Diffusion of the green innovation within the construction industry

The case of European Passive House in China

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ABSTRACT

The construction market of China is huge and blooming. But this enormous industry cause severe environment problems and energy consumption. At the same time in Europe, a new Green Building technology—Passive House has appeared and been used in many European countries. Passive House not only saves a lot of energy—which could improve environment problems, but also offer a more comfortable indoor environment. When it appears that China will certainly be a big adopter, reality is that till now there are only two completed projects in China. This thesis try to explain why this happens, what block Passive House transfer.

The theoretical framework of this study combines diffusion of innovation theory and technology theory, attempting to build up several block models in order to explain why Passive House transfer to China unsuccessful.

The empirical data includes an introduction about Passive House and its related stories in China. Two realistic cases are introduced in this part together with two interviews with relevant experts as supplement.

The analysis of empirical findings revealed some relevant conclusions by testing these block models. These conclusions come into the final reasons to explain what block Passive House transfer. Further discussion about theory and final findings are shown in the discussion part.

**Key words:** Passive House, diffusion of innovation, technology transfer, barriers
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1. INTRODUCTION

1.1 Background

Chinese construction industry is huge and still fast growing. In single residential real estate sector, China is building about 1.8bn m² per year. Putting the number in perspective, today China is building more than one third of all the buildings in the world, at the same time producing and consuming 55% of the whole world cement for doing so. For an analogy, China builds the equivalent in square meters of space of a city like Rome in about two weeks and a country like the UK or Spain in one single year. (EIU: Building Rome in a Day: The sustainability of China’s housing boom. April 2011.)

Certain huge and booming construction industry also cause severe environment problems in China. Air pollution can be seen as the most serious problem of them. In November 2010 the report published by China’s environmental protection ministry showed that about a third of 113 cities surveyed failed to meet national air standards (Factors and Details, 2015). In winter residential houses are heated in large part with power generated by the burning of coal. Coal combustion generates particulate matter also known as "PM" which is the primary factor of air pollution. House heating (using coal) and cooling system (de-centralized use of air conditioners) also cause high energy consumption (Report: The construction sector in China).

In 1988, two professors in German and Sweden respectively set primary Passive House standard which allow for energy savings of 75% compared with average new builds related to heating and cooling. Besides this, a ventilation system in Passive House consistently supplies fresh air offering superior air quality without causing any unpleasant draughts (Passivhaustagung, 2015). Building certain house in China not only improve the environment problems but also offering a better living condition compared to normal Chinese residential buildings.

1.2 Problem discussion

Whilst it would seem that China could be a great adopter of Passive House, it turns out till now there are only two completed and 20 planning Passive House projects in China since 2009 (China Daily, 2015) which is the first time for Passive House concept been introduced to China, compared to the fact that in European there are 65000 projects in 2012 (Pass-net, 2015).

The first time Passive House technology was introduced to China was at a certain high level stage. In 2009, German and China government officials hold a meeting to promote “Low energy building and passive house adaptable to Chinese conditions based on European experience”. Then in 2010, Shanghai Expo, “Hamburg House” as the first Passive House stood in front of Chinese people. Several planning Passive House
projects started in 2011. “The Water Side” resident house project is one of them. During its building process, the Chinese designers and engineers tried to overcome many difficulties and problems. Nowadays, part of its houses has completed.

Even with certain development background, the result is still not fruitful. In these six years since 2009, European countries especially German attempt to push forward Passive House technology in China, but still there is only two completed Passive House there. Considering the fact that “China builds the equivalent in square meters of space of a city like Rome in about two weeks and a country like the UK or Spain in one single year”, this situation is very weird.

Why China do not apply the certain technology and why EU cannot popularize it in China. “How can we explain this” is naturally our research question of this paper.

**1.3 Research purpose**

The purpose of this paper is to explore what blocks the spread of Passive House in China. First we try to find barriers with the help of diffusion of innovation theory. At the same time, as it is a technology intensive innovation, we also focus on technology transfer theory. We will combine the same content related with barriers in these two aspects to build our own block model. By verifying it with the Passive House stories in China, we will finally find what blocks Passive House transfer in China.
2 THEORETICAL FRAMEWORK

2.1 Diffusion of innovation theory

Diffusion of innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. In his famous book “Diffusion of Innovation”, Rogers (2014) defines diffusion as the process in which a certain innovation is communicated through different channels over time among social system members. Based on some innovation diffusion practical examples, Rogers (2014) summarizes four main elements in the process of diffusion of innovations, which are innovation, communication channels, time, and the social system.

(1) Innovation
Rogers (2014) defines innovation as an objects, practice, or idea which is identified as new by individuals or other adoption units. The rate to which an innovation is adopted is dependent on its five attributes-relative advantage, compatibility, complexity, trialability and observability (Rogers, 2014)

Attribute 1 Relative Advantage
Rogers (2014) defines relative advantage as a certain attribute that an innovation is identified as better than something or the idea it displays. It can be expressed as economic profitability and social prestige.

Attribute 2 Compatibility
Compatibility is used to describe a certain attribute that an innovation is identified as consistent with the needs of potential adopters, existing values, or past experiences (Rogers, 2014).

Attribute 3 Complexity
While some innovations are easy and clear to the adopters, others are not. Complexity is a certain term to describe that an innovation is regarded as relatively difficult to understand or use (Rogers, 2014).

Attribute 4 Trialability
Trialability refers to the fact that an innovation can be experimented with on a limited basis (Rogers, 2014).

Attribute 5 Observability
Observability is the means by which the results of an innovation can be visible to others. Whilst some ideas are easily observed and described to other people, other innovations are not (Rogers, 2014).

(2) Communication channels
A communication channel is defined as messages get from one person to another. It contains mass media channels-which means transmitting messages with mass medium, for instance newspapers, radio, television, and so on. Also it contains interpersonal
channels which means a face-to-face information exchange among individuals. Nowadays a new important means of diffusion is Internet communication (Rogers, 2014).

(3) Time
The innovation-decision process has different steps in the timetable. From an individual or decision-makers unit first get the knowledge of an innovation to their confirmation of that innovation. The length of time it takes is defined as the innovation-decision period (Rogers, 2014).
In this part the author discussed two issues related “Time”. First in the innovation-decision period, Rogers (2014) divides it into five main steps, (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation on the timeline. Rogers (2014) also classifies the different adopters in this part based on the time it takes to adopt the innovation. They are: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, (5) laggards.

(4) Social System
Social system refers to a set of interrelated units engaging in joint problem solving to accomplish a certain common goal. It should be considered that social and communication structure can positively or negatively affect diffusion (Rogers, 2014).
Rogers (2014) defined Change agent as a person (or unit) who focuses his efforts on the effect of changing technologies, structures and tasks on interpersonal and group relationships in the organization. (EX teachers, consultants, public health workers, salespeople, etc.) “All of these change agents provide a communications link between a resource system with some kind of expertise and a client system. One main role of the change agent is to facilitate the flow of innovations from a change agency to an audience of clients”

2.2 Technology transfer theory
Technology transfer is a complicated process which concluding new technology, bureaucratic red tape and human interaction. (Greiner, M. A., & Franza, R. M. 2003). The difficult in each process would take barriers for the successful technology transfer. According to this, our research aim to find the barriers in these processes and their influences on the technology transfer.

Technical barriers
The most important question in technical barriers is that if the technology has been developed in a new environment, we can’t make sure that if this technology can work in such a new environment (Guilfoos. 1989). Technical risk, defined requirements and absence of operational test are the key elements in technical barriers (Guilfoos. 1989). Because this technology is a new knowledge for the adopter. If they don’t test the workability of this technology before they decided to develop this technology to a new environment, then there would be a risk to do this technology transfer. Other researchers
examined issues of technical risk, and found that if the technology transfer is demonstrable, understandable and unambiguous, which means it would be easier to be success finally. (Smilor and Gibson. 1991). The technology transfer can’t be equivocal because the equivocality will lead to the technical barrier.

**Regulatory barriers**
The local government procedures and lows are included in the regulatory barriers (Greiner, M. A., & Franza, R. M. 2003). The local government have the existing specifications so that when a new technology has been developed, which should meet the existing specifications or the existing specifications are not available for this new technology. This will cause the barriers in technology transfer because the time for developing this new technology and procuring the materials is too long. (Guilfoos, 1989; GAO, 1995).

The existence of an environment driver could be a critical element for a successful commercialization of the technology transfer (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). If the regulation is not enforced to serve as environmental driver, and the result is that the regulation can’t be a driver and cause a fail technology transfer. (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).

**People barriers**
People barriers have been researched by Guilfoos (1989). It is hard to deal with the people barriers because when people decided to develop this new technology, and the capabilities of a new technology are often not noticed in technology transfer. (Guilfoos, 1989; Carr, 1992a, b). This problem will be complicated if people don’t want to be educated in a technically way. They thought that it is hard to understand all new things about the new technology and sometimes it was a waste of time to do such things. (Guiffoos, 1989; Spann, M.S., M. Adams, and W.E. Souder, 1993). People who involved in this technology transfer lack their self-motivation to learn and understand new knowledge Smilor and Gibson (1991).

The themes of information and the communication between the sender and adopter are two important elements connected to the people barriers (Greiner, M. A., & Franza, R. M. 2003). Smilor and Gibson (1991) have done a lot of interviews, archival data and surveys about the people barriers. They discovered that geographical distance are the main element cause the difficult in communication between the sender and adopter. Another important point is that the different cultures will lead to the different thoughts which will cause the gaps of information between the sender and users. (Carr 1992a, 1992b). These findings are supported by Edwards (1994) who claimed that the managers’ vision and pulling technology of engineers are the two main impetus for the development of technology transfer.

The General Accounting Office (GAO, 1995) notes that fear of technical risk at the field level, is a barrier in the development of environmental cleanup technologies.
Based on it, if the adopter don’t want to accept this technology transfer with the technical risk, then the technology transfer would finally fail (Gummere (1989)).

The public perception of the novel technology would hinder the technology transfer (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). For instance, a novel technology is large and difficult for the public to recognize in correct way, then it will hinder the technology transfer. On the other hand, if the public can accept this new technology but they don’t want use it near their house or their workplace. According to this situation, the adopter need to choose the right place to use this technology. Some researches can illustrate this point. For the debris water, there is a novel technology for solid decontamination and hazardous wastes. The equipment for this technology is large and it should be transported in a mysterious way which is hard to do. (Jain, R.K., Martyniuk, A.O., Elsenbeer, M.A., Harris, M.M., Niemann, R.E., Sun, X. and Woldmann, K. 2001). It will cause a negative public perception and hinder the technology transfer finally.

**Fierce competitive environment**

If the competitive advantage can’t be proved by the substantial in the new environment, then this new technology will face a lot of competition unless an applicable niche market found by the parties which is suitable for this new technology (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). Other researches about the first to market illustrate this fact. The first to market would occupy more than sixty percentage of the whole market share, the second to market may command less forty percentage and other companies could only share the rest of market (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). So if some similar technologies are the first to market or second to market then this new technology would only occupy little market share which will lead to a failed technology transfer.

**No current market**

An innovative technology can’t be commercialized if there is no existing market, which will hinder the technology transfer. (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). For instance, there are two choices to deal with the polluted soil. The first one is to provide the therapeutic method to solve this problem, while another one is to fill this land. People are more prefer to choose the later one. Because there is no existing market for the first one so that it can’t be commercialized in such environment (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).

**Knowledge barriers and process barriers**

“A process through one unit (e.g. Division, group) to another unit which will be affected by experience of later one” is defined as the knowledge transfer (Argote & Ingram (2000). A successful knowledge transfer is an important element for the firm’s competitive advantage which will lead to a successful technology transfer. (Argote & Ingram (2000). Von Hiippel (1994), “used the jargon to describe the costs in accessing and sharing information for technical innovation due to the fact that knowledge is socially embedded within the organization and its practice”. If the costs of accessing
and sharing information is increasing, then it will hinder the knowledge transfer and affect the technology transfer finally.

A new environmental technology which is extremely complicated to implement and use will present yet another barriers to technology transfer (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). When the adopter want to use this technology, the installation of this new technology and training individuals must be noticed because the new technology need to be installed in a special way and the individuals need to be understandable for this novel technology (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).

**Lack of field test and pilot scale operational data**
The lack of field test data or pilot scale operational data often can hinder severely the transfer of otherwise promising environment technologies (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). If the developer want to commercialize this new technology in new environment, the risks is that they don’t know if this new technology can be work or not. So that both developer and adopter will take risks for this novel technology.

**Cost and benefits**
It is hard to model the benefits and costs of technology transfer because it doesn’t happen in a vacuum and technology transfer may come in many form (Popp, D. 2009). Some researchers have done a lot of surveys and got the data from the AUTM (Association of University Technology Managers), which summarized that the office costs, legal expenses, patent fees, novel research grants and benefits gained from the target market are concluded in the costs and benefits of technology transfer. Economic elements can represent an important barrier for the commercialization of technology transfer. If this novel technology could only provide little profits for the adopter with high costs, then there are little chances for this technology transfer (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). Besides this, when developer consider for the remediation technologies, if the costs of a novel remediation technology is less than the existing technology and it can work very well in such new environment. The performance of speed can represent its benefits, which means the quicker, the better. Otherwise this new technology can’t be commercialized (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).
2.3 Block Models

In this part, we try to combine the similar points in above theories to build our own block models and all these models are listed below.

**Block model A-technical risk**

There are four elements: technical barriers in technology transfers, compatibility, trialability and observability in innovation diffusion, which are concluded in barrier model A. Compatibility, trialability and observability are both related to the technical risk. If the parties don’t test the work-ability of this novel technology before they decided to develop this technology to a new environment, then they can’t make sure if this novel technology can work or not in this new environment. As a result, they don’t know if this novel technology can fulfill the needs of potential adopters (Guilfoos, 1989). Also the parties don’t know if the novel technology can fit with the existing values or the past experiences. Compatibility of innovation can be defined as consistent with the needs of potential adopter, existing values or past experiences (Rogers, 2014). Trialability of innovation refers to the fact that an innovation can be experimented with on a limited basis (Rogers, 2014). If the sender and adopter don’t test the work-ability of this novel technology, they don’t know if this innovation can be experimented in this new environment. Parties can’t get the operational data if they don’t test the work-ability of this novel technology, which means this technology can’t be visible to others. According to these facts, we put the technical barriers, compatibility, trialability and observability together to build the barrier model A.

The following picture shows what the content is in the Block Model A
**Block Model B - Regulation barrier**

The regulation contains local government procedures and laws (Greiner, M. A., & Franza, R. M. 2003). If the time for developing this new technology and procuring the materials is too long, the regulation will block technology transfer. (Guilfoos, 1989; GAO, 1995).

Also in the commercialization period, if the regulation cannot be an environment driver, then it will fail in commercialization, thus affect technology transfer (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).

All these factors are related with innovation attribute 2, Compatibility of Rogers (2014) theory. We combined them together to form the Block Model B.

Also the following picture shows how we build Block Model B

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**Block Model C - People barrier**

People barriers often arise when people involved with the development and transfer efforts are not aware of the capabilities of the new technology (Guilfoos, 1989; Carr, 1992a, b). Their perspective, lacking self-motivation to learn the technical knowledge are connected with the innovation decision period of innovation diffusion theory. Also the fear of technical risks is included in this part.

Geographical distance and culture distance caused communication barriers which are closely related with people barriers. This part is included in the communication part of Rogers (2014) theory.

The two main impetuses for the development of technology transfer are the managers’ vision and pulling technology of engineers. In the diffusion of innovation theory, the content linked to it is the “Change Agent”.

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Thus in order to formulize our analysis, we combine People barriers theory with “innovation-decision period” “communication channels” and “Change Agent” in Rogers (2014) theory.

The picture below shows how we build Block Model C

**Block Model D-fierce competitive environment**

Barrier Model 2 consist of relative advantage of innovation and fierce competitive environment in technology transfer. The relative advantage is regarded as a certain attribute which means that this innovation can be identified as better than something or the idea it displays (Rogers, 2014). The relative advantage include the economic profit and the social prestige. So if we can achieve these goals, this novel technology can be a winner in the competitive environment. If the relative advantage can’t be proved by the substantial in the new environment, this new technology will face a lot of competitions. On the other hand, if this new technology can’t be the first to market or second to market, but the relative advantage can be proved and seen by the adopter and user, it can also occupy lots of market share (Tellis, G. J., & Golder, P. N. 1996)

The content of Block Model D can be seen in the picture below.
Block Model E-No current market
In Barrier Model E, we will discuss the relationship between the observability of innovation and “no current market” of technology transfer. If there is no existing market which is suitable for the novel technology, then this technology can’t be commercialized (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003). Observability is the means by which the results of an innovation can be visible to others (Rogers, 2014). The result is that this technology innovation can’t be visible to others. People can’t get more details about it and finally they won’t to accept this technology and this technology transfer will be fail.

The content of Block Model E can be easily seen in the picture below.
Block Model F-Knowledge and process barrier
In Barrier Model F, we will discuss the complexity of innovation, knowledge and process barriers of technology transfer. Complexity of innovation is a certain term to describe that a new technology is regarded as relatively difficult to understand or use (Rogers, 2014). Complexity of innovation is related with the knowledge and process barriers of technology transfer. If the knowledge transfer is complex, it will hinder the technology transfer because the adopters don’t understand it and also they don’t know how to use it. Process barriers of technology transfer reflect in the installation of this new technology and training individuals. The new technology should be installed in a professional way and the workers need to be skillful and experienced (Martyniuk, A. O., Jain, R. K., & Stone, H. J. 2003).

The picture below shows the content of Block Model F
3. Methodology

For our thesis, our purpose is to find the barriers in innovation diffusion and technology transfer. Based on the theory and empirical data, we build our own block model. We searched some theories from the our university database and Google scholar which were related to the innovation diffusion and technology transfer because our university database have much relevant literature and there are all kinds of literature from all over the world in the Google scholar. We searched the literature about the barriers in technology transfer on the internet. Firstly we used some key words like “barrier” “innovation diffusion” and “technology transfer”. Besides these key words we also use some detailed terms related with “technical risk”, “people barrier” to find out the relevant literature. There are lots of literature and we couldn’t use all of them so we choose some literature which are published in the famous newspaper or website. These literature have great value which can help us understand “innovation diffusion” and “technology transfer” more deeply. For our empirical data, we borrowed some Books from school library. Beside it we used the key words like “Passive House” and “China”. We found lots of literature. Finally, we chose these two literature because these two cases include lots of details about the Chinese Passive House. Also we got some useful data from the interview. We studied two cases which are related with the Passive House in China: “The Water Side Project” and “Passive Design of Coffer Bar”. “The Water Side Project” started in 2011 which is the first Passive House demonstration project. It located in the Qinhuangdao, a second-tier city. Another case of Passive House in China is the coffer bar which located in Dalian, a modern city in the northeast of China.

In our thesis, we need to do the in-depth research and get more details about the barriers in technology transfer and innovation diffusion. For instance, complicated process is one barrier of technology transfer. In construction industry, there are a lot of complicated processes to build a Passive House. For example, space heating energy system, primary energy system and airtightness are the three main criteria of the Passive House and it is very complicated to finish these points of Passive House. Some other barriers like the technical barrier, regulatory barrier, people barrier, lots of competitions, no current market, and lack of environment drivers, cost and benefits would also hinder innovation diffusion and technology transfer. We found out these barriers and used our empirical data to demonstrate if these barriers will hinder the transfer of Passive House.

In order to do the in-depth research and get more details about the Passive House, we interviewed two person, one is a construction industry PHD called John and another one is a Chinese senior designer in Xian Dai Architectural Design (Group). The interview we had a face-to-face interview with John. Firstly, we want to get more data about the Passive House. John knows all kinds of information about the Passive House so he sent us some websites which are related with the Passive House after meeting.
After this, we talked about the building process, John told us that the building process is not easy because of many reasons. We consulted something about the design of Passive House with John, and he said that in Sweden the design is alterable. Most time the design can just meet the requirement of functional unit of the building which means the existing building process cannot be borrowed for China because of regulation limits. This interview lasted for about fifty minutes and we got many detailed information. We also interviewed a Chinese senior designer named Qi Yuan, he told us something about the “Passive Design of a Coffee Bar” because this project was conducted by Xian Dai Architectural Design (Group). He provided us a lot of useful data like the design details about this project. This interview lasted for about thirty minutes.

Based on theory part, our second research is to build the block model. Some theories in technology transfer are related with theories in innovation diffusion so that we put them together and build the block model. There are six block models totally. After this we start to do the data analysis, and we used our empirical data to test the theory part. Some theories can be proved but others are not. Because our theory part is related with innovation diffusion and technology transfer which is a wide academic scope but our empirical data focus on the Passive House, a certain construction technology. According to this fact, we abandoned some models. So after analyzing all the empirical data, model B, C and F are our new block models and we give our reasons in the analysis and discussion part.
4. Empirical Data: The story of Passive House moving to China

4.1 Passive House Introduction

Definition

**Passive House**: A well-insulated, air tightness construction with mechanical ventilation is the basic idea of a Passive House. Building components which are necessary in any case; the building envelope, the windows and the ventilation system, are optimized to reduce the need of energy for space heating to the lowest possible level. Thermal bridges must be avoided, as must infiltration through the building envelope. Detailed planning is necessary to achieve a well-functioning passive house of sufficient airtightness. These improvements result in a building that works almost like a thermos (Passivhaustagung, 2015)

The German Passive House Institute defines a passive house as follows:

“A Passive House is a building for which thermal comfort (ISO 7730) can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to fulfil sufficient indoor air quality conditions (DIN 1946) – without a need for recirculated air.” (Passivhaustagung, 2015)

**Thermal bridge**: thermal bridge is an area of a building which has a significantly higher heat transfer than the surrounding materials- resulting in an overall reduction in thermal insulation of the building (Passipedia, 2015)

General Introduction

Passive House is a construction concept that can be applied by anyone that has stood the test of practice. A building standard that offers energy efficient, ecological, affordable, and comfortable conditions at the same time.

The Passive House standard originated from a conversation in May 1988 between two professors. Bo Adamson came from Lund University, Sweden. And Wolfgang Feist, who was in the Institute for Housing and the Environment, Germany. Their concept was then developed through a number of research projects, aided by financial assistance from the German state of Hessen. (Passivhaustagung, 2015)

Passive Houses effectively save cooling and heating related energy of up to 90% compared with traditional building stock and more than 75% compared with average new builds. Passive Houses use less than 1.5 liters heating oil per square meter in living space per year-much less than traditional low-energy buildings. It has been demonstrated that in warm climates Passive House also perform well in terms of energy saving when building requires more energy for cooling (Passivhaustagung, 2015). The following picture directly shows Passive House performance of heating energy saving compared with traditional low energy house.
Passive House also offer high level of comfort conditions for living room. The data collected from German Passive House Institute shows they use energy sources inside the building such as the body heat from the house owner or solar heat entering the building which makes heating much easier. Special windows and a building shell consisting of highly insulated exterior walls, roof and floor slab work cooperatively to keep the desired warmth in the house – or undesirable heat out.

A ventilation system consistently supplies fresh air making for superior air quality without causing any unpleasant draughts. A highly efficient heat recovery unit allows for the heat contained in the exhaust air to be re-used. The following picture 2 simply shows Passive House working mechanism.
Passive House requirements
For a building to be considered a Passive House, it must meet the following four criteria (Passivhaustagung, 2015).

1. The Space Heating Energy Demand is no more than 15 kWh per square meter of net living space (treated floor area) per year or 10 W per square meter peak demand. In climates where active cooling is needed, the Space Cooling Energy Demand requirement roughly matches the heat demand requirements above, with a slight additional allowance for dehumidification.

2. The Primary Energy Demand, the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 120 kWh per square meter of treated floor area per year.

3. In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascals pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).

4. Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10% of the hours in a given year over 25 °C.

All of the above criteria are achieved through intelligent design and implementation of the Five Passive House principles: thermal bridge free design, superior windows, ventilation with heat recovery, quality insulation and airtight construction.

The following basic principles apply for the construction of Passive Houses:

**Thermal insulation**
All opaque building components of the exterior envelope of the house must be very well-insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W/ (m²K) at the most, for instance. A maximum of 0.15 watts per degree of temperature difference and per square meter of exterior surface are lost.

**Passive House windows**
The window frames must be well insulated and fitted with low-e glazings filled with argon or krypton to prevent heat transfer. For most cool-temperate climates, this means a U-value of 0.80 W/ (m²K) or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).

**Ventilation heat recovery**
Efficient heat recovery ventilation is the main point, offering a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.
Airtightness of the building
Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurized and depressurized).

Absence of thermal bridges
All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges which cannot be avoided must be minimized as far as possible.

4.2 Passive House in Europe
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.

To establish a co-operation network of Passive House, the promoters in Europe set up an organization called “PASS-NET”. The target of the “PASS-NET” is to spread the knowledge about Passive House standard within Europe. This action increases the share of Passive House buildings within new buildings and the reconstruction of existing buildings. The partners participating project are coming from Austria, Belgium, Croatia, Czech Republic, Germany, Great Britain, Romania, Slovak Republic, Slovenia and Sweden. The chart below shows Passive House trends in the 10 Pass-Net countries.
The passive house concept has become a European wide accepted solution to reach a significant energy demand reduction in the built environment. The number of realized Passive House buildings in the 10 PASS-NET countries rises a lot every year since 2000. In 2010, there are nearly 27000 Passive Houses in PASS-NET countries and it is expected that in 2012, the number will be 64000.

4.3 The construction sector in China

Energy efficiency
Heating systems account for 26% of China’s energy demand. In the 1970s the share was only 10% and it is expected to reach 36% by 2020. Whereas it is relatively easy to increase energy efficiency in industry, the existing buildings are difficult to retrofit. Relatively cheap coal, the lack of insulation know-how, the disconnect between builders (paying for the insulation) and users (paying for the heating costs) and the central (district) heating systems used in Northern China have created a building stock that is grossly under performing in energy efficiency. The widespread (de-centralized) use of air conditioners in the last ten years has also added to the high energy consumption.

Labor efficiency
China construction sector has been experiencing a dramatic increase in labor productivity in the construction sector over the past few years. In 2010 the number of
Diffusion of the green innovation within the construction industry

employees peaked at 42 million and is expected to decrease considerably in the coming years. Whilst construction used to be a welcome pool to employ unskilled labor force – rice in summer, buildings in winter – the sector now have to deal with fast increasing salaries (>10% annually) and shortages of unskilled labor in many areas of the country.

Design and quality
With private real estate being a relatively new phenomenon, design has only recently entered this sector. As home ownership and available income increase, people want to enhance the quality of living and differentiate themselves through design and lifestyle. “Experience with the first generation of buildings and building materials is also increasing quality awareness in the market. Realizing the high cost of low quality (in maintenance, decreased aesthetic value or replacement costs), the market for quality products is growing faster than the average, creating more “European” market models.” (Source: EUSME Center Report: The construction sector in China, 2013)

4.4 China’s first contact with Passive House
Since 2009, Center of Science and Technology of Construction (CSTC) of Ministry of Housing and Urban-Rural Development (MOHURD) and German Energy Agency (dena) has been in cooperation to demonstrate and promote “Low energy building and passive house adaptable to Chinese conditions based on European experience” under sponsorship and guidance of Department of Building Energy Efficiency, Science &Technology of MOUURD as well as German Ministry of Transportation, Construction and Urban Development. This cooperation on promoting passive house in China to reduce energy demand to a maximum level was further emphasized in MOU on Technical Cooperation in Building Energy Efficiency and Low-Carbon EcoCity Development which was signed between MOHURD and German Federal Ministry of transportation, Construction and Urban Development in June 2011. Therefore, both agencies have been exploring the solution to Chinese passive house and low energy building in the aspects of design improvement, selection of energy efficient materials and products, construction quality control and supervision as well as acceptance of building.


Occupying an area of about 675 square meters, the permanently built Hamburg House was Germany’s only city pavilion at the Urban Best Practices Expo 2010.

The Hamburg House demonstrates the top-level of energy-saving and eco-friendly technologies for a “Passive House.” This means it can maintain a constant, year-round indoor temperature of 25°C without consuming any electricity from the National Electricity Grid, and without the use of air conditioners or heaters.
As the sister city of Shanghai and the largest German port city, Hamburg is dedicated to the preparation of the Hamburg House as a special gift for Expo 2010 in Shanghai,” said Lars Anke, director of the Hamburg Liaison Office in Shanghai and commissioner general of the Germany Hamburg UBPA section of Expo 2010.

Anke added, “The first certified new building project for a passive house in China, the Hamburg House will provide a comprehensive reference for improving building energy efficiency technology in China. I’m delighted to see BASF share the same vision with us. Its advanced insulation and coating technologies will help us better achieve the goal.”

4.5 “The Water Side Project”

“The Water Side Project” , or “Zai Shui Yi Fang” which is the first Passive House demonstration project, located in a north Second-tier city Qinhuangdao (Coordinates: 39° 56’ N, 119° 36’ E). The project started in 2011 and contained 9 demonstration buildings with total area 80344 square meters (Picture 5). Qinhuangdao Wu Xing Real Estate Company was developer of this project.
The building marked as C15 was first to start construction. It adopt a variety of passive energy saving technology to reach passive building standard. The major passive technology applied in this building were efficient palisade structure, anti-thermal bridge technology, air tightness measures, fresh air system with heat recovery, etc.

Picture 6 Construction workers doing external wall insulation
Cost analysis

Compared to normal energy saving house, the heat preservation materials, external windows, efficient heat recovery equipment and high standard construction requirements all made Passive House more expensive. But on the other side, in this case, Passive House canceled the traditional heating supply systems and thus reduced the city heating network supporting fees. The table 1 (next page) compares the cost between 65% energy-saving house and German Passive House, and the later cost more than 600 per square meters than the former.

The result of monitoring analysis for “The Water Side Project”

From 2013.1.15 to 2013.1.18, Qinhuangdao Wu Xing Real Estate Company conducted air tightness test with Ministry of Housing and Urban-Rural Development (MOHURD). During 2013. 2.17 to 9.7, they conducted the 24-hour indoor environment monitoring at East Room (building area 132m2) and West Room (building area 134m2). In 2013.2.17~2013.4.5, energy consumption test was conducted during heating supply period in winter and in 2013.7.24~2013.8.24 it was conducted during cooling period in summer.
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Table 1 Passive house cost comparison with 65% energy saving project

<table>
<thead>
<tr>
<th>Number</th>
<th>Project</th>
<th>Cost of 65% energy saving project (RMB/m²)</th>
<th>Cost of passive house project (RMB/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Precipitation</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Earthwork</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Slope protection</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Pile foundation</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Structure</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>6</td>
<td>Decoration and heat preservation</td>
<td>220</td>
<td>392</td>
</tr>
<tr>
<td>7</td>
<td>Doors and windows</td>
<td>208</td>
<td>333</td>
</tr>
<tr>
<td>8</td>
<td>Plumbing</td>
<td>380</td>
<td>297</td>
</tr>
<tr>
<td>9</td>
<td>Elevator</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>Heat recovery system</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>11</td>
<td>Anti-thermal bridge</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>12</td>
<td>Cost of construction units</td>
<td>1442</td>
<td>2046</td>
</tr>
<tr>
<td>13</td>
<td>Outdoor construction and afforest</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>14</td>
<td>Municipal works</td>
<td>200</td>
<td>130</td>
</tr>
<tr>
<td>15</td>
<td>Planning and design</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>Acceptance test</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>17</td>
<td>Land fund</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>18</td>
<td>Unpredictable fee</td>
<td>135</td>
<td>151</td>
</tr>
<tr>
<td>19</td>
<td>Management fee</td>
<td>116</td>
<td>129</td>
</tr>
<tr>
<td>20</td>
<td>Loan interest</td>
<td>285</td>
<td>318</td>
</tr>
<tr>
<td>21</td>
<td><strong>Totally cost</strong></td>
<td><strong>5028</strong></td>
<td><strong>5624</strong></td>
</tr>
</tbody>
</table>

1 Result of air tightness test
Air tightness is an important index to conduct Passive House performance evaluation. Rely on China’s “Standard for energy efficiency test of public buildings” (JGJ/T177-2009), which testing method is the same as German standard DIN EN13829-2001, those people conducted the air tightness test. In the condition of 50Pa atmospheric pressure difference between indoor and outdoor, the room air changes per hour should be less than 0.6. The testing result showed that among all the 6 testing rooms, air changes per hour were 0.68, 0.53, 0.41, 0.41, 0.34, and 0.23. Five rooms meet the requirements and one room not. The company then strengthened that room with assistance of German experts.

2 Result of indoor environment monitoring
24-hour indoor environment monitoring at East Room and West Room was conducted under the inhabited condition. Indoor temperature, humidity, carbon dioxide (CO2) content, noise and wind speed, all these parameters were tested in these two sample
East Room: Two people lived in it. Air condition control mode was set to control the indoor temperature 18 to 26 °C. When the indoor temperature was over 26 °C, air condition started cooling. And when the indoor temperature was under 18 °C, heating program began to work. The time percentage for Indoor temperature between 18-26 °C was 69%. Indoor humidity between 40-65% accounted for 13%. Other parameters, carbon dioxide (CO2) content, noise and wind speed met the Passive House requirement.

West Room: Three people lived in it. Temperature control range was 20-26 °C. Result showed that time percentage for temperature between 20-26 °C was 69%. For Indoor humidity between 40-65% was 49%. Other parameters, carbon dioxide (CO2) content, noise and wind speed met the Passive House requirement.

It was worth noting that due to the house owners’ living habit, in the summer time, the house owners in these two sample houses did not adopt the passive method to keep windows closed in order to keep air tightness. Most of time, the house owners opened their windows for natural ventilation, which caused high indoor temperature and humidity in their rooms. Some days in the winter time, the house owners did not live in the sample house and air condition shut down. These factors made the indoor temperature lower than control range.

3. Result of energy consumption measurement
Energy consumption test was conducted twice in summer and winter respectively. The result of the test can be seen in the following table 2.

<table>
<thead>
<tr>
<th>Project energy consuming</th>
<th>Passive House Standard</th>
<th>65% energy saving standard</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>East Room</td>
</tr>
<tr>
<td><strong>Hearting</strong> KWh/(m²a)</td>
<td>60</td>
<td>58.35</td>
<td>35.62</td>
</tr>
<tr>
<td><strong>Cooling</strong> KWh/(m²a)</td>
<td></td>
<td></td>
<td>3.48</td>
</tr>
<tr>
<td><strong>Illumination</strong> KWh/(m²a)</td>
<td></td>
<td></td>
<td>11.19</td>
</tr>
<tr>
<td><strong>Home Appliances</strong> KWh/(m²a)</td>
<td>120</td>
<td></td>
<td>38.71</td>
</tr>
<tr>
<td><strong>Total energy consuming</strong> KWh/(m²a)</td>
<td></td>
<td></td>
<td><strong>89</strong></td>
</tr>
</tbody>
</table>
The energy consumption test conducted in “The Water Side” project was under the condition that the whole building construction was not finished and only two groups of house owners entered the building. This condition was not benefit for heat preservation but still the energy consumption met the Passive House standard. When the project finished the energy consumption would be further reduced.

Compared to traditional central heating system, Passive House could save more than 80% heating fee and more than 40% cooling fee. The saved heating fee and cooling fee were 0.2RMB/m²/day and 0.04RMB/m²/day respectively. “The Water Side” project had 9 buildings with 80344m² total area. By simple calculating, the project can save 2.86million RMB heating fee and 100thousand RMB cooling fee per year.

**Project experience and problems**

1. Despite the fact that more than 80% of products and materials can be found in Chinese market, some major high-tech products and materials, for instance special window for Passive House, anti-thermal bridge connection element, waterproof and sealing materials, external wall thermal insulation accessories and so on, is not available in the market. Domestic material research and development falls behind making the way to gain these material only rely on input or customization. All these factors increase the construction cost and extend the construction time.

2. Passive House is totally new concept to China. Most of China’s architecture design institutions do not have professional knowledge and design capabilities. “The Water Side” project designers have spent nearly one year being coached by German experts and then gradually mastered design features. The demand level for construction process and workers’ operation method is also very high. The backward construction technology and non-standard on-site construction management are both critical factors blocking project progress. At primary period the project went on slowly and then gradually improved after several turns of education. Besides, in China, no relative standard for air tightness test can be applied in this project. The air tightness test was conducted under the guidance of German experts.


### 4.6 Passive Design of a Coffee Bar

In order to realize Passive House technology localization and put the lessons and experience into reality, Chinese designers start to design their own passive building in two years after learning the novel technology.

The scheduled project located in Dalian (Coordinates: 38° 55′ 15″ N , 121° 38′ 21″ E), a modern metropolis in north part of China. Dalian has maritime climate
characteristics, which is similar to most German cities. Natural conditions makes Dalian a good place to conduct this Coffee Bar Project.

The Passive Coffee Bar was designed by Shanghai Xian Dai Architectural Design (Group). The design stage last from June to December in 2011. Total floor area of the project is 420.5 square meters.

Picture 8 Passive coffee bar project planning drawing

Introduction about Xian Dai Architectural Design (Group) Co., Ltd
Located in the modern and beautiful metropolis of China, Shanghai, Xian Dai Architectural Design (Group) Co., Ltd. (hereinafter referred to as Xian Dai) has held its position as one of the largest and most influential architectural and engineering design groups in China for more than 60 years. Xian Dai has grown and developed into an integrated architecture, design, planning and consulting group incorporating 16 professional subsidiary companies since its origin in 1952. In many years, Xian Dai has been included in the list of “Top 150 Global Design Firms” published by the US magazine ‘Engineering News Record’ (ENR), widely referred to as the bible of the construction industry in China. In 2014, Xian Dai was ranked 58th by ENR.

One of its most outstanding work is the Oriental Pearl Tower, which is the landmark building in Shanghai. Another masterpiece of Xian Dai is Shanghai International Circuit, where hold F1 Race.
Experiment for localization
Besides absorbing the details design of Passive House design knowledge(Picture-10) including solar energy system, door-window system, external wall system, etc., the designers in Xian Dai attempted to conduct a variety of creative endeavors for localization.
In the main structure design, the design put “Isokorb”—which is a High-strength insulation material used in the joint area of balcony and main structure—into the middle of concrete cantilever eaves and structure roofing board as structural heat insulation connection (Picture 11). Abandoning German design method which break the connection of foundation beam and pile foundation and fill the space with heat insulation materials, Chinese designers applied their traditional “Wall - based beam - pile foundation” force transferring structure into this Passive Coffee Bar design with filling in heat insulation materials. The design also use thermal simulation software to test its performance. (Figure1)
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Picture 11 Changes for localization for Passive coffee bar design
As for external wall insulation, German Passive House tend to use XPS plate because of its closed honeycomb structure or mineral wool external wall thermal insulation composite system. But in China the regulation restricts the external wall thermal insulation material that the combustion performance of that material must be A—level. At the same time, considering construction factors that Chinese labor force is not familiar with the installation of the German system, Xian Dai designers abandoned German system and adopted hydrophobic rock wool plate instead.

Based on the whole passive design, the designers conducted annual energy consumption simulation. The annual energy consumption of this Passive Coffee bar is 175 kW•h ( / m²•a ). With the solar photovoltaic power generation system providing 55 kW•h ( / m²•a ) electric energy production, finally this Passive Coffee bar meet the German Passive House design requirement.
In this Passive Coffee Bar design project, at prime tense Chinese designers would like to check the construction cost advantage of Passive House comparing with other energy efficient building. But they found it hard to look for the alternatives for the major materials meeting Passive House requirements. In most situations, the channel to gain the major material only depended on imports, which inevitably cause construction cost rise. The construction level also effect some details design of the Passive Coffee Bar. (All source: Report: Passive Design of a Coffee Bar, 2012)

4.7 Passive House and Chinese University

Five years after Passive House entered China, at present among China's colleges and universities, only information about one university—Shandong Construction University can be found on the internet without detail information. The following picture shows the further project in that university.

Picture 13 Passive house planning in Shandong Construction University

4.8 Overall Passive House progress in China

1 The concept of Passive House was established in 1988 and after 30 years this kind of technology is finally transferred into China. After 5 years since 2010, at this moment only two Passive House projects have been completed and 20 design-build projects are process of development. Nearly all these projects locate in the north part of China in the central heating area.

2 Even the prime ministers of German and China signed an agreement to push forward this project, still in the 5 years the companies which actual participate in it are numbered. Learning from the interview, not only those Passive House projects are not focus of work in Xian Dai, but also never been heard by Chinese designers in other design institutions in Shanghai.

3 Chinese designers and construction companies involved in Passive House project are attempting to localize the technology which may slow down the project progress and effect the performance of Passive House.
4 The design knowledge and concept of Passive House has been absorbed by Chinese designers. But in the practical project, as mentioned before the material is the first problem. Construction process and management are the second. The labor force in China are mostly farmers and even they received several turns of education when project changes, those people change. The personnel fluidity in China’s construction sector will block the development of Passive House technology.

5 China’s regulation and complex natural conditions for instance earthquake increase complexity of potential Passive House projects.

6 At present, only “The Water Side” project try to commercialize their Passive House. Although the people of that project claim that their houses sales in good condition currently, no remarkable advertisement or propaganda work can be found in the market.

7 Few international cooperation between colleges and universities are conducted at present.

4.9 Interviewed record and analysis

The whole interview record can be seen in appendix 1.

The interview data can be regarded as a complement to Passive House story. In these two interviews, both sides, interviewer and interviewee, have a certain background in construction both education and working experience. That is why certain general question “what is passive house” is avoided to ask.

Chinese market is a huge and fast growing. This trend is widely known and easily seen in the interview.

The knowledge of Passive House is widely spread in Europe. The Website which contains Passive House database and knowledge is easily found on the Internet. But in China, none of this Website is shared with the public and because of the political reason people in China cannot connect to those European websites.

“Regulation” has been mentioned several times in the interview record, which matters “how to build Passive House up”. Even China designers can absorb its knowledge, they cannot directly use European Passive House system because of different natural conditions (earthquake) and different natural conditions lead to different regulations. The interview shows that for Chinese adopters, adopting “process” of Passive House is more difficult. China have not finished industrialization which lead to an overall low level of “construction capability”. This factor reflects in unskillful labor force, lacking materials and so on.
The interview also shows in today China construction industry environment, there are other factors could affect the usage of Passive House. “Decoration” unexpectedly effect Passive House usage because chemical components in decorative materials are more harmful to people in an airtightness indoor environment.
5 Analysis

In this part, we try to test the Block Models built in the theory part one by one with empirical data. Though this analysis, Block Models which really affect Passive technology diffusion in China will be listed.

5.1 Block model analysis

Block Model A
In our empirical data, the passive design of coffee bar and "The Water Side Project" are implemented by the parties. Before they decided to do these two projects, the experts involved in it tested the work-ability and they knew that the Passive House can work successful in China because the Chinese construction market is huge and the environment pollution is one of the biggest problems in China. The Passive House can fulfill the needs of potential adopters. Some passive design of residential buildings have been done by the designers so that there is no risk for the trialability of innovation because the Passive House has been experimented by the experts on this new environment. The passive design of residential building can be visible to other people because some buildings have been done by the workers so there is also no risk for the observability of innovation.

Block Model B

In this case, first “The Water Side” project, when Chinese engineers want to do the airtightness test, they find no standard for this test. The test is finally done under the guidance of German experts which affect construction progress. In “Passive coffee bar” project the designers knows in China the regulation restricts the usage of external wall thermal insulation material. In case of fire disaster, the combustion performance of that material must be A—level. The factor finally force them to change the external design. Also the regulation barrier can be found from the interview part. Even the Chinese engineer can directly apply the Passive House knowledge in their design, they cannot directly copy the ready-made construction structure and building method because China has regulation about earthquake. They need to re-design them which is more difficult than just absorb the knowledge.

The material problems also matters with “Compatibility”. In “The Water Side” project, lacking construction material in Chinese market rise the whole cost of Passive House. In the interview part, expert also worries about the way to get the essential material. Because of relatively backward environment, material problems certainly will block Passive House transfer.

Material problems not only reflect in lacking materials, but also the existing materials can affect Passive House performance. It can be found in the interview part that the
chemical compositions in decorative material are harmful to human body, if keep them in the closed indoor environment of Passive House, the situation will get worse. What’s more, the house owners’ living habit also affect the Passive House performance. Most of time in summer, the house owners opened their windows for natural ventilation causing high indoor temperature and humidity in their rooms.

All of these factors shows the Block Model B is correct.

**Block Model C**

Passive House project starts as a high-profile project since it is introduced into China. The Passive House project is led by German Energy Agency and Ministry of Housing and Urban-Rural Development (MOHURD), a China government department. The first Passive House in China was exhibited in Shanghai Expo 2010, a world class stage. All these factors eliminate people’s worry about the risk of Passive House technology.

Geographical distance and culture distance do not cause communication barriers in this case, in other words, communication barrier does not exist in Passive House project.

German has started its layout in China many years before 2009. When China established regulations about green building, it refers to German standard in 2005. It could have certain communication problems when the first time they cooperate, but in these Passive House projects in China, for instance “The Water Side” project, the engineers are under the guidance of German experts to conduct airtightness test.

But people barriers still exist. In this case “People” can be classified into two groups: mangers, engineers and designers, they belong to “Change Agent”, another group are the construction workers, who are doing their work under supervision and management of “Change Agent”. In these Passive House project, the “Chang Agent” make its effort and the result is fruitful. In the Passive coffee bar case, the whole Passive coffee bar by designed by Chinese designers. In “The Water Side” project, they overcome several difficulties and finally build the houses up and test their performance successfully. The truly people barrier is the construction workers, in China, the construction workers are unskilled farmers, lack of experience and hard to manager. When projects change, those people change. All these reasons explained why people barrier existing.

**Block model D**

The relative advantage of Passive House in China is obvious. Heating systems account for 26% China’s energy demand, and it is expected to reach 36% by 2020. The problem is that for the existing buildings are very difficult to retrofit because of barriers from many aspects, the absence of insulation know-how, cheap coal and little connection between builders (paying for insulation) and users (paying for heating system) and the
central heating systems used in Northern China, all these attributes have created a building stock that is grossly under performing in energy efficiency. Most of Chinese use the air conditioners which will add to higher energy consumption. The Passive House is a green building which thermal comfort can be achieved solely by post-heating of fresh air mass, required to fulfill sufficient indoor air quality conditions without a need for recirculated air. The Passive House can save 75% energy compared with the average new buildings. Another relative advantage of Passive House is that if can offer the high level of comfort by using the body heat from the people and solar energy which means that it is easier to heating this house. The ventilation system of Passive House can supply the fresh air in order to make the superior air quality without making any unpleasant drought. The heat contained in the exhaust air can re-used in the highly efficient heat recovery unit.

From the result of analysis of “the "The Water Side Project"”, the table one shows that the construction cost is a little higher than the existing building. Table 2 shows the energy consumption test in the "The Water Side Project", we can see that the energy consuming of Passive House standard is 60 KWh/(m2a), the heating of east room and west room is 35.62 and 48 separately, which means they are both less than the Passive House standard. Home appliances’ energy consuming standard of Passive House is 120 KWh/(m2a), and the test result shows that the consumption in east and west room are 38.17 and 46.17 KWh/(m2a), which are also less than the Passive House standard. According to these data, it can be found that the houses built in "The Water Side Project" are the typical Passive House. Our empirical data shows that the Passive House could save 80% heating fee or even more than this and more than 40% cooling fee so that the saved heating fee and cooling fee are 0.2RMB/m2/day and 0.04 RMB/m2/day respectively. "The Water Side Project" have nine buildings with totally 80344m2 area, so this project can save nearly 3 million RMB for heating fee and 100 thousand RMB for cooling fee every year by calculation. According to these facts, even the construction costs are higher than the existing buildings, the Passive House can save a lot of money for energy sources. In the future, technology in the construction industry will be improved so that the construction costs will decrease. But the energy sources won’t increase, saving energy is very important and Passive House can achieve this goal.

**Block model E**

“No current market” is one barrier in technology transfer and this barrier has been solved in this case. Chinese construction industry is huge and still fast growing. In single residential real estate sector, China is building about 1.8bn m² per year. Putting the number in perspective, today China is building more than one third of all the buildings in the world. Our empirical data illustrated that in 2009, the German Energy Agency and Chinese department relate with construction industry has been worked together to prove and promote the Passive House and low energy buildings which are adaptable to the Chinese conditions, because the Passive House has developed
The passive design of coffee bar has been done by the Chinese designers because they want to get in-depth understanding for the localization of Passive House technology. This scheduled project located in Dalian, which is a modern metropolis in north area of China, have the similar maritime climate characteristics to some German cities. There are many details included in the knowledge of Passive House design: the external wall system, door-window system, solar energy system and so on. In order to design the main structure, the designers put “Isokorb”, a high-strength insulation material used in the joint area of balcony and main structure-into the middle of concrete cantilever eaves and structure roofing board as the structure heat insulation connection. Besides this, Chinese designers used traditional “Wall-based beam-pile foundation” to force the transferring structure with filling in heat insulation materials for this passive design of coffee bar. The thermal simulation software was used to test the performance of this design. For the external wall insulation, Chinese regulation stipulate that the combustion performance of the external wall thermal insulation material must be A-level, which means that the XPS plate used in the German Passive House can’t be used in China. According to this situation, the Chinese designers used the hydrophobic rock wool plate to do this passive design of coffee bar. All these facts show that the knowledge has been transferred and absorbed by the Chinese designers which means there is no barrier in knowledge transfer.

The process of technology transfer contain the installation of this novel technology and training individuals. Our interview showed that even though the Chinese designers can absorb this new technology, they can’t directly use European Passive House system because there are many different natural conditions (e.g earthquake), the different natural conditions would lead to the different regulations. Secondly, some major high-tech materials and products are not available in Chinese market, for instance the Passive House should have its special window in order to fulfill the requirement of airtightness, but this special window is not available in Chinese market. Some other materials like the anti-thermal bridge connection element, waterproof and sealing materials, external
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Wall thermal insulation accessories are also not available in Chinese market. Chinese company can only purchase these high-tech materials and products from other countries which will increase construction costs and lengthen construction time. All these facts will affect the installation of this novel technology.

Training individuals is another important element in the process of technology transfer. China haven’t finished industrialization which will lead to an overall low level of construction capability. This factor reflects in unskillful labor force. Passive House is a new technology in China, which means most Chinese architecture design institutions have little professional knowledge about it so that they don’t know how to design and build the Passive House. The construction technology in China is laggard compared with German. Chinese designers involved in the “The Water Side Project” have spent almost one year coached by German experts, then mastered the design features gradually. On the other hand, the management of on-site construction is nonstandard which would hinder the project process. Even though the Chinese designers have been coached, the fact is that in China, the labor force are mostly farmers, which is hard for the designers to coach these farmers. Because the education level of most of them are very low and it is hard for them to understand such new technology and even they can received several turns of education, when project change, those people change. The personal fluidity in Chinese construction sector will hinder the transfer of Passive House technology.
5.2 Final block models

Based on the analysis above, Block Model B, C, F are verified existing in certain construction transfer process. The final model is shown in the following picture.
6 Discussion and Conclusion

According to the previous analysis, there are lots of barriers about innovation diffusion and technology transfer. Some barriers can’t be proved by our empirical data. In this discussion part, we will discuss why it happened. Our analysis about the Passive House showed that some barrier models established in the theory part didn’t match with our final block models.

In the barrier model A, we could see that if the parties don’t test the work-ability of a new technology, they can’t make sure if this novel technology can work in such new environment and may lead to a failed technology transfer. But in "The Water Side Project", the construction costs is 5028 (RMB/m2), and the totally area is 80344 (m2) which means the totally construction cost is 400 million RMB. The construction cost of other green buildings, which are similar to the Passive House, is also very expensive so that the parties must consider the compatibility, trialability and observability of this innovation before they decided to develop this novel technology in China. In order to achieve these goals, they must test the work-ability and they need to make sure that this novel technology can develop and work in Chinese market. So this is the reason why this barrier can’t be proved in our empirical data.

The theory part illustrates that the relative advantages of a new technology are very important because these advantages can help this novel technology get more market share. If the parties don’t realize the relative advantages of the novel innovation, this new technology will face a lot of competitions which will lead to a failed technology transfer. This is a barrier of technology transfer. But the example of Passive House in our empirical data shows that this barrier don’t exist. The S-curve can explain it.

S-curve can be defined as a display of labor hours, cumulative costs or other quantities plotted against time. The shape of this curve is just like letter S, the beginning and ending phase is flat and the middle phase is steep. A slow deliberate at the beginning then accelerating start. The ending phase represents a deceleration as the work runs out. (Wideman Comparative Glossary of Common Project Management Terms v2.1 Copyright R. Max Wideman, May 2001).
The following curve shows the Chinese construction sector. (EUSME Centre: The construction sector in China, 2013)

From this S-curve, we could know that the relative advantages of Passive House have been proved before they developed this novel technology. According to this fact, this barrier don’t exist in the transfer of Passive House.

The theory part also shows that “No current market” is a barrier in technology transfer. There is no existing market means that this technology can’t be visible to the people. In China there is a huge, blooming and open construction market for those parties to build the Passive House and certain novel technology buildings with relative advantage are welcomed by Chinese people, which means that “No current market” is not a barrier for the transfer of Passive House.

These facts are also suitable for all these green buildings similar to the Passive House because of the attributes of construction industry.

In conclusion, our thesis focus on the barriers related with the transfer of Passive House. We search for theories about innovation diffusion and technology transfer, and then combine the similar contend which are related with the barriers to build our six block models. Our empirical data are the two cases about the Passive House in China: "The Water Side Project" and the passive design of coffee bar. These two cases are the representative cases in China and we also use some relevant materials to support our empirical data. We used our empirical data to illustrate the theory part. Some theories can be proved by these two case but some can’t. We analyze the relationship between the theory part and empirical data and text six block models. Finally we select three block models which can be proved by the empirical data. Block model B contain the compatibility of innovation diffusion and regulation barrier of technology transfer. Block model C include three attributes of innovation diffusion: time, communication channel and change agent and the people barrier of technology transfer. Block model F consist of complexity of innovation diffusion and knowledge and process barriers of technology transfer. These block models can also be used for other green building
transfer process which are similar to the Passive House because of the attributes of the Chinese construction industry.

6.1 Shortcoming of our study

Our study still have some shortcomings. Firstly, we only choose two cases of Passive House in China as our empirical data because there are only few cases about Passive House and there are only little available information which can be collected from the internet, journals and other channels in China until now. We can just get the useful information from these two cases which means some other problems may be not noticed. If there is more information about the Passive House stories in China, then we can analyze it from all aspects. So this is one shortcoming for our study.

Secondly, we just interviewed two people because of limited time and defined conditions, one is the PHD in construction industry and another one is a Chinese senior designer and engineer. These two people provided us a lot of empirical data about the Passive House and its relevant information. But they are not experts who study the innovation diffusion theory and technology transfer theory because they are not on that academic background. So we can’t make sure if the theory part include all aspects about the innovation diffusion and technology transfer.

6.2 Practical implications

This study reveals the difficulties, barriers, problems that appears in construction technology transfer process from developed country to developing country with Passive House transfer as a practical example. These block models has managerial implications, helping both senders and adopters in construction technology transfer process. For the senders, they can find that compatibility (regulation, material, even users living habit), people barrier, process barrier are the main factors which should be focus on if they wish to successfully transfer their construction technology. For the adopters, they will know that sometimes the barrier is not the knowledge of technology but the process, also the people barriers are not on their own, but on the people under their management. We suggest that the senders start their layout in an early period, trying to influence the whole environment step by step, assist local government to establish regulation and standard. For adopters, research and development are also necessary in order to find substitute for materials, or to localize the technology for reducing cost. What’s more, educating people, instilling ideas, organizing and training long term workers are helpful actions in order to transfer construction technology.
6.3 Theoretical implications

For the academic reach area, the results of our study bring additional value. Our block models combined Roger’s (2014) diffusion of innovation theory and technology transfer theory abstract from literatures. These models are then verified with realistic projects. The final block models are relatively new academic results.

First the Block Model C shows that people barrier is a major fact that could block construction technology transfer. In the diffusion of innovation theory, based on the time it takes to adopt the innovation, Rogers (2014) classifies the adopters as innovators, early adopters, early majority, late majority, laggards. But here in this Passive House project, “time” is not the only criterion to classify people. Engineers and workers in China are Passive House technology adopters, it is hard to classify them in “time”, but it now appears that unskillful workers are the major problems. In order to further discuss and study certain construction technology transfer, the word “Capability” could be introduced to further classify adopters.

Our final Block Model F reveals that although “knowledge” and “process” both can be barriers to transfer technology, the analysis part reflect that “process barrier” cause more problems than “knowledge barrier”. In the Passive coffee bar case, it is evident that the knowledge of Passive House has been absorbed by local Chinese local designers, but the “process” even affect design ideas. Relative literature reveals that both “knowledge” and “process” could block technology transfer, but it has not focus on construction technology. The conclusion that “process” cause more problems than technology can be applied for other green building technology, which has the similar conditions as Passive House.

6.4 Further research

Our research focus on the barriers in innovation diffusion and technology transfer. We find some content related with the barriers in theory part. We also find some realistic barriers in the empirical data part. We use our empirical data to illustrate the theory, and build our final block models. There are still lots of knowledge gaps which can be researched. Our research is related with the Passive House, but we haven’t study what kind of technology level of this Passive House. So the further research can examine the level of this novel technology, to see if it belong to the high-technology or the low-technology. Because different level of technology will have different requirements and processes. For instance the high technology may need the complex materials and processes. And the cost of high technology is higher than the cost of normal technology. On the contrast, the low technology would require simple materials and processes which means the cost for transfer is low. So the further research could focus on these parts and build new theories.
LIST OF REFERENCE


EIU: Building Rome in a Day: The sustainability of China’s housing boom. April 2011

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Wideman Comparative Glossary of Common Project Management Terms v2.1 Copyright R. Max Wideman, May 2001
APPENDIX 1

Interview record

The first interview is conducted between interviewer and John, a construction industry PHD in Halmstad University, Sweden. The whole interview record is written down below and interview evidence is added after that.

Interviewer: Hello John, very nice to meet you today.
John: Nice to see you. Please have a set. So, what is your purpose for today’s meeting?
Interviewer: Today I am going to talk about Passive House. I got to know the Passive House concept from my learning experience in Sweden. The first time I knew this kind of Green building, I immediately got an idea that it can be used in China.
John: I absolutely agree with it.
Interviewer: Why are you so sure? Do you know much about China?
John: Not very much. But as I like to read news through TV and Internet, I know China suffers a lot for the severe environment problem. Even in its capital Beijing, right? The “PM” problem. And I know that China has a big construction market.
Interviewer: Right. As a Chinese construction engineer, I always want to apply certain Green Building technology to solve this problem. But I have not studied deeply about Passive House, its technology details. As you are the expert in construction industry, I would like to seek confirmation for some problems.
John: So what do you want to know today, the Passive House itself or how to build it up?
Interviewer: First the Passive House itself. I have collected some reading materials in some German Passive House website. But I think the more data, the better.
John: Yep, OK, I can send you other websites for some detailed information after this meeting.
Interviewer: Thank you very much. I have got a primary knowledge about Passive House. It seem not very hard to understand it, even if I am not a construction designer.
John: I agree. The work mechanism of Passive House is easy to understand.
Interviewer: But really design a Passive House is not that easy, especially in China. I think none European building is easy to be redesigned in China. Because China has earthquake.
John: Yes, so that firstly the construction main structure must be enhanced in case of earthquake. There are many other different natural conditions which will change the design.
Interviewer: Sweden has no earthquake right?
John: Yes. German also.
Interviewer: How about the building process? I do not think it is easy.
John: It is not easy especially you should make sure the airtightness. That means each functional part should be combined and installed very exactly.
Interviewer: That means you should have skilled workers.
John: Yes. Not only skilled but also experienced workers to build it up. The on-site construction need a certain long time.
Interviewer: How about change the building method, I mean, for instance, precast
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method. Because nowadays Chinese government encourage this building method.

John: The building method certainly can change but as you said that there is earthquake and other different natural conditions in China. These factors will force the designers to do lots of feasibility research. Or maybe you can find the country who has the same conditions as China, use their building system. Can you think of any country?

Interviewer: Japan.

John: Have you think of why China do not use Japanese building system.

Interviewer: Some historical reasons and regulation reason.

John: This the regulation will also be a big problem.

Interviewer: Yes, this is also what I would like to ask. In China, for example, we have regulation that defines “what you should do” or “what you are better to do”. But sometimes for saving time, those “what you are better to do” clause becomes mandatory clause. Do Sweden has this kind of problem? (Show him Chinese regulation clause).

John: Our design is alterable. Most time the design can just meet the requirement of functional unit of the building.

Interviewer: That means even the existing building process cannot be borrowed for China because of regulation limits.

John: Exactly

Interviewer: And what about the materials?

John: Ah, you mean can we find these materials in China. I do not know and the export progress would also be a problem.

Interviewer: Yes, I think I have solved a lot of problems. Thank you for today.

John: That’s all right.

The second interview is conducted between interviewer and Qi Yuan Peng, I senior designer and engineer in Shanghai Xian Dai Architectural Design (Group) who has more than eight years design experience.

Interviewer: Nice to meet you, sir.

Qi Yuan: Nice to meet you. Before we start I have a request that can we keep this interview a little short. Because I am a little busy at this moment.

Interviewer: No problem. As a Chinese experienced designer, have you heard a new Green building concept called “Passive House”.

Qi Yuan: Yes, and very interesting I just come back from a Passive House lecture in our company.

Interviewer: Really? Is it the first time you know the concept?

Qi Yuan: No, but you can say it in that way because I have only segmental knowledge about Passive House design.

Interviewer: During data collecting period, I found a very useful material “Passive Design of a Coffee Bar”. This project was conducted by your design group. If you know this project, can you tell me the story of it?

Qi Yuan: Sad to say that I do not know how the project going because I am not concluded in this project. But I know its designer.

Interviewer: How is he now? Is he still working on this project?
Qi Yuan: No, you see that in this material the project design time was 2011.6~2011.12. Four year has passed since that and he is working on other projects now.

Interviewer: Four years, then how about the progress in your design company. I means how Passive House study is going on. Is it the work focus in your company?

Qi Yuan: I do not think it is our working focus. But we still work on it. At this moment, we try to build it in our construction system, I mean, localization. And I think we are waiting.

Interviewer: Wait? Wait for what?

Qi Yuan: The whole environment. Especially the construction capability. You know our construction workers are almost migrant workers, right? We should wait for the time our country accomplish industrialization, thus the construction capability will level up.

Interviewer: You mean we still have a long way to go?

Qi Yuan: We need time, but that will not be very long.

Interviewer: What is about our own green building technology? How is that going?

Qi Yuan: We are absorbing the outstanding design concept, Passive House can be one of them. We try to combine these excellent designs in our own system to reduce cost and adapt the current environment. If you want to know more about this, I can offer some thesis documented in our company system.

Interviewer: Do we have certain website which tells Passive House information like Passipedia (show the website to him).

Qi Yuan: At this time I am afraid this certain database could only be find inside a construction company. For instance, we have a date base and also can link the German website. But this kind of date base has not been shared with the public.

Interviewer: From your perspective, what do you think will block the Passive House technology in China?

Qi Yuan: As I said that construction capability. Just now I think of decoration.

Interviewer: Why decoration?

Qi Yuan: The decorative materials in China market are not in strict management. Some of them contain harmful chemical composition. If they are used in that Passive House closed, airtightness indoor environment.

Interviewer: Thanks very much for today’s interview.

Qi Yuan: The Passive House is an interesting concept you also can work on it. I think it may be popularized in China when you are my age.

Interviewer: Ha, thank you very much.