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Residential Passive House Development In China

- Technical And Economic Feasibility Analysis

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Abstract

As the energy price goes up, more and more concern has been focused on the sustainable development of residential houses. One of the best solution will be the low energy housing-passive house. The concept of passive house has been popular in Germany and whole Europe in the last 10 years, however, there is no official residential passive house standard project in China now. In this thesis, the feasibility of developing passive house in China will be analysed. Combined with the mature experience from the passive house project in Europe, a Chinese way of building the passive house will be provided. According to the previous studies, a lot of knowledge of passive house projects in Sweden have been referred to help doing the analysis about the passive house development in China. Due to the fact that there is no passive house had done before in China, the some assumptions have been made to help with the economy analysis. It is assumed that one passive house residential project will be built in Shenyang city, Liaoning Province. After the analysing and calculating, it can be concluded that it is possible and profitable to develop the passive house standard residential projects in China. It has a bright future.

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CHEN CHEN

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1. INTRODUCTION

In 2010 Shanghai World Expo, Urban Best Practices Area exhibiting a strange building named "Hamburg House" by Germany which can be considered as the first passive house in China. Inside this house, there is no air conditioning and no heating equipment, air circulation can be achieved only by the natural effect of cool (Lin C 2010). It can not only provide good indoor comfort, but also at the same time energy demand will be lower than 15kwh / (m^2 a), primary energy demand will be lower than 120 kwh / (m^2 a). This is also the first time that concept of passive house is introduced into China, at present the world largest single building passive energy demonstration project is under processing in Cheng Du city of China. The building will be put into use in the early of 2012 (Business news of Chengdu). With the development of the modern industrialization, China and around the world now are facing such a problem of too many populations in the city and increasing energy price. It seems to be particular necessary for China to carry out the passive house for the residential sector.

The concept of passive house has been popular in Germany and whole Europe in the last 10 years, and now it is becoming the mainstream of energy saving building in Europe (Rosenthal, E 2008). As we know, sustainable development is the main topics of human development now, especially for the residential part. Also the energy consumption of residential sector has the biggest percentage of the total amount of consumption in China (Qing Z. 2004). Meanwhile, the average building life in China is only 35 years old (China Daily), there is such a need to implement sustainable development in real estate field of China, such as developing passive houses. Due to the first time that concept of passive house introduced into China, also the first actual passive house is still under construction, there are many uncertainties when developing this concept in China. The experience of passive house from Europe is very mature, but there are so many differences between Europe and China, we must learn the experience from Europe and analyse the feasibility of developing passive house in China. It is the main focus of this thesis.

China is a country with 5000 years' ancient history and more than 4000 years' civilization, Chinese people have accumulated a fortune of agriculture skills for residential house. They have already noticed the problem of location, direction of sunshine and self cooling system at the time of building the houses thousands of years ago (Jianhua G, et al,2000). In fact there is already exsiting one kind of the passive house in China before the the concept passive house officially classified by Professor Bo Adamson of Lund University, Sweden and Dr. Wolfgang Feist of Institute for Housing and the Environment, Germany (Institut für Wohnen und Umwelt) in May,1988 (Feist W, 2006). It is named as Tulou which is one type of the traditional residential building in Southern China (see the picture 1, 2). Tulou has also been one of the great world heritage admitted by the World Heritage Committee (WHC) since 2007 (WHC, 2007).

Picture 1. Outside looking of Tulou. (Fu Jian Tulou)

Picture 2. Inside looking of Tulou. (Fu Jian Tulou)

Due to the special climate zone of Southern China, there is no heating system needed inside Tulou, compared with that cooling seems more important and needed than keeping warm. Tulou is made of soil and wood, these are the materials can be reused, even if not, after the demolished of these buildings, you can return these soil and wood to the nature. Compared with the steel, cement, and bricks used in the modern building, which is not as environmental friendly. Firstly the building can get cooling by itself which is more like the passive house today, in other words, Tulou can been seen as the first generation of passive house in China (Fu Jian Tulou). Although there is no technical difficulties of building Tulou today, it is not realistic to build this kind of residential houses in the city of China. Energy saving houses such as passive house may be the smart choices now.

1.1. Purpose

The purpose of this thesis is to study the feasibility of passive house in China. In order to achieve this goal, several passive house projects in Europe have been studied to gain valuable experience and mature technical skills. This will be of great help for the just started passive house field in China. Meanwhile, economic aspect and technology aspect will be analysed for developing passive house in China. It is not only getting a better understand of passive house from both technical aspect and economic aespect, but also the thesis will include the information on the matter needing attention for developing passive house in China based on the examples in Europe. Also this thesis provides the information for the passive house developer on the economic dimension of investing and building passive house in China.

1.2. Research Question

Specifically, in order to get a better understanding of the main task and goal of this thesis, three main research questions have been elaborated.

Research Question One: What is a passive house ?

Research Question Two: What experience or lessons can be gained from the existing projects in Europe ?

Research Question Three: Is that possible and feasible to develop passive house in China ?

1.3. Thesis's Disposition

Coming to the next literature study part, there are two main subjects, firstly to answer the question of what is a passive house. In the second part, the studies of passive house project in Europe will be referred. The next part of the thesis is the analysis part for the feasibility of passive house in China. In oder to examine the feasibility, the under processing passive house projects in China will be investigated. Since these projects have not been put into use in the market, therefore hypothetic calculation will be done to test the economic aspect of processing passive house in China. At last, a conclusion of the whole thesis will be provided.

2. STUDY METHOD

In this thesis, several methods has been used to study the feasibility of developing passive house in China. In the first part is the literature study about the passive house, information will be gained mainly from the previews studies. To continue, in oder to gain more information from the already done projects in Europe, an interview with the company Swedish Housing (Svenska Bostäder) will be included in this paper. Then in the next section of this thesis, we will analyse the actual situations of processing passive house standard projects in China. Since it is hard to get information about this unfinished projects, therefore hypothetical calculation will be used to test the economic aspect of the developing passive house in China. This method also can be understood as the quantitative analysis. As well as this is the first time of passive house introduced into China, so a survey to the public of passive house is necessary. In this survey several questions about passive house will be included. Such as " how much do you know about passive house," and " "Willingness of paying for passive house". Based on all these methods, an comprehensive feasibility analysis of developing passive house in China is presented.

3. DEFINITION OF PASSIVE HOUSE

3.1. Historical Facts

At the very early stage of time, people used wood as the source of heating. Hundreds of years have passed, it has changed a lot for the source of heating. The generating of passive house is not only a coincidence but also an inevitability.

Based on the historical point of view, energy crisis is one of the main reason for building legislation change. In 1760, open fire were the only way of heating inside the houses of Sweden. Wood were the main source of material for heating. Due to the huge number of wood were needed to produce charcoal for the iron industry, the price of wood increased dramatically. This leads to the first energy crisis of Sweden (Smeds, J, 2004). As the time goes by, a new type of tile stove was invented by Carl Johan Cronstedt and Fabian Wrede in 1767. With their complex designed heating system, more rooms can be heated at the same time with the same amount of wood. The major contribution of this invention is that it improved the efficiency of the heating up to eight times than its predecessors and reduced the high price of wood (Sjoberg, L et al, 2004). With the develop of technology the tile stove and fireplaces were replaced by the coalfired central heating systems. Since then energy source for heating system has become important. After the World Wars I and II, in 1950s Sweden went through the shortage time of energy sources as well as all other countries in Europe. Coal became more precious than ever. Compare with coal, oil were much easier to gain. It began to replace the coal being as the main source for central heating system (Smeds, J, 2004). When Egypt took control over the Suez Canal in 1956, there has been a short-term impact on the energy price. However it was still believed that oil was the best energy source. In 1973 OPEC started to reduce the supply of oil, it has lead to the fact of increasing oil price. Due to the huge dependency on oil unemployment rate went up immediately in many countries around world. The Swedish way of solving this crisis was to implement building regulations. More district heating system should be used.

More and more house owners can heat houses with electricity. In 1980, the second oil crisis happened, it gave support to the generation of new energy for heating system of houses.

In the 1980s, a new energy standard for new buildings was legally issued in Sweden and Danmark, and this new rule was low-energy building. Since then many new technique for reducing the energy consumption of building has been developed. For instance, airtightness, insulated glazing and heat recovery ventilation (Feist W, 2006). In this case, it leads to the generation of concept passive house. The term passive house (Passivhaus in German) was first brought out in a conversation between Professor Bo Adamson of Lund University, Sweden and Dr. Wolfgang Feist of Institute for Housing and the Environment, Germany(Institut für Wohnen und Umwelt) in May,1988 (Feist W, 2006).

3.2. What Is A Passive House

Passive house is not just a brand new term, but the leading standard in the energy efficient construction field. Many studies have compared passive house with energy saving building, though it is a concept more than just a energy saving or green building. With the help of passive house, energy savings can be up to 90% compared with typical central European buildings (Passipedia). The exactly concept of Passive house is that "A Passive House is a building, for which thermal comfortcan (ISO 7730) be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air." (Passipedia) With the insulation passive house design, a comfortable indoor environment can be achieved. The heat from residents and solar heat entering the house can be used as the energy source. In this way, more than 75% of heating energy has been saved. (Feist W, 1993).

More specifically, according to the study of Dr. Wolfgang Feist (1993), we can have a better knowledge of the passive house concept. It is said in his studies that most parts of the central Europe are the areas with quite cloudy weather, therefore it is not surprising to find that most of the energy demand of area is for space heating. It has the largest percentage of the total usage. Also Feist (1993) mentioned that most part of Central European are using radiators, pipes and oil or gas boilers as hot-water heating system in the building stock. Usually, the maximum heat load is about 100 W/m² {32 Btu/(h ft²)} or 10 kW {34.2 tons} for a 100 m² {1,080 ft²} dwelling (Feist 2006). If adopting passive house design, the heat consumption can be reduced to such a small percentage, that there is no need to keep the separate heating system. When the maximum heat load reaches the level of less than 10 W/m² {3.2 Btu/(h ft²)}, the heat can be easily spread just by the supply air. In other worlds, if this required heating level is reached, the building can be named as a passive house. (see the figure 1)

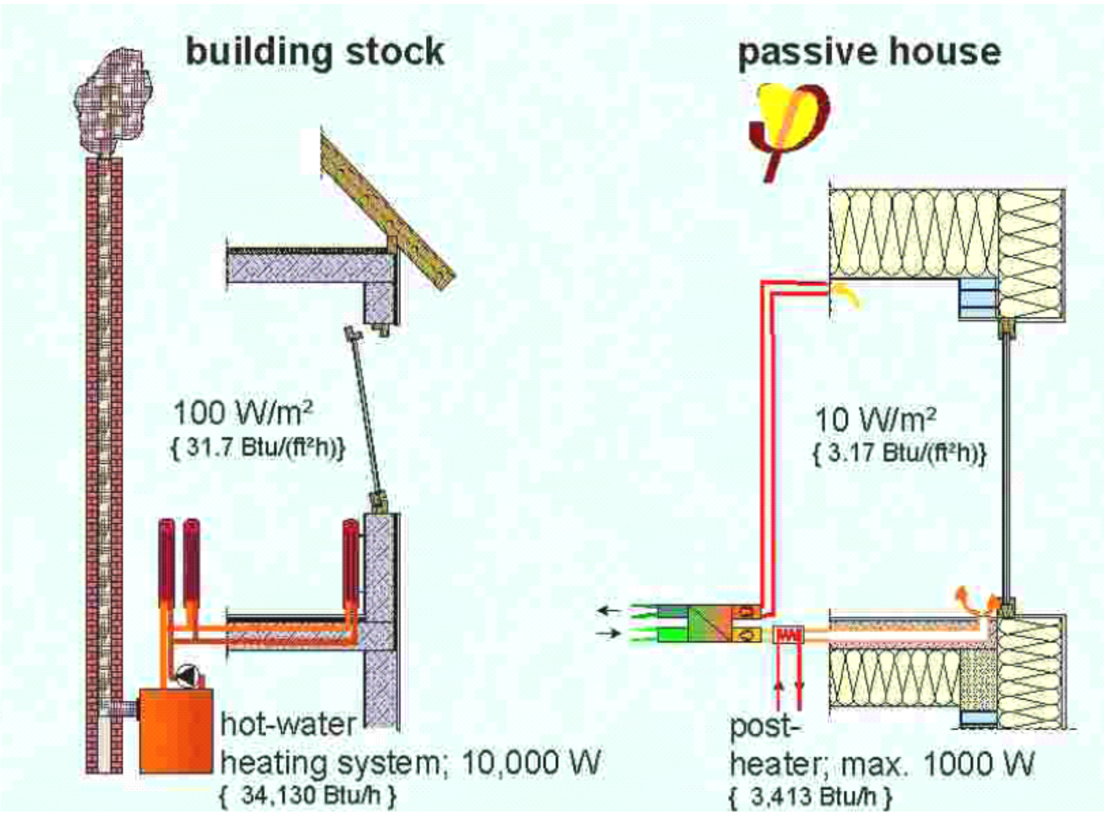


Figure 1. Comparison of radiator heated . (Wolfgang, Feist 1993)

3.3. Work Principle

Since no natural energy resources such as oil and coal are used in a passive house, it is believed that passive house is much more sustainable compared with the standards buildings. For passive house, there is no reliance on gas for heating or air conditioning. They are designed in a certain way to gain the energy from sun and transfer these power to heat and cool the building (Desbarats G 1980, 232). As the energy price keeps increasing, cheaper energy of a passive house are in a such competitive position. Then here comes with one question , how does a passive house work to heat and cool the building with such a low price ?

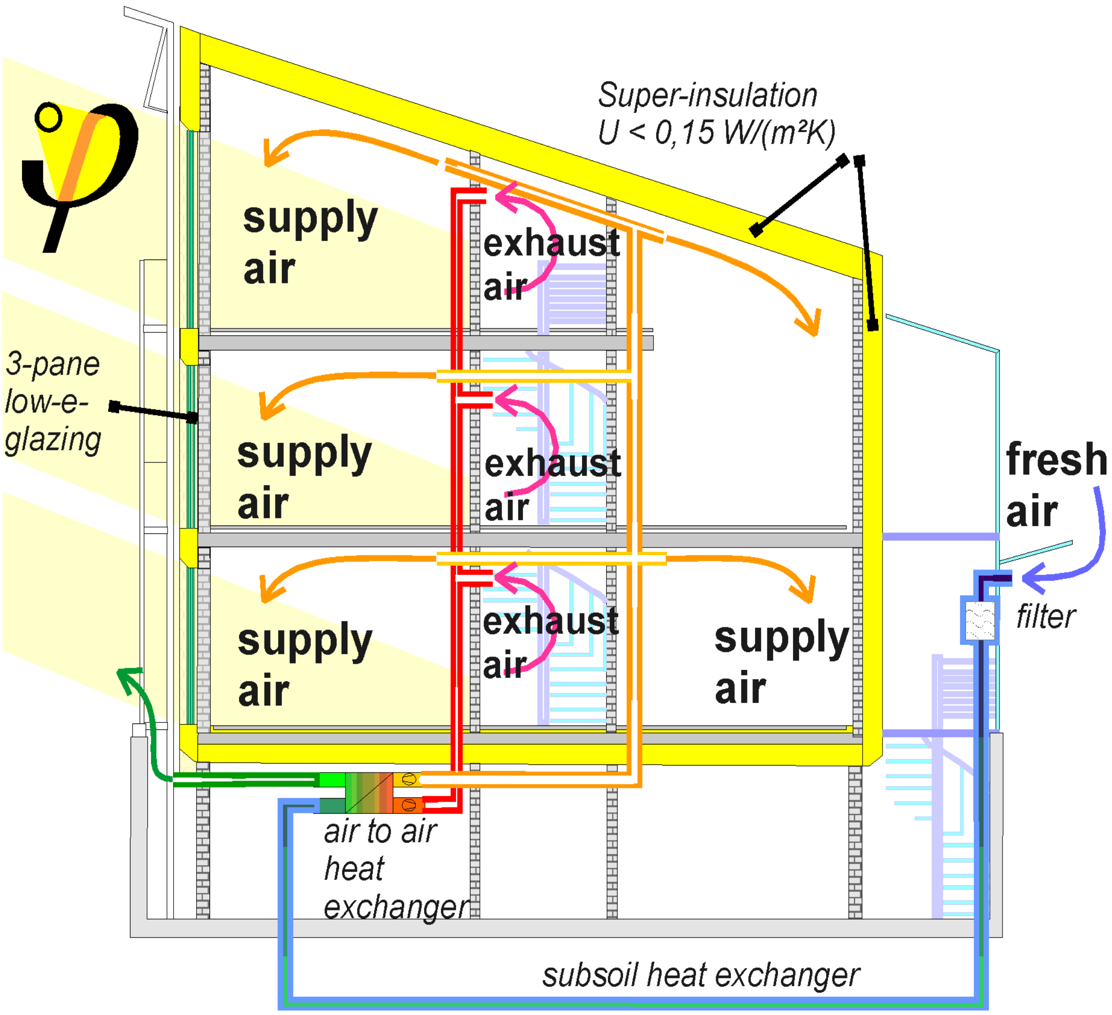


Figure 2. Passive house working principle. (Wolfgang Feist 1993)

The design of the passive houses may vary from different climates zone, however the work principle are as the same as the first original passive house. There are several key strategies to achieve the essential idea of a passive house.

3.3.1. Insulation

Firstly, Super Insulation (see the figure 2). To achieve this, several elements are included. Before going deep about this part, one important term which is U-Value should be defined first. It is a way to value the heat losses through a standard building component, for example, external wall, floor, ceiling or roof, formerly named K-value. (Passipedia) It stands for the efficiency of the insulation. It can be understood that the smaller the U-value, the better the level of insulation. Table 1 shows an example of the heat losses for a typical European single family house with an 100 m² external wall area (Feist W, 2006).

U-value *W/m²K*	**heat loss rate** *W*	**annual heating losses** *kWh/yr*	**annual costs external wall only (2005)** *€/yr*
1.00	3,300	7,800	429.00
0.80	2,640	6,200	343.00
0.60	1,980	4,700	257.00
0.40	1,320	3,100	172.00
0.20	660	1,600	86.00
0.15	495	1,200	64.00
0.10	330	800	43.00

Table,1. U-value. Wolfgang Feist , 2006.

According to the study of Feist (1993), in order to keep the house cool and at a comfortable and constant temperature, passive house is designed in a certain way of using Super-insulated frames which is U~0.15 W/(m^2 K) {~R-40} ceilings, walls and slabs: insulation thickness 25-40 cm {10-16 inch}. It is a single move with two advantages. As Feist (1993) mentioned that with this super insulation design, heat can be kept inside during the winter time with less energy consumption. Less energy is needed to ensure as good thermal comfort a in the conventional houses. Also the insulation design helps keeping the extra heat outside the house in the summer time, and maintain a comfortable and consistent temperature inside the house. To implement the super insulation, there is another element is included which is high efficiency windows. As shown in the figure 2, triple pane R-8 superglazings with two low-e coatings are adopted in the design of a passive house (Feist W,1993). This glass with a U-value of 0.7 to 0.8 W/(m^2 K) helps with retaining solar heat from the sun, which guarantees more heat can be kept inside the house in winter time.

3.3.2. Airtightness

Another essential element of a passive house is the airtight construction. The water vapour content of the inside air is higher than the outside door air, if any cold outside door air penetrates into the house, the inside air will be cooled, and the cooled inside air can not keep the same amount of water vapour, leading to a condensing inside the construction. This is a potential serious damage for the house. (Passipedia) This is the reason that the outside construction should be airtight for the passive house. Also based on the study of Feist (1993), we find that the airtight thermal envelope design can reduce the thermal bridges in a passive building to about zero, which is important for energy saving. After the construction period, the actual level of airtightness will be tested, different countries have different standards for it. In Germany, the standard for the air leakage should be not higher than 0.6 h^{-1}(air changes per hour). In Sweden, the standard is almost the same, which is expressed in different units of 0.3 l/s, m^2 .

3.3.3. Ventilation

The next strategy of a passive house is Mechanical Ventilation with Heat Recovery. It is the main source for the space heating inside a passive house. As mentioned, airtight is one of the characteristics of a passive house, proper ventilation is even more critical for a passive house. In order to exchange the inside air, as shown in the figure 2, a filter has been installed outside the house, which is the only way for the air coming inside. Fresh air can be gained through this filter. Underground there is a subsoil heat exchanger connected with the air filter. This is specific for earth heating, it is not necessary for all the passive house. As showed in the figure 2, the exhaust air from the polluted rooms such as kitchen and bathroom can be emitted from the red pipe. In return, fresh air can get into the living rooms through the yellow pipe (Feist W,1993). However the exhaust air is not just emitted. Before it came outside, it will go through the Heat Recovery Ventilator, which is the air to air heat exchanger in the figure 2. The cold fresh air from outside meets the warm inside exhaust air inside the heat exhanger, fresh air will be heated up then inlet to the living roomswith the temperature of 20-22℃. At last, exhaust air outlet the house with a lower temperature , (Passipedia) Due to the heat recovery, the temperature inside rooms can be comfortable and consistent. Meanwhile the insulation of the house has been strengthened. As mentioned above there is almost no heating requirement inside a passive house, however in the very cold climate, there is a need of using some other methods to secure temperature of heated air. Additional solutions may be needed to improve the efficiency of ventilation system. (Passipedia) For example, after the introduction of passive house to USA, some more methods have been found to heat the incoming air. For instance, Small combustion unit for biomass fuel and Small condensing gas burner. (Passipedia)

3.3.4. Climate Zone

The principles above is a general rule for all the passive house in all climate zones around the world. Insulation system works as thermal in cold days and keep warm inside, during summer time, it will keep cooler inside the house. However different countries have different traditional building style and special climate conditions, the specific design of the passive house project will be quite different. Depending on the different climate conditions, some solutions need to be adjusted, such as degree of insulation, U-Value for windows,or shading etc. Also in some cases, floors are used for the heating on the consideration of the people's lifestyle. In Central Europe, such as Germany has developed a lot of experience of building passive houses, however when coming to northern Europe countries, like Sweden, although same passive house standard has been adopted, some adjustments have been done to meet swedes habits.

4. EXPERIENCE FROM EUROPE

4.1. First Passive House

Since the developing of passive house is much more mature in Europe than the rest part of the world, therefore there is such a need for China to gain knowledge and experiences from Europe to build passive houses. It has been more than 20 years since the generation of the concept passive house, there has been more than 15, 000 residential passive houses, and the vast majority of them are built in Germany and Scandinavia (Rosenthal E,2008). The first demonstration project of passive house residencies were built at Darmstadt near Frankfurt of Germany in 1990, after that several projects of passive houses have been constructed in the central Europe (Feist W, 1993).

Picture 3. Passive House Darmstadt Kranichstein, Photo: H.G. Esch.

4.1.1. Design

The first passive house at Darmstadt were designed by the architects Prof. Bott, Ridder, Westermeyer for four private clients (see the picture 3). This passive building is a four unit row house with each unit having a floor area of 156m² (Feist W, 1993). It is the first building that has such a high energy efficiency with an annual heating requirements of 10 kWh/(m²a). Also it is the first time of adopting insulated windows frames. According to the report of Dr. Wolfgang Feist (2006), 5 building elements are included in the construction of this house. The First one is the roof. As mentioned in the work principle part of the passive house, the most important element is to achieve thermal insulation and heat recovery ventilation. Therefore it is critical to select and use the exactly materials for the roof. The grass roof with the functions of humus, filter fabric, and root protective membrane has been adopted for this passive house. The U-Value of he roof is 0.1 W/(m² K). The next element is exterior walls. To reinforce the insulation, fabric is used to strengthen the external plaster, also with the emulsion painted wallpapers. It has a value of U~0.14 W/(m² K). For he basement ceiling, materials of fiberglass is introduced to the reinforced plaster skim coat. With this design, it has a value of U~0.13 W/(m² K). For the windows, a special design has been done to consolidate the insulation, which is triple pane glazing with Krypton filling and U~0.7W/(m² K). Also for the wooden window, polyurethane foam insulated framework has been adopted in the construction. The next important aspect in the design of the passive house is the heat recovery ventilation. In this project, designers made the decision of using the counterflow air-to-air heat exchanger. It is placed in the cellar. This is the first time to use electronically commutated DC fans for the heat exchangers.

After this first passive house being put into uses, a test has been done in October 2001. According to the results of this test by Dr. Wolfgang Feist, the function of airtightness still does work. There is a vacuum tube collector used for heating the hot water, another extra heating source is from the natural gas. About 66% of the hot water used in the house are coming from the solar thermal system. In the central Europe, it the freezing period of temperature during December to February. Winters are quite cloudy, in case of losing so much heat in winter, Dr. Wolfgang Feist (2006) mentioned in his report, "For the first Passive House at Darmstadt Kranichstein we did not yet dare to do without radiators." continued with Dr. Wolfgang Feist's report (2006), however, there is evidence from the following projects after passive house Darmstadt Kranichstein which proved that the maximum heating loads of a passive house in winter were less than 10 W/m^2 of floor area. So this heating requirements can be comfortably achieved by using the fresh ventilation air.

4.1.2. Efficiency of Energy

Is has been measured that under the conditions of the available technology, the electrical consumption for the households in the passive house Darmstadt Kranichstein has been reduced by 30%. Moreover, the natural gas consumption for additional heating has been reduced by 15% , what is more, with the design of the heat exchangers, a 80% of heat recovery efficiency has been realised (Ebel and Feist, 1997).

4.1.3. Economical Aspect

In the study of Feist and Werner (1994), several tests have been done for the passve house at Darmstadt Kranichstein after the completion of the construction process. According to the tests results, the initial objectives of passive houses have been reached. Compared with the heating energy consumption of traditional dwelling, passive house is only 8% of that in the first year 1991/92. When coming to the second year which is 1992/3, it is not surprisingly to find the fact that passive house is only of 5.5% heating energy consumption of other normal dwelling. Without doubts, the expectations of economical aspect for the passive houses had been successfully fulfilled. Much more of the energy cost have been saved for the households. Even in the extreme cold winter of 1996, the passive houses at Darmstadt were not only still comfortable warm inside, but also kept the low level of the energy consumption.

4.2. Demonstration Sites In Sweden

As mentioned above, the majority of passive houses are completed in the German speaking area and Scandinavian area, thus three example passive house residential sites in Sweden have been investigated. As Ulla Janson (2008) stated in his study of the passive house in Sweden, energy consumption of the residential sector is accounted for 36% of the total energy in Sweden. A decision has been made by the Swedish parliament in 2006. Specifically, that the energy consumption of the residential sector should reduce by 20% per heated unit area before the year 2020. Which means more energy efficient residential houses should be built as a strategy to respond this new policy. It is seems like that processing passive house is an appropriate choice in Sweden. Also studying of the finished projects is one good way to make improvements and developments of passive house.

4.2.1. Oxtorget - Värnamo

Värnamo is located in Värnamo Municipality, Jönköping County, southern part of Sweden. And Oxtorget is at the central part of Värnamo. Five multifamily passive houses were completed at Oxtorget in 2006 (Janson U, 2008). This project was built for the client of Finnvedsbostäder which is the public housing company in Värnamo. There are all together 40 rental apartments in 2.5 storeys. Treated floor area is 598m^2, with 2 to 5 rooms in every apartment. This project is designed by Architect Karin Arvidsson from BSV Värnamo. After the completion of the construction, the tenants moved in during june 2006 (Janson U, 2008). (See the site location picture 4)

Picture 4. Picture: bsv arkitekter, Värnamo.

Picture 5. The Oxtorget passive house.

http://www.bofast.net/1/1.0.1.0/65/1/?item=art_art-s1/1047 2011-02-01

There are two types of the houses, each of them contains 8 apartments. Each apartment has their own entrance enclosures which are the uninsulated area used for airing during the summer time. Also from here you can get a good view of the whole apartment. The kitchen and living rooms are directly connected with the balcony on the south-west. With the design of big windows, enough light can be gained during the daytime. During the summer time, windows and balcony doors can be let open to gain more light and fresh air for the houses. (see the picture 5) The main materials for the loading bearing structure of the houses are concrete and cast (Janson U, 2008). According to the study of Ulla Janson (2008), following data can be gained.

To reach the passive house standards, basement floor is designed with a U-Value of 0.09W/m2K. Exterior walls, U~0.10 W/(m^2 K); Roof, U~0.07 W/(m^2 K); In order to achieve the insulation, wooden roof was mounted on site. Insulation was completed on a sheet of particle board, then roof slope. Using of particle board is to make sure that processing of roof insulation is properly ventilated. A plastic foil is placed facing the room to ensure the impenetrability. For windows,there is an average value of U~0.94 W/(m^2 K), and Entry door, U~0.60 W/(m^2 K). It is hard to find any entry door with such a low U-Value in Sweden, therefore the only way is to design and produce the these special doors on their own. The plnned level of airtightness is 0.21/s m^2 at 50 Pa, but after the construction process the airtightness is tested to be 0.41/s m^2 at 50 Pa. Although the final figure is not the same as we expected, it is still good enough for a passive house standard house in Sweden. In order to achieve the heat ventilation, there is one single air-to-air heat exchanger in each apartments. Moreover, an active solar system on the roof of each house has been designed to meet the needs of domestic hot water. During the cold winter days, an electric heating battery has been placed to deliver heat in the supply air (Janson U, 2008). Based on the results from the measurements from the developer of this project, it is can be gained an 85% efficiency of the heat exchanger. For the purpose of keeping tenants feel comfortable inside the houses, the temperature is set to be 20°C inside the house. To help the tenants learn about the temperature inside the houses, there is a special design of installing a small energy bill. On the wall , a small display mount will show the current figure of temperature inside the house. For the better thermal comfort, such as in the bathroom, there is an electrically heated towel rail in each bathroom (Janson U, 2008).

After the tenants moving in, some records have been reported by Finnvedsbostäder. They pay SEK 1.20 / k Wh for the consumption of electricity including the fixed cost, which is a large cost saving for the households. The final cost for the clients of this project was SEK 55 700 000 including total cost and purchasing cost, and for the contractor was SEK 36 700 000. Compared with other regular residential projects that Finnvedsbostäder have built before with the cost of SEK 15 000 /m^2 , this passive house standard project is SEK 2898/m^2 more than that. As we can see that there is a big difference of the cost between clients and contractor, that is the money had been spent on the design stage (Janson U, 2008). The average residential rent has been calculated by the Swedish Public Housing Company. In 2004, the average rent of Sweden was SEK 754 /m^2 for the regular houses. For this new passive house standard houses the average rent level was SEK 888 /m^2 not including heating. Based on the study results of Ulla Janson (2008), for passive house standard residential site, the rent (no heating,electricity and domestic hot water including) for apartments are :

2 rooms, 62 m^2	3 rooms, 80 m^2	4 rooms, 105 m^2	5 rooms, 107 m^2
SEK 5 100 984 SEK/m^2	SEK5700 852SEK/m^2	SEK 7 600 862 SEK/m^2	SEK 7800 876 SEK/m^2

Table 2. Rent for different types of apartments.

4.2.2. Villa Malmborg - Lidköping

The next demonstration site is the first single-family villa passive house in Sweden. It is located at Lidköping near the lake Vänern in Lidköping Municipality, Västra Götaland County, Sweden. (JONAS, B. 2008) In April 2007, the project was completed in compliance with the passive house standards. As Ulla Janson (2008) mentioned in her study, the Malmborg family has lived in a traditional Swedish single-family house which was constructed in 1970s for years. The old house needs a large mount of maintenance. Then the family decided to cooperate with Vårgårdahus which is a small company with the business of building single-family houses. Together with architect Hans Eek, the old one will be rebuilt into a villa with two storeys and one separate garage, with a total 171 m^2 living area. (see the picture 6,7)

Picture 6. The old Villa Malmborg, Photo: Jonas Wedebrand

Picture 7. The new Villa Malmborg, Photo: Mikael Malmborg.

Even if the Villa Malmborg is a single-family house, we also strictly meet the requirements of passive house standards. Here are some main requirements for villa malmborg. For the windows, we have a average U-Value of 0.85 W/m^2 K for the operable windows, which is the same as planned at the very beginning stage of the construction process. These windows were bought as the fixed windows with a total U-Value of 0.71 W/m^2 K. Regarding to the energy saving, different size of the windows have been designed. When building the outer wall, the U-Value is set to be 0.09 W/m^2 K. These walls were mounted on site. The outer walls is made of mineral wool in a wooden frame construction. According to the original structure of the villa, the outer roof was designed to be with a 10° slope. Steel sheeting covered roof has a U-Value of 0.08 W/m^2 K. To gain more light in the house, one small window was installed on the roof. The skylight window has a U~1.0 W/m^2 K. For the floor facing ground, the U-Value is 0.103 W/m^2 K. Normally the airtightness is measured in the factory before the installation of the walls. However in this project, the measurement had been done on site after all the parts of the houses were mounted. According to the measurement, the airtightness is 0.2 l/s, m^2 at 50 Pa. After the clients moving into the house, they claimed that there was a problem of air leakage around some windows. Therefore, a new measurement of airtightness had been done. The results showed that the metal nailing plates used for fixing the windows were the reason of the air leakage.

In this villa, no solar collector equipments has been installed. The domestic hot water were directly heated. The same as the project of Oxtorget, house is heated by the air, and the air is transferred by the ventilation system. The air-to-air heat exchanger efficiency is 85% during the first year (Janson U, 2008). The temperature inside is kept around 20°C , it depends on the preference of the households. According to the clients (2008), after one year's living in the villa, the consumption of heating for warming stopped at 3071 kWh at April 19, 2008.

According to the study of Ulla Janson (2008), the clients paid SEK 103 400 for rebuilding the villa, which also meant to be SEK 21.75 /m². For the water and drainage, the cost was was SEK 26 940 or SEK 24.50 /m². Since it was a single family house, so the connection to the electricity grid is necessary. It costed like SEK 17 500. As mentioned before, there were no solar collectors for this villa, therefore the clients paid SEK 40 000 for the connection to the heating system. In the following year, they will be charged a fee of SEK 777 per year, or SEK 0.55 /kWh. for the further maintenance and operation of this villa, it is believed that there will be an additional cost of 10%-20%. As the operator Vårgårdahus company mentioned in their report for this project, the whole process of this project took much more time than an ordinary project. Especially more time have been spent on the planning process. Compared with other normal houses project, it is not profitable for the company to process the passive house project, even if they can get paid more money. However, it is said that every coin has two sides, there are also benefits existing for the company to complete passive house project. As we know that, passive house is a new concept to the public. After the completion of Villa Malmborg, almost every media was talking about this project, it has been the headline for a while. Thanks to the advertising on the newspaper, television, radio, and Internet, public knows Vårgårdahus company better than before. The value brought to the company in this way can not be calculated. Based on the experience gained from this project, Vårgårdahus company is discussing for the opportunity of starting an exclusive line of passive house business. This might increase the profits for the company in the future (Janson U, 2008).

4.2.3. Hökarängen - Stockholm

Compared with other cities in Sweden, Stockholm seems to lag behind in the development of passive house. It has been 3 years since the first passive house of Stockholm hits the media. It is called Passive house Granbäck, located in Vallentuna, at the north part of Stockholm, Sweden. This project is a single family house built by Andreas Granbäck and his partner Linda Wester.

After 3 years development of the passive houses in Stockholm, more and more passive house standard projects have hit the market and public. The residential project-Kvarter Blå Jungfrun is one of them. It is the first passive house standard rental project located at Hökarängen, the southeast part of Stockholm. On distance, it is about 10 miles away from downtown and 20 minutes from the central station by metro. (Kvarteret Bla Jungfrun) In order to gain more information about this project, an interview with Allan Leveau who is the Nybyggnadschef, Teknikavdelningen/ Nybyggnadsenheten of Swedish Housing Company has been done on the Feb 11th, 2011. According to the interview, in order to achieve the EU directive of "developing energy-neutral new buildings, and national energy efficiency action plan ready 2011 with energy effectivisation during renovation", Stockholm started its first rental passive house project in 2008. This residential project is constructed by a Swedish company-Skanska which is one of the world's leading construction company. The project was requested by Swedish Housing (Svenska Bostäder in Swedish). It is the largest municipal housing company in Sweden owned by the city of Stockholm, with the slogan of " Caring for Stockholm and its residents since 1944".

Picture 8. Kvarter Blå Jungfrun . (http://www.skanska.com/)

After planning section of the project during June and October 2008, it started to construct the main part of the building. The first group of tenants moving in is during May and June in 2010, and the last moving in is from September to November of 2010. As planned in the preparing section, 97 flats in four blocks have been completed at the end. Four different types of apartments are included. See the tables below. The goal of this project is to achieve " good and environmentally effective waste management, no environmentally dangerous substances in buildings, sound indoor environment, minimize effects on climate and develop environmentally construction." (Svenska Bostäder)

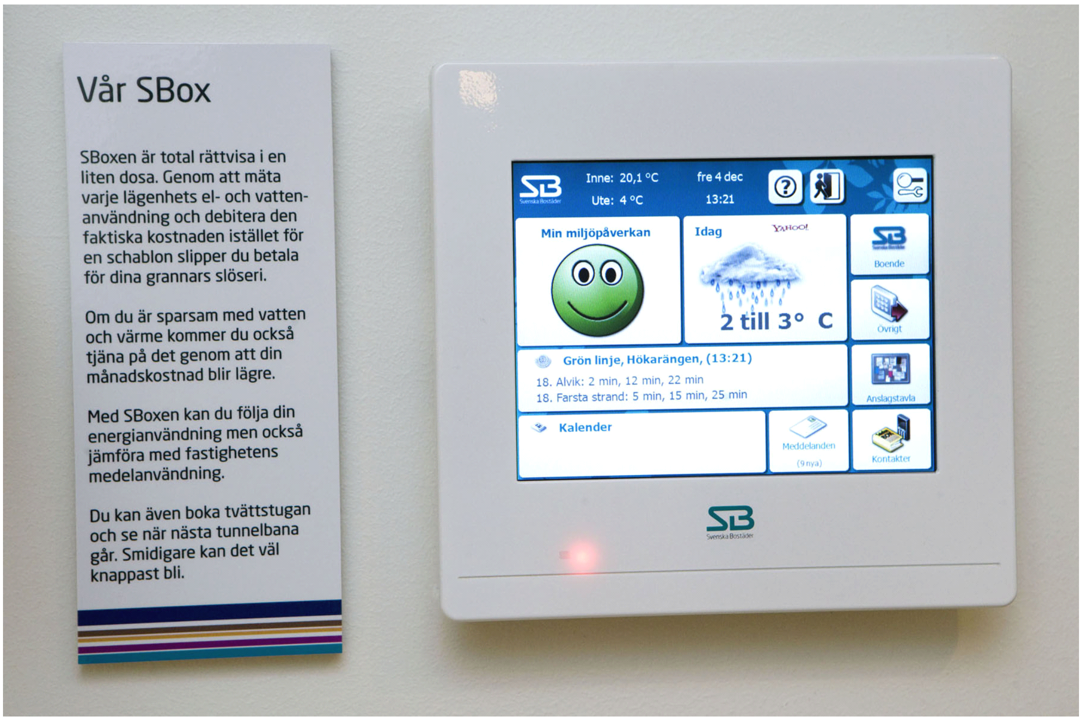
Project Kvarteret Bla Jungfrun

Type	Number	Area (Sqm)	Rent / month SEK
2 Bedrooms apartment	21	53 - 55	6280-6389
3 Bedrooms apartment	36	73 - 85	8203-9333
4 Bedrooms apartment	20	88 - 105	9454-10786
5 Bedrooms apartment	20	111	10606-11657

Table 3. Types of apartment

In each building, there are four storeys. Every apartment has a large and private patio or balcony facing south for enjoying the sunshine during summertime. The special and unique about this project is that a small machine with a full size screen called sbox has been installed in the hallway of each apartment. Household can easily learn about the consumption of the water and electricity and some basic weather temperature information from that. Also booking of the laundry and the time schedule for the subway and buses can be informed by this smart box. For the developers, it is much more convenient for them to figure out the differences between theoretic and realistic consumption of water and electricity. (see the picture 9) It has been calculated by the SB after one year of living, the result of the energy consumption is supplied by the Swedish Housing. (see the figure 3) Compared with the requirements of the applicable energy legislation 2009 (BBR), this project has a low level of energy consumption. For instance, energy consumption for heating has been saved around 85% compared with the standard of BBR.

SBOX



Picture 9. SBOX. By Johanna Nordström 2010-02-02

Energy using in Blå Jungfrun compared with the requirements of the applicable energy legislation 2009

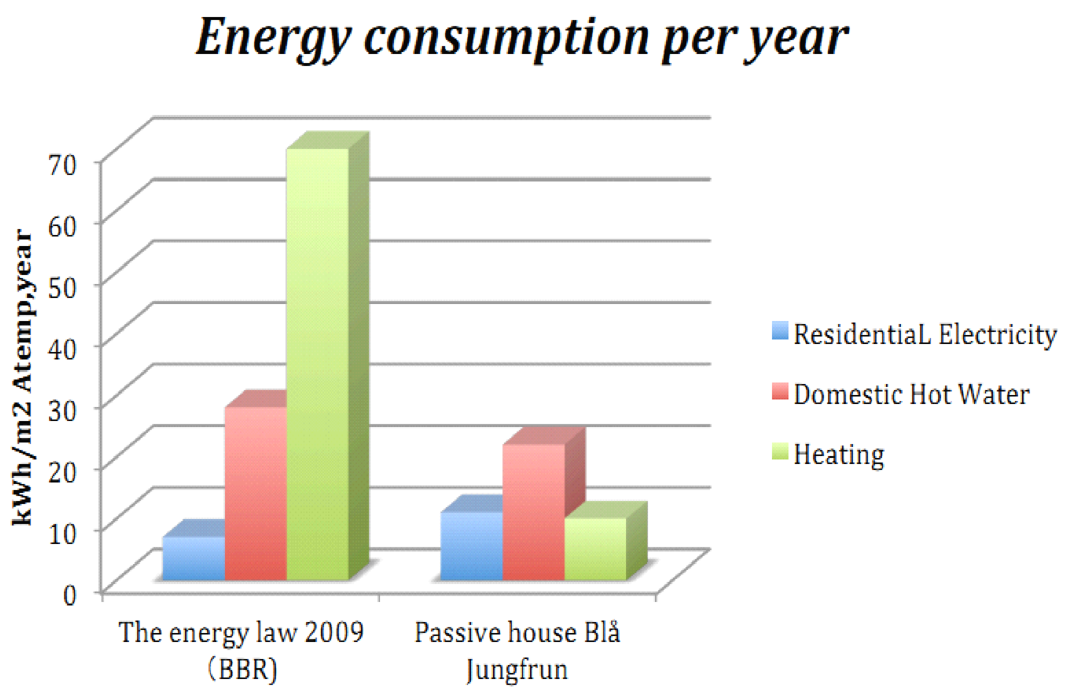


Figure 3. Energy consumption.

As Allan Leveau mentioned in the interview, the U-Value for the adopted windows, exterior wall, roof, and floor facing ground are 0.9 W/m² K, 0.15 W/m² K, 0.10 W/m² K, and 0.15W/m² K. After this project, the airtightness has been measured for these four blacks. The result followed as 0.10/s, m² at 50 Pa, 0.05/s, m² at 50 Pa, 0.08/s, m² at 50 Pa and 0.11/s, m² at 50 Pa. Compared with the required standard which is 0.3 l/s, m² at 50 Pa is way of better. As mentioned in the interview, there is no solar collectors adopted in this project. Also additional electrical heating is installed in each apartment, tenants just pay for the electricity they used. The air heat exchanger has an efficiency between 80% and 85%. As planned, the supplied air has a temperature of 21°+C. After tenants moving in, the actual temperature of apartments has a average level of 20°+C. Compared with other projects accomplished by SB, Allan Leveau claimed that the construction process is much more careful than others. In order to reach the high standard of passive house and minimize the mistakes during constriction process, after finishing the the inside system of first building, the people who constructed the first building moving to the step of processing the second building, exactly the same construction workers were responsible for every single building.

According to the information maintained during the interview, the construction cost based on the latest forecast from Skanska is 167920 kkr. It can be understand as that the construction cost is 20500 SEK/m² for the BOA (BOA is the actual livable area). Plus the 25% taxes and fee for developer, then the construction cost is 27200 SEK/m² . also it has a construction cost of 14400 SEK/m² for the BTA (BTA is the total space, including wall thickness and other spaces not used for living), after the taxes and developer cost, the construction cost is 19 000 kr/m² . In this project, 97 apartments have a BOA area of 8 173 m² and a BTA area of 11 681 m² . Due to the passive house standard, 5% additional cost have been spent on this project compared with other conventional ones. For a 77 m² apartment, the rent is approx 8900 SEK/month. The withstand level of this project is 28 000 SEK/m² for BOA, and 19 600 SEK/m² for BTA. In other words, if only calculated the BOA area,this is a project with a profits of

800 SEK/m^2 (28000-27200). For the total area (BTA) in this project, the profite should be 600 SEK/m^2 (19600-14400).

At the end of the interview, another question has been discussed. There might be a problem of noise for the tenants who live at the top floor. That is because the air to air heat exchanger is placed at the top floor of the building which is the roof for the tenants who live at the top floor. However there has been no complaints about the noise from the tenants until now. As Allan Leveau said this interesting factor would be investigated in the next time tenants' survey.

4.3. The Rest of Europe

At present, passive house standard has been the stream of low energy in the whole world, approximately 17,000 Passive house buildings worldwide. Also more and more renovations of passive house projects has been already processed in more than 38 countries in the whole Europe. Such as Sweden, Norway, UK, Germany, Austria and Switzerland, etc. Not only flat blocks projects, but also commercial office buildings, gyms and schools have been completed in the passive house standard in Europe. (Feist, W. (2010) Although statistical number of the passive house standard projects in Europe is limited to some factors, there is no doubt that the biggest number of passive house standard dwelling is in Germany and Austria. It is estimated that there are around 9000 dwelling projects in Germany, 500 of them are located in Hamburg city. These 9000 projects are only that fulfill the passive house standard also registered. By saying the passive house standard which is established by Passive House Institute Germany, Darmstadt. (passiv.de) Moreover there must be other projects adopting the passive technique without fully achieving the passive house standard. According to Passivhuscentrum, there have been only constructed 400 passive house standard projects by 2009. The number is estimated to be 3000 in 2011.

5. PASSIVE HOUSE IN CHINA

5.1. Demonstration Project In China

Passive house can be considered as the new standard of energy saving or green building. As mentioned above, the Tulou from old time of China are the original model of passive house. It might inspire the people today to develop passive house technique, especially for the passive house development in China. In 2010 Shanghai World Expo, building with the name of Hamburg House is the first certified passive house in China. It is a four storeys building combining both office and residential using. According to the interview with Carsten-Ludwig Lüdemann who is the secretary of Hamburg, Germany, he described "Hamburg House" as a special gift to the Shanghai World Expo. This project is built up referred to the project of H20, it is a passive house standard building in the "HafenCity" of Hamburg City. He hoped that this new type eco-friendly house could bring some uesful ideas to the real estate field of China. "After the exhibition, "Hamburg House" will become the property of the municipality and a symbol marking the friendship between Hamburg and Shanghai", Ludemannsaid. (Xin Hua Daily)

Picture 10. Hamburg House. (Xin Hua Daily)

However this building is just used as one of the exhibits, no planing for any actual residential or office using. Therefore we can say that it is not the formal real "first" passive house project in China (Lin, C 2010).

5.1.2. Current Project

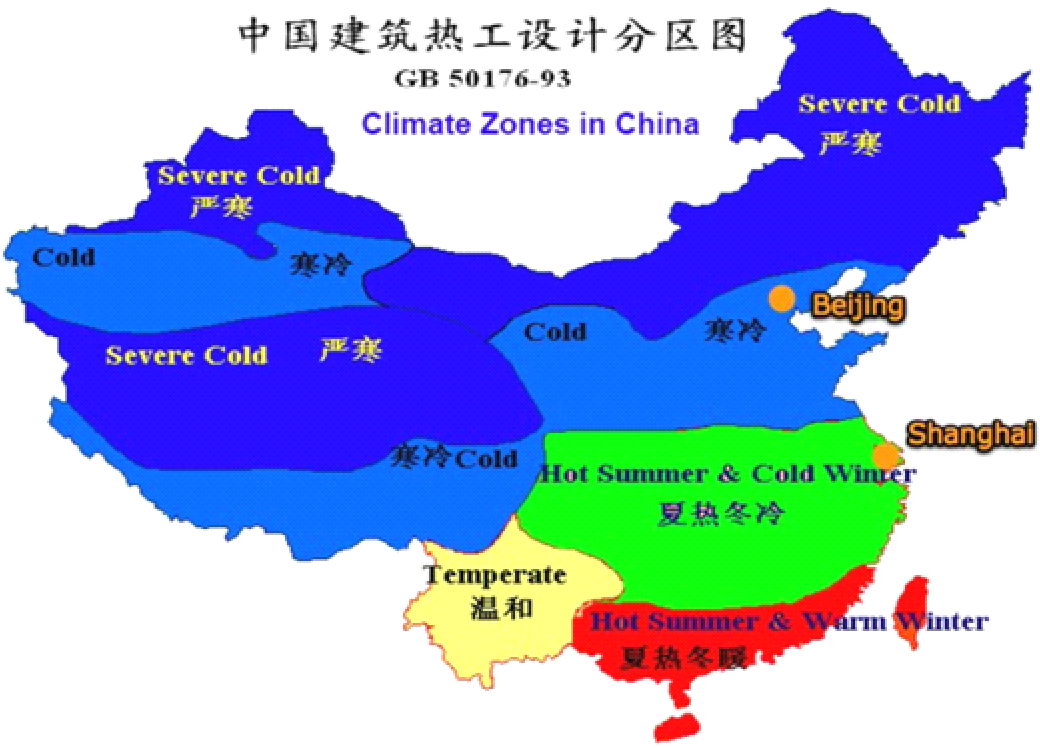
Being inspired by the Hamburg House, another passive house standard project is under processing in China at present. It can be marked as the first passive house standard project that will be put into actual using. This project is located in Chengdu city, Sichuan province of China. With the name of Northern New International Port Of Things, this 4.8 million square meters project aims to be the first port for Hardware and Electromechanical trading base in China even around the world. By integrating the technology of Internet of Things (IOT), Radio Frequency Identification (RFID), cloud computing, and e-commerce, to achieve the full perception of the traffic flow, logistics, capital flow, and information flow inside this project. Ultimately changing the traditional Hardware and Electromechanical market into an intelligent and modern trading port. Prof. Ludwig Rongen of Erfurt University , Germany who is also called as "the father of passive house" has reached an agreement with this project as the Chief Technology Evangelist. In the support of Germany government, Prof. Ludwig Rongen will design and participate in the processing of one passive house standard building with construction area of 50,000 square meters inside the project of Northern New International Port Of Things. It will be used as a building combined business and brand exhibiting. As Prof. Ludwig Rongen said that with the help of the influence of this biggest passive house standard building in the world to promote the development of low-carbon and energy-saving building in China and the whole world.

According to the interview with Yulin Yuan who is the vice president of the project developer , in order to fully reflect the architectural concept of Prof. Ludwig Rongen , an additional 15% budget has been approved. What is more, the project is estimated to put into use in the year of 2012. As reported, an annual open day will be set for free to the public, it can help people get a better understand of this new trend architectural concept and promote the concept of low-carbon energy and green residential.

Picture 11. Renderings of the passive house standard building in the project. (Huaxi metro daily)

5.1.3. Climate Zone In China

Along with the rapid both economic and urbanization development in China, the residential energy consumption of most cities raised up in such a speed. Being as the major energy consumption sector, also concerning of the increasing energy price in the whole world, there is such a need for China to process passive energy technique for residential projects. However there are some uncertainties for China to process the passive house residential projects, such as government support, policies, criteria and climate zones. Apparently the first factor that should been taken into consideration is the climate zone. (see the climate zone of China picture 12)



Picture 12. Climate zone of China , China Academy of Building Research 2010.

China is a country with a land area of 9.6 million km². It is a country made up with mountainous and flat plains. These diversities of the complex topography in China contribute to the fact that different regions have different climatic features. As showed in the map above, generally speaking, there are five major climate zones in nine geographical regions of China. Severe cold, Cold, Hot Summer & Cold Winter, Temperate and Hot Summer & Warm Winter. The under processing passive house standard project is located in Chengdu city which is involved in the Hot Summer & Cold Winter zone. Because of the different temperature of each climate zone, designs of the passive house standard projects can vary a lot from different regions. The average temperature in the coldest month (ATCM) of Severe Cold zone is below minus 10 degree. The hot summer has an average temperature of 25 degree. In the Cold zone, the average temperature in the coldest month is between zero to 10 degree. During the coldest month of Temperate zone, temperature varies from zero to 13 degree, the average temperature in the summer is about 18 degree to 25 degree. When coming to the Hot Summer & Cold Winter zone, the average temperature is more or less as same as in the Temperate zone. On the contrary, in the Hot Summer & Warm Winter zone, the average temperature in the coldest time is above 10 degree, and the average temperature of the hottest month (ATHM) is between 25 degree to 29 degree. (Joseph C, etc 2006) (see the summary 1).

Climatic zone	Temperature
Severe Cold	ATCM ≤ -10℃
Cold	ATCM = 0℃ - 10℃
Temperate	ATCM = 0℃ - 13℃, ATHM = 18℃ - 25℃
Hot Summer & Cold Winter	ATCM = 0℃ - 10℃, ATHM = 25℃ - 30℃
Hot Summer & Warm Winter	ATCM ≥ 10℃ , ATHM = 25℃ - 29℃

Table 4. Summary 1 of the temperature.

City	Annual average temperature	Climatic zone
Shenyang	8.5℃	Severe Cold
Beijng	12.3℃	Cold
Shanghai	16.2℃	Hot Summer & Cold Winter
Chengdu	16.2℃	Hot Summer & Cold Winter
Kunming	14.9℃	Temperate
Guangzhou	22.1℃	Hot Summer & Warm Winter

Table 5. Summary 2 of temperature.

Also temperature of several cities in these different climate zones have been listed as above (see summary 2). Shenyang which is the capital of Liaoning province located in the Severe Cold zone has an annual average temperature of 8.5℃. The capital city of China, Beijing which is in the Cold zone has an average temperature of 12.3℃ during the whole year. In the Hot Summer & Cold Winter zone, Shanghai has the same annual average temperature of 16.2℃ as Chengdu has. Kunming, the city in the Temperate zone has a number of 14.9℃. The Hot Summer & Warm Winter city - Guangzhou has an annual average temperature of 22.1℃.

5.2. Feasibility Analysis

5.2.1. Technical Design

Location

As mentioned above, that there are five different climate zones in China, which is vary a lot compared with Sweden. Therefore in this part, the feasibility analysis of processing passive house standard residential dwelling will be done only focused on one kind of the climate zone in China. In the previous part, three demonstration projects in Sweden have been fully studied, so it will be more comparable if we choose one similar climate zone of China as Sweden. Sweden is in the northern cold part of Europe, where can be considered as the same as Severe Cold zone of China. As we can see in the climate maps of China above, one part with Severe Cold climate is on the Northeast of China. Three provinces have included in this part of China. Liaoning province, Jilin province and Hei longjiang province. The target area will be Liaoning province where I spent more than two decades of my life. The capital city of Liaoning province is Shenyang, with an annual temperature of 8.5℃. Since 1980s the chinese government began trying to promote energy-saving buildings. For instance, in 2006, Shenyang started a new policy to enforce residential building to reach the level of 65% energy efficiency. Under this new rule, the total energy-saving construction area reached 60 million square meters by the end of 2008, also it can be calculated that amount of 50 million tons of coal used for the heating have been saved during the winter time of Shenyang (Shenyang daily). Shenyang is the only city in the Severe Cold zone to implement this standard. Therefore, it s no doubt that the concept of passive house will lead the energy-saving mission of Shenyang city to another new level.

Since there have been no passive house standard residential projects built in China, some hypotheses will be adopted in the studies of feasibility analysis in Shenyang city. It is assumed that there will be a residential dwelling project processed in the passive house standard in Shenyang. The average residential house price of Shenyang city is around 5648 RMB / m² by August 2010 (LING, Y, L.2010). It is supposed to locate at Hunnan New district, it is in southern of the city. This area is a new planned district officially started on october 15, 2001, the development of Hunnan relying on the high-tech industrial. As the the municipal administration claimed that the same development pattern of Shanghai Pudong new district will be adopted in this area, with a goal of developing a new Shenyang in 10 years time. Now after 10 years development, Hunnan New district has turned into the new CBD district of Shenyang city with an average residential house price over 5000 RMB/ m² by August 2010. (Shenyang daily) It can be considered as the most expensive area in Shenyang now. In the preparation period, the first problem should be solved is the design of the each single building. No matter where the passive house are built in the world, building components for a passive house are necessary. They are the insulated windows, airtight building envelope and the ventilation system. These elements are the key to reduce the energy for space heating inside the houses. The familiar actual climate condition of Shenyang as Sweden offers us an opportunity to refer to the completed projects in Sweden.

Project View

It is assumed that there will be 10 dwelling in this passive house project of Shenyang, and each building has six storeys with 12 families. According to the Residential

Design Code issued by the Chinese government in 1999, elevators must be set in a residential building if the building has 7 or more floors. So it is not necessary to build elevator in this project. It is one of the option for developers to reduce the cost. At the same time no elevators design is another way to expand the actual using area for the households. The reason is that in China, the construction area of an apartment is counted of the actual using area plus the public area. And the area of elevator is part of the public area. The percentage of public share for the elevator is usually about 17% - 20%, there is no legal rules for that at present. The next step is to design the building envelop. It is important to place the window of each dwelling in an optimal direction. It can help achieve higher passive solar efficiency. The windows in this project should be designed facing south. Compared with Sweden, northeast of China has the same cold winter but with more sunshine time in the whole year, especially in the winter. South side window will achieve more gain more sunshine in winter. During July to September , in the northeast of China, it is hot summer time. The average temperature is around 28 ℃ to 30 ℃. So a window shade outside the window is necessary to avoid the strong and long time sunshine, and achieving a comfortable temperature indoor. This might be the first time for the residential projects to have window shade in the northeastern part of China. During the spring and autumn, it is the most comfortable time of the year, indoor temperature can be kept in a very comfortable level mainly by the south windows.

Insulation

Passive house standard projects in different area has different U- values to achieve better insulation. For instance, the mean value of the U- values for the building envelopes in Sweden is about 0.1 W/m^2 K, not including windows.(Janson U, 2008) But required number of the Germany standard only needs to be below 0.15 W/m^2 K. The lower the U-value, the higher efficiency of the insulation. Which means lower U-value materials can keep more heat inside the room. Also different parts have different U-values. For the windows, which are the most important factors for insulation should be below 0.8W/m² K for the Germany passive house standards. For the normal residential project in Germany, the U-value is set to be 1.08W/m² K. In China, the standard U-value for outwall windows of the normal residential projects is around 2.0-3.5 W/m² K in the Severe Cold area. This is even much higher than the normal residential standards of Germany, not to mention the passive house standard. Most of the residential housing in China used to have the single tempered glass for windows. After years' development, China is the second country after Japan has the capacity have the product line of vacuum glass. And in the latest 5 years, more and more Low Emissivity Glass (Low E) are adopted in the residential projects in China. According to the information provided by Beijing Synergy Vacuum Glazing Technology Company, one vacuum tempered Low E glass can achieve a U-value of 0.6-0.7 W/m² K. For the double vacuum glass, the lowest U- value can be reduced to 0.44 W/m² K. (ZHENG, J, T. 2008) However, it is not necessary to use such a window with 0.43 U-value. The lower the U-value means more cost of the project. Also combined the experience of the projects in Sweden, it is assumed that the U-value for the average fixed windows in this project need to be 0.8-0.9 W/m² K.

For the roof, U-value should be designed to be about 0.08-0.15W/m² K. Outer walls are supposed to be 0.10-0.15 W/m² K. For instance, to reach the U-value level of 0.13W/m² K for the outer walls, "15.8 metres concrete with a thermal conductivity of 2.1 W/m² K or 6 metres of solid brick with a thermal conductivity of 0.8 W/m² K is needed". (Janson U, 2008) By using of the insulation materials, the required level of U-value for the passive house standard can be reached. It is not hard to find the insulation materials in China. Only the production cost of this project will be higher than the normal ones.

Airtightness

Airtightness is one of the key factors to achieve comfortable indoor conditions. the higher level of the airtightness, the better the insulation. According to the Germany passive house standards, airtightness should be below 0.6 air changes per hour at a pressurisation of 50 Pa. A goal of 0.2-0.4 air changes per hour at 50 Pa should be set for this project. After the construction process, leakage test will be done to see the actual condition of airtightness. In the northeastern part of China, in the summer and spring time, people there are used to open the windows to get more fresh air and enjoy the sunshine in the morning. Based on this habit, windows in this project should be designed to be openable.

Ventilation

Energy consumption for the heating during the winter time is one big part in the total cost amount. Only in the northern Severe Cold part of China is there has an independent central heating system. Most of the heating systems are supported by coal. In the past 5 years, more and more coal heating system has been replaced by electricity heating. But the consumption of the energy for heating is still at a high level. It is said that the existing heating area in Shenyang city is about 86,000,000 m^2, 82% of that are for residential heating. The rest is for the public heating. The consumption of coal for residential heating only in Shenyang is about 240 million tons. The heating price is about 28 RMB/ m^2. Even so, the heating efficiency is at such a low level. (JIN L,O etc,2009) Lots of the energy and source are wasted in this way. If passive house standard adopted in each dwelling, an air to air heat exchanger will not only help providing more efficiency heating, but saving more of the energy source. In the project, an air to air heat exchanger will be set on the top of each dwelling, not in the open air roof. With the help of the heat exchanger, the temperature is estimated to keep at 20-22℃ inside each apartment. It also has the function of circulating the air. Meanwhile, in case of more heating is needed in the cold winter time, an independent electrical heating radiator will be set in each apartment. It is up to each household, when and how much heating you need. The more heating you use, the more you pay. It is much more fair and reasonable than the situations at present. In Shenyang, or we can say in the whole northeastern area of

China, the central heating fee in the winter time for each household is the same and fixed. As long as you need the central heating, then you get the same temperature and cost.

Solar Energy

In the past 10 years, solar energy has been developed a lot in China. Now, it is common for the residential dwelling has one solar water heater in China. According to the regulation set by Shenyang construction committee in 2007, all the new residential projects must be able to install the solar water heaters. Even one solar residential project has been completed in 2007. In this project, at the southern balcony of each apartment one solar collector has been installed. The solar energy collected is used for the consumption of each household's daily living. However, more studies should be done to test whether the solar energy is enough for the daily life use. Therefore, in this project, only solar water heater will be installed on the roof of each dwelling in the open air for the domestic hot water using.

5.2.2. Economic Assumption

Cost

As Schnieders and Hermelink's (2006) mentioned in their study, there is evidence to show that the additional cost for the passive house in Europe is between 10% to 17% or even higher. The higher passive house standard of the residential projects, the more cost of the project. In China, most of the real estate companies are private ones, and most of the projects are for sale not rental. Profitability is the basic requirement for a company to process the passive house standard residential project. As we know that the labour and raw material cost is much cheaper in China. The cost will be controlled in an reasonable way. Compared with the regular residential projects in China, we can get a conclusion of profitability for a passive house standard project in Shenyang.

As mentioned in the above, 10 dwellings with 120 apartments with different kinds of area will be built in Shenyang, Hunnan New district. The average are for one apartment is about 80 m^2 . The total living are is about 9600 m^2 . It is planned that the green space in this project will be another extra 10% of the total living area. Also including the public facility area like parking area, the total construction area will be around 11500 m^2 . All the apartments are for sale instead of renting. There are several parts that are included in the total cost. The basic construction cost is fixed for the regular project. Land cost may vary a lot, depends on the different area. If built based on the minimum standards of the national regulation, the basic construction cost will be around 1000 RMB/m^2 . For the high standard projects, the basic construction cost will be 2000 RMB/m^2 . The higher standards, the more cost will be. In order to achieve the passive house standard, more budget will be spent on the basic construction. Since higher standard windows with lower U-value will be adopted in this project, the cost will be around 150-250 RMB which is 20% higher than the regulaer project. Also the insulation concrete used in the construction will be 5% higher than the normal one. The cost for the insulation of the walls, the training for the workers to gain the construction skills, installation of the solar water heater, air ventilation system, and cost for testing airtight, etc will be more. Also it will cost more in the advertising and design stage, due to this new concept of passive house standard in China. On the whole, the total cost will be 10% - 15% more than the conventional residential housing. Therefore it is not hard to tell that the estimated basic construction cost will be 2200 - 2500 RMB/m^2 . According to the information provided by the Shenyang Land Trading and Reserve Center, the starting auction land price of Hunnan New district is between 1000/m^2 to 2200 /m^2 (Shenyang Land Exchange Center). Taking other unpredictable cost into account, the total cost of this project will be around 3500 RMB /m^2 . As we mentioned above the average housing price of Hunnan New District is more than 5000 RMB/ m^2, even the selling price is starting from 5000 RMB/ m^2, it is still profitable for the developers.

In order to find out the willingness to pay for this new type of residential projects, a small survey has been done. This small survey taken at KTH of main campus during three days, 32 Chinese master students have provided the answers to the questionnaire. Since almost no one knows the term of passive house, i gave a brief introduction of passive house concept to the people before they answer the questions. This survey can not reflect most of the people's willingness. Because the sample is small and all the people who provided the answers all have the same education level and same age level. The result just can be used as an reference in this thesis. At least it can reflect some pinions about the passive house in China. The result showed that 56% (18 people) of them want to pay more this project. And most of them (12 people) want to pay 8%-10% more than the regular projects. And 4 of them want to pay 2%-5% more, 2 of them has the willingness to pay 5%-8% more than the conventional houses. (see the chart below). The rest of that do not want to pay more for this house. However, due to the sample of the survey is at a small level and other limitations. Such as education levels and age level. the result can not reflect most opinions of the public, it is only used as one reference. As a result, the final selling price should be between 6100-6500 RMB/ m^2 or more.

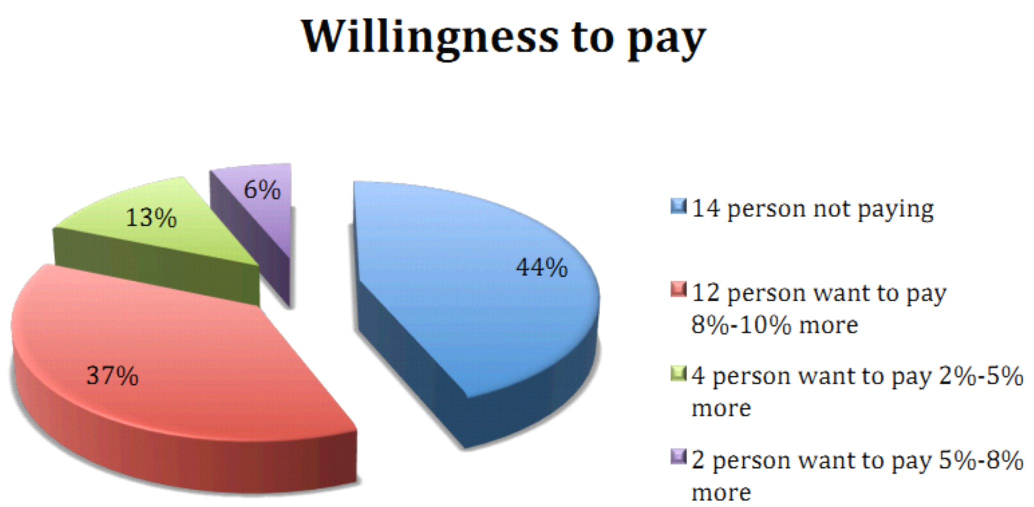


Figure 4. Willingness to pay.

Profitability

In a world of economy, the most attractive deal is always the one with satisfied return. It works the same in the real estate field. Developers and investors are always interested in the profit rather than the others. It is no doubt that the investment models are always the best tools to reflect the profitability of a real estate project. In oder to do the calculation, besides the assumptions made above, the following assumptions have been made.

1). The referred project is a 9600 m^2 living area with 120 apartments, and the selling duration will be four years. Estimated total cost for this project is 3500 RMB /m^2 . The selling price is about 6100-6500 RMB/ m^2. Average price is 6300 RMB/ m^2. It is assumed that 50% of the apartments will be sold in the first year, 20% in the second year, 10% in the third year, and 5% in the last year.

2). For the regular residential projects in Hunanan New district of Shenyang, the total average cost will be 2800 RMB /m^2 , the average selling price is 5648 RMB / m^2 by August 2010. (LING, Y, L. 2010)

3). In Shenyang, the normal cost for the residential electronic using is about 0.50 RMB / kwh and the heating cost in the winter time is 28 RMB / m^2, for the passive house project the electronic cost level will be the same. Based on the experience, the cost level will not change in five years. The actual average electronic consumption is about 150 kwh per each family per month, during the hot summer and cold winter (3 months summer,4 months winter), the electronic using will be 210 kwh per month. For the passive house, we assume that the heating and cooling load will be reduced to an average level of 10 kwh / m^2 per year.

4). According to the information provided by the people's Bank of China by 9^{th} February 2011, the required rate of return (r) is about 6.45% for 3 to 5 years. (The

People's Bank of China)

Result

Based on these assumptions, it can be calculated that the total cost of one passive house standard apartment is around 10% more than the regular one for a developer. As a tenant who are the potential investors, one 80m² passive house apartment in this project will cost 52160 RMB more than the normal ones. However, much more energy cost have been saved for a passive standard apartment. Such as the cost for central heating and air condition using in the hot summer and the cold days without radiator. In the northern part of China, the radiator or central heating starts from the first of November to the next March 1st. But the central heating only can achieve a 15 -18℃ inside the room, more electricity for air condition will be consumed. Therefore in these four months' winter, the heating cost for a 80 m² will be 2360 RMB per year ($28\times80+(210-150)\times0.5\times4$). In the hot summer and cold days, air condition using will cost extra 90 RMB per year ($(210-150)\times0.5\times3$). It means the average heating and cooling cost in will be 30.6 RMB / m² per year. Due to the passive design, there will be no cost for the central heating, the energy consumption for heating and cooling will be 5 RMB / m² per year (10×0.5) in this project.

	Passive house standard	Regular standard
Heating and cooling/ m² yr	5 RMB	30.6 RMB
Average price/ m²	6300 RMB	5648 RMB

Table 6. Comparison of cost for households.

As the energy price goes up, the cost will be higher in the future years. If the electricity price remains unchanged in the next 25 years, it is assumed that the savings from the electricity consumption will recover the extra money of buying passive house. According to the calculation, it is found that the selling price should not be set in a very high level for this project. It is believed that a passive house project should has a maximum of 15% more than the regular ones. Otherwise, it will take more than 33 years to recover the extra money. Potential buyers may turn to the normal apartments, since most people prefer a housing mortgage of 20 years in China.

Passive house is also a good private investment for private house renting companies or private landlord. An even higher rent level of passive house still can attract more tenants. More specifically, assuming the rent level for a 80 m^2 residential apartment is 12000 RMB per year in Shenyang, then the specific heating cost will be 2448 RMB per year, excluding the cost of water and other factors the total cost for renting this house is about 14448 RMB. For a passive house, the heating cost will be 400RMB per year. As a landlord, you can gain more by setting a higher rent of 14000RMB per year, it is still saving 48 RMB per year of total cost for the tenants.

	Total renting cost for tenants/year	Returns for landlord Per year
Passive house standard	14400 RMB	14000 RMB
Regular standard	14448 RMB	12000 RMB

Table 7. Comparison for the tenants and landlord.

5.2.3. Sensitivity Analysis

Since the result above is calculated based on the assumptions, the question will be brought up what will happen if some factors have changed. Firstly, it is assumed that the cost of a passive house in Shenyang city will be around 10% more than the conventional houses. However, when the project is actually processed in the real life, more uncertain additional cost will be added into the total cost. Such as the emergencies happened in the process period or some technical problems. The selling price will go up at the same time when more money spent on the project. It can be calculated in the same way as above, when total cost goes up to 15% more than the regular project, the selling price of this project will be 6500 RMB / m^2 and even higher. For the potential households, it will take more than 33 years for them to recover the extra money spend on the passive houses. In this case, the households may have hesitations of buying passive house, in other hand, developers will take the risk of dead stocks. However, it can also be understood as a long term deal. For the households, in my opinion, if taking passive house as an investment, although more investment have been spent in the passive house, more return will be gained when selling the house. Also if taking the passive house as a lifetime residential place, more cost of a passive house brings a better quality life and maybe longer lifetime. From the point of view, passive house is still a good deal for households.

For the developers, as the first real estate company to process the passive house in China, although more cost and risk you will take as mentioned above, as long as you have the ability to achieve passive house projects, the cost for the next passive house projects will be saved. For instance, the first project may cost 15% or even more than regular ones, but after gaining the experience in the first project, the cost maybe 5%-10% more. Or even as the same as the regular ones. Also as the energy price goes up, the demand for the passive house will be higher and higher, more returns will generated in the long term. What is more, as the first company to have the experience and ability to process the passive house, you can switch from developers to the consultant. This new identity brings not only more profits but also reputation in the field. Therefore, even if the cost changed in somehow, for both the developers and households, passive house is still a good deal with bright future.

6. DISCUSSION

Processing the passive house project is not only bringing more profits, but also with better reputation and more competitive position for the real estate companies in the field. Although the result of the investment indicates a very positive profitability, some problems and uncertain factors are still existing for the future development of passive house in China. Some adjustment should be done in some aspects, there are still some issues should be pointed out.

Risk

Real estate is such a high profit field in China, not so many private companies want to take more risk to be the first few companies to process an investment project like passive house. Passive house project can take longer time and more cost. Therefore, it is necessary for the government to carry out some incentive systems to encourage private companies to invest and process this environmental friendly residential dwelling. For instance, special lower tax for passive house projects, lower cost for the land price.

Standardized Design

As mentioned above, there are five different climates zones in China. It means different design strategies should be adopted in different area. However, until now there has been no standardized design for the passive house in China. Which means if the developer want to process these passive house projects, more money should spend on the design stage. This is another factors blocking the development of passive house in China. As a result, a design standard of passive house for different climate zone in China should be done by the related government departments. In this way, real estate companies could save a lot from the design phase, and more and more companies may have more passions to process passive house projects.

Education

Another issue will be the training for the labours. Until now, almost no specific experience and formal educations can be gained in China, what we can learn is the experience from Germany, Sweden and other countries. In order to develop the passive house, there should be the specific education in China to direct the labour how to construct the passive house, since there is higher requirement of caution for constructing passive house than the conventional ones. In this way, the labours can gain the knowledge about how to do the construction of a passive house in a proper way and how to do the maintenance.

Also the educations to the public should be done to promote the development of passive house. In the survey of 32 people, only 3 of them have heard the term of passive house, almost no one can tell what is the real passive house it is. Some actions can be done, like public free speech or lessons in the universities, or public advertisements.

Prices

The last uncertainty for developing the passive house in China is the higher selling price. As we all know, when the average salary level into account, the housing price in China maybe the top 5 in the whole world. And it still continues to rise in such a high speed. In this way, most of the potential households may not be willing to pay 10% more for the passive house standard apartments. To solve this problem, tax policy should be made by the government to support the passive house. For instance, if developing a passive house project, less tax will be charged for both the developers and tenants. Also energy consumption incentives should be made by the government. For example, as a tenant, if you living in a passive house, less electricity cost will be charged. As thus, more real estate companies may prefer to developing a passive house project, also household may have the willing to pay for it.

7. CONCLUSION

The main aim of this paper is to study the feasibility of processing the passive house in China, according to the studies of previous literatures and projects in Europe , a better understanding of what is the passive house has been gained. the answer of what is the passive house and how the passive house works have been provided in this thesis. When it is coming to the processing of passive house in China, both design strategy and economic analysis have been provided to examine the feasibility in the thesis. Based on the analysis and studies above, it has a bright future for developing passive house in China.

Also as i suggested above that there are still some other aspects should be done to meet the need of passive house development. Such as the tax policy. Further studies concerned passive house development in China should be done when there is a real residential project processing in China. All in all, it is possible and profitable to process the passive house standard residential project in China. In order to achieve sustainable development for the real estate market not only in China, but all around the world, more low energy houses like passive house should be built. Moreover, passive house is also one of the best solutions to deal with the raising energy price and high pollution generated from the real estate field. It is not only saving the energy, but also offering a better quality life.

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Appendix A - Interview Questions

1, Planning, why passive house standard are adopted in this project, not low energy saving house.

Why have you decided to build passive houses. Also the factors that contribute to the decisions : LCC, profitability, environmental footprint, and company goal.

2, Basic information of this project

U-values,Airtightness Air heat exchanger efficiency, Any solar collectors, Source for the domestic hot water, Heat ventilation system Air Temperature of each apartment How this passive house standard dwelling work?

3, Processing

During the process, are there any difficulties in the construction of windows, walls, roofs, floors, and doors. How does this project differ from others.

4, Economy

Total cost for this project, the differences cost between this project and normal residential project, cost for the media advertising, how long is the duration of this project, what is the rent for this project compared with other normal ones.

5, Basic introduction to this project

Location, how many apartments are built, types of the apartments.

Appendix B - Survey Questions

Question 1

Do you know the term passive house.

Yes   NO

Question 2

Do you want to pay more for a passive house apartment.

Yes   No

Question 3

If you want to pay more for a passive house, how much.

2%-5%   5%-8%   8%-10%