Double-layer glasses steel window
Building entrance	• Install auto-close insulated building gate	• Install auto-close insulated building gate	• Install auto-close insulated building gate

After refurbishment, energy consumption is reduced a lot and the indoor comfort level was improved in the same time. As the data we collected, the energy consumption for heating and electricity in winter time is listed in Table 6.23, for making it clearer, energy consumption data of building 514 which was not refurbished is listed as reference. We can find both heating energy consumption and electricity consumption is reduced in winter. In fact, in summer, because of improvement of ventilation and thermal performance, energy conservation rate of electricity consumption is even more than that of winter.

Table 6.23 Energy consumption comparison before and after refurbishment of case study 4

	Before refurbishment (2005-2006)		**After refurbishment (2006-2007)**		**Energy conservation rate**	
	Heating energy consumption	Electricity consumption in heating time	Heating energy consumption	Electricity consumption in heating time	Heating	Electricity
509 building	107 kWh/m^2	2937 kWh	68 kWh/m^2	2517 kWh	37%	14.3%
515 building	108 kWh/m^2	2793 kWh	71 kWh/m^2	2490 kWh	35%	10.85%
514 building (reference)	103 kWh/m^2		104 kWh/m^2			

Source :

- Tangshan building and construction authority, 2008, Experience Summary of No.1 Hebei Residential District Refurbishment, Tangshan city, China. (in Chinese), available at: http://www.mohurd.gov.cn/zxydt/201110/t20111012_206559.html.
- G Dai, 2009, implementing existing residential building energy conservation refurbishment----report of existing residential building energy retrofitting in Tangshan City, available at: http://www.eeeb.org.cn/ (in Chinese).
- Zhao, B., 2008, Introduction of demonstration project in Tangshan city, Tangshan demonstration project introduction, available at: http://www.chinaeeb.gov.cn/upfiles/200804151343031.PDF. (in Chinese).

Lessons learnt:

- Several typical buildings could be selected as the demonstrations buildings to be refurbished in the big scale residential community;
- Heating system refurbishment plan should be made according to the real status quo of the original condition;
- Try to make house control heating system.

6.4.3 Energy consumption and emission reduction effectiveness

Most greenhouse gases (GHGs) emissions in China are attributed to coal burning and the amount of SO_2 and particulate emissions varied closely with the total energy consumption. Although the increasing rate of coal consumption tends to slow down due to energy profile restructuring in recent decades, it still accounts for about 70% of the total energy consumption in China (NBS, 2010). China is divided into area with heating and without heating by Qingling and Huai River. Coal was the main source for supplying energy widely used for heating in north China. while which with no doubt contributes to both ambient and indoor air quality issues, especially for those areas engaging coal for cooking activities. In fact, in south China where without heating, during summer and winter air conditioner is used more and more in urban area for cooling and heating in recent years.

In China, electricity is mainly made by burning coal. Huge electricity energy consumed by air conditioner caused terrible emission every year.

China hopes to conserve at least 20% of the energy consumption by improving the efficiency in the heating systems used in buildings in order to achieve the 50% BEC target as stated in JGJ 26-95 (MoC, 1995). In winter, since air pollution caused by coal burning was serious, centralized heating (including city, region, and community scale centralized heating system and boilers) was encouraged to use in urban and suburban areas. (Zhang et al. 2011) The aim of setting centralized heating system is intending increase the overall efficiency by replacing many small heating power plants by centralized heating system.

On the part of residential building energy consumption, facing to the complicated pressure of carbon emission problem which is caused by coal burning for energy supply, policymakers must make proper plan to mitigate carbon emissions to find a proper way for residential building development and improve living comfort level. Inhabitants and building industry should come together to realize the importance of low carbon emission issue and seek methods for improving energy conservation of existing residential buildings which hold enormous potential for reducing energy consumption. In Europe, housing energy and environmental performance is assessed and it is expressed in primary energy consumption per m² and in emitted CO_2 kg/m² for instance. (Stanislas, 2011)

However, current and proposed energy-saving policies focus primarily on setting minimum standards for new homes through building codes. Actually, in the previous projects, CO_2 emission reduction issue was ignored because macroscopically inherent characteristic. When we evaluate the energy conservation from the point of CO_2 emission, we can find there are close relations with economy, environment, society and energy. Refurbishment measures using clean energy and reducing CO_2 emission is critical solution for reducing environmental pollution.

6.4.3.1 Renewable energy application

For existing residential building refurbishment, renewable energy should be adopted on the base of available energy option analysis and utilized in refurbishment if it is possible. Renewable energy is also called clean energy which means no or little environmental pollution in the process of energy transferring.

Compared with broadly use of fossil fuel energy, technology of utilization of renewable energy was not improved until recent years. Although renewable energy application in building is an issue of great importance and urgency, current problems are embodied in two aspects: lack of policy support and suitable technology. At present, there is no compulsory requirement for the building application of renewable energy in national design standards. Thus there is only few pilot demonstration building projects which use renewable energy in China.

Benefits of renewable energy application:

- *Reducing energy consumption of fossil fuel*

To reducing CO_2 emission which caused by coal burning, the best way is to use renewable energy instead of fossil fuels to improve living environment. Fossil fuels, which have a negative impact on the environment could be partly replaced by renewable energy and the negative impacts can be reduced or avoided all together through the use of renewable energy utilization of renewable energy could contributes a lot to climate change. By utilization of renewable energy, energy shortage caused by obsolescence HVAC system could be solved and traditional pattern of HVAC operation could be refurbished. As we mention in section 6.3, National People's Congress (NPC, 2005) enacted the first Renewable Energy Law of PRC in 2005 and further revised in 2009.This,along with the Medium and Long-Term Development Plan for Renewable Energy in China (NDRC, 2007), greatly promoted the development and application of renewable energy for building energy usage either directly or indirectly.

- *Reducing chemical pollution*

In the other hand, apart from the thermal comfort level and energy saving of fossil fuel, cola burning for heating and thermal power station also cause chemical pollution and affect indoor air quality and also outdoor air quality. For example, the mass transfer process of volatile organic compounds (VOCs) from various building materials includes the diffusion in both solid and gaseous phases (usually depicted as 'Diffusion Coefficient'), as well as equilibrium at solid-air interface (usually depicted as 'Partition Coefficient'), in which both are highly temperature dependent. Both VOCs and material proper ties affect the partition coefficients, which are also strongly influenced by indoor temperature and humidity (Meininghaus, 2000). Many efforts had been involved in the measurement and prediction of VOCs emission from building materials (Huang and Haghighat, 2002; Li and Niu, 2005; Zhang, 2007). With the growing demand of living environment, in existing residential building, chemical contaminates from various building and decorating materials (e.g. paints, carpets, wall paper, PCV materials, furniture, etc.) have become more and more important in both building energy consumption and living environment.

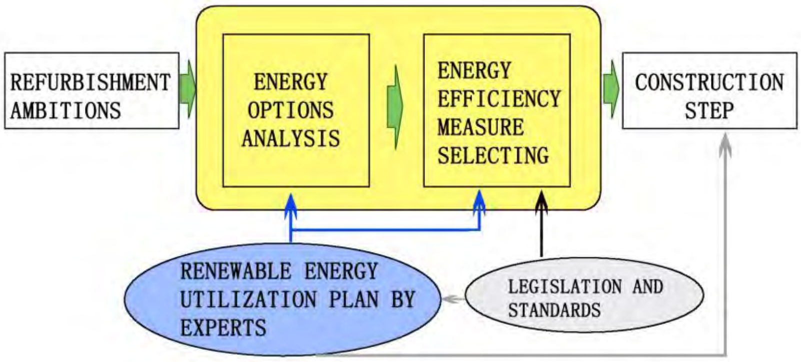


Fig. 6.29 Renewable energy application procedure in residential building refurbishment

Renewable energy application procedure

Renewable energy application is an important content in energy option analysis and selecting step. The renewable energy application procedure is shown in Fig. 6.29. After refurbishment ambitions had been set, professional experts could make renewable energy utilization plan which is part of whole refurbishment plan. The utilization plan would be discussed and in this period, simulation could be made to help checking the feasibility. In case the simulation result could not meet ambition demand of refurbishment, the energy option should be modified to reach it. Compared with discussion and setting ambition step, professional experts play an important role in energy option analysis and selecting step and also professional suggestion should be given in construction step.

Generally speaking, utilization of solar energy is become more and more important in residential building in urban area of China. Solar energy becomes the center attention of with the nature of being clean, safe and permanent. It is reported that, for water heating purpose alone, the total solar thermal collecting area had reached 80 millionm^2 as of 2005.Inaddition,the total installed capacity of photovoltaic (PV) solar power in China was about 70 MW, mainly for supplying power to the residents in remote rural areas (NDRC, 2007). Chinese government formulates a series of policies and regulations to encourage solar energy utilization.

Solar energy is used for thermal utilization and lighting utilization in building energy system. For thermal utilization, solar energy is used for domestic hot water and heating or cooling. For lighting utilization, solar energy is used for getting electricity by solar batter and natural lighting. In residential building, considering energy demand, using solar energy for domestic hot water and natural lighting are two methods suitable. In case budget and building structure are available, there are potential of using solar energy for heating and cooling.

In the other hand, wind energy is a valuable clean energy which can be used in residential building. Natural ventilation (open window) is the best way for ventilation and getting fresh air in residential building. Especially in existing residential building refurbishment, with the limit of economic factor and structure of existing building, it is impossible to reconstruct automatic fresh air system in existing building. Passive ventilation equipment can be installed in windows while refurbishment, in winter when it is too cold to open window or in summer there is too much solar radiation, ventilation could be done by low cost passive ventilation equipment.

Table 6.24 Application mode of renewable energy in residential building refurbishment

Energy application	Measure	Energy utilization	Feasibility
Thermal Utilization of solar energy	Heat pump	Domestic hot water	√
		Heating	○
	Cooling system	Cooling	○
Lighting utilization of solar energy	Solar battery	Electricity	X
	Natural	Lighting	√
Ventilation utilization of wind energy	Automatic ventilation system	Ventilation	X
	Passive utilization	Ventilation	√
		Cooling	√

(√--recommend; ○--Optional, X—not recommend)

There are two kinds of solar energy system could be used in residential building. The characteristics of household separate and centralized solar energy system are listed in Table 6.25, by comparison between two systems; we can find that there are advantages of each system. They can be chosen based on energy ambition of project. Compared with gas and electricity heater for domestic hot water, there is essential advantage in solar energy system. (Table 6.26)

Table 6.25 Comparison of two solar systems

	Collector location	Water tank location	Influence to building façade	maintainability	Technique feasibility	energy meter	Investment
Household separate	Balcony of each family	Inside each dwelling	A lot	Bad	Mature	Convenience	Normal
Centralized	Roof top	Under building roof	A little	Good	New	Adding Water meter	Cheap

Table 6.26 Comparison of solar domestic hot water system (Jiang et al. 2006)

	Gas water heater	Electronic water heater	Solar hot heater	
			Panel	Vacuum tube
Heat mode	Realtime	Pre-heat	Thermal storage	Thermal storage
Object	Family	Family	Family / public	Family/public
Number of shower	1(one time)	2-3 times	2-4 times	2-4 times
Use age	5 years	3-5 years	5-15 years	10-15 years
Installing	Easy	Easy	Very easy	Very easy
Space	Indoor installation, small space	Indoor installation, small space	Outdoor installation, big space	Outdoor installation, big space
Environment effect	Air pollution	Power station pollution	No	No
Safety	Potential safety hazard	Potential safety hazard	Safe	Safe
Accessibility	Convenience	Not convenience	Off in Winter, not convenience	Not convenience in rainy weather
Maintainability	Regular descaling	Regular check by professional	Regular check by professional and descaling	Regular check by professional and descaling
Operation	Adult	Adult	All	All

Integrated design principle:

Design of solar system should be considered harmonized with the whole refurbishment plan so as to reach the effect of energy saving and keep architectural aesthetics of the building. In residential building, solar energy system is usually integrated with building roof. There are three issues should be considered of:

- Integration of solar energy collector and building roof;
- Bearing performance of roof structure;

- Insulation performance of roof.

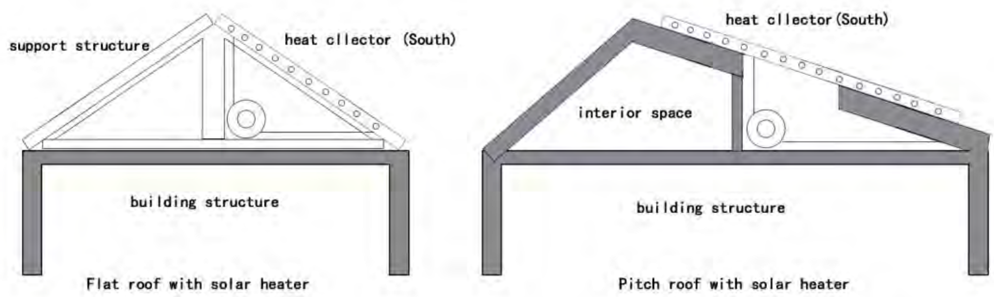


Fig. 6.30 Sketch drawing of integrating solar heater on the roof of residential building

Flat roof

For flat roof, solar collector could be installed on the top of the roof, collectors' weight should be less than allowable bearing ability. From the point of architectural aesthetics, collector could be combined with roof elements in material and color to get feasible effect.

Pitched roof

When solar energy collector is installed in pitched roof, the slope space of existing should be used and measures to prevent the building falling reinforcement should be taken. For example when solar energy system is integrated in buildings which are made "flat to pitched roof" refurbishment, the solar energy equipment could be put in additional space while solar energy collector could be put on the surface of pitched roof. In addition, the slope of southern roof could be designed larger than northern part for getting more solar energy. (Fig. 6.30)

6.4.3.2 Emissions from construction materials

With rapid growth in building and construction industry, chemical contaminants releasing from building and redecorating materials have attracted increasing amount of attentions, especially to 'Sick Building Syndrome' and other potential health effects. WHO has identified, based on sufficient toxicological and epidemiological evidence, the urgent need for guidelines development for nine pollutants, namely formaldehyde, benzene, naphthalene, NO_2, CO, radon, particulate matter (PM2.5 and PM10), halogenated compounds(tetrachloroethylene, tricholoethylene) and polycyclic aromatic hydrocarbons (PAHs, especially BaP) (WHO, 2006). Many of them are associated with source emission from building and decorating materials. Others contaminants of great concern includes toluene, styrene, xylenes, acetaldehyde, TVOC, etc. Several related government agencies (i.e. MoC, MoH and others) have been communicating and set up concentration limits against certain chemical contaminants in the related codes, such as the Residential building code (GB 50386) (MoC and SQSIQA, 2005) and the Code for indoor environmental pollution control of civil building engineering (GB 50325) (MoHURD, 2010), as shown in Table 6.27. Five contaminants are listed as high priority in China because of the strong correlation with health concerns and high concentrations detected in the newly constructed buildings. (Zhang et al. 2011) In existing residential building refurbishment project, inhabitants have to stay in the residence while refurbishment process or they just move out for a short time; the indoor air quality should be controlled strictly on the base of GB 50325-2010.

Table 6.27 Concentration limits of five major indoor air pollutants in different codes/standards (Zhang et al. 2011)

	WHO guidelines	GB/T 18883-2002 (SQSIQA et al., 2002)	GB 50386-2005 (MoC and SQSIQA, 2005)	GB 50325-2010 (MoHURD, 2010)	
	Ambient	Residences/offices	Residences	Grade-1[c]	Grade-2[c]
Formaldehyde (mg/m^3)	0.10	0.10	0.08	0.08	0.12
Benzene (mg/m^3)	no[a]	0.11	0.09	0.09	0.09
Ammonia (mg/m^3)	n.a.[b]	0.10	0.20	0.20	0.50
TVOC (mg/m^3)	n.a.	0.60	0.50	0.50	0.60
Radon (Bq/m^3)	no	400	200	200	400

In the other hand, emission caused construction materials for outdoor environment in refurbishment process is also an important factor for evaluating refurbishment effectiveness. Final CO_2 reduction is calculated with CO_2 reduction of energy saving in one year by measure multiply by utilization age of target building after refurbishment minus CO_2 reduction caused by refurbishment construction. The utilization life of each measure is not same; some of them have to be refurbished after several years. So in the calculation, CO_2 emission of refurbishment constructions should be considered with how many times refurbishment will be done before end of building utilization age (Equation (2) and Table 6.28).

$$E = E_{es} \cdot H - E_c \cdot n \qquad (2)$$

E---- CO_2 emission reduction

E_{es}— CO_2 Emission reduction by refurbishment per year

H---- Building utilization age after refurbishment

E_c---- CO_2 emission caused by refurbishment construction

N ---- Refurbishment time until end of building utilization age

Table 6.28 Construction CO_2 emission effect and constitution

Energy			Unit	Effect		
Refurbishment construction energy consumption (E_c)	Solid waste (t)		T	-	E (t)	Coal saving
	Construction material	Recycled (t)	T	0		
		Unrecyclable (t)	T	-		
	Transportation		T	-		NO
Energy saving by refurbishment (E_{es})	Heating energy saving		Kw	+		CH
	Cooling energy saving		Kw	+		CO_2
	Gas energy saving		M^3	+		SO_2
	Electricity energy saving		O	+		Dust

Good European Practice:

Although CO_2 emission reduction has not been paid much attention in China until recent years, the research on CO_2 emission reduction in EU is an important aim for building refurbishment. There are some examples focused on this energy consumption and emission for residential building refurbishment in EU.

Breda (NL) ENPIRE

In the project at Breda (NL), in energy option analysis step, five solutions had been proposed. An energy efficient ambition is listed as reference and the following 5 alternative packages of energy saving measures were compared and also emission of each package is also simulated as an indicator of selecting energy option. (Fig 6.31 and Table 6.29)

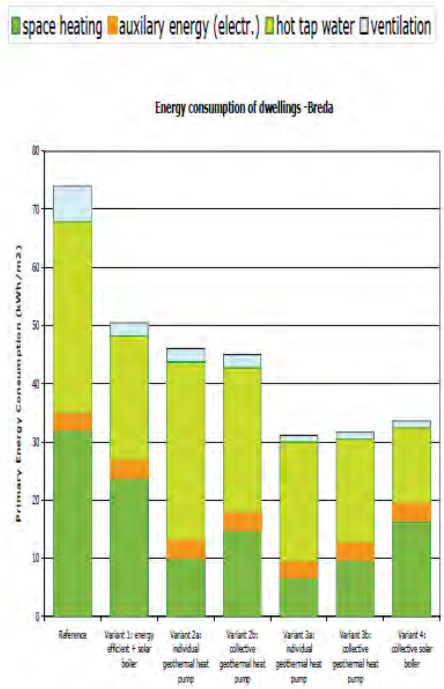


Fig 6.31 Energy consumption of different variants in Breda case study

Reference: building envelope thermal insulation & more natural ventilation: low-temperature under floor heating, efficient condensing boiler for domestic heating and hot water, natural gas infrastructure.

• Variant 1: like reference, with better thermal •insulation, more efficient natural ventilation and solar thermal collector for domestic hot water.

• Variant 2a: compared to reference: better thermal insulation, more efficient natural ventilation, individual heat pump per residence for domestic heating, hot water and highly efficient cooling.

• Variant 2b: like variant 2a, not individual but collective ground source heat pump, heating and cooling infrastructure.

• Variant 3a and 3b: like variants 2a and 2b, with demand-driven natural ventilation (CO2-concentration), shower-drain heat-recovery.

• Variant 4: compared to reference: better thermal insulation, demand-driven natural ventilation (CO2-concentration), collective solar collector for domestic heating and hot water, heat supply infrastructure.

Table 6.29 Energy option analysis of project Breda (NL)

	Reference	Variant 1: energy efficient + solar	Variant 2a: individual geothermal heat pump	Variant 2b: collective geothermal heat pump	Variant 3a: individual geothermal heat pump	Variant 3b: collective geothermal heat pump	Variant 4: collective solar boiler
Investment per residence	€ 6.250	€ 12.900	€ 13.850	€ 10.850	€ 16.250	€ 13.250	€ 19.100
User cost [€/year]	€ 1.074	€ 857	€ 667	€ 1.072	€ 490	€ 908	€ 968
Primary energy consumption [kWh/m²]	74	51	46	45	31	32	34
CO2-emission [kg/m²/year]	15,3	10,4	11,5	10,9	7,8	7,6	7,0
CO2 mitigation (€/kg CO2)		14	20	10	13	9	15

We can observe that in this case the variant 4 with the collective solar boiler gives the highest CO_2 reduction but also has the highest investment costs. For the variants with heat and cold storage the collective systems are more attractive not only in terms of CO_2 reduction, but primarily in terms of cost. The costs for the user are the lowest for variant 3a, while variant 3b is more attractive in terms of CO_2 reduction per invested euro.

6.4.3.3 Case study-- Zijin residential building residential district refurbishment, Hangzhou, China;

Project Introduction:

Hangzhou City, the capital of Zhejiang Province, is a typical Hot Summer and Cold Winter city in the region. It is located in the South Wing of the Yangtze River Delta, which is the most economically developed region in China. The per capita GDP of the city grew three times than that of China average during 1996 to 2005. The energy shortage of the province has also restricted the economic development and normal residential life seriously.

A seven-floor typical urban residential building built in 1995 was selected as case study. It is located in the Zijin Neighborhood of Hangzhou. There are 28 households in the building without vacancies. Most of the residential storied-buildings before 2001 were built with the same structure and materials as this building. Therefore, it holds typical value for the research of energy efficient renovation of general urban residential buildings.

Source:

- Gong M, Ouyang J, Ge J , 2008, Existing residential building energy conservation retrofit measure and CO_2 emission reduction effectiveness---- the case of Hangzhou city in the hot summer and cold winter region of China , Jurnoal of Zhejiang University (Engineering science), Vol.42, No.10.
- Ge J, Wang J, Ouyang J, Hokao K, Potential of energy conservation through renovation of existing residential buildings in china --the case of Hangzhou city in the hot summer and cold winter region of China, 2009, The 4th International Conference of the International Forum on Urbanism (IFoU).

Energy option analysis

In energy option step, 6 energy efficiency measures were listed and analysis of CO_2 reduction effectiveness of each measure had been simulated. (LCA software is used in this case study).

- Measure 1: installing safe door to each floor in stairway + installing widows to stairway (12)
- Measure 2: Replacing external windows by double glazing plastic steel window
- Measure 3: Installing curtain / window-shades
- Measure 4: Adding 40mm XPS in roof
- Measure 5: Adding 10mm XPS in external wall
- Measure 6: Adding light color paster/ coating in external surface

Table 6.30 CO_2 emission reduction effectiveness analysis of case study 5

	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5	Measure 6
CO_2 emission by refurbishment construction (kg)	4639.57	68159.76	91.562-9339.12	15115.66	14698.03	1463.08
CO_2 emission reduction by refurbishment(kg)	9314.36	27859.05	14287.21	27842.17	27810.79	4275.36
Refurbishment time	2	2	4/2	1	2	4
CO_2 emission reduction (kg)	363295	978042	57122/552810	1098571.14	1083035.54	165162
Energy consumption (kWh/m^2)	86.85	78.99	84.74	79.00	79.28	88.98

By comparison energy saving effect and CO_2 emission reduction effect, measure 2,3,4,5,6 were selected because of energy saving effect while measure 1 was selected because of CO_2 emission reduction effect. After refurbishment, energy consumption for heating and cooling per squire miter in this building is reduced 46.28% and CO_2 emission reduction of one year after refurbishment is 94022 kg, saving rate is 46.6%.

Lessons learnt:

- Proper analysis methodologies could be used as evaluation tools for the project in decision-making process.

6.4.4 Functional improvement of residential community

Besides energy conservation and CO_2 emission reduction effect, living environment improvement could be expressed in functional improvement by modernized refurbishment and façade refurbishment.

6.4.4.1 Modernized refurbishment

The improvement of residential living environment is directly experienced by inhabitants after refurbishment. Indoor facilities are energy consumption terminal. Indoor facilities should be refurbished as while heating system and building envelope refurbishment. Functional improvement can be achieved by making modernized refurbishment. Furthermore, by modernized measures, not only living environment of residential building but also quality of residential community could be improved in the same time. Significance of modernized refurbishment to existing residential building could be summarized as follow:

- Energy consumption could be reduced by newly energy efficiency indoor facilities;
- Living comfort level could be improved by indoor environment modernized (re-decoration or reconstruction of building façade, internal wall, balcony adjustment, dwelling door and public space e.g. stairway);
- Building value could be promoted by modernized refurbishment.

It is shown in Table 6.31, building elements which could be refurbished and related refurbishment measures. Obsolete facilities in toilet and kitchen should be replaced by newly energy efficiency facilities for energy saving and comfort level improvement. Redecoration to indoor structure like stairway wall, interior wall inside dwelling and internal doors could make the indoor environment more comfort and value of building could be improved in the same time. Re-decoration of building façade could be made both in the aim of energy saving and value promotion. Modernized refurbishment is important for existing building because two reasons: building elements and facilities in existing building are obsolete and not energy efficiency; the other reason is most of inhabitants living in existing buildings are of low-income or mid-income class who can afford new house in recent years. So we can find that functional improvement is extremely important for inhabitants. In case the dwelling plan could not meet using demand, reconstruction could be made to internal wall or balcony for improving comfort level.

Table 6.31 Functional improvement by modernized refurbishment of building elements

Building elements		**Refurbishment measure**	**Energy saving**	**Indoor comfort**	**Value promotion**
Facility	Toilet	Replacement	√	√	
	Kitchen	Replacement	√	√	
Indoor structure	Stairway	Re-decorations		√	√
	Interior wall	Re-decorations		√	√
		Construction addition		√	
	Internal door	Replacement		√	√
Façade		Re-decorations	√		√
Balcony		Construction addition		√	

6.4.4.2 Architectural context heritage

When we make residential building refurbishment, we should consider of the surrounding environment where target building located in. Some existing residential are built in districts with culture context which has to be protected.

There are several measures could be used in refurbishment project for improving architecture heritage:

Heritage building:

- Reparation: For historical buildings which should be protected, we can make reparation on these buildings to protect and enlarge utilization of these buildings.

Residential building without protection value

- Demolition of illegal construction: If the historical buildings were blocked by the buildings without value to be protected such like distance limit and transport accessibility, these residential building could be demolished.
- Retrofit of nearby buildings: With the decade's year's development, some buildings were built next to heritage building and there it is impossible to demolish.

In real practice, if there is historical buildings needed to be protected, reparation of heritage building is always implemented with demolition or retrofit together. For each combination, there is advantage and disadvantage (Table 6.32). Comprehensive refurbishment should be made by functional improvement and energy efficiency.

Table 6.32 Retrofitting methodology of historic district

Mode	Reparation +Demolition	Reparation+Retrofit
Advantage	•Convenient for culture heritage;	•Low economic cost; •Less limit to urban transportation •Less disturbing to inhabitants' life
Disadvantage	•Economic cost and time cost ; •Amount of resettlement work	•Increasing reparation difficulty
Functional improvement of community	•from multifunction to culture heritage zone •Improving	•Improving quality on the base of original multifunction •Improving sustainable development of the city

6.4.4.3 Case study -- Residential building refurbishment in Chunguang community, Henan

Project introduction:

Henan is a big province locates in middle of China with huge population. Henan is developed fast in agriculture and industry. With the development of industry, residential communities were settled during past decades. In the period of economic transition, there are many residential buildings needed to be refurbished and the inhabitants who live in are mainly low come groups in the city.

Fig. 6.32 Original plan of case study 6

Fig. 6.33 Plan of pilot building after refurbishment of case study 6

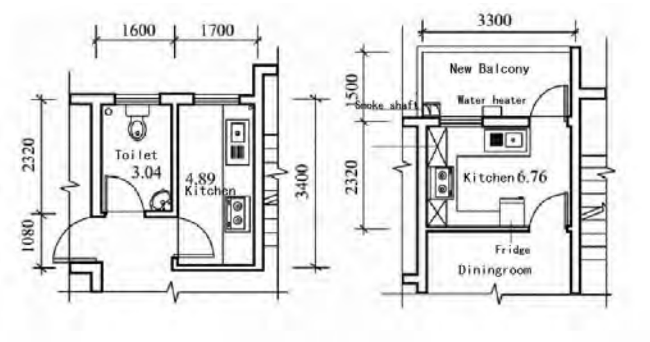


Fig 6.34 Plan of kitchen of case study 6

Left: before refurbishment

Right: after refurbishment

In this case study, we focus our attention on a residential building in an industrial city in south part of Henan. This five storied building was built in beginning of 1980s and constituted with two units in which there are three unit homes in each floor. From the original plan of this building, (Fig. 6.33) we can find that the problems of existing building are: there is no living room; space of dinner room, kitchen and toilet are too small to meet basic requirement; bad ventilation and lighting condition and etc. In the refurbishment plan, internal space is reorganized and building envelop is retrofitted to get functional improvement of this existing building and achieve the aim of improving comfort level of existing building.

Functional improvement measures:

The refurbishment measures were taken in two aspects: internal space refurbishment and building envelop retrofitting.

Internal space refurbishment:

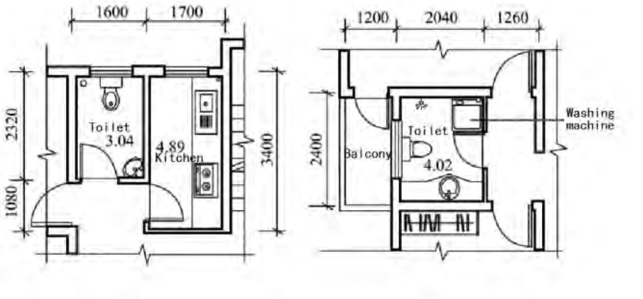


Fig 6.35 Plan of toilet of case study 6
Left: before refurbishment
Right: after refurbishment

- Combining 3 dwellings 2 dwellings (demoli part of not bearing wal For improving area existing building, in this plan, three unit homes (three bedrooms, one bedroom and two bedrooms) in each floor are re-divided into two unit homes (three bedrooms and two bedrooms dwelling). With this solution, space for living room can be arranged and space of kitchen, toilet can be enlarged in the same time. There is even a storage room in each unit home after refurbishment.
- Constructing new balcony in north side and move part of external wall. On the base of statics calculation, new balcony ($4.39m^2$) is added in the north face of the building and some part of external wall which is connected with this new balcony is planned to move 1.5meter. Adding pipe shaft and smoke uptake for laying all the pipes.
- Enlarging kitchen and toilet and renewed facilities. In original plan, the space of kitchen and toilet is so small that there is not enough space for laundry machine, shower fittings and other facilities. After refurbishment, the plan of kitchen and toilet is rearranged and facilities are made modernized refurbishment. In the same time, there is more natural light and better ventilation than before.

Envelope refurbishment:

- Roof: retrofitted flat roof to mono-pitch roof and roof garden. In this case, instead of simple pitch roof, flat roof is retrofitted into mono-pitch roof and the other half roof is retrofitted to green roof with garden. By this measure, insulation property of roof is improved and natural environment is created on the top of residential building.
- External window: refurbishing windows in south direction into bay window (double glazed aluminum window). By this bay window, they can enlarge internal

space, beautify the facade and leave space for AC.

- External wall: adding external insulation layer (25mm EPS).

Lessons learnt:

This is experimental plan of residential building retrofitting, there is still a lot of problems which are not considered too much, but there are some experiences valued to be learnt in real practice:

- Getting functional improvement by integration of internal space refurbishment and energy conservation refurbishment;
- On condition of maintaining stability, method of adding constructions (balcony, move walls) could be used.
- Considering green roof and green facade is a good solution for reducing CO_2 emission and improving living environment.

Source:
Li W, Dang B, Zhu Z, 2011, Existing residential building retrofit principle based on sustainable development theory-- The case residential building retrofit in the hot summer and cold winter region of china, Sichuan Building Science, 37(3), pp270-274, (in Chinese).

6.4.4.4 Case study—Shangzhidajie residential building refurbishment, Harbin, China

Project introduction:

The residential building refurbishment project in Shangzhidajie (Harbin, China) is a typical case which was brought respect on architectural context of historic district. Harbin locates in northeast of China and is the most north provincial capital. Due to historical reason, Harbin is famous for multiculturalism, as a Chinese city but with a strong sense of European culture. (Fig 6.36 and Fig 6.37) Aimed at improving districts quality, buildings in Shangzhidajie were refurbished since 2006 to make generation of city central.

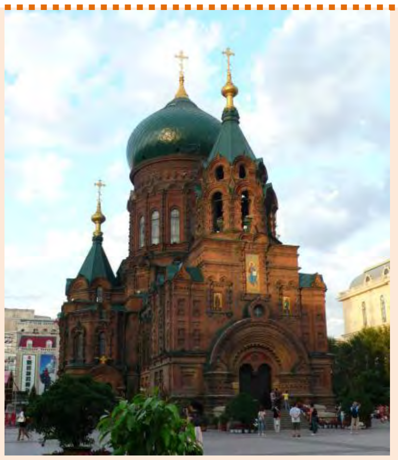


Fig 6.36 Photo of San Sofia Church

Fig 6.37 Photo of Central Street

Functional improvement measures:

In recent years, Harbin is paying much attention on culture heritage during the urban development. Historic district regeneration in central city is a crucial problem for urban development.

A pedestrianized zone is set up with Central Street at the center and it's the biggest pedestrianized area of Asia. There are buildings in this zone which were built over one hundred years by European and a lot of residential buildings which were built in recent years. Renaissance style in 15th -16th century, baroque style in 17th century, eclecticism style in 18th century and new art movement in 19th century, these European architectural cultures influenced a lot in these buildings. Shangzhidajie is on the edge of this pedestrianized zone and parallels to Central Street. Before refurbishment, historical buildings were promiscuously surrounded by residential building since 1980s.

In 2006, Harbin construction committee started the refurbishment project of buildings along Shangzhidajie. The project includes six buildings: one high-rise office building (office building of Telecome, A2), one four storied office and commercial building

Fig 6.38 Refurbishment plan of A1 building in case study 7

Fig 6.39 Refurbishment plan of A4 and A5 building in case study 7

(A6), one single story office building (Industrial and Commercial Bank of China, A3), three residential buildings (A1, A4, A5). We would talk about refurbishment plan of these residential buildings (A1, A4, A5). A4 and A5 building are connecting together.

Through preliminary survey, the thermal insulation lay of these buildings are good enough to meet the local standard, but the building façade are decrepit and there are additional balcony added illegally by inhabitants. These decrepit buildings seriously disturbed architecture and culture context of surrounding environment. In the refurbishment to these residential buildings:

- Adding air-condition support element in façade. There is heating system but not cooling system in these buildings. In recent years, many families installed air-condition for cooling in winter. But the AC equipment was hung up in building façade promiscuously. By adding air-condition support element, existing AC equipment could be put properly and there is reserve space for every house.
- Façade retrofit with simple elements to express respect to architecture context. This is the most important measure for harmonizing architectural context with nearby historical district.
- Reparation to finish layer of external wall.
- Changing flat roof to pitch roof.
- Unifying ground floor commercial space. As the culture and commercial center of the city, the ground floor of these buildings had been changed to commercial function spontaneously. In refurbishment, the façade of ground floor were retrofitted in the unify form.

Lessons learnt:

By these measures, in one hand, the comfort level of these residential buildings got improved; in the other hand, the function of this historic district had been integrated and improved.

- Integrating energy conservation effect could be got by façade retrofit.
- Respecting architectural context of surrounding environment.

6.5 Implementation

In China, since there was no complete framework for energy conservation refurbishment of residential building, in most of the previous projects, energy efficiency measures adopted are not considered in its entirety. Energy conservation effect would be reduced and the utilization age is shortened. Energy conservation refurbishment was not widely accepted by inhabitants. Architects should try to develop a long-term energy conservation refurbishment plan for residential building. A long-term energy conservation refurbishment provides a complete energy efficiency plan which includes energy options design and construction supervision and project monitoring as implementation of energy efficiency plan. After architects chose energy efficiency options with suggestions by multi-players, energy efficiency measures would be actually realized in practice in the building. In the implementation phrase, different kinds of obstacles will arise and influence the energy conservation plan. Technical, financial or organizational obstacles maybe cause delay, modification or even cancel of the measures in plan. Implementation step is very important phase for finishing a complete energy efficiency plan.

Communication with new players

There often are new participants involve in the project in implementation step. For example, in some cases, contractors and supervisors may be not been involved in until construction step; project acceptance engineer will not be involved until the construction is finished. For the aim of reach original ambitions, project manager should communicate and transfer the plan to new participants:

- Preparing materials of energy ambitions and energy options. Detailed documents and proper communication should be done between project groups and builder by the leading of project coordinator;
- Getting support by new players for ambitions and energy option plan which had been set in the earlier phases;
- Fixing contract includes agreement energy plan / refurbishment plan;
- Regular meetings should be made by project coordinator with all participants who get involved at later stages about the energy plan.

Working framework of implementation phase

Working framework of implementation phase is shown by Fig. 6.40. The work in implementation step could be summarized into two fields: project construction and monitoring and maintenance for target building. Following actions could be done in this phase:

- Selecting builders and fine communication with all players at the very beginning of implementation phase; Architects and builders with relevant experience are suggested to be collected;
- Transferring ambitions and energy plan which had been fixed to this step. Financing factor should be taken care of for insuring support follow-up work.
- Discussing with all players who is involved in implementation phase to fix final plan and plan of division of work. Taking care of the financing of necessary follow up work: detail studies, support in contracting procedures. A minimum performance level of installations can be laid down in a contract with the builder;
- Coordinating work with inhabitants is necessary if there are any modification in energy plan have to be done;
- Supervision and acceptance of constructing process;
- Regular check should be made in target building to get data about building performance;
- Maintenances measures could be done by the analysis of monitoring result.

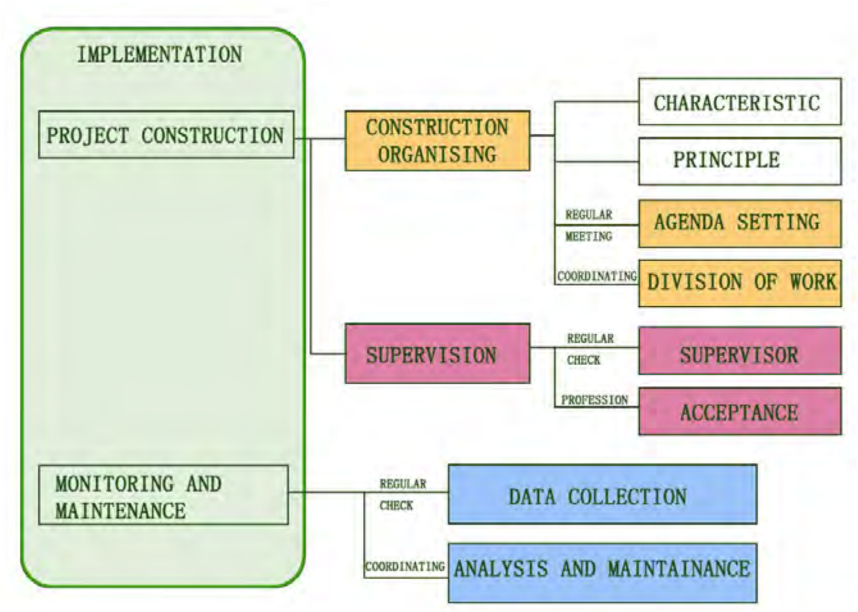


Fig. 6.40 Research road map of implementation phase for residential building refurbishment

6.5.1 Project management

In constructing step, all energy measures and retrofit plan would be implemented. Different from the previous phases which are did in plan steps, constructing work is more complicated. There are a lot of urgent problems in practice process. So coordinating work in construction step is an important guarantee for implementing a successful residential building energy conservation refurbishment.

6.5.1.1 Construction organization

Constructing work in existing residential buildings is much more difficult than other type of building because the complex situation of existing building and inhabitants who are still living in the building while constructing process.

Construction characteristics

- *Complex normal basal condition*. After decade's year's utilization, there maybe is lot damage in target building. In addition, inhabitants' property should be protected well during the constructing process. Normal life of inhabitants who is living in the building should be guaranteed.
- *Disordered interference factors*. Multi factors would influence the constructing work.

  Avoiding disturbing inhabitants, so the working time, sound pollution, light pollution, energy control and dust pollution would be strictly limited.

  There is no enough space for constructing actions. Different from new building constructing neither other building (commercial building, office building and etc.) refurbishment, the surrounding space is already occupied in residential buildings that there is always not enough space for laying construction materials and waste.

  Attention to protect other building elements which are not be refurbished. In one hand, builders have to refurbish building elements which had been fixed to be refurbished in energy plan in previous phases, in the other hand, other building elements which are not have to be refurbished should be protected during the whole refurbishment process.
- *Disrupt home-in constructing*. The best solution for successful home-in constructing is to sign contract with builders and inhabitants on the base of agreement of constructing time. If the contract is signed, builders should follow

strictly with the contract in working time.

- *Working period is decided by season and climate influence*. In northern China where has cold winter, for guaranteeing construction quality, constructing actions should be only done in the environment with temperature higher than 5 ^oC.

Construction organizing framework

The construction organizing framework is shown in Fig. 6.41. In real practice, after the builder had been fixed, a contract could be signed for guaranteeing the construction quality. All the players in implementation group could discuss the construction implementing plan and set agenda with work division plan. Project coordinators have to organize regular meeting with all related multi players. After the construction plan is fixed, a contract with inhabitants could be signed for fixing home-in work schedule and protecting individual property of inhabitants.

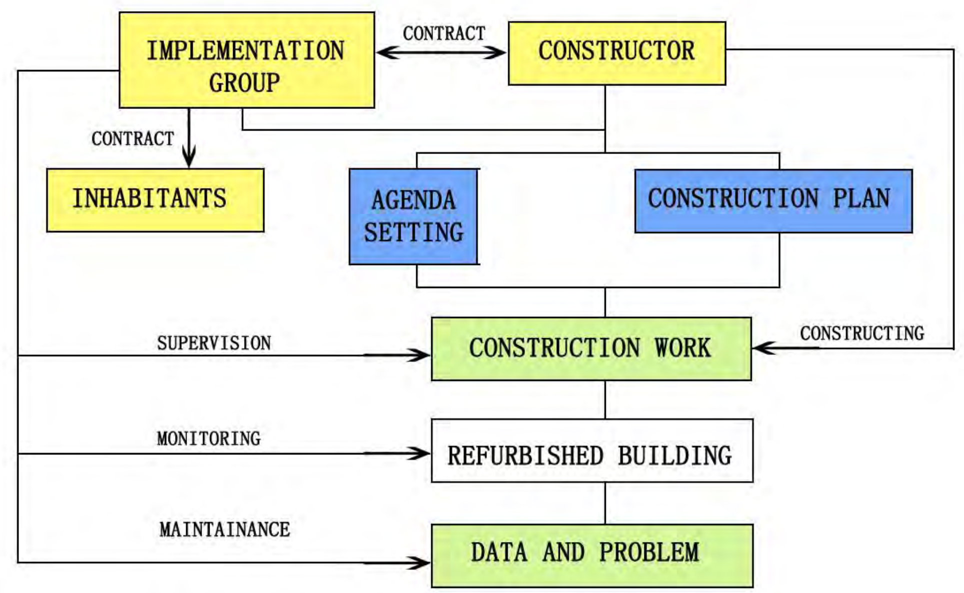


Fig. 6.41 Construction organizing in implement phase

In the constructing process, strict supervision should be made on construction work. Monitoring and maintenance are important measures to implement energy efficiency measures in target building. Professionals should plan regular check of building on energy aspects.

The joint work between energy conservation plan and constructing process is very important step and is usually neglected in China before. As we have talked in section 6.1 and 6.2, since the local authority plays an important role in controlling a residential building refurbishment project and construction builders are usually fixed by them, there is no enough communication between construction builders and architects who made energy conservation plan. For solving this problem, detailed agenda and work division plan must be set before constructing actions.

Agenda setting

- Preparing an implementing plan with clear targets by multi players: this will help to keep the process on track;
- Integrating the energy conservation plans with regular building retrofit and setting it as an important aim on the agenda;
- Updating energy study in case there is any modification or delay in the project.

In constructing process, project coordinator and architects must pay attention that energy measures are properly included in decision documents and propose recommendations as much as possible to construction builders.

Table 6.33 Working route of setting agenda in constructing step

	Context	Description	Inhabitants	Builder	Coordinator (Groups)
A	Working time	Fixing time for home-in work if in-door construction needed	√	√	○
B	Regular meeting	Setting regular meeting plan for discussion	√	√	√
C	Work division	Getting agreement with clear work division by relevant players	-	√	√
D	Process	Reporting work process regularly	√	√	√
E	Regular check	Regular exam of work quality and technical suggestion	-	√	√

√: very relevant ; ○ : not too much relevant ; - : not relevant at all.

6.5.1.2 Construction supervision

In supervision step after construction is finished, construction of refurbished building could be divided in to several parts and the supervision work result could be composited with result of supervision of each part.

Table 6.34 Division of energy efficiency supervision in GB 50300 (MoC and AQSIQ, 2001)

No.	Building elements	Sub-construction
1	Wall	Structure; insulation material; finish layer;
2	Window/door	Window ; door, glass; shading facilities;
3	Roof	Structure; insulation layer; protecting layer; water proof, finish layer;
4	Floor	Structure; insulation layer; isolating layer; protecting layer; water proof, finish layer;
5	Heating	Heat radiator; equipment, valve and meters; insulation material; heating equipment adjusting.

For residential building refurbishment constructions, there is no existing regulation neither standard suits on supervision in China. In real practice, the supervision could follow GB 50300 < Unified standard for constructional quality acceptance of building engineering > in which there are division of energy efficiency elements in building.

The acceptance standard of materials could follow GB 50045 < Code for Fire Protection Design of Tall Civil Buildings > (MoPS and MoC), GB 50222< Code for Fire Prevention in Design of Interior Decoration of Buildings > (MoPS and MoC) and GB50016 < Code for Fire Prevention in Design of Interior Decoration of Buildings > (MoC and AQSIQ, 2006) and etc. In addition, a list of acceptance items with details is proposed in Table 6.35. (the acceptance is needed if the building element is refurbished)

Table 6.35 Acceptance items in residential building refurbishment

No.	Building elements	Sub-construction
1	Wall	Conductivity, density, bearing ability and moisture content of materials;
		Bond-strength of binding material;
		Thermal performance of all insulation materials;
		Resistance to corrosion of finish layer material and grid;
		Setting time of concrete / cement / mortar.
		Frost-resistance of finish layer material in cold climate zones.
2	Window /door	Tightness, wind pressure resistance, water permeability of external wall
		K-value of external wall

		Tightness, water permeability and thermal insulation property of joint with external wall
3	Roof	Conductivity, density, and bearing ability of insulation materials
		Physical properties of water proof materials
4	Floor / foundation	Conductivity, density, and bearing ability of insulation materials in foundation/ ground floor
		Bearing ability of main structure
		Conductivity, density and waterproofness of finish layer material
		Waterproofness of water proof material
5	Heating / cooling system	Conductivity, density and moisture content of insulation materials
		Design performance of heat radiator / valve/ pipe
6	Ventilation system	Fresh air system

6.5.2 Project monitoring and maintenance

Monitoring the process is very important as it allows you to stay on top of it and identify potential problems in time. In this step, professionals and inhabitants are involved into monitoring process. Main actions to carry out during the implementation phase are:

Effectiveness collection:

- How is energy consumed: energy consumption data collection / tracing test;
- Environmental effectiveness by CO_2 emission reduction: coal saving; CO_2 emission statics;

Making a monitoring plan:

- How long / how often will the data been collected/ tracing test be done;
- Coordinating test professionals, equipment / inhabitants (investigation/ tracing test in home)

Verifying energy targets during and at the end of the process;

Establishing a maintenance plan:

- Maintenance measures in order to ensure energy efficiency values throughout the dwelling / area lifetime;

- In the first few years technical equipment may show initial problems especially in the case of technically complex installations. Monitoring will help to signal equipment failures in time thus avoiding long periods of malfunction.

The main items which should be collected in monitoring phase are listed in Table 6.36.

Table 6.36 Data collection and tracing test item in residential building monitoring

<table>
<tr><td rowspan="3">Building information</td><td rowspan="2">Area</td><td colspan="2">Before refurbishment</td><td colspan="2">After refurbishment</td></tr>
<tr><td>Construction area (m^2)</td><td>Using area (m^2)</td><td>Construction area (m^2)</td><td>Using area (m^2)</td></tr>
<tr><td>Building element</td><td>Roof(pitched/ flat)</td><td>Balcony (closed/ open)</td><td>Roof(pitched/ flat)</td><td>Balcony (closed/ open)</td></tr>
<tr><td rowspan="18">Energy consumption</td><td rowspan="7">Heating</td><td colspan="2">Indoor temperature (^oc)</td><td colspan="2">Outdoor temperature (^oc)</td></tr>
<tr><td>Lowest</td><td>Average</td><td>Lowest</td><td>Average</td></tr>
<tr><td colspan="4">Temperature in wall surface (four directions) (^oc)</td></tr>
<tr><td colspan="2" rowspan="3">Terminal Energy consumption (kwh)</td><td colspan="2">One dwelling</td></tr>
<tr><td colspan="2">Unit</td></tr>
<tr><td colspan="2">Building</td></tr>
<tr><td colspan="4">Heating system (30% equipment lose, 40% capacity loss) (kwh)</td></tr>
<tr><td rowspan="7">Cooling</td><td colspan="2">Indoor temperature (^oc)</td><td colspan="2">Outdoor temperature (^oc)</td></tr>
<tr><td>Highest</td><td>Average</td><td>Highest</td><td>Average</td></tr>
<tr><td colspan="4">Temperature in wall surface (four direction) (^oc)</td></tr>
<tr><td colspan="2" rowspan="3">Terminal Energy consumption (kwh)</td><td colspan="2">One dwelling</td></tr>
<tr><td colspan="2">Unit</td></tr>
<tr><td colspan="2">Building</td></tr>
<tr><td colspan="4">Cooling system</td></tr>
<tr><td rowspan="4">Electricity</td><td colspan="2" rowspan="3">Electricity energy consumption
(lighting, cooking, Electrical Appliance, domestic hot water,) (kwh)</td><td colspan="2">One dwelling</td></tr>
<tr><td colspan="2">Unit</td></tr>
<tr><td colspan="2">Building</td></tr>
<tr><td colspan="4">AC (per dwelling) (kwh)</td></tr>
</table>

		Energy supply from power station (kwh)			
Living environment	Thermal performance	Moisture (%)		Indoor	
				Outdoor	
		Condensation / Thermal bridge/Mould (Yes/No)			
		Air quality (good/middle/bad)		Tightness	
	Building element	K value of building envelope elements after refurbishment (roof, external wall, external window/door, basement/ ground floor)			
Environmental effectiveness	Carbon emission reduction	Coal saving (t)			
		CO_2 emission reduction (t)			
Satisfaction by inhabitants (good/middle/ bad)		Temperature	Moisture	Cold wind /air quality	Energy consumption

In China, in the previous cases, the implementation phase is a very crucial phase in which loss of focus on the energy efficiency may occur and practical problems may arise. A clear route plan, good communication with the project players and a set of back-stop options will help to guarantee energy ambitions to be achieved. Performance-based installation and maintenance contracts will help to realize the continued good results from the planned system. In another hand, actual energy consumption monitoring is a very important tool for finding energy consumption problems.

Thanks to the cooperation from architecture technology department of Tsinghua University. Here is an example of electricity energy efficiency analysis by monitoring in Beijing in several residential buildings. Five residential building which are built up in different time were selected to be monitored by professional researchers in Tsinghua University.


A


B

Fig. 6. 42 Photos of target buildings

Building 1 is 5 stories residential building built in 1986, 74m^2/unit, split unit without cooling system; building 2 is 18 high-rise stories residential building built in 1996, 141m^2/unit, spilt unit without cooling system; building 3 is 26 stories high-rise residential building built in 2003, 103m^2/unit, split unit without cooling system; building 4 is 26 stories high-rise residential building built in 2004, 132 m^2/unit, one outdoor & multi indoor units; building 5 is 26 residential building built in 2005, 280 m^2/unit, Central AC system. Monitoring is focused on electricity energy consumption in 2006 and 2007. And the monitoring result is shown in Fig. 6.43. Electricity energy consumption in E building is most and much higher than any other buildings. And building B consumed least while the order from less to more be building A, C and D.

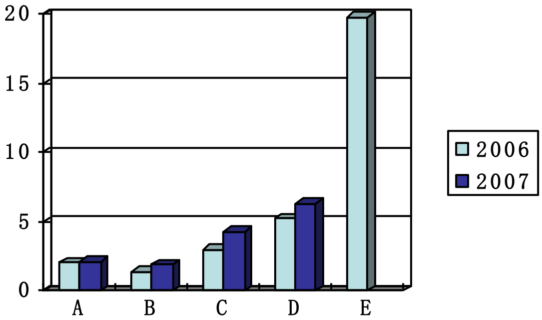


Fig. 6.43 Electricity energy consumption by target buildings in 2006 and 2007

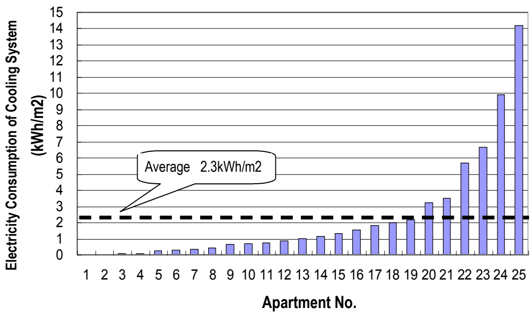


Fig. 6.44 The measured energy consumption of AC in every units in a residential building A

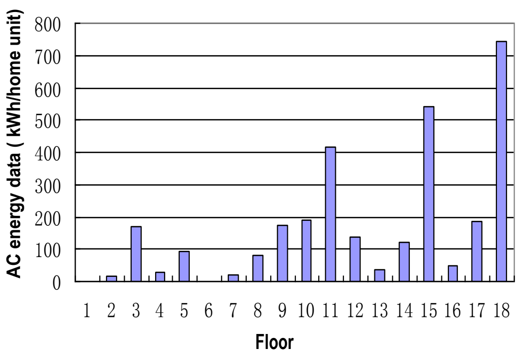


Fig. 6.45 Electricity consumption by AC for home units at same location but different floors in building B

Further monitoring is done specific to electricity consumption by AC for home unit in residential building A and at same location but different floors in building B.

From the monitoring result, we can find that building E with central heating and cooling system consumed much more energy than others, but even in the same building, electricity consumption of each home unit is different (Fig. 6.44 building A) and electricity consumption of home unit in the same location but different floors is different (Fig. 6.45 building B). As we mentioned in section 6.1, there are many factors which could influence energy consumption of residential building. Monitoring result is useful material for analyzing energy efficiency status of these residential buildings. With other data, analysis about energy efficiency plan for each building could be fixed.

This research is listed in this part is because it shows the significance of monitoring clearly through the comparison of monitoring results. Usually, refurbishment is not be made unless there are too many problems with the building and the refurbishment is aimed at buildings with long service life. But in fact, even some buildings which are built in recent years without well energy efficiency design are needed to be refurbished. In this case study, we can find that the building E which is adopted more technologies is not efficient and waste much more energy.

6.5.3 Case study-- Huixinxijie residential district refurbishment, Beijing, China

Project introduction:

It's a residential building energy conservation project in Beijing. Although residential building 65% energy efficiency design standard is completely complemented for residential building in Beijing, there are still more than 93 million m^2 residential building are not energy efficiency building. There is huge energy waste since the average heating energy consumption of these inefficiency residential buildings is about 2.17 times of standard data. Residential building energy efficiency still has to be implemented in Beijing.

Huixinxijie residential district locates in Huixinxijie. It's quite near to Olympic stadium and the distance is only 2000 meters. The district is composited with 4 buildings of 18 stories built in 1988. For each building, there are 144 home units and the total area is

11000m^2. There is boiler room specific for this community. Before refurbishment, the heating energy consumption of No.12 building is 26.2 W/m^2 while the standard value in residential building 65% energy efficiency design standard is 14.65 W/m^2.

Data Source:
BUCC, 2009, Report of Huixinxijie residential building energy conservation refurbishment in Beijing, available at: http://www.chinaeeb.gov.cn/upfiles/200804151334101.PDF, [in Chinese].


Before refurbishment


Under-going refurbishment


After refurbishment

Fig. 6.46 Photo of pilot building in case study 8

Energy conservation plan implementation

Because of the limit of weather, the refurbishment construction is divided into two periods. The refurbishment construction is concentrated in adding insulation in external wall, energy efficiency window replacement; fresh air system retrofit, modernization of heating system, adding insulation and water proof layer in roof. In this project, the construction process is well organized. A detailed agenda with detailed work division is fixed at the very beginning.

- *Setting agenda*

Table 6.37 Construnction organization agenda of case study 8

First period (01/10/2007-10/11/2007)			
Wall	Adding insulation layer (100mmeps) Fire separation layer	Installing scaffold and suspended basket	01/10/2007-01/10/2007
		Removing AC	03/10/2007-04/10/2007
		Cleaning external wall	05/10/2007-31/10/2007
		Insulation constructing	06/10/2007-

			31/10/2007
		External wall paint constructing	26/10/2007-10/11/2007
Window	External window is replacement by double glazed aluminum alloy window	Removing public window	03/10/2007-04/10/2007
		Removing home-in window	12/10/2007-22/10/2007
		Installing public and home-in window	
		Repairing window in balcony	
Heating system	Outdoor heat system retrofit	Outdoor heat pipe retrofit	20/10/2007-31/10/2007
		Installing heat meter for boiler and building	
Ventilation	Fresh air system	Installing nopower turbine ventilator on the roof	No information
First period: (15/03/2008-30/06/2008)			
Roof	Adding water proof layer	Insulation and water proof measure	03/04/2008-30/06/2008
Heating system	Indoor heating system retrofitting	Retrofitting indoor heating system into Pipe circuit heating system and renewing heat radiator and meter	15/03/2008-30/06/2008
		Installing heat radiator and meter in basement	

- *Work division*

There is a group includes one lead group and five departments controlled the management of construction. The lead group is in charging setting general plan, policy making, supervision and management of implementation. Executive office is in charging the project operation, implementing plan and policy made by lead group and coordinating multi players who involved in the project in different phases. Design department is in charging fixing refurbishment plan, drawing blueprints and communication of modification to the plan in construction phase. Constructing department is in charging fixing constructing plan, organization, process and quality and etc. Mass working department is in charge communication with inhabitants, signing contract with inhabitants and making

Fig. 6.47 Regular meeting photo of case study 8

investigation and coordinating. Field command department is not involved into the project until constructing phase. It is completely in charging constructing work, implementing refurbishment plan and coordinating. Although the division of work group is not complete in this project, it is a progress in project management and maintenance.

- *Regular meeting*

Since the beginning of constructing phase, weekly regular meeting is fixed and continued. The content of the meeting including: checking and supervising work progress of last week; coordinating problems in constructing field; planning work for next week and making management and communication of the project. Modification of energy plan is could be decided in regular meeting.

- *Regular check:*

Regular check is insisting during the construction process. In one hand, workers made strict check for material incoming; in the other hand, professionals make check and acceptance inspection to construction regularly and report to multi players in weekly meeting.

Fig. 6.48 Work photo and document of regular check

- *Monitoring and maintenance*:

After the refurbishment is finished, tracing test is continued in 2008. The test is focused on four fields: building thermal performance; heating energy consumption; inhabitants' energy conservation behavior investigation and heating system energy consumption. With the monitoring result, energy saving effect could be analyzed. Compared with Table 6.36, Data collection and tracing test item in residential building monitoring, relevant data is summarized in Table 6.38.

Table 6.38 Data collection and tracing test item in monitoring of case study 8

Building information	Area	$11000m^2$	Story	18
Energy consumption	Heating	Indoor temperature (^oC) [Temperature recorder tested in home unit located in different floor and direction]		
		Heat radiator thermostatic control utilization frequency [Survey]		
		Terminal Energy consumption (kWh) [heat meter]	One dwelling [Heating season total energy consumption]	
			Unit [-]	
			Building [Heating season total energy consumption]	
		Heating system energy supply (kWh) [Heat meter, everyday]		
	Electricity	Electricity energy consumption [electricity meter]	Total energy consumption in the Building	
Living environment	Thermal performance	Moisture (%)	Indoor [Moisture recorder tested in home unit located in different floor and direction]	
		Condensation [Thermal infrared imager test]		
		Tightness [Tested in fixed home unit]		
	Building envelope	K value of building envelope elements after refurbishment (roof, external wall, ceiling of basement) [Heat flow meter method]		
Environmental effectiveness	No			
Satisfaction by inhabitants	No			
Open window frequency [Investigation]				

Lessons learnt:

In this case study, we analyzed the implementation phase of Huixinxijie residential building district refurbishment (Beijing) on the base of resource data. It's a demonstration project in Beijing for implementing energy efficiency technologies in residential building. From the analysis, some experiences had been summarized:

- Proper arrangements for home in construction. Agreements about construction should be signed with inhabitants. Before working inside dwelling, an appointment should be made.
- Setting efficiency agenda before construction. Arranging relevant home in work in the same time as less as possible to improve efficiency of home in work and reducing disturbing to inhabitants as much as possible.
- Making comprehensive monitoring after refurbishment and maintenance to the building.

6.6 Chapter Summary

In present chapter, as the further research on the base of scheme stage, the general working procedure of residential building refurbishment in China can be divided into 8 steps which are similar with that of Europe and new constructions. But since the participation of stakeholders is more complex, in real practice, there are more difficulties for achieving the refurbishment goal. In the point of energy, the refurbishment design framework is constituted with four main steps: Energy survey phase, Discussion and setting ambitions, Analysis of energy options and optimizing of energy options and Implementation.

In each step, actions in the procedure and final goal of the step had been set as design methodology. In order to expound and prove the methodology, in the end of each section, case study which figured a good experience in relevant aspect had been analyzed with the design methodology set in present research. Some are excellent European case study in which we can lessons and some are Chinese case studies which has representativeness in a certain step. Proper technology measures and design methodology for residential building refurbishment in urban areas had been proposed in details. These methodologies constitute a whole work framework for comprehensive residential building refurbishment in urban area of China which has innovative significance for architectural research field in China.

Chapter 7 Conclusion

- Lessons learnt from case study---- Framework comparison of residential building refurbishment in EU and China
- Roadmap of policy and integrated design for existing residential building refurbishment in China
- Improving energy performance and comfort level in residential buildings and community synergistically
- Emerging trends of sustainable development for existing residential community refurbishment in urban area of China
- Research conclusion
- Research contribution
- Research limitation and future scenario

7 Core support for low carbon emission residential building development in China

In this chapter, we will make a conclusion of the main fruits and results of this study, and summarize the contribution and benefits of this research, in the same time, some exploration research connected with evaluation and low carbon urban planning will be made. Although we focus our attention specific on the topic of energy conservation of existing residential building refurbishment in urban area of China, the strategy and design framework is in an extended scope of residential building refurbishment and deep exploration of building energy efficiency. As the further exploration, we make certain analysis to connect this building energy conservation research with low carbon sustainable urban planning. Based on the cased studies in chapter 6, comparison of residential building refurbishment between EU and China is roundly sump up. Then emerging trends of sustainable development for existing residential community refurbishment in urban area of China is summarized. In allusion to the imperfect legal system in China, roadmap of policy and integrated design for existing residential building refurbishment in China is proposed. In the meanwhile, we emphasize that in refurbishment projects, energy performance and comfort level in residential buildings and community should be improved synergistically. And the emerging trends of sustainable development for residential community refurbishment in urban area of China had been proposed. At last, we points out the limitation and deficiency of present research and the fields where further work should be undertaken.

7.1 Lessons learnt from case study---- Framework comparison of residential building refurbishment in EU and China

China and the European Union (EU) together account for around 30% of global energy consumption and 30% of global emissions. China and the EU also both face common challenges in energy and climate security. Their common interests provide a foundation for deepening collaborative efforts on energy and climate security over the next quarter-century (Chatham House, 2007). Hence, it is imperative for China and the EU to take advantage of the opportunities offered by their interdependence to achieve win-win solutions that generate shared technology goods of energy and building design.

EU has launched action plans to reduce carbon emission for many years. The maturity of the EU's aspiration to global leadership has been reflected in the promises and actions on energy and carbon emission. Specific on residential building sector, indeed, a variety of studies suggest that 40% to 60% of all efficiency savings and/or carbon emission reduction potential in the buildings sector are associated with retrofit improvements to existing homes (Neme et al., 2011). Compared with China, EU had started research on energy efficiency in residential building much earlier. Not only by policy support from European Union and some national governments, but also some energy conservation residential building refurbishment projects had been accomplished or undergoing in recent years.

We make comparison between EU and China because both of them have long history and city developed sequentially; both of them have to face to the problem of social development and building demand. However, not all the means implemented in EU cities can adapt Chinese cities well. The transformation of procedure and methods is necessary and essential. Thus, in order to execute low carbon in residential building sector in China correctly and properly, it is significant to implement a comprehensive comparison of framework for residential building refurbishment strategy presented in this research. The research of establishing comprehensive energy conservation strategy in present research has referred many advantages from EU experiences, from strategic scheme to tactic techniques. While, distinct background and energy scope of two economic entities lead to a number of dissimilarities exiting in these two framework systems. The comparison of two framework systems will initiate from the perspective of framework background, scope, procedure, system and experiences. We hope by this comparison (Table 7.1), the differences from two framework systems could be visualized clearly and it could help to understand the significances of present research.

Background:

The most important distinctions of background bring on the different scopes and approaches of EU and China, and they further induce various procedures and methods to achieve the targets of energy conservation and carbon emission reduction. As we discussed in previous chapters, research on energy conservation of residential building is related with many influence factors and is sub-item of low carbon urban plan system and building design system. When we talk about residential building refurbishment strategy, the urban plan and building design system should be considered of. Three principal backgrounds can be observed obviously, which are economy development, social development, and energy demand, in addition, we also make comparison of residential building demand and development.

Table 7.1 Framework Comparison of residential building refurbishment in China and EU

		China	EU
Background	Economic	Rapid growth	Stable growth
	Social development	• Undergoing urbanization. • Aging society with population growth and huge wealth gap. • Private house property is limited up to 70 years.	• Finished Urbanization. • Aging society with population reduction and less wealth gap. • Permanent/tax adjustment.
	Energy demand of residential building	• Low energy resources per capita. • Serious environmental pollution. • Household energy consumption fast increasing.	• Moderate energy resources per capita. • Environment protected well. • Household energy consumption is steady.
	Demand of residence	• Fast increasing of area. • Increasing of quality. • Huge market of refurbishment needs to be explored.	• Area and number keeps steady. • Quality is kept improving. • Existing building refurbishment is implemented systematically.
Scope	CO_2 reduction goals	45% energy intensity promotion by 2020.(in general)	20-20-20. Possible 80% reduction by 2050. (in general)
	Energy policy	• Some policies including energy efficiency, utilization of renewable energy and production in residential building sector. • Existing residential building were built without energy efficiency policy. • No specific policy for refurbishment.	• Active policies covering energy efficiency, utilization of renewable and energy production in residential building sector. • Energy efficiency policy for residential building was implemented since 1970s. • Some policies specific for refurbishment in national and local level.
	Energy targets	Energy mitigating when economy increasing	Energy reducing while environment improving when economy developing
Management	Framework	Under construction	In action
	Coordinator	Lack of specific coordinator, MOHURD and Local municipal	Local municipal and building/planning bureaus
	Executor	Lack of specific executor, Temporary office under local municipal	Professional group fixed by local municipalities
Procedure	Focus	Mainly focusing on structure or façade refurbishment for obsolete buildings.	Energy conservation refurbishment for improving energy performance in existing building.
	Design	• Single building or community design lack of systematic cooperation with urban plan and local environment. • Lack of technical support and connection with energy efficiency production.	• Covering from city sustainable plan to energy efficiency buildings. • Considering comprehensive energy performance effect. / Consciously adopting innovation energy efficiency technology and evaluation methodology.
	Mechanism	• Non-governmental promotion mechanism; • Semiofficial incentive mechanism; • Cooperation mechanism	• Specific financial facilities; • Supporting structures by local authority. • Technical support by benchmarks of excellence / Local Energy Days.
		Spur local authorities involving the actions	Encourage enterprise and other public stakeholders to participate.
Best practice		• Few successful pilot project; • Lack of comprehensive refurbishment conception.	• Some excellent demonstration projects and research. • Comprehensive refurbishment with innovation technology.

After prosperous and fast development period after WWII, EU economy has entered a stable growth period. By its prediction of global economy development for next ten year, EU will still keep stable growth rate, while China will slow down its speed a little bit and develop at 8.6% per year from 2011 to 2020.

Social development is also a critical background to discern the distinction between EU and China. Historically, the process of rapid urbanization in today's more developed regions first started the beginning of last century. EU and other developed areas have finished their urbanization process in the end of 20th century. Concurrently, China is still on the way of urbanization and industrialization. To the contrary, China is under fast urbanization process now and urbanization rate over 50% in 2011. However, China has already entered aging society due to its population control policy. The accelerating aging population in China will soon end its demographic dividend however China has not finished its modernization. With the development of economic, there is a huge wealth gap exiting in Chinese society. The Gini Coefficient[1], which represents the economic inequality, of China has been over 0.4 for more than 10 years. Specific for house, in China, the land-use and property is controlled strictly by government. It is different from most other countries in the world, the property of the private house is limited up to 70 years since the land is approved. But in EU, although there are differences among countries, the property for the private house is permanent and adjusted by tax control.

In the side of energy, although EU is influenced by energy crisis, China is facing more serious energy crisis since two reasons: low energy resource per capita and environmental pollution. In addition, energy demand of household is kept increasing.

In the same time, fast urbanization caused big gap between supply and demand of residential building. Area of unit, residence number and quality of residential building are urgently needed to be improved in China. While residential building is improved steady in EU since 1970s. For existing building refurbishment, EU has already launched actions on energy conservation refurbishment including research and real case study. In China, since the huge scale of existing building, the market of refurbishment is needed to be explored.

[1] Gini Coefficient, is a measure of statistical dispersion developed by the Italian statistician and sociologist Corrado Gini and published in his 1912 paper "Variability and Mutability" (Italian: *Variabilità e mutabilità).* It is commonly used as a measure of inequality of income or wealth. Worldwide, Gini coefficients for income range from approximately 0.23 (Sweden) to 0.70 (Namibia) although not every country has been assessed.

Scope:

EU and China proposed their international promises respectively according to their own capabilities and benefits. EU's leaders committed Europe to transforming itself into a highly energy-efficient, low carbon economy. The "20-20-20" target was set to initiate this process. According to this target, EU will execute a GHG reduction at least 20% below 1990 levels, consume 20% energy coming from renewable resources and promote a 20% primary energy reduction by improving energy efficiency. A recent report by the European Climate Foundation, *Roadmap 2050*, concludes that it is possible to reduce carbon emissions by 80% by 2050. China proposed its autonomous domestic mitigation actions in 2009. According to its information to UNFCCC Parties[1], China will endeavor to lower its CO_2 emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level and increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020. (Copenhagen, 2009)

Afterwards, EU and China all formulated specific energy policies to achieve their international promises as we introduced in Chapter 3. EU conceived active energy policies covering energy efficiency increase, renewable energy production and alternative energy use. All the EU's policies aims to reduce energy consumption from both energy demand and energy supply perspectives. China proposes comprehensive policies including energy efficiency improvement, optimization of fossil energy application, and renewable and alternative energy production. But in China there is no policy specific for improving energy efficiency of building refurbishment. Currently, the aim of energy consumption in building sector in China is mitigating when economy increasing while in EU the aim is reducing energy consumption when economy is developing and environment improving.

Management:

A good management is positive for successful implementation of low carbon building development. EU has committed a special mechanism and organized specific institutions to support low carbon urban plan and low carbon building since 2010. From EU level to national level and local municipality, attention had been paid to building energy consumption and refurbishment. A serious of "Smart City" plan is implemented in many EU members. There is still lack of such mechanism in China. In China, there is no similar experience to organize and coordinate the actions of city development in so many cities. The only national institution, which is in charge of the city planning and construction and

[1] UNFCCC Parties, United Nations framework convention on climate change. http://unfccc.int.

is capable to coordinate all the cities in China, is the Ministry of Housing and Urban-Rural Development (MOHURD). The MOHURD is responsible for drafting policies, laws, and development plans related to city, village, and town planning and construction, the building industry, and municipal works in China as we have discussed in present research. Although there were some refurbishments pilot projects had been done, there is lack of neither specific coordinator nor executor. In recent years, with the improvement of international communication between EU and China, there is awareness that China could get some excellent experiences from the practices in EU.

Procedure:

The procedures of energy conservation of residential building refurbishment in EU and China both obey the basic design methodology to explore the route for energy consumption and GHG mitigation, which is often summarized as: discover, research and solve problems.

EU had made some refurbishment exploration on the aim of reducing energy consumption in existing residential buildings and improve built environment in the same time. With the favorable basic of low carbon city plan and building energy efficiency development, refurbishment is concentrated on comprehensive energy performance effect with the adoption of suitable technology. Energy reduction target is focused on general urban level and distributed into each building sectors. Refurbishment measures for residential buildings are adopted in the aim of improving energy efficiency in existing residential buildings. Policymakers, efficiency practitioners, the media, and the general public all have important roles to play in changing the narrative around efficiency so that residential building retrofits become more universally recognized as a least-cost strategy for reducing GHG emissions that produces economic benefits to all system users.

China is in the progress of setting low carbon urban development, but single building or community design lack of systematic cooperation with urban plan and local environment. The refurbishment is concentrated in obsolete structure retrofit and façade refurbishment but not energy efficiency nor built environment improvement because of being out of line with technical research. Huge market of residential building refurbishment in China requires comprehensive refurbishment strategy to guide the refurbishment getting maximum energy conservation and built environment improvement and minimal economic cost.

Best Practice:

From the case studies which had been analyzed in present research, we can come to the comparison of residential building refurbishment between China and EU. There are some excellent demonstration projects and research had been done in EU and there is already comprehensive refurbishment with innovation technology exists in EU while all of these are needed to be developed in China. In research field, international cooperation could be implemented by research institutions; in practice field, international experts could be involved in the process of refurbishment in real pilot case study in China.

In present research, the theoretical research is proposed and then analyzed with selected case studies, so that the feasibility of implementing present methodology in China could be proved. We must guarantee that the methodology and strategy proposed in present research is suitable to China's actual condition and could be implemented in a feasible way in next step.

7.2 Roadmap of policy and integrated design for existing residential building refurbishment in China

The present research had shown that the efficient deployment of building refurbishment in residential sector is based on complex factors. In the background of implementing low carbon building in most parts of the world, China must make action for improving energy efficiency in residential building. Thus, relevant regulations are the guidance and guarantee for improving energy conservation refurbishment of residential building.

As we discussed in chapter 5, the house property in China is controlled strictly by government. Consequently, there is more initiative for responsible governmental department to set up energy efficiency target in refurbishment projects of residential building. Since China starts later than developed countries like EU in building energy conservation, there is still huge gap of regulations for existing residential building refurbishment in China. Based on present research, proper regulation encouraging a combination of energy efficiency effect and improvement of built environment with investment reduction is very useful, in practically for big and middle scale cities which facing conflicts of economic development and energy crisis.

Key-points of residential building refurbishment plan

Of course, refurbishment plan should be fixed on the base of target existing building and corresponded with local environment including natural environment, social environment and architectural context. Simultaneously, related stakeholders would take part into the decision making process. But this is precisely why, there is more limitation when we make design plan for refurbishment project. General speaking, different from the design of new constructions, design for refurbishment project is limited by existing status and existing site plan and building plan to a great extent. We can summarize the relation between building elements and possibility for energy saving in refurbishment in Table 7.2, through the analysis, key-points of design content for refurbishment projects can be listed.

Table 7.2 Analysis of key-points in residential building refurbishment design process

		Possibility	Light environment	Thermal environment	Energy consumption / CO_2 emission		
					Heating/ cooling	Electricity	Water /gas
Window/ door	Area	NP	Y	Y	○	□	Δ
	Orientation	NP	Y	Y			
	Material	P	Y	Y			
Wall	Orientation	NP	N	Y	○	Δ	Δ
	Material	P	N	Y			
Roof	Form	P	N	Y	○	Δ	Δ
	Material	P	N	Y			
Floor	Material	P	N	Y	□	Δ	Δ
Facility	Pipe	P	N	Y	○	□	Δ
	Fixed installation	P	N	Y	Δ	○	○
	Household appliance	P	Y	N	Δ	○	□
Building	Orientation	NP	Y	N	Δ	○	Δ
	Story	P	Y	N			

P-possible; NP-impossible; Y-related; N-no related; ○ - closely related; □- related; Δ- not related

Focusing on single residential building, building location, envelope and indoor facility are the main content in building design process. But for refurbishment project, the location, plan and façade are already fixed in existing building. In most cases, the position and orientation of building elements are fixed and hardly to be reconstructed. But some elements could be refurbished by adding additive materials and even partly reconstruction in existing building. For residential building, the environment control system is simpler than public buildings, the energy saving measures are concentrated in municipal infrastructure like pipe of heating, electricity, gas and water. Building envelope refurbishment is mainly concentrated in improving thermal performance and façade renew. By implementing energy efficiency measures for building envelope, energy for heating or cooling could be reduced and lighting and ventilation environment could be improved.

Sometimes, if it is possible, addition story could be constructed on the top of existing building. In the side of energy consumption, energy consumed in residential building are mainly embodied in heating/cooling for adjusting thermal environment; electricity for light environment, domestic hot water and household appliances; water and gas for daily lives. So we can get the conclusion that refurbishment should be mainly focused on material of building envelop, construction of roof, basement, story (height) of the building, municipal facility pipe and lines, internal decoration etc.

We can summarize the recommendation for policy from different point of views. The regulations and standards for residential building refurbishment should be embodied in some key points such like thermal property of roof and basement; replacing window and doors by innovation energy efficiency productions; retrofitting material of façade for improving insulation property and ventilation system; regeneration of heating and distribution boar; modernization of indoor decoration and facilities. And the regulations should set in the national mechanism: legislations in national level; special design parameters for different climate regions; methodologies for different types of building.

Table 7.3 Recommendations for policy setting

Regulatory mechanism:	
Key points	Thermal insulation of the roof and basement
	Renewal of windows and doors
	Façade insulation (includes ventilation system)
	Heating system and current distribution boar
	Indoor facility and decoration
Regional	• National level
	o Climate region
	o Provincial level
	• Municipal level
Typology	Single dwelling
	Multi-stories apartment
	High-rise apartment
	Culture heritage residence
Recommendation :	
a) Regarding CO_2 emission reduction target in sector if existing residential building as part of plan of sustainable city and make refurbishment plan in line with the whole city development plan.	
b) Considering the energy efficiency retrofit as the essential part of the whole	

	residential building refurbishment, devise and implement policies to improve energy performance and built environment in the same time.
c)	Compromising energy efficiency improvement as a legal requirement whenever refurbishment is undertaken in existing residential building to maximize cost-effectiveness of investment.
d)	Facilitating the support of new funds to improve sustainable, energy efficiency residential building refurbishment---- especially for first level cities where there are amount of existing building urgently needed to be refurbished and there is no structural funds for house refurbishment nor energy demand management exist as yet.
e)	Realizing implementation of general energy efficiency delivery mechanisms that could be used, amongst other purpose (employment, economic, public opinion etc.).
f)	Completing the gap in building design legislation and decision-making rules to improve refurbishment.
g)	Linking all actions to implementation of built environment of building, energy efficiency/ carbon emission, relevant energy service directives.

Since China is in the period of fast developing of urban construction, refurbishment of existing residential building could help to solve the complex urban and building development problems. We summarize the recommendation for comprehensive residential building refurbishment policies. (Table 7.3)

Integrated design of residential building refurbishment

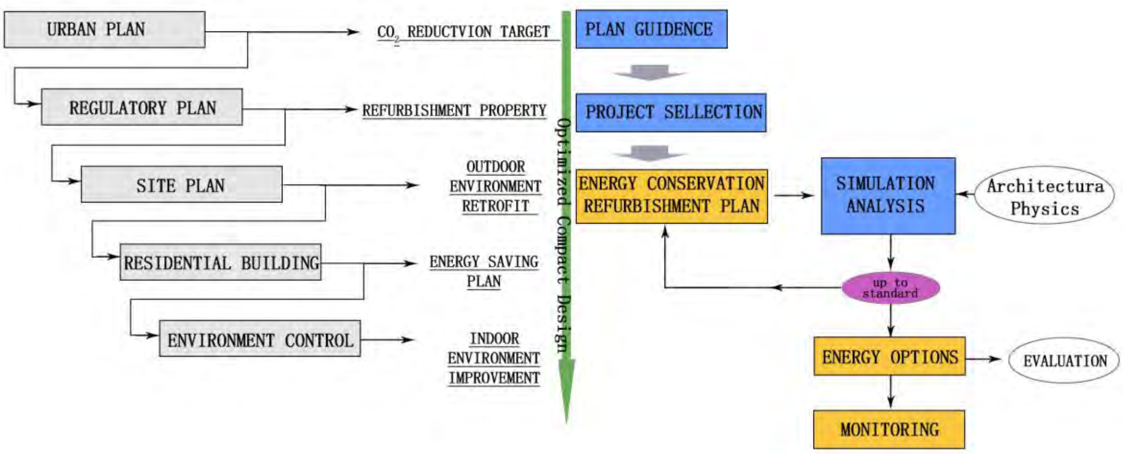


Fig 7.1 Route map of integrated design for residential building refurbishment

From the point of architects, an integrated design should be adopted for fixing a comprehensive residential building refurbishment plan (Fig 7.1). In a top-down mode, starting from the urban plan level, the refurbishment target could be clearly fixed step by step; coinciding with the relevant regulations, refurbishment measures could be selected; using simulation and evaluation system, refurbishment plan could be finally fixed.

Embodying in the framework we set in chapter 6, when the sustainable plan for the city is fixed, as the part of the city, we can calculate the CO_2 reduction aim to meet requirement of low carbon urban design, certain existing residential building could be selected as the target building. First of all, survey about energy performance and built environment in existing building could be made. Referencing the building regulations, relevant stakeholders could discuss the possibility for refurbishment and ambitions by refurbishment. According to the joint agreement for refurbishment, professionals could make simulation with software to calculate the energy saving effect and economic estimate. If the decision makers are satisfy with result of the simulation and the result is up to the standard, architects could go deeper to fix proper energy options to implement in plan. After refurbishment construction, monitoring and maintenance should be pursued. In this step, the refurbishment effect could be expressed in saving of energy consumption and cost for energy, improvement of outdoor and indoor built environment. From the description above, we can get the conclusion that energy efficiency conception is integrated into the whole process of refurbishment. It is necessary to synchronize the objectives of various government departments and other authorizes involved in the delivery of low carbon house. To reach the aim of refurbishment, policy support and integrated design method should be strengthened in China.

7.3 Improving energy performance and comfort level in residential buildings and community synergistically

Through the analysis of comprehensive design framework, we have already known very well the complexity of residential building refurbishment. Since there are so many influence factors in the design progress of residential building refurbishment, there are some specific characteristics of evaluation for residential building refurbishment project. Evaluation result not only is the judgment after the project is finished, but also could be the references material in decision–making process of refurbishment plan.

□ Implementing comprehensive evaluation criteria

Effectiveness is the most important evaluation criteria (Neji and Astrand, 2006). Evaluations of relevant themes have usually measured effectiveness through analysis of the impact and feasibility of them, in terms of energy saving, performance of built environment, management and relation with urban planning. Each of single themes could not be used as the evaluation criteria for judging whether the refurbishment plan is worth to be done or not. For example, in some cases, although the energy consumption is lower than other buildings, if the built environment e.g. indoor comfort level or transportation accessibility is poor, this building should be refurbished. The decision property is owned by multi-players related with project, by comparing effectiveness of each criteria, they could fix the proper plan as the “balance point” among each themes.

However, due to lack of complete evaluation mechanism and mature measuring methodology, there is some illusion in evaluation criteria of residential building refurbishment. In a rather long period, because of social development demand, feeding basic living requirements the primary issue in residential building sector in China. People paid too much attention on energy consumption but neglecting the improvement of built environment. Hence, it is necessary to set up comprehensive judgment criteria system specific for residential building refurbishment in urban area of China.

To make a clear evaluation mechanism, we may summarize the influence theme into four aspects: ***Energy, Built Environment, Management*** and ***Urban Plan*** and there are sub indicators in each theme (Fig 7.2).

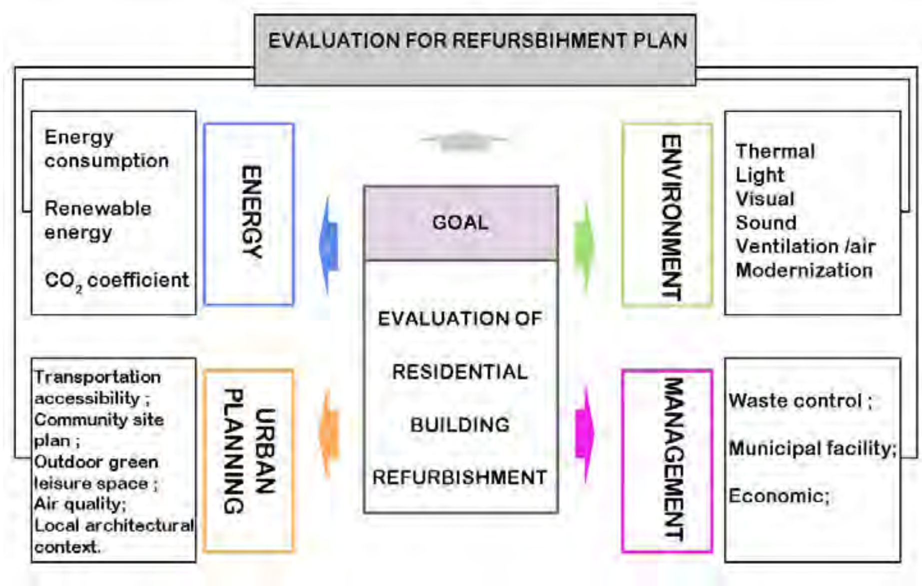


Fig. 7. 2 The organization of the Marco area of evaluation system for residential building refurbishment plan

Energy performance is the most important criteria in the refurbishment plan. With the analysis in previous chapters, the refurbishment plan should aimed at both energy saving and low carbon emission of existing residential building. The energy consumption can be divided into electricity energy, heating/cooling energy, water and gas in typology. We should pursue optimizing energy saving effect, reducing energy waste in transportation. Improving utilization of renewable energy and reducing CO_2 emission could minimize effect to environment and climate.

In the other hand, indoor built environment is another important evaluation criterion for residential building. In a residential building refurbishment project, the plan should improve indoor comfort level and promote the thermal, visual, sound, light environment; improve air quality and make modernization for existing building. Collaborating with environment design standards, the refurbishment plan should get the effect above the minimal limit of this type of building in the same regions and pursue the optimizing comfort level in living environment.

Residential building is part of the urban and usually located in residential community. The refurbishment for existing residential building is also related with urban planning. For an existing residential building, the location and orientation of the building and community is fixed, refurbishment is only refers to transportation refurbishment to improve accessibility and site plan rationality; retrofitting outdoor green leisure space and supervision of regional air quality to promote convenience and health index of outdoor environment; façade refurbishment to harmonize to local architectural context.

In addition, the management control of the building is another important theme for evaluating a residential refurbishment project. By the refurbishment, the target building should cooperate with municipal department and waster control system closely to play active effective in a low carbon city. And the economic invest and cost saving in long term should be estimated as an important indicator for analyzing feasibility of the refurbishment.

□ Pursuing comprehensive promotion of existing residential building/community

For a country lacking of building energy efficiency experiences, it is essential to encourage to emphasize pursuing comprehensive promotion of exiting residential building/ community in both energy performance and comfort level of indoor and outdoor environment synergistically. Comfort level is refers to humanized reaction that is related with outdoor and indoor environment, the functional convenience of residential building, operation and supervision management of the building etc. It is an organic system and the criteria should be adjusted according to real condition of different projects. Combining with the regulation and building status, refurbishment plan should be fixed follow the framework we established in Chapter 6.

The core motivation of present research is to state that energy saving and economic cost reduction is not the only aim of refurbishment, comprehensive refurbishment should include synergistically functional, comfort and sustainable energy efficiency promotion compared with the status of residential building. Not only badly broken building should be refurbished, but also building with bad energy performance and low comfort level should be refurbished by proper measures. The refurbishment for residential building/ community is an issue not only related with building sector, but also related with the whole national society. Especially on residential building refurbishment in urban area of China, the comprehensive framework is also related with financial mode, energy policy and urban development.

The statistical weight of each indicators is depends on the detailed condition of target project, and there are already analysis methodology to make evaluation of weight. Since the building evaluation is another important research topic, we would not go to deep research in present thesis. We just propose that in making-plan procedure, refurbishment plan is a compromise result and a useful measure for improving living environment and developing low carbon urban. In next step, further research would be made specific on establishing an assessment system for evaluating energy efficiency effect of residential building (new construction/refurbishment) project in China.

7.4 Emerging trends of sustainable development for existing residential community refurbishment in urban area of China

Residential building plays an important role in an urban system. Sustainable development of residential community is essential guarantee for low carbon sustainable city development. The residential building in urban area of China is given expression to development of Chinese society. In a certain long period, the only aim for constructing residential building is solving basic living problem, however, the quality of residential building is neglected. Hence, with the social and building development, these disadvantaged existing residential communities are developed in a sustainable way to get functional promotion. Besides the design framework for residential building refurbishment, we also summarized the emerging trends of sustainable development for existing residential community refurbishment in urban area of China.

□ Revitalization of disadvantage neighborhoods through refurbishment

In existing residential community, sustainable neighborhood revitalization is a growing trend in urban regeneration of disadvantaged neighborhoods. New planning processes, suitable to satisfy the complex needs of these neighborhoods, have been experienced by local administrations in China in last decades. And disadvantage neighborhoods commonly exist in residential communities which were built decades ago. Various local authorities, urban planner and architects partnerships have developed the means to meet community needs in improving living conditions, balancing the investment for urban regeneration, securing cohesion in the community plan structure and building plan organization, encouraging disadvantaged communities to undertake responsibility for development processes, opening new opportunities for stakeholders to take part in refurbishment, addressing a wide spectrum of complex interdependent problems, ranging from poverty to lost cultural identity. Revitalization of disadvantage neighborhood effects extraordinary significance for city sustainable development such like simulating the vitality of historic urban area and gray urban area which failed to catch up the speed of urbanization (e.g. obsolete industrial districts); reducing development investment and saving land-use for agriculture; reducing carbon emission in building sector and transportation sector of the city etc. In some historical cities, residential building refurbishment could be implemented with culture heritage regeneration; in industrial cities, residential building refurbishment could be implemented with industrial district regeneration. Building is an organic part of urban constitution; existing building refurbishment is an effective mean for improving sustainable development of the city. Sometimes, the residential building refurbishment can be implemented combined with commercial building or public buildings together to formulate a dynamic zone by functional reorganization.

□ Market attractiveness of energy efficiency refurbishment design

As we know, there is broad market for residential building refurbishment in China. Until 2004, the area of residential building in China is over 30 billion m^2; most of them could not match with energy efficiency standards and needed to be refurbished. In 2004, Total primary energy consumption in China is 2320 mill t SKE; Energy saving through retrofitting building energy efficiency is 35.55 mill t SKE; Energy saving through retrofitting building energy efficiency is 1.53%; Energy saving through retrofitting building energy efficiency is 56.66 mill t SKE and 2.44% of the total. If we talk about CO_2 emission, the total CO_2 emission in China in 2005 is 5327 mill t; reduction through retrofitting building energy efficiency is 90 mill t and 1.69% of the total; reduction through retrofitting building energy efficiency and network is 144 mill t and 2.7% of the total (GTZ, 2009). Official statistics shown that by 2009, the total construction area of residential building in urban area of China is 17.5 billion m^2. If we presume the investment for residential building refurbishment is 300-400 RMB/m^2 (it's depends on the real status of the building and location of the building) and 1/3 of existing residential building is going to be refurbished, the potential market is about 1750-2333 billion RMB.

The huge market potential would strongly simulate attractiveness of residential building refurbishment. The local authority should make a clear statement of housing related rules to provide a strategic basis for comprehensive approaches across the whole housing market. In the meanwhile, the training for professional energy designer and workers should be implemented by the support of local authority; industry for energy efficiency productions should be improved, attention should be focused on especially adoption of local materials. For all the cities over China, a low carbon sustainable urban plan should be fixed and market influence should be set as the main factor of the energy plan.

- **Awareness of citizen representative on energy conservation of residential building**

Energy saving and low carbon development is not only the conception or a watchword by government, especially for residential building, citizens participation is an essential factor for improving energy conservation of building. As we discussed in previous chapters, the local authority should effects cooperation with inhabitants from the very beginning of the refurbishment project. Since the special characteristic of residential building, the cooperation of inhabitants is extremely important.

- In proposal stage, inhabitants should make the decision with local authority together to discuss the feasibility of refurbishment. Project manager and local authority should adopt willing of inhabitants.
- In energy survey stage, the professional energy designer should collect the energy data and existing problems with the help of inhabitants.
- In setting ambition stage, multi-stakeholders including inhabitants, project managers, relevant department of local authority, energy company and professionals should work together and get joint agreement of refurbishment ambitions and financial structure. Usually, the benefit of refurbishment project refers to urban, economic and social development of the city while inhabitants would get most benefit directly by refurbishment.
- In choosing energy options construction stage, inhabitants should corporate the implementation of refurbishment plan and indoor construction.

- After refurbishment construction, the inhabitant would play an important role in monitoring and maintenance stage. Valuable experience would get by result of monitoring and good examples could be advertised widely by participant of citizens.

After all, more actions should be implemented to arouse the awareness of citizen representative on energy conservation of residential building in China and the residential building refurbishment in urban area would effect a lot on energy saving and carbon emission reduction.

□ Integrating low carbon conception in residential building refurbishment design

Influenced by successful EU experiences and technical support, energy conservation of residential building is becoming the core content of residential refurbishment project. Present research has attempted to assess the current situation and potential for energy efficiency in residential building refurbishment in urban area of China and establish comprehensive design strategy framework. In order to develop a way forward for urban sustainable development and creating low carbon green society, energy efficiency and low carbon conception should be integrated as the main aim in residential building refurbishment plan.

In China, shortage of technical support and incomplete administration mechanism caused the neglecting of building energy efficiency in past decades. However, pushed by social and economic development stream, low carbon sustainable planning is the best direction for Chinese cities and adoption of energy efficiency technology is the strongest guarantee for this target. We hope the comprehensive refurbishment strategy could be implemented broadly in China and get fruitful result in the future.

7.5 Research Conclusion:

The general goal of this research is to establish a comprehensive energy conservation refurbishment strategy framework and formulate innovate technical procedures and methodology for residential building in urban area of China. The goal has been successfully achieved through the previous statement. The outcome of the research not only proved the significant and feasibility to implement energy conservation refurbishment for residential building in urban area of China, but also established the framework and devised a package of methods to accomplish it.

The topic of present research is a critical problem in Chinese cities. The analysis starts from the review of building energy consumption status quo and summarize the reasons for implementing energy conservation refurbishment in existing residential buildings in urban area of China, classification induce is made for Energy-saving and Energy utilization through the study about existing relevant regulations and standards for residential building in China. The feasibility of improving residential building refurbishment in urban area of China is demonstrated by two aspects: both the requirement in China and advance experiences of EU. In China, clean energy application and technology is an emerging development direction for all kinds of industries to achieve the target of changing “extensive” economic development mode to “intensive” mode. For building sector, low carbon sustainable urban planning is the development trend and energy conservation building is an essential part of constitution of urban development framework. In last decades, energy consumption for residential building in China is lower than developed countries because of unconscionable economic structure and is increased sharply with the adjustment of social-economic structure. We can predict the residential building energy consumption will be increased near or even overall that rate of developed countries. Along with the urbanization accelerates, China is urgently need improvement of energy efficiency of residential building. In the other hand, Europe is playing a leading role in promoting emission reduction. In the period after IIWW, Europe explored a way of sustainable development. They firstly put forward of low carbon urban strategy and specific Energy Performance Building Directive including energy efficiency policies covering city, district and building levels. Furthermore, there were several residential building refurbishment projects successfully implemented as the trendsetter of real practice for existing residential building energy conservation refurbishment. ENPIRE is representative of the good example which includes six residential building refurbishment projects in six European cities from six countries. Thanks to the increasing of international researching communications, it is possible to draw on ENPIRE’s experiences and expanding cooperation between EU and China to set up a comprehensive strategy and methodology framework for residential building refurbishment in China. As far as concerned social development condition and house retention, there is more similarity between urban area of China and Europe, thus present search proved the feasibility for improving residential building refurbishment in urban area of China.

For making further research on residential building refurbishment in urban area of China which related with multi-subjects, relevant domain knowledge had been researched in three aspects: data collection (including urban coefficient and energy consumption in target residential building); analyzing method (integrating AHP and ANP processes); energy efficiency technology which suitable for residential building refurbishment.

In scheme stage, present research focuses attention on residential building in China. Firstly, an analysis on residential building in urban area is made to identify the problem clearly. In this section, category and characteristic of existing residential building is classified and general problems of existing residential building have been summarized.

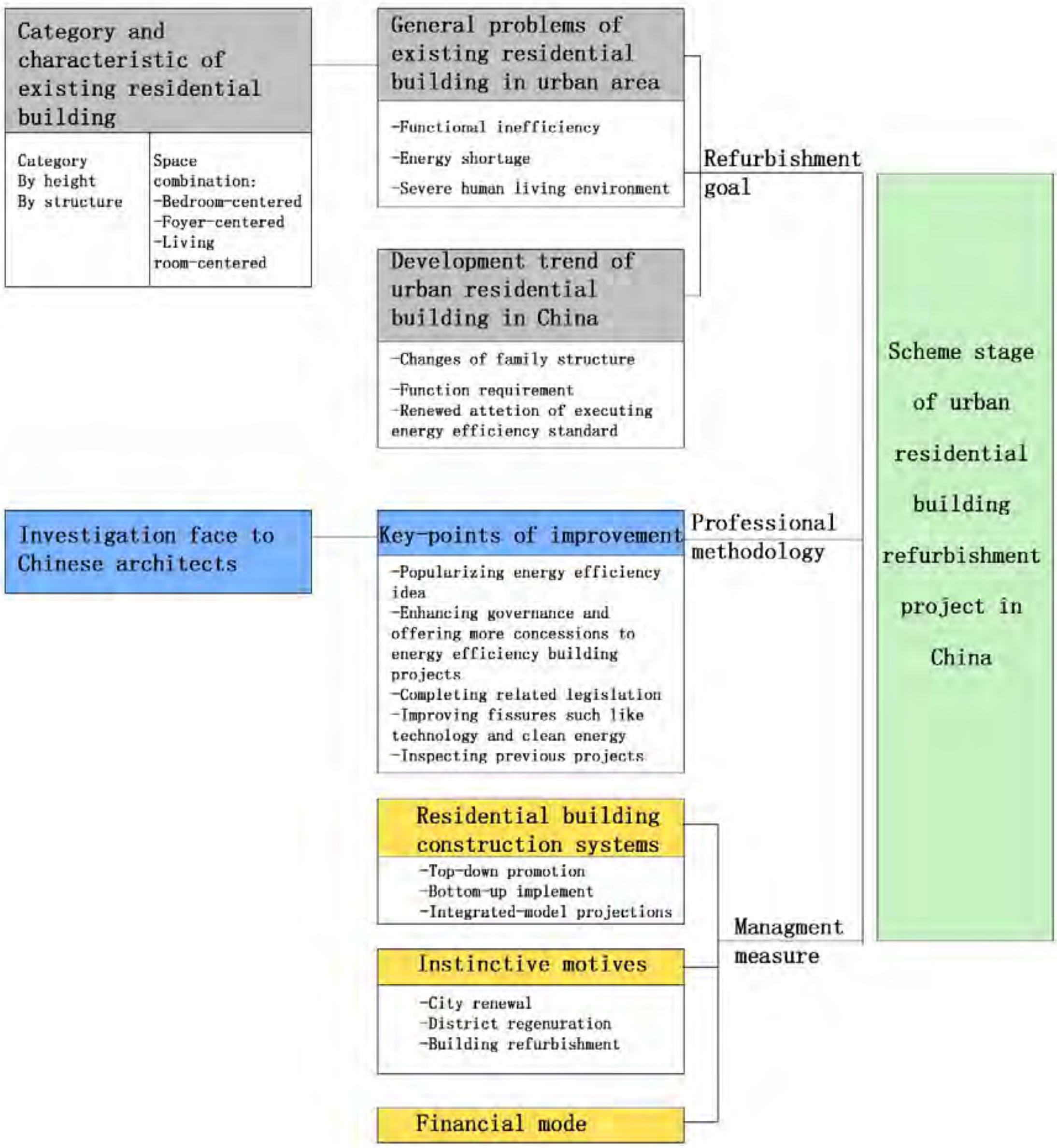


Fig 7.3 Context of scheme stage of residential building refurbishment in China

Along with the development trend of urban residential building in China, we can find what should be improved in existing buildings to catch up with the emerging trends and meet the new demands. Secondly, the current identification of residential building refurbishment design strategy is directly influence the development and implementation of energy conservation effect of refurbishment, an investigation faced to Chinese architects is made. Through results of this investigation, key-points of improvement for residential building refurbishment in professional view have been refined.

In the meanwhile, China is still in the mode of Central Planned Economic, the government strongly controls the economic market and construction system. Present research also analyzed the internal operation model of residential building refurbishment in China. Construction system of residential building refurbishment is in a good state of both Top-down promotion and Bottom-up implement, a balance of Integrated-model projection could be found for residential refurbishment. And there are multi-level instinctive motives to drive the refurbishment for residential building: city renewal-district regeneration- building refurbishment. From the analysis, it is easily to find the refurbishment of existing residential building is an inevitable outcome of urban and building development. For an existing residential building which is in occupation, the influence factors are more complex than new constructions. Among these factors, an important determining factor is financial support for refurbishment project. Available multi-level financial mechanism for residential refurbishment in China is established. By analysis from three aspects, the aim of refurbishment, professional methodology and management measure are summarized and prepared for next step (Fig. 7.3).

In technical framework for energy conservation residential building refurbishment in urban area of China is established and could be used as the guideline for general residential building refurbishment project in urban area of China. (Table 7.4)

The general working procedure of residential building refurbishment in China can be divided into 8 steps which are similar with that of Europe and new constructions. But since the participation of stakeholders is more complex, in real practice, there are more difficulties for achieving the refurbishment goal. In the point of energy, the refurbishment design framework is constituted with four main steps: Energy survey phase, Discussion and setting ambitions, Analysis of energy options and optimizing of energy options and Implementation. In order to expound and prove the methodology, in the end of each section, case study which figured a good experience in relevant aspect had been analyzed with the design methodology set in present research. Proper technology measures and design methodology for residential building refurbishment in urban areas had been proposed in details.

Table 7.4 Framework of energy conservation residential building refurbishment design procedure and methodology

<table>
<tr><td rowspan="8">Working procedure</td><td>Basic data collection</td><td>Collecting original blueprint; formulating investigation table; mechanic and material analysis.</td></tr>
<tr><td>Initial plan submittal</td><td>Finishing investigation; initial financial program; discussion ambitions for refurbishment target on the base of regulation.</td></tr>
<tr><td>Construction draft submittal</td><td>Schedule of construction documents of authorization.</td></tr>
<tr><td>Preparation of the approve document</td><td>Drawing s and context documents for refurbishment; coordinating municipal engineering offices.</td></tr>
<tr><td>Improve the construction plan</td><td>Selection of energy options; Construction drawing design.</td></tr>
<tr><td>Bidding and tendering</td><td>Project quote price; coordinating modification plans;</td></tr>
<tr><td>Monitoring plan and implementation</td><td>Detailed construction schedule; regular meetings; supervision problems.</td></tr>
<tr><td>Project trailing and control</td><td>Save data management; return visits; post tracking service.</td></tr>
<tr><td rowspan="4">Energy consumption process</td><td>Energy survey phase
<u>Actions:</u>
• Summarizing the energy consumption quo status of pilot building
• Preliminary investigation</td><td><u>Goal:</u> collect past energy consumption and existing problems of pilot residential building and analysis the preliminary feasibility of refurbishment.
<u>Procedure:</u>
• Basic survey
• Key-points survey
• Inhabitants' investigation</td></tr>
<tr><td>Discussion and setting ambitions
<u>Actions:</u>
• Regular communication
• Searching available energy efficiency technology and production
• Estimating of energy saving effect</td><td><u>Goal:</u> reach a joint agreement of energy saving ambitions by comprehensive communication with all stakeholders.
<u>Procedure:</u>
• Coordinating multipartite participants
• Studying national and local regulations for setting ambitions
• Choosing suitable methodology
• Setting refurbishment ambitions
• Embedding joint agreement</td></tr>
<tr><td>Analysis of energy options and optimizing of energy options
<u>Actions:</u>
• Choosing energy efficiency measures
• Calculation CO_2 emission reduction
• Fixing construction plan</td><td><u>Goal:</u> fixing energy conservation refurbishment plan with suitable energy efficiency technologies
<u>Procedure:</u>
• Making an inventory of measures to reduce energy consumption and use renewable energy.
• Screening of this inventory of measures and selection of a number of promising options which seem feasible for the project.
• Compilation of measures: suitable combinations of demand and supply side measures which are tailored to the project at hand.
• Detailed simulation of cost and performance.
• Recommendation of the best combination of measures and on practical issues with regard to implementation.</td></tr>
<tr><td>Implementation
<u>Actions:</u>
• Controlling the project
• Analyzing monitoring result
• Choosing suitable maintain plan</td><td><u>Goal:</u> management a skilled and well organized refurbishment project
<u>Procedure:</u>
• Fixing construction plan.
• Supervising the process.
• Monitoring building operation condition after refurbishment construction.
• Keeping maintains.</td></tr>
</table>

For China which is under the stage of social development, there are still numerous imperfections needs to be refurbished. Especially in sustainable building design field, China is effecting to establish comprehensive urban plan and building design strategy and methodology. Besides setting up the innovation design framework of energy conservation residential building refurbishment, present research hammers away at connecting present topic with low carbon sustainable urban plan to consider low carbon issue in an overall level. The final comparison in present research made a summary of residential building refurbishment project between EU and China. (1) Through the analysis and lessons learnt from case studies, the universal comparison is made out to drive towards the right develop direction of residential building refurbishment in China. (2) In regulations aspect, the consideration of low carbon in residential building induce the central government and local authority to implement a detailed energy efficiency policy and regulations for residential building both for refurbishment and new constructions. (3) In the meanwhile, in allusion to the tradition and current situation of energy efficiency research in China, an innovation point of view that improving energy performance and comfort level in residential building and community synergistically has been proposed and it will be made further research with establishing evaluation system for residential building in China in next step. (4) With respects to urban plan level, emerging trends of sustainable development for existing residential community refurbishment in urban area of China have been presented.

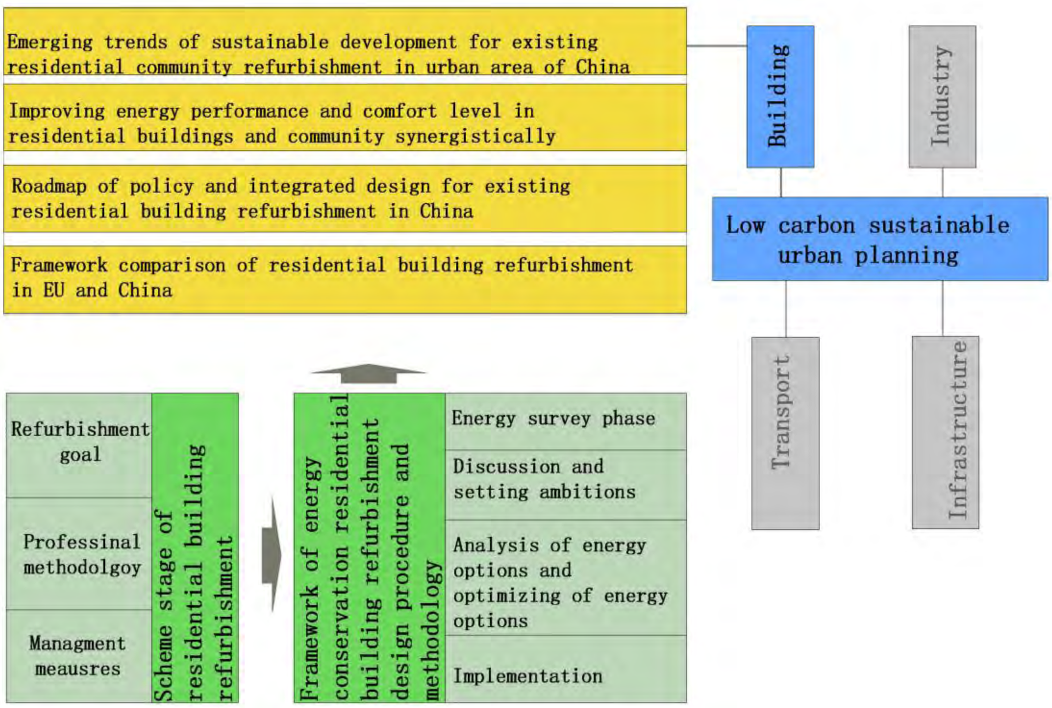


Fig. 7.4 Link with low carbon sustainable urban planning

Recommendation:

- Local authorities are in a good position to initiate the process of preparing an energy vision. It's better to set up energy vision for residential building under the complete energy vision framework in urban plan level.
- Good communication, a clear route plan and perseverance are essential ingredients to keep the high ambitions alive in the final step of project implementation.
- An important step for residential building refurbishment is that a wide range of participants should be involved in initial discussions about ambitions. These discussions may cover more aspects than only energy or CO_2 reduction but can also address energy costs and comfort levels for inhabitants, technical building improvement, etc. In this way a common set of interests can be identified with regard to improvement of existing buildings or the requirements for new buildings.
- Technical analyses should be used to support and guide this ambition setting process, but parties themselves will have to decide on the ambition they want to commit themselves to.
- An energy vision study should consider also the options for the project area as a whole and not be restricted to measures on a building level.
- Technical solutions should preferably have a high degree of flexibility to accommodate future changes in energy infrastructure, energy demand and energy pricing.

7.6 Research contribution

The dissociation of new requirement for existing residential building and lack of energy conservation strategy and design mythology is a serious problem that restricted the low carbon development and urgently needed to be solved in China. Historically, efficiency policies in China was focused most attention heavily on new constructions perhaps it easier to address compared with refurbishment project. In contrast, most of refurbishment projects are finished discretionary and occasionally. Furthermore, for refurbishment project, the energy efficiency improvement requires more complex construction technologies but less expensive cost. Refurbishment is not simple the sense of reconstruction nor repair treatment, energy efficiency measures adopted in retrofit would lead to both improvement of built environment and energy conservation effect, would refurbish the performance of existing building. However, despite the challenges, it is clear that low carbon urban planning to address sustainable development need aggressive efforts in building retrofitting market.

Depending on the country, building sector occupies over 40% of total energy demand in China and the rate is going to be raised in the future. While aggressive refurbishment effort is necessary for all types of building in China, present research focus exclusively on residential building refurbishment, particularly in urban area of China which are mainly multi-storied apartment. The reason is residential building refurbishment in urban area of China is complex enough since their property and current status, but also because the residential building in urban are of China is expanded as a critical theme in the context of meeting fixed GHG emission reduction goals and solution for alleviating contradiction caused by economic development and urbanization. We can summarize the contribution of present research into following four aspects:

☐ Arousing the benefit of refurbishment

Present research provides an analysis on the feasibility to implement energy conservation refurbishment in residential building in urban area of China and arousing the full-scale benefit of refurbishment. The benefit can be summarized as:

- Associated technical and financial benefits;
- Associated environmental benefits: CO_2 savings from reduced generation load;
- Associated employment benefits;
- Associated comfort and wellbeing benefits.

The analysis indicates that there are clear benefit and broad market for residential building energy conservation refurbishment; hence the energy conservation refurbishment would be implemented in the future.

☐ Abstracting the existing illusion on the topic of energy efficiency of residential building in China to help to complete systematic policy

Present research executed a systemic analysis on the dilemma, problem, advantage, impetus and potential of Chinese cities to adapt energy conservation refurbishment of residential building. Understanding the existing illusion is in favor of highlighting the significance and necessity of integrating energy efficiency to refurbishment process in urban area of China. It also identifies the responsibility of each stakeholders who participants in the process of refurbishment.

In addition, many provinces and cities are in the process of developing and implementing efficiency action plan and other polices to deliver aggressive levels of efficiency or they may be in the future. The analysis of existing problem and development direction presented in this research would offer practical guidance for those efforts as well as a useful check-list for residential refurbishment initiatives under consideration.

- **Establishing a innovate strategy framework for energy conservation of residential building refurbishment in urban area of China by referencing European method**

Present research developed a framework of design procedure and a package of corresponding methods for energy conservation of residential building refurbishment in Chinese cities at the current stage of development. Four stages and available tools are elaborated in details. With the design principle together, a framework to implement energy conservation refurbishment in residential building sector in China is established. We set a procedure framework and combining the energy efficiency technology and design methodology into each step. Such kind of framework will be more adaptable in China, due to the incomplete energy mechanism in most cities of China.

In the other hand, there is no research focus on comprehensive residential building refurbishment in urban area of China, previous research were either focused on heating energy saving in northern China or façade retrofit. And there is no research that has executed a comparison analysis between Chinese and European case studies in recent years. Present research grab advantage refurbishment strategy for residential building refurbishment in EU as reference. Besides the and good examples in EU, the research acquired several real case studies which is implemented in China in recent years and represent good behaviors in a certain aspect and analysis them follow the methodology we proposed in each step.

- **Getting link with low carbon sustainable urban planning in China**

As an exploration, present research efforts on analyzing building energy efficiency in a macro level ---- get the residential building refurbishment link with low carbon sustainable urban planning.

In real practice, residential building refurbishment is not implemented to a single building but to a residential community or even part of urban district regeneration. When we make the refurbishment plan for the target building, the professional architect/energy designer should consider the energy efficiency in a more comprehensive view so that we can get long-term energy effectiveness. The refurbishment for residential building could spur the activeness and built environment of disadvantage neighborhood and improve the living quality of the local city. Central government and all local authority should put residential building refurbishment in motion for constructing a low carbon sustainable city.

7.7 Research limitation and future scenario

As a PhD research, this thesis is mainly focus on establishing strategy framework for residential building refurbishment in urban area of China which is a result of part of my work during the three years. Due to the space constraints and finite of my personal ability, there are some limitations in present research.

First limitation is research boundary. The present research is a composite topic which related with building design methodology and adoption of energy efficiency technology. The research topic covers multi-subjects and complex factors. While, limited by research period and the data obtainable, present research propose the general strategy for all Chinese cities. For different regions with different climate and building status, there should be specific design standards with relevant thermal or material parameters. Thus, the strategy framework could be used as the general guidance for arranging work procedure and refurbishment plan of residential building refurbishment in Chinese cities while the detail of energy calculation still needs further architectural physical research. Second, lack of successful Chinese case study. Since the topic is a problem urgently needed to be solved in China, relevant researches are in the beginning step in China. there is no project that has implemented this innovation framework in China. The Chinese case studies are selected to explain a certain issue. It's better to take part into the whole process of a real refurbishment practice to verify the feasibility. However, it is impossible to completely carry out such kind of work within a short period and acquire convinced conclusions. The third limitation is lack of effective assessment system to evaluate the effect of refurbishment suitable for China. Due to the complexity of evaluation system, it is hard to set up a specific evaluation system as part of this research. But a comprehensive evaluation criterion has been proposed as the addition in Chapter 7.

The aims and objectives in this thesis have been successfully achieved, and during the research, some areas were found to have the potential to develop in the future study. The suggested areas are as follows:

- Interviewing on more professionals, covering more cities in different climatic regions and economic levels, will get more complete first hand materials and would be a potential field to launch in the future. The diversity of research will benefit to formulate specific methods in accord with their own features.

- Collecting or following more real case studies which locates in different climate regions and built in different time, would help us to understand the status quo energy consumption and refurbishment measures for residential building in China comprehensively. Furthermore, the experiences of these case studies would help us to make further research to set up regional regulations and standards specific for residential building refurbishment in China in next step.
- It's meaningful to study the efficiency effectiveness and feasibility for adopting energy efficiency technologies especially low cost technology, because different cities have various geographical situations, natural sources and environmental backgrounds, it is important to identify which kind of technology will be more suitable for the city.
- The quantification and methodology of evaluation will be made further research in the future. The evaluation of energy efficiency effect is an important guarantee for an energy conservation building and there are various evaluation methods existing. The comprehensive evaluation criteria have been talked as exploration part of resent research, we have already understand that the energy efficiency and comfort level of residential building built environment should be improved synergistically. In next step, establishing a specific evaluation for residential building refurbishment with clear evaluation criteria is critical to ensure the realization of energy efficiency target by all stakeholders.

All in all, residential building refurbishment is an essential part for guarantying building energy efficiency and low carbon sustainable development. For China such a big energy consumption country in a high speed of development, how to change the development into a sustainable way, how to take the responsibility as a big country and achieve the short and long term low carbon target, how to solve the problem of increasing demand for residential building and limit land and energy available and keep the society steadily, energy conservation refurbishment for residential building would play an important role in all procedures.

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Appendix

Appendix 1 List of Acronyms

EC^2	EU-China Clean Energy Center
IEA	International Energy Agency
IFC	International Finance Corporation
OECD	Organisation for Economic Cooperation and Development
GDP	Gross Domestic Product
BEC	Building Energy Consumption
CERT	Carbon Emissions Reduction Target
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
GHG	Greenhouse Gas
PACE	Property-Assessed Clean Energy
HVAC	Heating, Ventilating, and Air Conditioning
PV	Photovoltaic
Kgce	Kilogram of standard coal equivalent
kWh	Kilowatt Hour(s)
kWh/m^2	Kilowatt Hour(s) per Square Meter
kWhPe	Kilowatt-hour of primary energy
tce	Ton of standard coal equivalent
toe	Ton of oil equivalent
Mtoe	Million tons of oil equivalent
MTCE	Metric tons of carbon equivalent

Appendix 2 Sample of investigation in 5.2

Energy Efficiency Popularization Investigation

建筑节能问卷调查

This is an investigation for energy efficiency issues which is specific faced to architects. Please fill the basic personal information and answer the questions below.

请填写个人基本信息，并回答下面的问题。

No.

Professional: 专业：	Age: 年龄：	Gender: 性别：	City: 工作城市：
Education background: 学历：	Professional time: year 从业时间： 年		Title: 职位：

（1） Do you pay attention to the development of building energy consumption in China?

您平时是否关注中国的建筑行业能耗发展？

A． Yes, I always pay much attention to it; B. sometimes; C. I don't care about it.

A． 很关心 B.一般 C. 不关心

（2） China says it will cut its CO_2 emissions 40-45% per unit of gross domestic product by 2020 compared with 2005 levels. Do you think China could reduce CO_2 emission by 40-45% in building sector?

在 2010 年世界中国政府承诺 2020 年前，碳排放量减少 40%-50%，就建筑能耗方面，您认为是否可以实现这一目标 ？

A． It's very difficult; B. If China can improve energy efficiency level, it can be done; C. I've never think about it.

A． 很难 B 大力推进节能措施，可以实现 C 没考虑过

（3） Can you describe the proportion of sustainable and low energy consumption building design projects in your works?

在您所参与的项目中，以节能或低能耗为主要设计理念的占多少比重？

A． most B. many C. medium D. medium, but more and more E. a few F. a few but more and more

A． 大多数 B. 较多 C. 一般 D. 一般，但越来越多 E. 较少 F. 较少,但越来越多

（4） Is there training for learning building energy efficiency legislations in your company?

就职单位是否提供建筑节能相关规范的培训？

A． often B. sometimes C. a few/ no

A． 经常 B. 偶尔 C. 很少或没有

（5） When you work for a project, would you think about of using renewable energy (solar, wind, etc.) initiatively?

在设计过程中，是否会主动考虑使用可再生能源？（如太阳能，风能等）

A． Yes, I'd think about it initiatively; B. Just to meet the demand of related legislation; C. No, I wouldn't

A． 主动考虑 B. 达到相关要求即可 C.不考虑

（6） In your opinion, what should architect do for reducing building energy consumption?

您认为建筑师在建筑节能减排工作中应该起怎样的作用？

A． Just follow the basic legislation; B. enhancing concern of using energy efficiency technologies; C. cooperating with other relevant partners initiatively to improve building energy performance.

A． 被动执行相关规范即可 B. 在设计过程中加强节能技术应用的意识 C. 主动协调相关专业及业主，提高节能水平

（7） Do you think applying energy efficiency measures is an important procedure in design process?

您是否认为，节能设计是住宅设计中的重要环节？

A． Yes, it's really important; B. moderate; C. It's not important at all

A． 是的，很重要； B. 一般； C.不重要

（8） What do you think about the possibility of implementing energy efficiency standards for residential building in China

目前中国住宅建筑能耗标准在实际项目中的执行性？

A． Easy; B. medium; C. difficult

A． 易 B. 中 C. 难

（9） Do you think it's possible to improve the energy efficiency criterions for residential building in China?

您认为，现有住宅建筑的节能标准是否有可提高的空间？

A． Because the current standards have already been used for several years, With the technology improvement, it's possible to improve the standards for building energy efficiency

B． I've never think about it, I just follow the current standards passively.

C． It's already difficult to implement the current standards. I don't think it should be improved.

A． 现有规范制定时间较长，目前随着科技进步，在节能标准上有很大提升空间;

B． 没有考虑过，被动执行标准;

C． 现有规范执行起来难度已经很大，不需要改进.

（10） In all the residential building projects which you've taken part into, Are there many refurbishment projects in residential building projects compared with new residential?

在您所参与的住宅项目中，有多少住宅改建的项目？

A． A lot of B. Many C. Medium D. Few

A． 很多 B. 较多 C. 一般 D. 较少.

（11） In the residential building refurbishment projects which you've done, how many projects have been put forward the demand of energy conservation or low energy consumption?

在您所参与的住宅改建项目中，是否明确提出节能或低能耗概念要求？

A． A lot of B. Many C. Medium D. Few

A． 很多 B. 较多 C. 一般 D. 较少.

（12） Do you think the standards for energy efficiency of residential building refurbishment are completed or still have to be improved?

你是否认为中国现有的住宅改建节能措施已经相对完善？

A． It's still have to be improved; B. it's already completed; C. I've never think about it.

A． 有待提高； B. 已经很完善； C. 没考虑过

（13） In your opinion, is it possible for China to improve living comfort level on the condition of just keeping low energy consumption as status quo?

您认为中国是否有可能在保持目前居住建筑低能耗的前提下，提高居住舒适性？

A． Yes, it's possible if we implement energy efficient technologies.

B． No, it's impossible. Energy consumption must be risen with the improvement of living comfort level.

C． I've never think about it.

A． 是的，如果加强节能措施的话，有可能；B 不可能，提高舒适性必然耗能增加 C 没考虑过

（14） In your opinion, which is the best way to control residential building energy consumption in China in the near future? 您认为，以下哪些方法能最有效的控制中国住宅能耗的增长？ A． Applying energy efficiency technologies B. Changing living customs C. Raising energy price D. others A． 应用节能技术 B 改善生活习惯 C 提高能源价格 D 其他
（15） In your opinion, which phenomena should be improved in residential buildings? (Multiple Select) 您认为，下列哪几点应该在住宅改造中改进？（多选） A. Indoor temperature; B. Indoor moisture and condensation; C. Cold/hot wind infiltration; D. Noise; E. Ventilation and fresh air; F. Living environment; G. Others (Welcome any suggestion you think should be added here) A． 室内温度； B. 室内湿度和冷凝； C. 冷/热风渗透； D. 噪声； E. 通风和新风； F. 居住环境； G. 其他（欢迎补充）

Thank you very much for your cooperation for this research investigation!

If you have any questions, please don't hesitate to contact with:

非常感谢您的合作，您为我们此项课题提供了很大的帮助！欢迎联系：

yu.zhang@polito.it