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Sustainable renovation projects of residential buildings

5 examples in Austria

WENYUE GAO, PENG ZHANG

Master thesis at Chalmers Architecture
Program of Design for Sustainable Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden May, 2011

MASTER THESIS

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CHALMERS UNIVERSITY OF TECHNOLOGY
SE-412 96 Göteborg
Sweden
Telephone: +46 (0) 31 - 7721000

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Abstract

Now, we are facing the challenge of constructing in a sustainable way. However, discussions of sustainability tend to focus on new buildings while the existing building stock is often overlooked. More attention should be paid to sustainable renovation. The existing residential buildings, which have a direct relationship with people’s life and environment, account for a large amount in European countries. This thesis focuses on the sustainable renovation of residential buildings in Austria. The aim is to present recent practice into sustainable renovation of residential buildings with two highlights: decreasing of environmental impact and increasing of the comfort of life; and to provide a checklist to analyze and communicate examples of sustainable renovation. Firstly, an understanding of sustainable renovation is formed. Then a checklist is developed for selecting and discussing of relevant cases. Five cases are chosen: “Dieselweg” a residential district in Graz, "Fussenau" a residential district in Dornbirn, House “Zeggele” in Silz, residential buildings "Tschechenring" in Felixdorf, and a house in Pettenbach. Two of them are typical multi-family residential buildings which are found in a great number in Austria. Two are renovation of historical residential buildings; and one is a single-family house which represents 40% of the residential building type after the war in Austria. The five cases are analyzed by the checklist. The results are compared and experiences are summarized for future renovation project of residential buildings and new buildings. The result of thesis, for architecture, can be a part of a case library related to sustainable renovation of residential buildings, and a guideline to achieve sustainable design; for public, it can be a demonstration of the benefits of sustainable renovation, and promote wiling and awareness of sustainable renovation. What is worth to mention is that all measures and methods may great help the future project in China, which can promote sustainable development in China

Keywords: Sustainable renovation, residential buildings, Austria, environmental impact, living comfort, environmental aspect, technical aspect, architectural aspect, social aspect, cultural/emotional aspect

Preface

This thesis work is the final examination to receive a master-degree in studies of Architecture in Chalmers University of Technology in Sweden. Supervisor and examiner is Assistant Professor Liane Thuvander at Chalmers (Department of Architecture). Wenyue Gao is from program of Architecture and Peng Zhang is from program of Design and Construction Project Management. Both of us joined in a studio of sustainable building last year and participated in a sustainable building competition. We are both interested in this field and want to learn more about it. That's why we choose this topic as our master thesis.

We should like to thank all those persons that have made our master thesis a learning and inspiring adventure.

First of all, we want to thank our supervisor and examiner Assistant Professor Liane Thuvander for her infinite support, qualified supervision, and enthusiasm. Without her commitment this thesis would never have come about.

Other persons have provided help during different phases of the work: Hans-Peter Lorenz who provide us the information for Case 2; Daniel Heiß who gave the result of the renovation in case 3; and Günter Lang who was the consulter in Case 5.

We should also like to thank our fellow students worked in the same topic of the master thesis. The discussion with them have inspired us a lot.

Lastly, but not the least, we wish to thank all the friends in Sweden and our parents, for supporting us unconditionally.

WENYUE GAO
PENG ZHANG
Göteborg, 2011

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1. Introduction

1.1 Background

Construction industry plays a key role in sustainable development

Environment issue is an important aspect of sustainability. Now, we are facing the challenge of natural resource shortages, landscape and biodiversity depletion, and global climate change. There is a consensus that the construction industry has a considerable impact on the environment. It consumes both renewable and non-renewable natural resources and generates emissions and waste during construction and management of the buildings. In short, during the whole life time of building it has impact on the environment. Even though most “sustainability” issues concentrate on environmental performance, it is important to remember that sustainability is a concept with a tight connection to society. (Bugl et al, 2009) Because as a kind of result of construction industry, sustainable buildings, has great positive influence to peoples’ daily life, which can promote social harmony and stability. Still, building can act as a cultural carrier to promote cultural transmission, but this was not paid enough attention in the past.

Residential building around Europe

The number of existing residential building is very large in European countries, accounting for about 70% of the total building stock (Meijer et al, 2009). It has a direct relationship with a good life for people and environment.

One fact is that European countries have a relatively low rate of newly construct residential buildings. The annual residence production in Europe barely exceeds 1% of the total housing stock (Thomsen and Flier, 2009). The number of existing residences largely exceed the number of newly built dwellings in most developed countries, and the existing residences will continue in a dominate state in the next 50 or more years. Therefore, there is a potential trend that the rate of building renovation increases.

The other fact is, most of the housing stock in the European Union was built after the Second World War (Figure 1.1), which falls to fulfill modern needs, especially regarding energy consumption, and is consequently threatened by large-scale demolition. In this case, Thomsen and Flier (2009) argue that renovation should be considered when updating residential buildings.

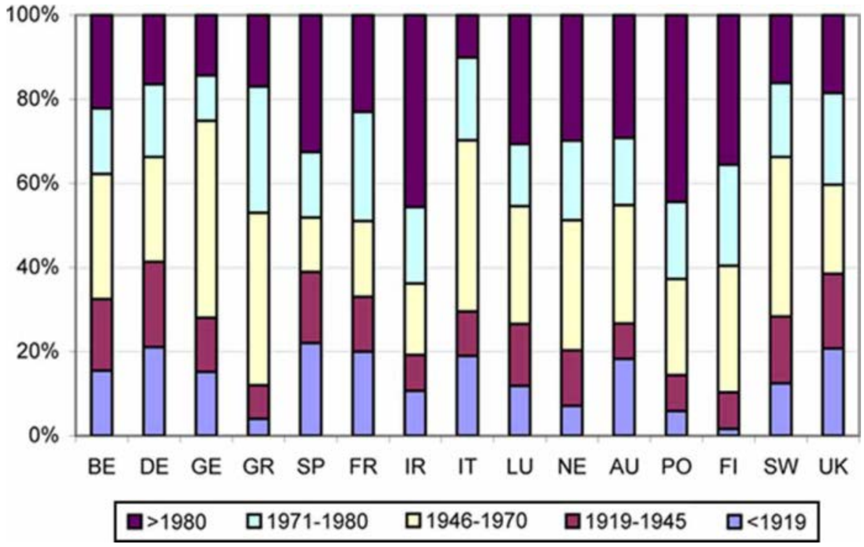


Figure 1.1: Age of the housing stock in selected countries in Europe. (Itard and Klunder, 2007)

As a result, the European countries should achieve sustainable building, with an emphasis on exist residential building.

Neglect of existing buildings

The awareness of sustainable building has been raised, but the existing residential stock and the activities related to it are often overlooked. Although last decades, have seen growing policy attention for the existing residential stock (Kohler and Hassler, 2002; Thomsen and Flier, 2009; Kohler, 2006; Sunikka, 2006; Thomsen and Meijer, 2007), building regulations and other instruments are still mainly focused on new built residential buildings.

As can be seen in Figure 1.2, the demolition rate (the ratio of demolished residential building and the total residential building) of some main countries in Europe is growing fluctuant. The reasons for the “demolish and new construction” become the prime choice rather than renovation varies, mainly due to: new construction is not that complex compared with renovation; and many architects anxiety for and prefer to new design style. The focus is largely centered on the new buildings, and sustainable trend has not caught on to the same degree in the renovation of existing buildings.

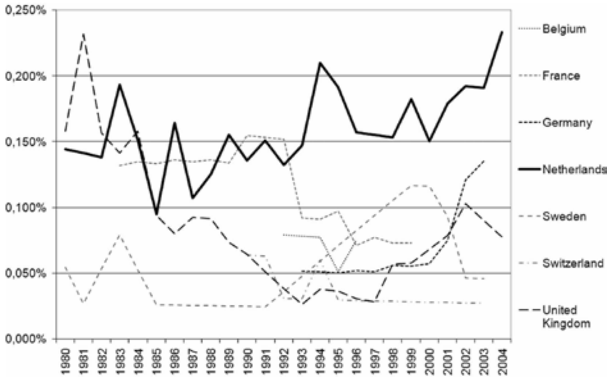


Figure 1.2: Demolition rate of selected countries in Europe
(*Thomsen and Flier, 2009)*

More attention paid to renovation

Why have existing buildings been overlooked? It may be mainly because of new buildings and high-tech systems have attracted all the attention, which can provide architects and engineers opportunities to create new things. In comparison, cleaning boilers and installing new windows does not seem terribly exciting. But we think it is a misunderstanding of sustainable renovation which can also be very exciting and get a huge sense of achievement and satisfaction

Fortunately, the awareness of the importance of existing buildings is increasing. Recently, researches have shown the positive of renovating existing buildings, and point out the existing building stock is one of the key issues for sustainable building. Sunikka (2006) and Sunikka and Boon (2004) emphasize the importance of the existing stock for CO2 reduction, and also the reduction of the burden of demolition waste as addressed by Thomsen and Flier (2009). They also show that by following the Kyoto treaty guidelines, renovation-based strategies are a much better alternative than demolition, due to decrease environmental impact and reduced energy consumption. Awareness of the potential of the existing stock is becoming widespread among stakeholders on different levels; the European Union, national governments, constructors, building owners, and housing associations have become interested in trying to achieve a more sustainable existing building stock.

As shown above, the trend of acknowledging the importance of renovation in Europe has birthed, renovation is still an infant, which need to be feed and grew up.

Good sustainable renovation cases should be researched and popularized

Awareness generation is necessary, because awareness can help us to know what to do. But without good examples as references, it is hard to know how to do. Currently, there is no doubt that sustainable building renovation is not a megatrend in the construction sector, but, there are several good examples of sustainable renovation projects, for example in Germany, Austria and Netherlands, and on the way of being popularized (Thomsen and Flier, 2009). These good examples can act as a knowledgebase to support and carry out future sustainable building renovation projects.

1.2 Aim

The aim of this thesis is to present recent practice into sustainable renovation of residential buildings with two sub-focus: to show examples of decreased environmental impact and increased comfort of life; and to provide a checklist to analyze and communicate examples of sustainable renovation.

The result of thesis, for architecture, can be a part of a case library related to sustainable residence renovation, and a guideline to achieve sustainable design; for public, can be a demonstration for the benefits of sustainable renovation, and promote willingness to achieve and awareness of benefit from sustainable renovation.

1.3 Scope and method

According to the research of "Building renovation and modernization in Europe" carried out by Itard et al (2008), sustainable renovation policies in Austria had two priorities on promoting measures to reduce energy consumption and increase the comfort of life such as upgrading socially downgraded areas, supporting quality of life in rural areas, and health risk reduction. These priorities are matching the two highlights of our aim. Five residences renovation project in Austria have been selected. The sustainable characteristics of these five cases are the focus of the research.

There are two main parts in this thesis. One is the theoretical framework in which understanding of sustainable renovation is formed and a checklist for discussing cases is developed. This part is based on literature. The other part is collection and analysis of each five renovation cases in Austria. The methods used in this part are: 1) data collection from multiple sources such as documents and proceedings from the process, drawing and early sketches, brochures and information from the website, emails from the relevant people; 2) analysis of good points and weak points in each case; 3) comparison between cases; 4) conclusion of what can be learnt for future renovation projects and new buildings.

1.4 Structure

In this thesis, the cornerstone is renovation. The research background and aim are put in the introduction part, which are the starting point and lead the direction of research of the whole thesis. There are three core parts in thesis; i.e. theoretical frame work, current situation of sustainable renovation, and the case studies (Figure 1.3).

In the theoretical frame work Chapter 2, the concept sustainable renovation is defined, driving forces and restrictions of sustainable renovation are analyzed, and appropriate approaches to stimulate development of sustainable renovation are proposed, which can have the ability to push sustainable renovation forward.

Chapter 3 has three parts, firstly, is the institution and policy toward sustainable renovation in Austria; then the current situation of sustainable renovation; finally, the five case studies. The former two parts define the macroscopically atmosphere for the cases study, and the cases study in turn is based on microcosmic perspective to representation of the former two parts.

Finally, the discussions and conclusions in Chapter 4 give us a platform to express our ideas and suggestions.

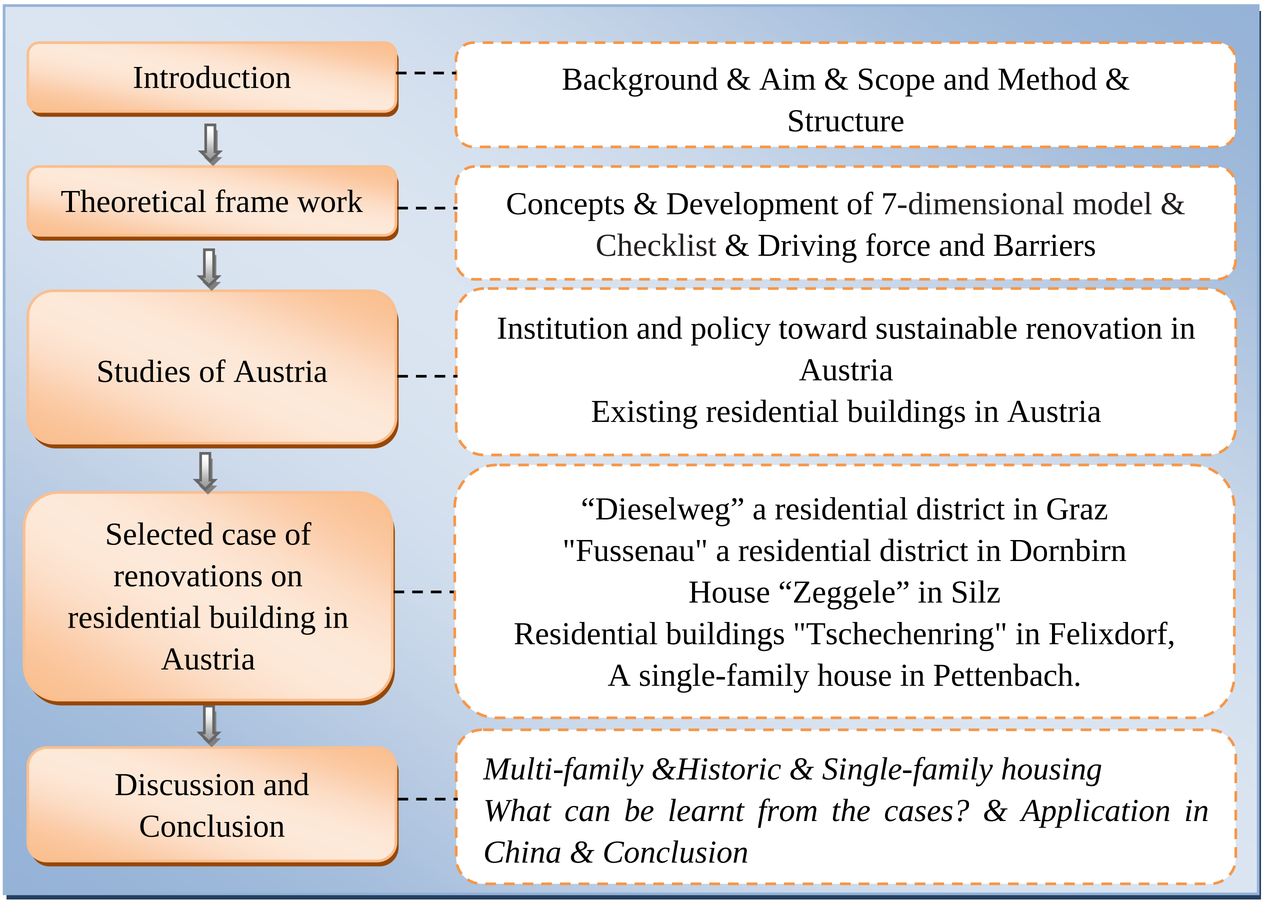


Figure 1.3: The structure of this thesis

2. Theoretical Framework

In order to analyze the cases of sustainable renovation on residential buildings, we firstly clarify the following concepts in the theoretical framework:

- The concept of renovation
- The concept of sustainable building

Based on the discussion of renovation and sustainable building, a concept of sustainable renovation on residential building comes out, which is a contribution of this thesis, and named “7-dimension” model.

In order to use the “7-dimension” model for the discussions of the cases, we develop parameters for the “7-dimension” model and modify it based on the aim of this thesis. Accordingly, a checklist is formulated (contains 5 dimensions), which is the guilder for the cases study.

For the discussion of benefits and barriers in every case study, the general driving force and barriers is stated at the end of the theoretical framework.

2.1 Renovation

Two kinds of lifespan of building: Cycle & Linear

Generally, there are two lifespans existing in the construction sector (Figure 2.1). One kind of the lifespan of buildings can be described as a linear development which includes briefing, design, construction, delivering, usage and demolishment. Thomsen and Flier (2009) describes the linear lifespan as a decay process, and in this process, dwellings as the gradual loss in time of the original (physical) performance capacity: the decline issues include the technical and functional qualities of the building. This process can be called from ‘cradle to grave’, be demolished is the destination of building. The other can be described as a cyclic revolving process of building initiative, design, construction, utilization and redevelopment or recycling (Straub, 2001).

Figure 2.1 shows that the biggest difference between cyclic lifespan and linear lifespan is that there is a “loop” after building project delivery and usage. The goal of this “loop” is reuse; the core of “loop” is renovation.

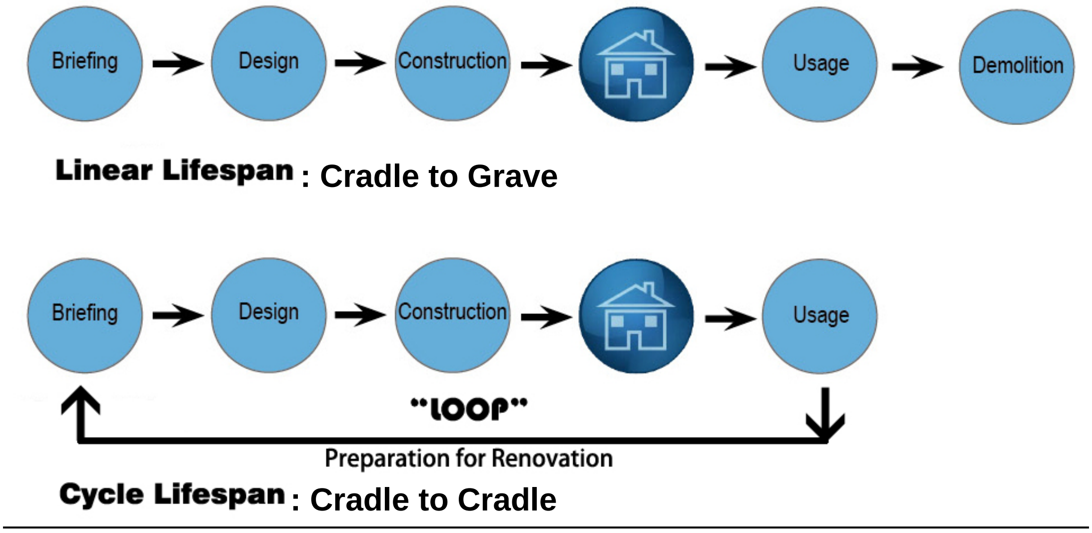


Figure 2.1: Two kinds of lifespan, Linear and cyclic lifespan

It is obvious that the buildings with a cyclic lifespan can reduce quite a lot of waste than those with a linear lifespan. At the end of their linear lifespan, considerable resources are wasted and the buildings themselves become large amount of construction trash. Although there is apparent advantage of a cycle lifespan, some buildings are inevitably demolished because mere maintenance cannot help to extend their lifespan or make them reused.

Renovation may fill the gap between simple housing maintenance and demolition, providing opportunities for establishing closed loops for the usage of buildings. It is an important tool for usage of buildings shifting from 'cradle-to-grave' to cradle-to-cradle, which means 'Renovation' can provide opportunity for buildings to reborn through reusing some old component that still reliable, and upgrade some elements that should 'retire'. In this case, renovation can be seen as the corner stone of the 'loop'; or in other word, 'renovation' play a key role for building reusing.

Some discussion and definition of renovation

According to Oxford English dictionary, renovation (also called remodeling) is the process of improving a structure. We understand the word' renovation' is generally used to cover modernization, remodeling, retrofitting, restoration and rehabilitation, each of which is a method for renovation.

Mostly, renovation refers to reuse an existing construction (including structure and components etc.) on the site, integrate its structure, and possibly upgrade it or extend it. It is now relatively common in the field of heritage structures as they are seen to

have cultural value. While in many other existing building with little historic or cultural values, renovation is also possible to improve their quality.
According to Latour (1999), renovation design, unlike the design of a new building, has two emphases: immutable and mobile. Immutable refers to the old, respecting the history and culture of the building, and mobile refers to the new, satisfying the modern requirements. They are equal items, putting onto each side of a balance. And for renovation of residential buildings, people occupied the residences need to be carefully thought.

2.2 Sustainable building

Today, with people highlighting the environment, renovation should satisfy sustainable requirement as well. In this case, it is necessary that we should have a correct understanding about sustainability and sustainable building before we go in for renovation project.

From sustainable development to sustainable building

During the past 20 years, various kind of definitions of sustainability or sustainable development have been generated, of which the most wide spread definition is

Design of sustainable development has to satisfy the needs of the present without compromising the ability of future generations to meet their own needs. (WCED, 1987)

This political concept was presented in World Commission on Environment and Development (WCED), 1987, and with more than 20 years' development, the concept of "sustainability" has highlighted by many industries, no doubt also to include the construction sector.

As the product of construction industry, building is an essential thing for every people's life, especially residential building, which can not only provide a shelter for people live, but also recently, is treated as a work place, such as SOHO (small office home office, which means work at home).

Adapted to sustainable development of residential buildings, the definition can be translated as design of sustainable residences has to satisfy the needs of the present without compromising the ability of future generations to meet their needs of having a good live condition.

The definition of sustainable development set in 1987 plays an important role. By using the adapted definition, the sustainable development of residential building can be guided to a positive direction. Moreover, the number of residential building is large and special for living, which is the corner stone of people's happiness. And the sustainable residences will definitely push the whole sustainable development forward and the whole society.

Sustainable building definitions

Sustainable development is a rather ambiguous term, covering a wide variety of aspects, sustain the natural environment is the starting point of sustainable development. Unfortunately, a narrow sense, which is sustain natural environment equals to sustainable development, is still deep into many people's mind (Figure 2.2). Kibert (2007) mentioned that with respect to sustainability, construction sector prefer to improve the performance of buildings through using hi-tech things, resulting in less consumption of energy and materials, and a good way to treat trash. Construction sector only focus on green performance and concentrate on techno-sphere and ecosphere (Cole, 1999).

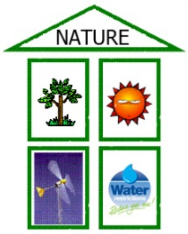


Figure 2.2: Narrow sense of the concept sustainable building with focus on the environment

Then there is a shift from 'narrow' to a global perspective of environmental, economic, and social aspects of understanding of sustainable building (Cole, 1999). Kibert (2007) stated that sustainable building construction is about how the construction industry together with the built environment, among many sectors of the economy and human activity, can contribute to the sustainability of the earth including its human and non-human inhabitants. Cole (1999) has argued that sustainable building projects must include a low nature resource usage and natural environment impact, and positive effects social systems, and sustain growth of economy. Adams (2006) presented a model with including environmental, economic and social aspects just like three pillars (3-P), to hold and support the "sustainable building" stand erect (Figure 2.3). Each "pillar" is not isolated; they create a network, and strongly connect to each other. Any change happens in one pillar results in the response of the other two. This kind of definition, which integrates three sustainable fields, is widely used to explain sustainable building project. This is in line with the Brundt Land definition in 1987.

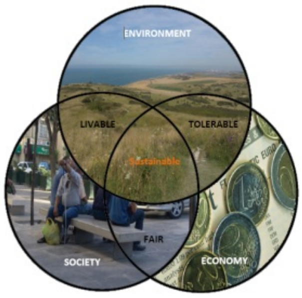


Figure 2.3: Three Pillars of sustainability
(Trachte & Deherde, 2011)

Resource is a frequently used word in sustainable building. Pearce (2006) presented an understanding of sustainable building from another perspective which strong relates to the volume of resource increase or decrease. He enlarged the concept of resource, and stated that all the resources can be treating as "capitals", and there exist four main capitals, i.e. man-made, human, natural and social. Variations and transformations always happen between these capitals (Figure 2.4). Each capital is a substitution of others. Reducing one capital is not consistent with sustainability unless another capital is increased. Pearce argued that the real sustainable building is actually no more than a breakeven point, the reduced volume of one kind of resource will equal to the increase volume of other resources.

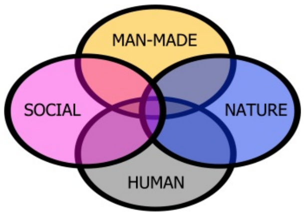


Figure 2.4: Definition of sustainable building based on the concept 'capital'
(*Pearce, 2006)*

Mutable and enlarging concept

Sustainable building is a complex issue; various kinds of aspects need to be considered. New problems will continually be found one after another on the way we pursue sustainability. Consequently, the definition of sustainability is not immutable, it is mobile, and always varies, in order to become more comprehensive. Much of the literature on sustainability has therefore multiplied entities rather than narrowing them down in an effort to ensure more meaningful discourse. In the building field, the definition has shifted from ‘nature only’ to ‘three-pillar’ and to understandings from other perspectives, and this kind of shift will constantly go on. Definition and redefinition will never stop (Figure 2.5).

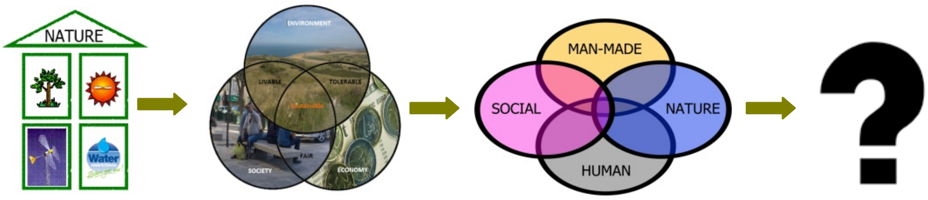


Figure 2.5: Redefinition of sustainable building goes on

2.3 Systematic thinking of sustainable renovation on residential buildings

7-Dimension Model

Through the discussion of sustainable building theories mentioned above, such as 3-pillar and 4-capital ideas, we can conclude that sustainable renovation is a complicated issue, in which a number of entangled and interacting factors are relevant for the process. The factors, such as natural factor, social factor, human factor etc., are in different fields.

Kain (2003) came up a model named *The MAIN*^{TRTRA} (Figure 2.6), which is for localized infrastructure planning and sustainable urban development. Four kinds of capitals (mind, artifact, institution, nature) make up a network, of which, mind means human knowledge and skills affect development; artifact means issues created by human skill or agency; institutional means the aggregate of actual or potential resources; and nature means capitals that are created by bio-geophysical processes and not human action.

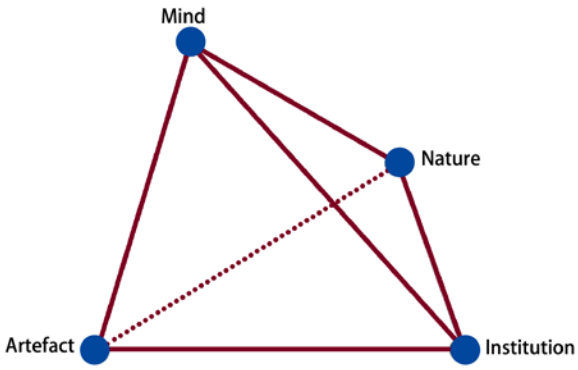


Figure 2.6: The MAIN^{TETRA} *(Kain,2003 , pp 328)*

Lomas (2009) argued that lots of problems will be met in the process of Sustainable renovation on residential buildings, in this case, renovation must be an interdisciplinary work, which involve many people who work in different fields to deal with those problems.

Inspired by the understandings of sustainable building and the theories mention before, we come up with a 7-dimension model of the sustainable renovation on residential buildings which generate a network for sustainable renovation.

The model (Figure 2.7) has a pentagonal roof, with each corner representing an aspect of “environmental”, “technological”, “architectural” “social”, and “cultural (emotional)”, and all of them are under the heading of “mind” and closely related to “economic”. Under this roof is sustainable renovated building.

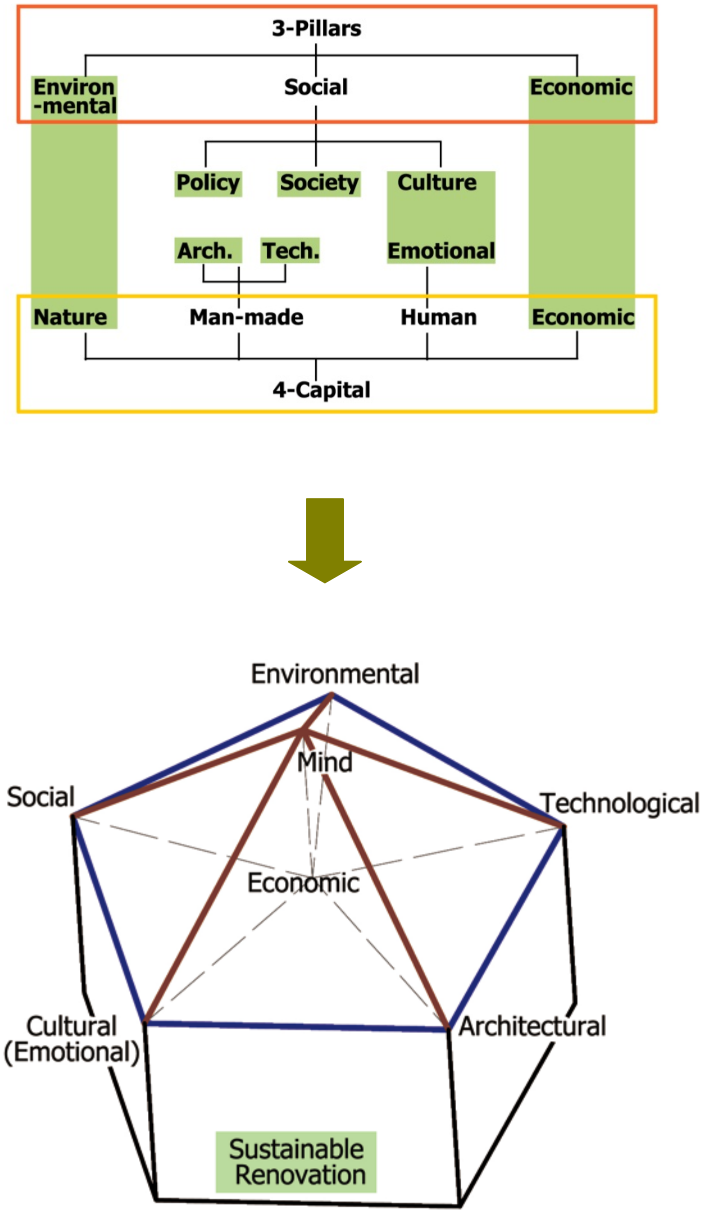


Figure 2.7: Development of 7-dimensional model of sustainable renovation

- Mind: policy and awareness

Mind plays a leading role in the field of sustainable renovation on residential buildings. There are two kinds of minds in this field. For every people who involved in this field, mind shows itself as the sustainable awareness. And for the decision-makers such as government, policy is the form of their mind. In most cases, local and national governments are important players in the renovation process of the housing stock. Sometimes, other people involved like specialists/consultants and house owners also greatly affect this process. If sustainable renovation appears positively to people, they will do it consciously. Meanwhile, policy can help or even enforce people to have a mind to work on sustainability. Moreover, mind enables the other six dimensions complement each other instead of working separately.

Policies (institutions and regulations) are the rule of the society, our actions should follow them, otherwise society will sink into chaos. Therefore, policy is above all the other issues, and located in the core status of “7-demension” concept, leading the development of the rest 6 dimensions. As in the report ‘building renovation and modernization in Europe’ by Itard et al (2008) stated that there are three main tools for policy: regulatory instruments such as building codes and standards; economic instruments of subsidies, taxes, etc.; and communicative instruments which mean education and information for public. In recent years many countries have upgraded their housing and construction regulations in order to stimulate more sustainable developments. The main applied incentives for sustainable renovation seem to be subsidies and tax reductions (Itard et al, 2008). Communicative instruments are located in an assistant status, but it is equally important with the regulatory and economic, because public awareness can be raised through information and communication.

- Economic

It is unwise to pay too much, but it is worse to pay too little. When you pay too much, you lose a little money- that is all. When you pay too little, you sometimes lose everything; because the thing you bought is incapable of doing the thing it was bought to do--- John Ruskin (1860), as quoted in Sustainable Construction, Halliday, 2008.

Expense of sustainable renovation should be reasonable and must be affordable to people and not too expensive (Chwieduk, 2003). The meaning of “expense” should be based on the consideration from lifecycle perspective rather than only the construction period. As to the field of renovating residential buildings, economic goal can achieved through purchasing products with reasonable price, good house management, energy efficiency, low operational cost etc.

- Evironmental

Renovating existing building obviously saves energy, natural resources and building materials, and minimizes construction waste as well. To run the renovation in a sustainable way, environmental aspects need to be more carefully considered. To realize environmental goal, sustainable renovation should rely on wisely use of resources such as the land use, use of renewable construction materials, the extraction of materials, the manufacturing of products, the assembly of products into buildings, the maintenance and replacement of systems, and the ultimate disposition of waste, building systems, noise, air quality, etc.

- Technological

Sustainable renovation on residential building often adopts some technical strategies such as HVAC technologies, energy saving technologies, etc. to achieve its goals of efficient use of resource. Choose a proper and affordable technical strategy usually can lower operational energy consuming, which is an important issue.

- Architectural

The basic function of residential building is to provide a place for people to live in. Sustainable renovation on residential building is a strategy to enhance this function through a comfort and aesthetic form and environment, both inside and outside building. During the design process, architects should concentrate on Layout flexibility; Space utilization; Grouping of function; Design for deconstruction; Architectural aesthetic. This is not only based on architects' idea, but also an understanding of the occupants` behavior and emotional needs. Any attempts to improve the environmental performance of housing stock could not be separated from improvements to its occupants' living conditions.

- Cultural & Emotion

Sustainable renovation is concerned with much more than can be measured –a large part of it is the cultural/history question and people's emotional issue such as neighborhood relationship, memory of residents, and aesthetic.

In the field of common residential buildings, it is more about an emotional conserving issue. Usually, it represents the memory of people and influences people's feeling of happiness and satisfying. So these needs for happiness, security, belonging, etc. should be taken into account. Sustainable renovation not only refers to the physical entities, but also to cultivating a good humanistic environment. When people walk out from home, they have to blend into the social network. A good community environment and harmonious neighborhoods will have positive influence on people's mood. What is worth to mention is if a residence is a historical building, its culture identities should be considered during renovation.

- Social

Social sustainability is a core topic of designing built environments that are not overly complex but serve as a social facilitator and symbol that affect security or social segregation (Canter, 2008). Residence renovation allows people continue using buildings and upgrade living condition. It is a kind of embodiment of facilitating the social safety and equity that contemporary people and future generations can have a safe and comfortable home which can promote social stability. Sustainable renovation on residence is a need for investments to stabilize social systems (Sassen, 2001) or for freedom of choice that enables people to realize their capabilities (Sen, 2001). Good example and data collection and popularization are what some social organization should do, which is a part of foundation for renovation development.

All the seven dimensions are closely related, complementing each other and influence renovation efficiency. Sustainability dimensions are inseparably connected, i.e. usage of innovative technologies in building renovation can satisfy ecological and economic needs, or cultural and architectural dimensions encourage social needs satisfaction. All in all, it is about ensuring a better quality of life for everyone, now and for future generations.

"Sustainable baton" delivered during whole renovation process

Since the early 1990s, a substantial part of policy analysis for a sustainable built environment has been dedicated to exploring the effects of life-cycle thinking (Chau, 2000). Rather than treating each stage in the life cycle of a building or construction in isolation, sustainable renovation emphasized the interconnections between the individual stages.

Halliday (2008) presented an interesting idea, which is a "sustainable baton" (Figure 2.8); he said that the whole building renovation process is a kind of relay race which covers many stages, including briefing, information collection, design, construction and usage. In the briefing stage, someone decides to start a renovation process. Important/interesting here is why a renovation process started. The information collection stage is to analyze the building's characteristics and cogitate how much of the existing facility can be reused and how those elements influence the design approach. The design stage is complex, including discussion, decision making and solution selection. In this stage, many people in different fields are involved, and the 7 dimensions should be fully considered. The following stage is construction during which on-site and off-site management are very important. In the last stage of usage, occupiers should be well informed of how to use their renovated home properly.

Sustainability is just like a "baton" delivered during each stage. The interconnection between stages is as important as the stage itself to keep sustainability throughout whole renovation process. Thus it is necessary to fully consider all stages that involve in renovation process, and safely deliver the sustainable baton at every stage.

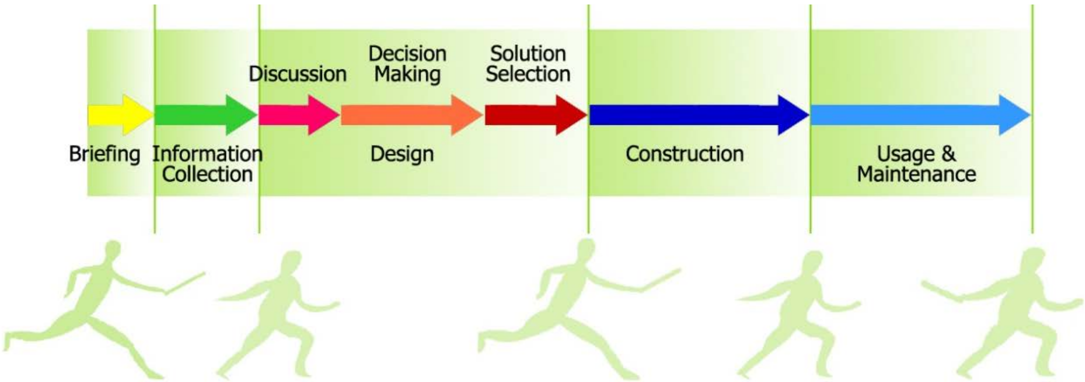


Figure 2.8: Sustainable baton transferred in the whole process of renovation. Inspired by Halliday, (2008)

People in different fields involved

The application of the measures directed towards achieving sustainable renovation, requires close cooperation among various professionals, policy-makers and other stakeholders (Bakens, 2003, p. 9). Figure 2.9 shows some key players involved in the process:

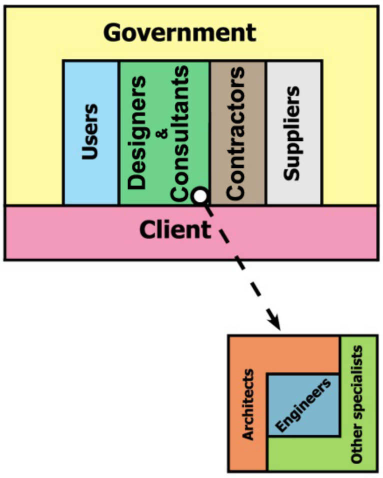


Figure 2.9: Participants in (sustainable) renovation process

Government is an important player for sustainable renovation because they are the rule-makers and can create the institutional environment for sustainable renovation. The positive policies issued by government can incent sustainable develop or vice versa.

Client is the one who starts and plans a renovation process, pays for it, make the final decision and chooses the designers, consultants, contractors and suppliers. Their attitude and ideas will determine the direction of whole project.

Designers and consultants are not only refers to architects, but also engineers and other specialists. Other specialists include such as building archaeologists or restorers for historical investigations, social experts and even professional photographers. They should form a trans-disciplinary team, and have close cooperation with each other.

Contractors have responsibility to create good site environment, reduce impact to surrounding environment and increase the productivity of site work through advanced managerial method. Suppliers, as the partner of contractors, should well cooperate with contractor, such as transport material to site in time and keep quality of material in a high level. What is more, suppliers have to remember that they also have responsibility to lower the emission and impact during the transportation.

Before a renovation process, users should be well communicated so that they can understand the benefit of renovation. Cooperation relationship should setup during the design process between designers and occupiers, in order to have a better understanding of the existing building. Pearce (2006) stated that residents' opinion sometimes is better than scientific research. After renovation, occupiers should be given enough information to use new installed equipment in a right way to realize sustainability.

To make progress for sustainable renovation at all levels, it is vital to cover all the 7 dimensions, think of entire process, and consider all the stakeholders and players involved in this process (Figure 2.10).

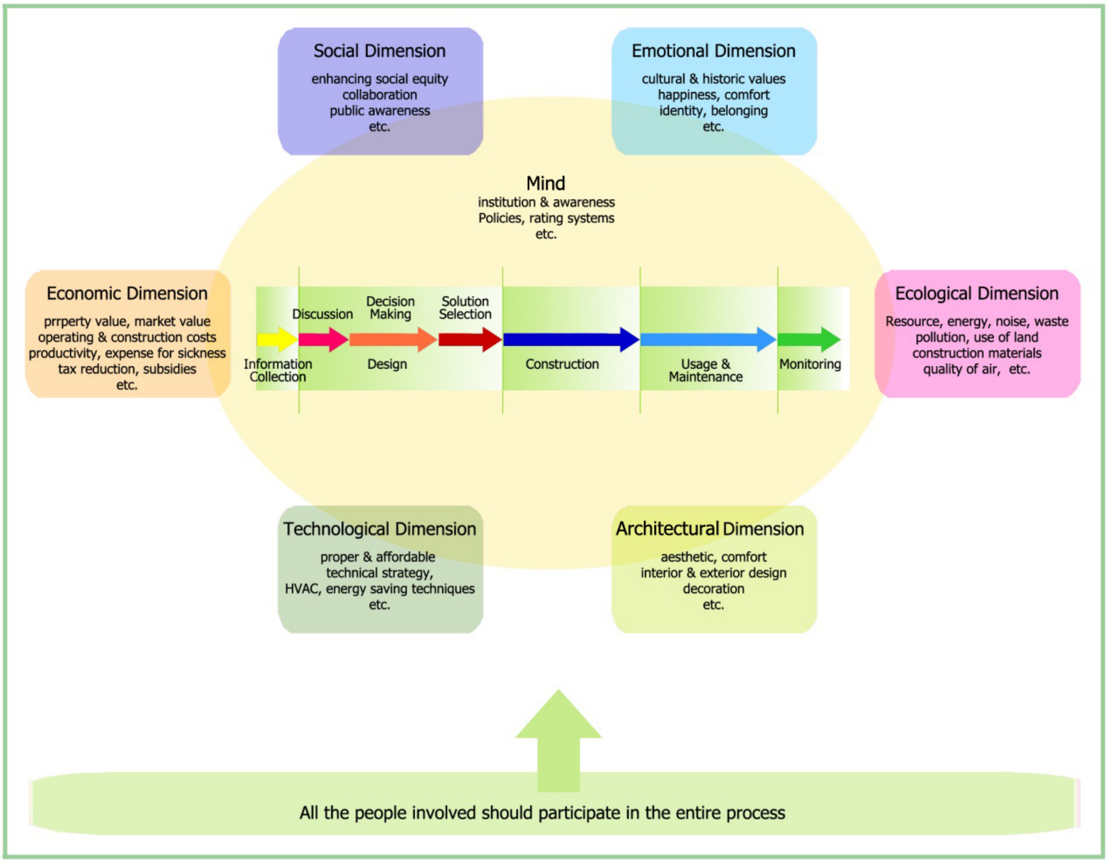


Figure 2.10: Systematic thinking of sustainable renovation

2.4 A checklist for case studies

Sustainable renovation is such a complex concept including many aspects that there is no analysis that can capture them all and there is no one case that can reveal and take care of all sustainable issues. In this part, based on two highlights in the aim of thesis which are decrease environmental impact and increase the comfort of life, we select five aspects from 7-dimensional model and develop parameters of these selected dimensions, in order to formulate a checklist for discussing the cases (Table 2.1). In the cases study, the rest two dimensions, mind (mainly refers to policy) and economic (mainly refers to cost) are not highlighted, but still mentioned.

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
TANGIBLE	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
TANGIBLE	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction
			• Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
NON-TANGIBLE	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 2.1: Checklist for case studies. In this checklist, issues of environmental, technological and architectural aspects can be visualized and felt directly. We defined them as tangible issues. Issues of cultural/emotional and social aspects cannot be visualized or evaluated by a clear standard. We defined them as non-tangible issues. Architectural aesthetic, which is an architectural issue, belongs to both tangible and non-tangible field.

■ Environmental aspect

Main issues about decreasing environmental impact are reducing natural resource such as energy, water and land; reducing waste and pollution; and using low impact materials. To increase the comfort of life, we will focus on the issues of increasing air quality and outdoor space, which means preserve the biodiversity of existing flora and fauna.

- Technological aspect

We will focus on analyzing the issues of technical system such as HVAC, lighting and acoustic system; efficient appliance like tap, valve, shower and electrical installation; and renewable technologies. Technical systems also contribute to the comfort of life.

- Architectural aspect

Better construction way and reasonable layout contribute to satisfying both needs of decreasing environmental impact and increasing comfort of life. For example, using prefabricate models during construction can decrease the noise and waste which negatively affects the environment and the life of residence surrounded. Flexible layout enables occupiers to use a space for different purpose which facilitates their life. It also extends the building's lifespan which can reduce waste by avoiding demolition. The shape, form and envelope of buildings help to reduce the impact on nature by careful considering of insulation, air tightness, thermal inertia, solar protection, window conception, etc. Good looking at interior and exterior helps to provide a comfort living environment.

- Cultural (emotional) aspect & Social aspect

These two aspects are mainly about increasing comfort of life. We will focus on social equity by provision of disabled facilities, outdoor space which is good for social interaction, preserving historical values and keeping residents' memory maximum.

This checklist shows possible issues related to these two needs of minimizing the environmental impact and maximizing the living comfort. Environmental, technological and architectural aspects are tangible aspects that can be directly seen and felt by people, while the cultural (emotional) and social aspects are non-tangible aspects that bring potential or future benefits that people cannot realize right now and feel them directly. The aesthetic issues in architectural aspect are non-tangible as well. In the following case studies, we will use this checklist to define what issues are dealt with in each case, and analyze them.

2.5 Driving force & Barriers

Benefit

Sustainable renovation on residential building is initially motivated by the needs of minimizing the resource input as well as waste and maximizing the comfort of life. McAllister and Fuerst (2008) suggest that developers, occupiers, and owners may obtain a verity of benefits that are associated with sustainable building renovation. According to McAllister, other benefits are also important driving force for sustainable renovation.

Through minimizing the energy consumption and resource input, lower operating, maintenance and construction costs can be gained. Increasing living comfort can add value to the property. Space is more valuable, providing potential for higher rental growth or improving marketability. It reduces healthy risk caused by dust, noise, smell, resonance, smoke, excessive heat or cold, radiation or moisture, avoiding extra expense for sickness such as compensation costs. Since many people choose to work at home, a comfortable living environment, giving people a good mood, can increase people's productivity, which results in the economic benefits. Preservation of cultural and historical elements has educational and social effects, rising public awareness. Social equity, which increasing the comfort of life, also contributes to the social stabilization.

Barriers

The main barriers for sustainable renovation on residential buildings relate to policy, information, culture, technique.

Renovation incentive policies have generated one after another, but some of them have poor communication with economic advantages will negative influence the institutions carry out (Lutzkendorf and Lorenz, 2007). Owners sometimes have a narrow sense to understand benefit; most of them have a short-term perspective and prefer immediate low cost. Since they consider more about cost, residents' feeling and emotion usually always is neglected, which will enhance investors to despise renovation. And they have very limited budgets for technical research. The R&D expenditure in construction sector in Europe is lower, just 0.3% (average is 2.0%) (Bremer and Kok, 2000, pp. 103), and when new technology emerges, companies are slow to adopt as this will lead to unforeseen risk, which cause building systems hard to be upgraded. Good sustainable residence renovation information and examples are hardly available is another barrier, and without references, companies will hesitate to invest to sustainable renovation.

3. Studies of Austria

3.1 Institution and policy toward sustainable renovation in Austria

As mentioned before, mind, including institution and awareness, plays a leading role in sustainable renovation, providing a macro environment for practices. In this chapter, in order to explain the reason why we select sustainable renovation of residential projects in Austria, we will study the general situation about institution and policy toward sustainable renovation in the Austrian context, and find that if Austrian priorities match the two highlights of our aim.

Existing policies on energy in Austria

In recent years, Austria has adapted their housing and construction regulations in order to stimulate more sustainable developments in residential sector. Insulation, heating regulations and such has been sharpened. In general, the reduction of the environmental impact of existing housing is an important subject on the political agenda. In Table 3.1, we list some regulations and their role of residential sector. An obvious emphasis on minimization of consumption of energy can be observed.

Name	Aim	Role of residential sector
Limits of energy consumption are implemented in housing subsidy schemes of all provinces	Policies to improve insulation measures	Thermal quality in new construction and refurbishment has improved dramatically during recent years
Part of housing subsidy schemes of most provinces	High efficiency installations	Incentives for low consumption water installations, high efficiency heating installations etc.
Building codes	Min. requirements on energy use	Recently adopted, still no limits for cooling energy consumption
Subsidy schemes in the provinces	Support Solar thermal	Medium

Table 3.1: Existing policies on energy and their roles in residential sector in Austria. (Itard et al, *2008.)*

Existing renovation policies in Austria

Besides the aspect of energy consumption which is highlighted in the existing policies, Austria has some other goals such as Improve asset value, upgrade social quality of neighborhood and improve comfort. Table 3.2 presents some existing regulations related to these goals.

Goal	Name	Role of residential sector	Effect on energy use / sustainable renovation quality
Upgrade socially downgraded areas	a) Subsidy schemes in the provinces b) Regional development plans c) Federal Refurbishment Law	a) Very successful, large-scale refurbishment in urban and rural areas b) For strategic decisions c) Insignificant	Low segregation has generally high spinoff effects
Stimulate economic development of neighborhoods	a) Promotion programs by chamber of commerce and local governments b) Housing subsidy schemes	In some provinces commercial space within housing projects is subsidized as well. Significant integrative effects	Integration of housing and labor reduces traffic and energy consumption. Generally the tendency towards segregation has not yet stopped
Stimulate building economy	Housing subsidy schemes	Strong incentives	High
Support quality of life in rural areas	Housing subsidy schemes	High	Regional integration has generally positive spin-off effects
Health risk reduction	Housing subsidy schemes		

*Table 3.2: Existing renovation policies in Austria. (*Itard et al, *2008.)*

According to the research of “Building renovation and modernization in Europe” carried out by Itard et al (2008), in recent years, sustainable renovation policies in Austria have two priorities on promoting measures to reduce energy consumption and increase the comfort of life such as upgrading socially downgraded areas, supporting quality of life in rural areas, and health risk reduction. These priorities are matching the two highlights of our aim, which means some renovation projects in Austria are the projects we are looking for. What is worth to mention is many policy in Austria try to connect sustainability to economic advantages, such as subsidy will be provided if sustainable activities be implemented, which will stimulate sustainable renovation development, and people’s sustainable awareness may increase through doing sustainable activates.

3.2 Residential buildings in Austria

Types and age of residential buildings

According to the data coming from GWZ (Gebäude- und Wobnungszäblung, Statistik Austria) (2007), there are approximately 3 863 000 residential building in Austria. They can be divided into two types, one is called single-family house, with the amount of 1 810 000; and the rest 2 053 000 residential buildings are called multi-family house.

The age of residential buildings in Austria are not very young, with 70% of residences were built before 1981; and from 1961 to 1980, the construction rate is a little bit high, 31% of residential building were built during this 20 years; residences who were built after 1990 is just account for 18%, which means new building is not the dominate type of residence in Austria (Table 3.3).

	<1919	1911-1944	1945-1960	1961-1970	1971-1980	1981-1990	>1990	Total
Percentage	19	8	12	16	15	12	18	100

Table 3.3: The age of Residential buildings in Austria. (Itard et al, 2008)

Insulation and type of external walls, roofs, floors and glazing

Austria highlights insulation in cavity wall, almost 100% of cavity walls have been insulated. But insulation can hardly be found in solid walls; only 20% of the solid walls are insulated. Double glazing is the dominant kind of glass in residential buildings, with 90% in total, while triple glazing just accounts for 5% (Table 3.4).

Insolation type	Insulated Solid walls	Insulated Cavity walls	Insulated roofs	Insulated Floors	Double Glazing	Triple glazing
percentage	20	100	50~70	30~60	90	5

Table 3.4: Insulation and types of residential buildings in Austria. (Itard et al, 2008)

Energy Use

Final energy consumption is always a hot topic. In Austria, just like other countries, residential buildings consume a large portion of energy, twice more than non-residential building, with 7051 Ktoe, and non-residential just consume 3005 Ktoe *(Table 3.5)*. The single-family and multi-family dwelling stock built between 1945 and 1970 have for a large part (30%) low thermal quality and energy efficiency.

Type	Total Final Energy Use (Ktoe)
Residential Building	7051
Non-residential Building	3005
Total	10056

Table 3.5: Energy Use in Austria in Ktoe (Kiloton of Oil Equivalent). (Itard et al, 2008)

Heating and cooling systems

According to the data showed in GWZ (Gebäude- und Wobnungszäblung, Statistik Austria, 2007). 80% of single-family houses have central heating radiators, of which, 78% use a gas, oil or coal boiler, and about 12% is central heating with wood or biomass and 6% is electric heating. In multi- family residences, individual central heating is occupying 52% of dwellings and collective central heating is about 25%. Both individual and collective central heating is mainly relying on coal, gas or oil and half of this is a high efficiency system. Less than 5% of the total dwelling stock uses local air conditioners, but this number is rising. *(Itard et al, 2008)*

Ventilation

Generally, there are 3 kinds of ventilation system; they are 'natural ventilation', mechanical exhaust ventilation, and heat recovery mechanical ventilation (Figure 3.1). In Austria, 95% of all dwellings are naturally ventilated; and ventilating mainly through via windows. Only 1% has heat recovery mechanical supply and exhaust ventilation. In this case, ventilation energy consuming is relatively low.

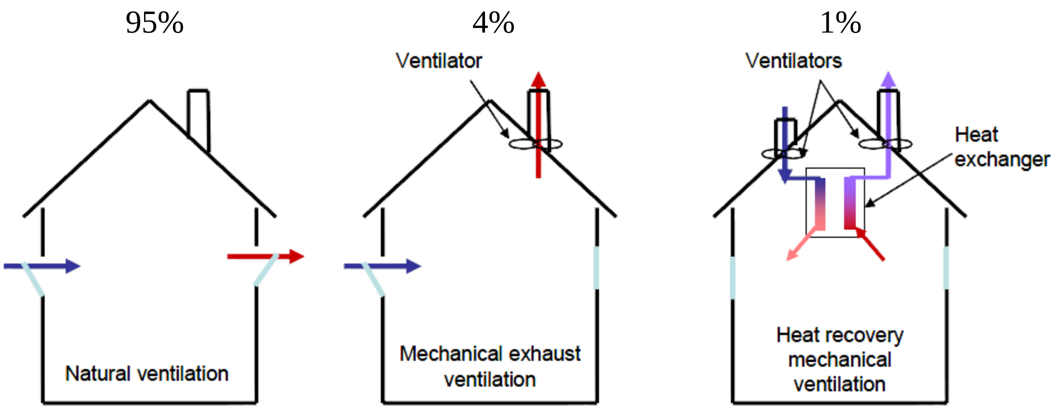


Figure 3.1: 3 kinds of ventilation systems for existing dwelling in Austria. (Itard et al, 2008)

Resource for domestic hot water

According to Itard et al 2008, about 50% of single-family houses use a gas, oil or combination warm tap water boiler, and the figure in multi-family dwellings is 60%. Electrical water heaters are used in 40% of single-family houses and in 30% of multi-family dwellings. Solar thermal boilers are employed in 2% of single-family houses and in 1% of multi-family dwellings.

Reasons for renovation of residential buildings

In Austria, about 45 000 new dwellings are built annually while approximately one hundred thousand dwellings undergo renovation. The main reason for renovation in all types of building is that the service life of the building components has been exceeded (*Itard et al, 2008*). Another reason is that the social housing sector tries to realization of energy ambitions. What is more, increase both indoor and outdoor environment is also a focus. Moreover, the upgrading of the social issues, the improvement of the asset value and turnover are all important factors. What is worth to mention here is the fact that subsidies aimed at the natural environment protection, social upgrading of the neighborhood work as a strong incentive to renovate dwellings. The spending on housing renovation subsidization in 2005 is Austria was €0.53 billion; with the involvement of roughly 25% of the total investment (Total investment means the sum of investment of new construction and renovation).

Renovation activities

In Austria, the renovation activities are especially aimed at (simple) maintenance and modernization activities, like modernization of the kitchen and bathroom, install new technical system etc. and generally to meet new demands for comfort. Every year 4% of the Austrian housing stock is provided with a new heating system; nearly two-thirds of the dwellings have undergone thermal renovation by replace old material, reducing energy consumption in these buildings by install new equipment, and layout redesign, increase accessibility etc. (Bauer et al 2007). The Function of renovation activities can be concluded as decreasing the environmental impact and increasing the comfort of life.

Energy consumption seems to be the key factor in sustainable renovation. In the past, oil and gas are the major resource for energy generation, and this situation is now changing to renewable energy like solar, wind etc. Requirements about energy issues for existing buildings have set out in Austria, which means residential buildings have to try to fulfill special requirements through renovation, and those requirements can be treat as a guideline to help sustainable renovation development. The main requirements for residential building renovation in Austria include:

- Minimum annual final energy consumption per m² of floor area.
- Maximum u-values of different elements of the building.
- Prevention of thermal bridges.
- Requirements on quality of boilers, aeration systems and chillers.

The proof of compliance with the requirements must be made before and after completion of the building. Municipal authorities are responsible for controlling whether the requirements are being met.

4. Selected case in Austria

Motivation of case selection

The choice of cases was motivated by several factors (see more detailed explanation in each case). Firstly, these cases covered two dominated residential building types. One is multi-family residential buildings which are found in a great number in Austria, and the other is single-family house which represents 40% of the residential building type after the wars in Austria. The cases also involved the specific historical buildings. Secondly, all these cases have a focus both on decreasing the environmental impact and increasing the living comfort, matching our aim and checklist.

Selected cases in Austria

Figure4 .1 shows the position of selected cases in the map of Austria.

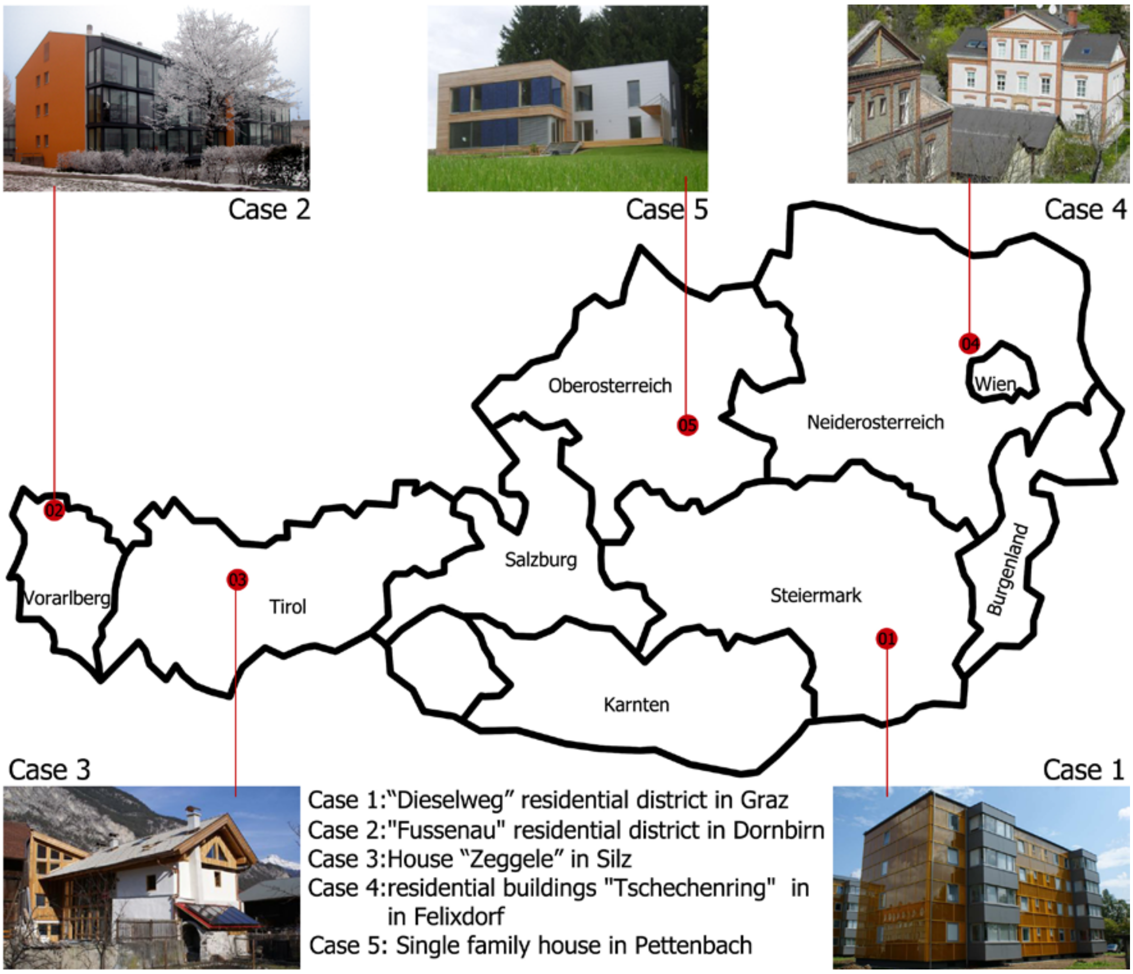


Figure 4.1: Selected cases in Austria.

Structure of the case studies

There are 5 parts for each case analysis. The first part contains the background of each case, including basic information before renovation. In the second part, we state the reason why we have chosen this case and why it is interesting for us. The following part is a description and structuring of the collected material, and analysis of what efforts were made to reach the renovation goals. The description and structuring was organized with focus on our two highlights to minimize environmental impact and maximize comfort of life, and the five aspects, environment, architecture, technology, social, and culture / emotion in the checklist presented in Chapter 3. In the description, data has been divided into two parts: tangible aspects including environmental, architectural, and technical issues; and non-tangible aspects including cultural / emotional, and social issues. The forth part focuses on the analysis of the efforts and effects, comparing the situation before and after renovation. In the last part, success factors, barriers and difficulties in each case will be analyzed. Table 4.1 gives an overview of five cases, some general information about cases are listed in it.

Table 4.1 Cases overview

	Multifamily residence		**Historical residence**		**Single-family house**
Name	Dieselweg-4 in Graz **(Case-1)**	Fussenau-1 in Dornbirn **(Case-2)**	Zeggele in Silz **(Case-3)**	Tschechenring-A in Felixdorf **(Case-4)**	a single-family house in Pettenbach **(Case-5)**
Aim	· Minimizing the environmental impact · Raising the comfort of life · Setting an example for future	· The energy aim is "Factor 10" · Improve indoor air quality · increase the living space · Upgrade the appearance of residences	· To reduce energy consumption and increase thermal comfort · To employ renewable energy. · To increase living space · To preserve the historical values	· Living space expansion · Optimization of the thermal envelope · Keep original façade · Renewable energy materials · Increase accessibility and security · Maintenance after renovation	· Reducing energy consumption · Improving the living comfort · To use renewable materials · To achieve an affordable renovation · To establish new and innovative renovation procedures.
Renovation highlights aspects	· Envelope · Space Heating & Hot Water · Pre-fabricated construction · Redesigning the layout of the district · Process · Guide of users' behavior	· Envelope · Space heating and hot water · Rigorous promotion policy · Communication with the tenants	· Envelope · Heating System · Enlarge living space · Conserve the history · Well-organized process	· Envelope · Heating & Hot water, Ventilation · Outside of the building · New interior layout · Use of renewable materials · Security and equity · Historical value conservation · Regular maintenance after renovation	· Envelope · Domestic system (heating and ventilation) & Energy · Maximize living comfort through better layout, enough daylight and better · appearance of the house · Renewable material · Good Process

Success	· Reduce resource consuming and increase the living quality. · Have well-organized construction process · Data collection & popularization	· Reduce resource consuming and increase the living quality · Communication with residents	· Cooperation among people · Good preliminary work · The careful measures · The experiences of other cases renovated were helpful to this case	· Energy consumption is reduced · Living area was enlarged · Living quality increasing · Represent social security and equity · Addition of public area construction · Maintenance after renovation · Historical value conservation	· Architectural design was integrated into the overall concept · The well-organized process contributes to the success of this project
Barriers	· Risk to use a new technology (e.g. the ventilation system) · The renovation cost	· Pay less attention to the embodied energy of material · Data collection is not precise	· It is impossible to get the residents 'opinion. · Energy consumed for heating is still high · Household garbage transportation could be an energy consuming thing	· Effort for historical value conservation is not enough due to too many original elements were taken off	· The living space after renovation for 4 people is a little bit large

Table 4.1 Cases overview

4.1 Case 1: Renovation of "Dieselweg" residential district in Graz

1 Background

Dieselweg is a residential district, which is located in the southern suburban area of Graz – the capital of Styria. Figure 4.2 shows the location of the residential district.

Figure 4.2: Location of "Dieselweg" residential district. (Google, 2011)

There are five free standing buildings (built in the 1960s and 1970s) and one long building (built in the 1950s) in this residential district, and totally, 204 apartments. Dieselweg-4 is our research object, which is one of five free standing residential buildings (Figure4.3).

Figure 4.3: The site plan to the left shows the five free standing buildings and one building row. The red-marked building is our research object, Dieselweg-4. The photo to the right shows Dieselweg-4, the entrance façade. (Square, 2010, pp 1)

Since the time of construction, no improvement have been made. The 204 apartments are in extremely poor condition with non-insulated exterior walls, floor structures and attic, windows in extreme need of repair, a mix use of oil or solid fuel fired single ovens and electricity for heating and hot water. Therefore, the GIWOG (Gemeinnützige Industrie Wohnungs AG), owner of the properties, carried out a renovation of this district in 2007, aiming at changing the current situation and improving the living quality. Dieselweg-4 was renovated in 2008 and 2009. The 204 flats are all rental units, which means running costs for space heating and hot water were all paid by the tenants. The improving of energy performance will no doubt release residents' economic burden.

Dieselweg-4 is a free standing building with 4 stories, including a basement. 4 apartments are grouped around the staircase in each floor. The apartments are in the size of about 90 to 100 m². (Figure 4.4)

Figure 4.4: Section and plan of Dieselweg-4.
(Square，2010，pp 3)

Basic information about Dieselweg-4 before renovation is shown in Table 4.2:

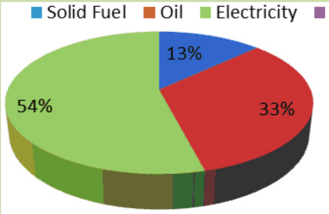
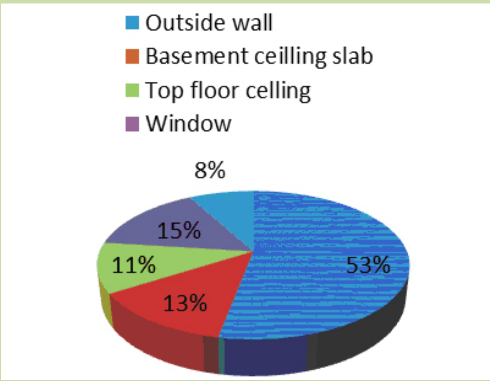
Basic information about "Dieselweg-4" before renovation	
Year of construction	1960s
Years of renovation	June-2008 - August-2009
Owner	GIWOG
Architect:	Architekturbüro hohensinn zt gmbh
General contractor	Gmbh
Layout	
Orientation	Southwest & northeast
Number of stories	4 (with a basement)
No. of apartment	16
No. of apartment in each floor and layout	4 apartments (grouped around the staircase)
Structure	Wall: brick or concrete brick Ceilings: reinforced concrete
Energy	
Heated floor area	1.091 m²
Total heating energy	184 kwh/a m², 200.855 kwh/a
Heat supply	
Hot water supply	By electricity
Thermal insulation	
Envelope	non-insulated exterior walls, floor structures and attic, windows in extreme need of repair
Thermal bridge	Slabs for the balconies reached out without thermal separation
Transmission heat losses of the thermal envelope	
Cost for renovation	The average renovation costs for all phases was 816 Euros/m2 (net floor area after retrofit) or 862 Euros/m2 (net floor area before retrofit).

Table 4.2: Basic information about Dieselweg-4 before renovation

The result of renovation is positive. The project was nominated for Energy Globe Austrian Award 2009, World Energy Globe Award 2010, and Climate Protection Award 2009. It was also the winner for Energy Globe Styria Award 2009 and Exemplary Housing 2010. This project had been selected for SQUARE project (EIE/07/093/SI2.466701), which stands for A System for Quality Assurance when Retrofitting Existing Buildings to Energy Efficient Buildings. The project is co-funded by the European Commission, supported by its Program Intelligent Energy Europe (IEE). It was also supported by the Austrian system of public housing subsidize and a special subsidize provided by the governor of environmental affairs of Styria.

2 Why did we choose this case?

This case is a typical multi-family residential building in Austria. The building stock has 3-4 stores. The area is suburban and the buildings were built in the 1950s, 1960s and 1970s. This kind of residences is found in a great number in Austria. Therefore, sustainable renovated solutions for this kind of residences have a great potential for multiplication.

Another reason is that this project provided a solution to renovate an occupied residential building without relocate the tenants during the construction stage. The key issue was renovating the existing envelope with minimal disturbance to the occupants.

3 Renovation Activities

The owner GIWOG set the following goals for this renovation.

- To minimize the environmental impact including to reduce the energy demand for space heating, to reduce the greenhouse gas emission and to eliminate construction damages and thermal bridges.
- To raise the comfort of life by providing high quality of indoor and outdoor environment such as good air quality and thermal comfort, increasing the living space and barrier-free access to all tenants. All occupants should be minimum disturbed and remain in their flats during the construction works.
- To establish new and innovative renovation procedures, setting an example for future projects.

The goals were achieved by means of the following measures listed in our checklist (Table 4.3).

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction • Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 4.3: Renovation activities. The red-marked issues are relevant renovation measures involved in this case.

Tangible: Environmental, Architectural, and Technological

■ Envelope

One key measure in this project was a solar-thermal facade, which integrates heating and mechanical heat recovery ventilation (MHRV), as well as high-performance windows, by employing a patented honeycomb technology. As shown in Figure 4.4, the façade was constituted of three main parts: the original wall, compensation insulation and the prefabricated solar wall.

Old stock	300 mm Existing exterior wall
Compensation insulation site applied	100 mm Rock wool
prefabricated solar wall (from outside to inside)	6 mm Toughened safety glass 29 mm ventilation layer (air-gap) 30 mm Solar honeycomb 15 mm MDF(Medium-density fibreboard) 120 mm Rock wool between wooden construction 18 mm OSB-board

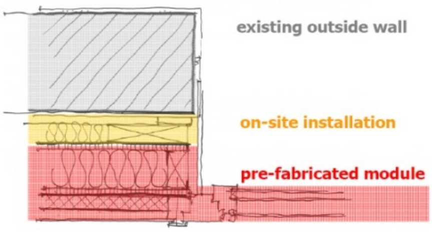


Figure4.4: Construction of the façade. (Square, 2010， pp 4)

There are four factors of the envelope: 1) an energy-efficient solution to reduce heat loss; 2) single room ventilation with heat recovery; 3) increasing the living space; and 4) A new appearance to the old building.

1) The major heat loss in Dieselweg-4 is from wall before renovation. This envelope is a special solar façade, providing an energy-efficient solution. The secret resides in the special cellulose webbing that resembles a honeycomb (Figure 4.5). Johann Aschauer from GIWOG stated that the low-lying winter sun penetrates the honeycomb structure and heats it, while the high summer sun creates cooling shadows. Thus the solar façade achieves a year-round perfect climate zone.

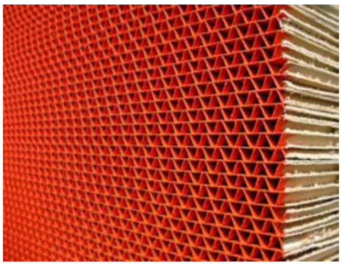


Figure 4.5: Honeycomb structure. (Square,2010， pp 5)

A layer of toughened safety glass is in the surface of the wall, protecting the inside layers. There is a gap between glass and honeycomb to keep air which is inside the wall dry through ventilation, preventing mold and erosion. An average U-value of this façade, ranging from 0.02 to 0.12 kWh / m², can be achieved. A test shows that even in the winter night, the temperature of the interior surface is higher than 16 ° C, which means greater comfort and lower heating costs, as well as low energy consumption.

This facade has a strong sound-absorbing as well. And on the roof, there are several PV-panels installed (Figure4.6), aiming at providing some renewable energy to generate electricity for appliances, and reducing traditional energy (oil, fuel etc.) consumption.

Figure 4.6: PV-panels on the roof (Hohensinn architektur, 2009, pp 2)

2) Another factor of the envelope is the integrated single room ventilation units with heat recovery, which can not only ensure the fresh air, but also avoid excess humidity and prevent mold growth. Fresh air is drawn in to the supply duct through a slot at the bottom of the façade panel and exhausted air goes out through a slot at the top of the panel. The ventilation units are decentralized to single room with heat recovery (about 73% recovery level). The air that goes into the living room through the ventilation system is filtered many times and cleaner than the air coming directly through the open window. If a resident suffers from health problems such as asthma and pollen, he will be greatly helped by the filtering. Air ducts are hidden behind the new façade. This solution can be used especially in the redevelopment area where suspended ceiling is not feasible because of the lack of height. This integrated ventilation system solves the problem of not interrupting the residents. Existing windows are removed from the inside at the end of construction, representing the only disturbed part of the entire operation.

3) The third factor is the extension of living area by enclosing the original open balconies (Figure 4.7). This formed a buffer zone between inside and outside, warmed up by the sunshine, and extended the using time of balconies throughout the year. Well enclosed and insulated balconies can eliminate thermal bridges and improve the usability of the dwellings and increase the comfort of living.

Figure 4.7: Enclosed balconies. (Square，2010, pp 3)

4) The final factor is that the solar facade can be painted in any color and the shape of each piece also can be changed. From architecture perspective, the free combination of different shapes and colors of panels will provide more possibilities for the appearance of the building.

■ Space Heating & Hot Water

The total energy supplied for hot water and heating is collected by solar façade. A generously sized solar heating system (about 3 m² / flat) is installed on individual homes. The honeycomb in the outer wall will be warmed by the sunshine to ensure a comfortable temperature for the building. A large storage tank (*Figure4.8*), which is designed with "insulating bricks", ensures that the heat is available when it is needed.

Figure 4.8: Square，2010, pp 4)

■ Pre-fabricated construction

To minimize environmental impact and disturbance to residents, the envelope is constructed in prefabricated modules, of approximately 12 x 3 m. the detailed design of the modules were based on the laser of each façade. The pre-fabricated modules are brought to the site by a truck and trailer. Afterwards they are lifted by a truck-mounted crane. Two additional mobile-cranes are positioned on each side (Figure4.9).

Figure 4.9: Process of installing the pre-fabricated façade.
(Square，2010, pp 6-7)

This construction method resulted in a short construction period on sites. Occupants were less disturbed during the construction period and the existing static system kept unaffected. It is weather-independent as well. And the components are easily to maintain and reuse.

- Redesigning the layout of the district

According to the Hohensinn Architektur, who was the planner and architect for this case, the roads in this district were redesigned. The former long road for vehicle was considered to be harmful for the residents and children due to the heavy traffic and noise. It has been designed into smaller manageable pieces. The long road space has thus been broken. At the same time a center public space is defined in the district to encourage the communication among residents. In addition, each building has been connected to a green space with additional installations such as gazebos, playground, pergolas, etc. Lifts and ramps were installed and entrance was enlarged to achieve barrier-free access. A new and energetic outdoor space has been created.

Non-tangible: Social, Cultural / Emotional

- Process

The process of this case is long and has involved many actors. Figure 4.10 presents the whole process of this case. And the project timetable shows the steps from the planning to the construction and the monitoring. We can observe that the time-span for the work on-site is very short. The yellow bar shows the ongoing monitoring of consumption data for heating and ventilation system.

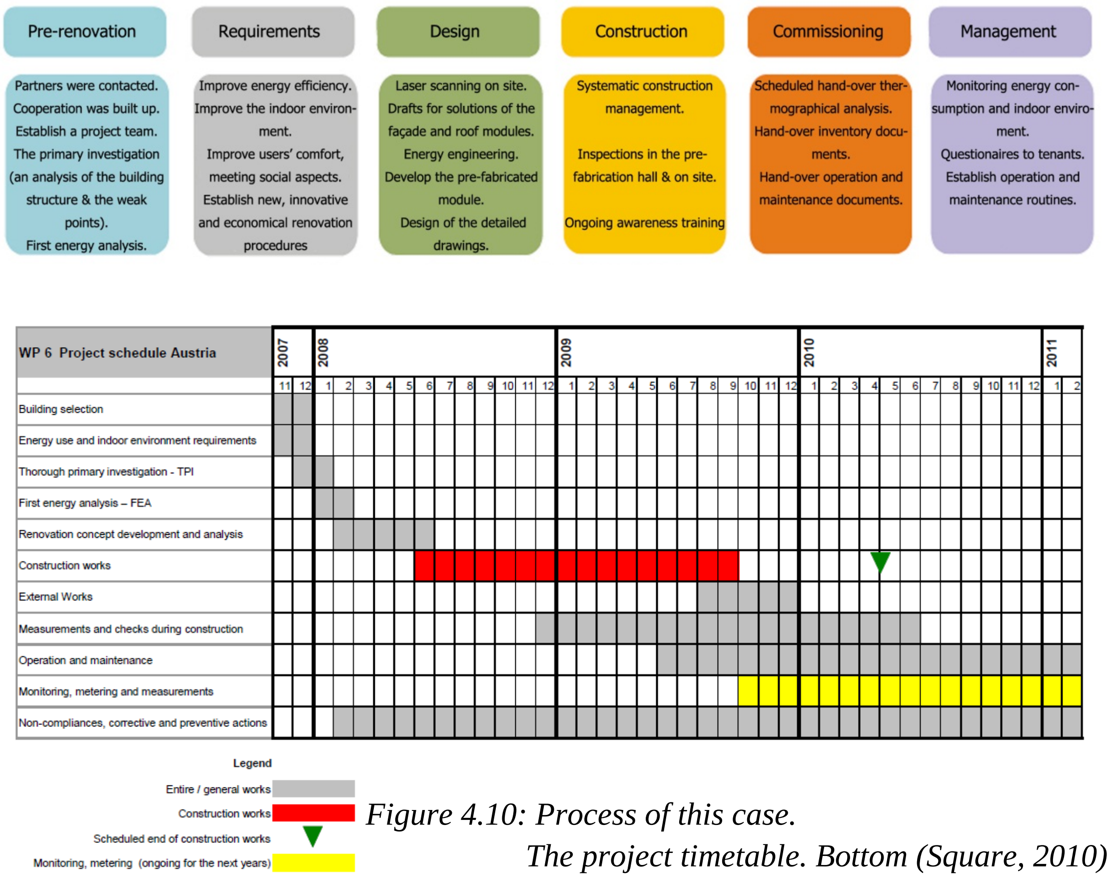


Figure 4.10: Process of this case.
The project timetable. Bottom (Square, 2010)

The process was well organized. After the decision of starting the renovation project, a project team was established. Primary investigation (an analysis of the building structure and the weak points) and the first energy analysis were carried out. Objectives were defined. The design stage started with the laser scanning of building façade. Following were the drafts for the façade and roof modules, energy concepts, development of the pre-fabricated module, and detailed drawings. Communication system was established and regularly site consultation meetings (Figure 4.11) were held during construction period. There were regular inspections on site as well.

A number of temperature and humidity sensors were installed on the inner surface of the apartments, which are transferring wireless monitoring data to an external data base. As a result, after the building had been in usage, the data of energy consumption for heating and hot water can be collected by the property owner. A series of presentations and tours were held by the owner to raise the public awareness. Information is popularized by means of folders, info point, actions, exhibitions, etc. (Figure 4.12)

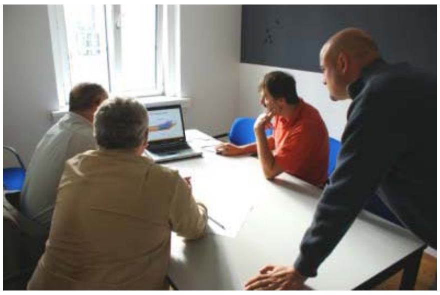
 

Figure 4.11: *Regularly site consultation meetings. (Left)*
Figure 4.12: "Ökosan 09" Technical tour 07th Oct. 09(Right).
(Square, 2010, pp 7)

On October 15th – a presentation held by the head of the measurement department of the AEE INTEC – Mr. Waldemar Wagner should raise the awareness for quality checks after the finished construction works.

■ Guide of users' behavior

Users' behaviors were carefully guided to avoid common mistakes in this case. The new ventilation system installed in each apartment is a very new technique for the tenants, because until now they have been used to their single heating devices and opened the windows for ventilation. The new ventilation system will change the user's ventilation habit. Therefore the GIWOG prepared a printed brochure to give information about key topics to the tenants. For example, the tenants were commended to use their familiar method for ventilation before renovation, opening the window for a rapid exchange of air, no longer than 5 minutes to keep the indoor temperature, because the old ventilation method allowed cold air enters the building in winter and cooled not only their own apartment, but also the neighboring apartment.

4 Comparisons: before and after

The result of renovation is positive. The floor area was enlarged from 1091 m² to 1589 m² (Figure 4.13); the total energy demand for heating was decrease from 200.855 kWh/a to 15.258 kWh/a; and the CO_2 emissions reduced to 80 t / year from 700 t / year since renewable energy sources was used (Figure 4.13). What is more, after renovation, the U-value of façade, top-floor and ground-floor are all less than 0.2 W/m²K; and U-value of window is approximately 0.85 W/m²K (Figure 4.14). Sonja Geier (2010) of AEE (The Association of Energy Engineers) claims that "even in winter days with low solar radiation, the efficient U-value shows an improvement of approximately 21% …" Moreover, amount of heating cost also goes down to €0.11 per m2 /month from €2.00 per m2 /month.

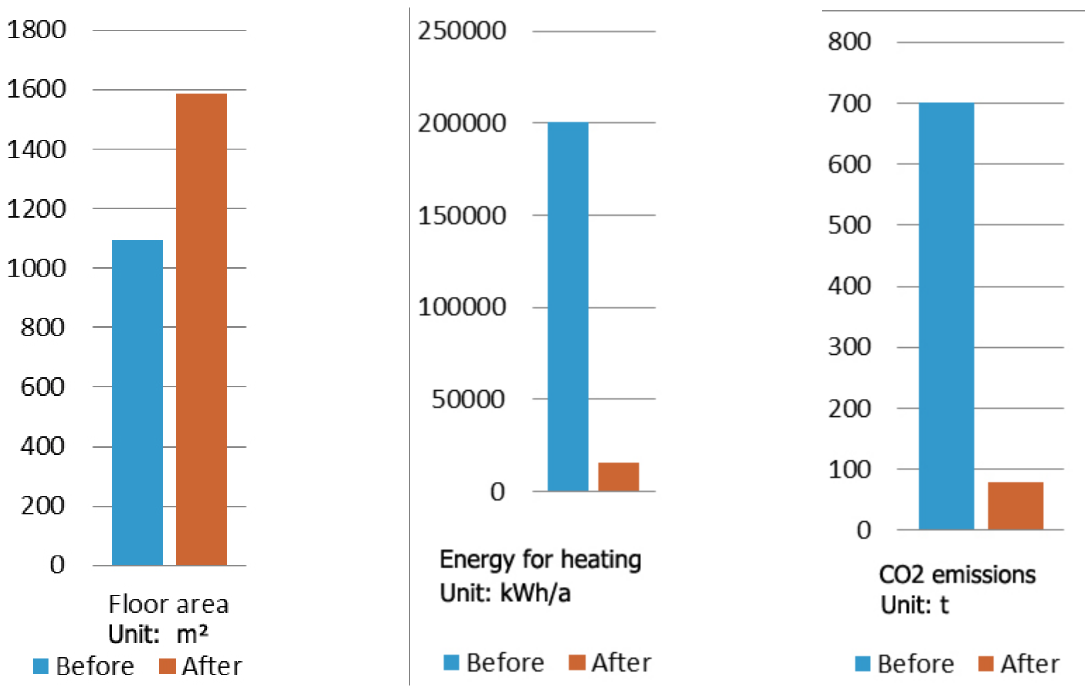


Figure 4.13: Floor area (left), Energy for heating (middle), CO2 emission (right)

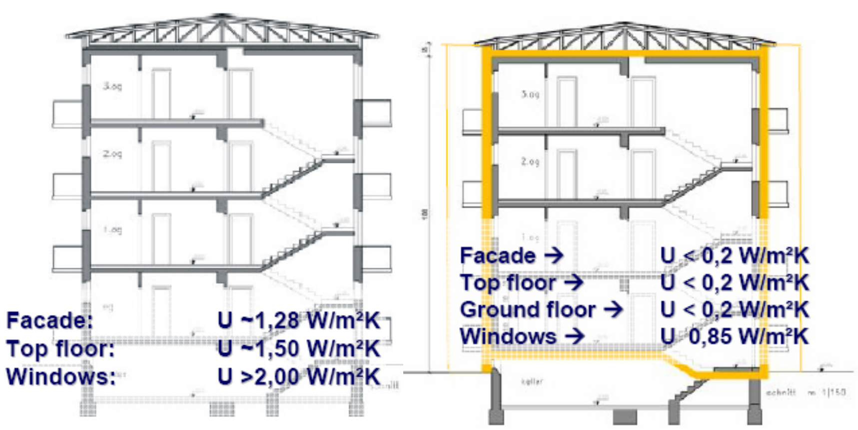


Figure 4.14: U-values

According to the data above, the living area is increased; energy consumption, CO2 emission and operational cost are dramatically decreased. Other improvements which cannot be shown in numbers have been achieved as well. Prefabricated and large-scale façade modules improved the building appearance; an elevator was added to help the disabled and senior inhabitants; a harmony and energetic outdoor environment was created; and education changed user's behavior.

Georg Pilarz, the Chief Executive Officer of GIWOG, stated that they achieved affordable sustainability. "*The evaluation of the first results makes us confident, that we can keep our promises, given as well to our customers, as to the aiding institutions and our shareholders.*"

5 Successful factors & barriers or difficulties

As discussed in the previous paragraph, the highlights of this renovation project are the application of new technology, low energy consumption, façade transformation, outdoor environment upgrading, residents' education, and also no relocation of residents. Those tangible and non-tangible actives mentioned above can both reduce resource consuming and increase the living quality.

The whole construction process, include design, construction and operation of the project, was also pretty good. Prefabricated element, monitoring after renovation, low construction impact to community etc. are the merit of this project. It established a new and innovative renovation procedure and set a good example for future projects.

After the renovation finished, a lot of interested groups and experts visited the site. Also, a lot of tenants watched the whole construction processes on-site with great interest. With more and more people becoming interested in this project, as a good example, it will surely help other multi-family residential buildings achieve a successful renovation.

There are two main barriers in this project. One is the risk to use a new technology (e.g. the ventilation system). Since the technology is brand new and not a familiar one to the tenants, it is hard to convince a builder, a stakeholder and tenants to trust in it. The risk is the biggest barrier to impact new technology practice. The other barrier is the financial aspect. The renovation cost is considerable, but financial difficulty is not that hard to be solved. The easy way is to raise the rents if the flat-standard is raised. The GIWOG calculated that if rent raises about 30 to 40 € per flat, the renovation fee can be covered. But the occupants will still convinced to vote for the renovation, because the running costs will decrease about 100 € per month. (Source: Kleine Zeitung 11.04.2008). It is necessary to have a long-term perspective to consider such financial matters, and in most case, renovation fee is worth to pay in order to dramatically reduce operational cost.

All in all, this project is a relatively comprehensive and successful example which will not only benefit the residents, but also as a reference which can benefit the future renovation projects.

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4.2 Case 2: Renovation of "Fussenau" residential district in Dornbirn

1 Background

Fussenau is a living district, which is located in the outskirts of Dornbirn – a city in the area of Vorarlberg province. It has a Central European Climate. The aerial photo (Figure 4.17) shows the location of the residential area.

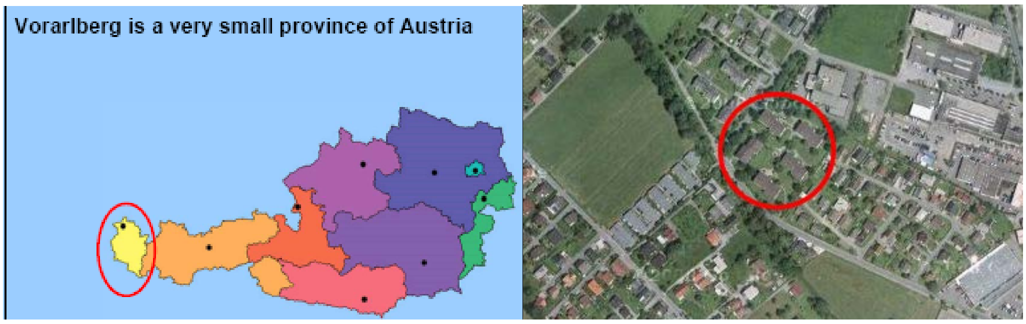

Figure 4.17: Position of Fussenau. (Google, 2011)

There are five multi-family residences in this living district "Fussenau", the stories of residences are varied, between three-story to five-story, and all of them were constructed in 1980 by the Vorarlberg housing association Vogewosi (Figure 4.18).

Figure 4.18: Site plan (left). Appearance of the building (Right). (Caue, 2010)

The estate was already somewhat run down in 2004. Their beige facades were blotchy, the reddish-brown windows and balconies were faded, the green awnings were inappropriate. The brick exterior walls were poorly insulated and the original windows still in place. Massive heat bridges were observed in the field of roller shutters, window mounts, cantilevered balconies, upper floors and in the concrete basement walls, visualized by using thermal images. The space heating was supplied by a gas heating.

In 2004 the inhabitants in Fussenau wanted a renovation to upgrade the appearance. Under this situation, the owner VOGEWOSI decided to renovate the residences, using the approach “Factor 10”, set itself the goal of energy consumption for heating times lower after renovation. The renovation project was unanimously agreed by the tenants. All the refurbishment was carried out in the occupied state, in order word, all the residents still occupied in their homes during renovation.

Fussenau-1 is the research object, which is a free standing building with 3 stories, and has a basement and an attic. There are 4 apartments in each floor. The total living area of this apartment is about 900 m² (Figure 4.19).

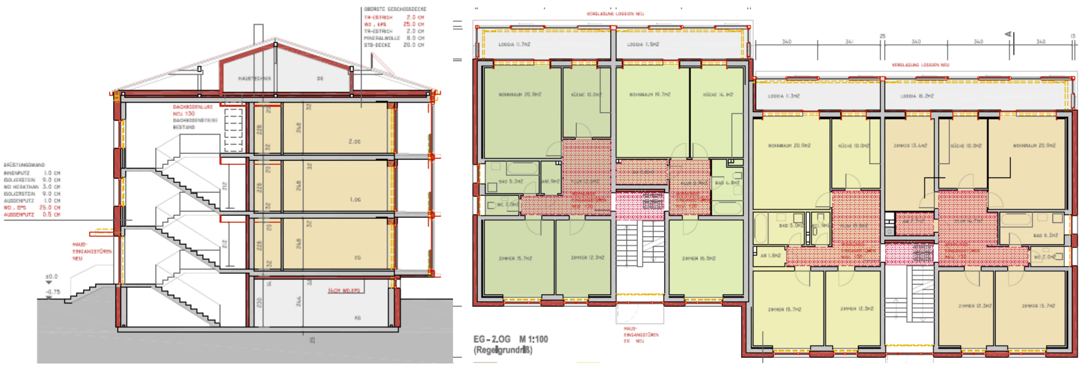

Figure 4.19: Section (Left), Plan (Right)
(Drawing, 2008.)

Table 4 .4 shows some basic information about Fussenau-1 before renovation:

Basic information about Fussenau-1 before renovation	
Year of construction	1980s
Years of renovation	2008
Owner	VOGEWOSI
Architect:	Helmut Kuëss, Bregenz
Energy Planning	Planungsteam E-Plus Kaltheier & Kraus GmbH, Egg
Structural	Elmar Hagen
Layout	
Orientation	Southwest & northeast
Number of stories	3 (with a basement)
No. of apartment	12
No. of apartment in each floor and layout	4 apartments
Structure	Concrete Structures
Energy	
Heated floor area	892 m²
Total heating energy	250 kwh/a m², 223.000 kwh/a
Heat supply	By gas
Hot water supply	By gas
Thermal insulation	
Envelope	non-insulated exterior walls, floor structures and attic, windows need to be repaired
Thermal bridge	Slabs for the balconies reached out without thermal separation
Cost for renovation	EUR C1. million in total, 752 EUR / m^2

Table 4.4: Basic information about Fussenau-1 before renovation

This project was received the subsidy from the state of Vorarlberg. The result of renovation is positive. It is nominated for the Austrian State Prize for Architecture and Sustainability 2010. And VOGEWOSI was awarded the Energy Globe of Vorarlberg for its exemplary approach in the field of energy renovation of buildings in 2008. All over Austria, multifamily housing projects from the 1970s and 80s are waiting for refurbishment. The Fussenau housing estate shows how the path from run-down energy guzzler to attractive passive-house can be successfully undertaken in an environmentally friendly way.

2 Why did we choose this case?

The choices of this case are motivated by the following factors:

- This case was nominated for the State Prize 2010 for Architecture and Sustainability, Austria. According to the jury, the renovation of this case impressively demonstrates how energetic refurbishment of problematic housing stocks from the 1970s and 80s can be successfully carried out and can serve as an example for other buildings of this type in Austria.

- The renovation is subsidized by the state of Vorarlberg which means this case fulfill the goals of energy reduction.

- One interesting thing in this case is that one of the start points for renovation is the residents' demand. In 2004, some residents wish to have a renovation. And the renovation work carried out by VOGEWOSI won the tenants' agreement in a very short time. We want to explore how this consensus was achieved and how the renovation group worked with the tenants.

3 Renovation activities

In 2004, some residents asked for renovation of their appearance, and in 2008, the renovation project was run. The followings aims were set by the residents and the owner:

- The energy consumption aim is Factor 10, which is to have a reduction of heating energy demand by 90%, i.e. from 250 to 25 kWh / m² a. The best result could be that heat demand reduced even to 15 kWh / m² a, meet "Level 3" standard
- Reduce natural gas consumption, Use renewable energy
- Improve indoor air quality, optimize ventilation services
- To increase the living space
- Upgrade the appearance of residences
- Satisfy the residents' requirements

In order to realize the above aims, renovation activities listed in our checklist were carried out (Table 4.5):

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction • Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 4.5: renovation activities. The red-marked issues are relevant renovation measures involved in this case.

Tangible: Environmental, Architectural, and Technological

■ Envelope

The existing structure of balcony is concrete, and the cantilevered balcony slabs are a cold bridge. The best and easy solution would be to cut the slabs connection to building and erect new detached freestanding balconies. But this could cause stable problems. Because the soil condition in Fussenau is bad, fall of peat, freestanding balconies have risk to collapse.

An alternative solution is packing the balconies with a glass envelope, which acts as a thermal buffer or air log, and can reduce energy loss from balcony（Figure 4.20）. This solution finally has been selected. Through enclosing the balconies with glass, the rooms are not very close to outdoor environment, and a sliding door installed between balcony and rooms can have positive influence to a good indoor temperature. Since balconies were enclosed with glass and Aluminum framework, the balconies as a buffer space have been integrated into the façade of building. The U-value of Aluminum framework with double-glazing is good, about 1.0 W / m^2 K.

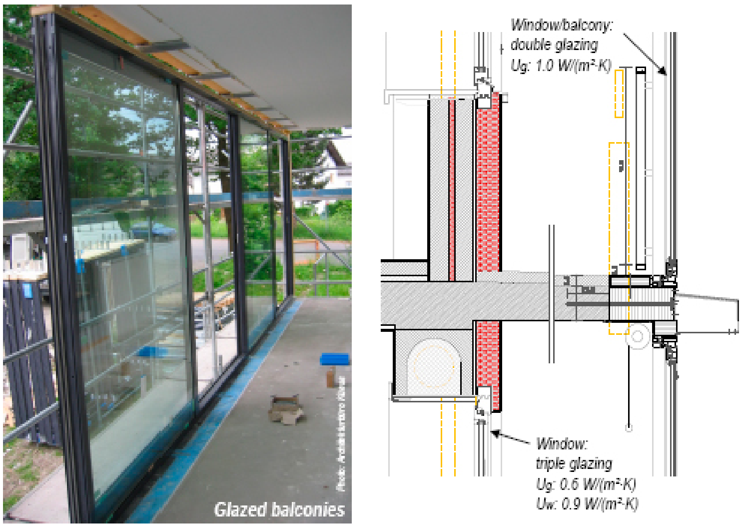

Figure 4.20: Balcony with a glass envelope (left). Section of balcony (right) (Architecture and sustainability, 2010, pp 39)

Packing the balconies with a glass envelope, from architecture perspective, can enlarge living area. In summer, balcony is still a good place to have an afternoon tea; in winter, balcony also can be used as a winter garden, due to the glass envelope hinder the cold air directly coming in （Figure 4.21）.

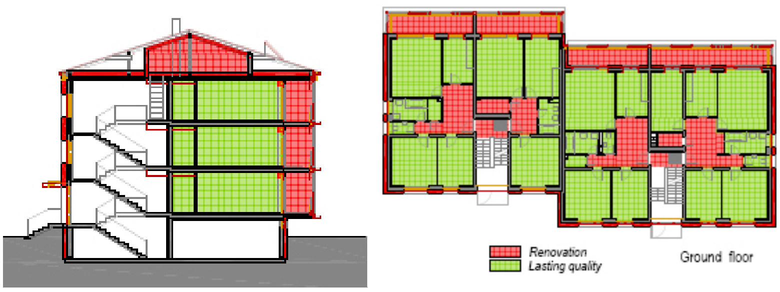

Figure 4.21: the red part in section (left) and plan (right) marked the enclosed balconies. (Drawing, 2008.)

Expect balcony, the performance of the exterior also has been significantly improved by applying a layer of external insulation of 25 cm thick sheets of expanded polystyrene (EPS) (Figure 4.22), and the top floor and the basement ceilings are add the layer of EPS insulation. Reduce energy loss also through replacing all the windows in to triple glazing window.

Figure 4.22: insulation of EPS (Omoregie, 2008)

In addition, the envelope renovation programs not only focus on the energy issue, but based on architectural aesthetical consideration, highlight on the renovation of the appearance. As a result, building was given a new color of painting. *Table 4.6* shows the construction of the roof and walls.

Roof detail (interior to exterior)----- U-value: 0.111 W / (m²·K)	**Wall detail (interior to exterior)----- U-value: 0.109 W / (m²·K)**
dry screed 20 mm	plaster 10 mm
expanded polystyrene EPS 250 mm	brick 90 mm
dry screed 20 mm	polyurethane rigid foam sheet 30 mm
rock wool 80 mm	high temperature insulating brick 90 mm
reinforced concrete 200 mm	plaster 10 mm
surface 5 mm	expanded polystyrene EPS 250 mm
	plaster 5 mm
Total 575 mm	**Total 485 mm**

Table 4.6: Construction of roof and walls.

■ Space heating and hot water

Before renovation, the energy for hot water was only supported by gas burning. Through renovation, on the roof, the 150 m² solar collectors (*Figure 4.23*) on the south-facing roof were installed, which can achieve an annual solar fraction of 60% for domestic hot water preparation. In other words, solar energy partly replaced the fossil fuse energy. After renovation, the hot water supply system depends on both gas (40%) and solar energy (60%).

Figure 4.23: solar collectors (Omoregie, 2008)

The temperature of hot water is controlled by a central controller. Some sensors and meters are installed in hot water pipes in order to keep the comfortable water temperature, and can also avoid energy waste caused by unnecessary high temperature hot water supply. The hot water is distributed upgraded existing piping, which save the construction cost and time.

The new ventilation system function applied in this residence can lower energy consumption by supplying warm fresh air though heating recovering. The core of heat recovery is the air exchanger, which is set in attic (Figure4.24*)*. The air "inlet" and outlet are all located on the roof, but have a different direction. Cold fresh air should firstly go into the air exchanger to increase temperature by receive exhaust air's heat, and after the heat exchange process, warm fresh air will flow to the living area and exhaust air will be discharged. Noise problem is not being neglect in ventilation renovation. Since air exchanger is located in attic, sound insulation is installed there to create a quiet living condition to residents. This ventilation system with heat recovery is controlled by the main office, and can supply fresh and warm air to the all apartments as well as attic and staircase. What is worth to mention is through installing this system, 85% energy that used to use for increasing fresh air temperature can be saved.

This ventilation system still has other advantages that satisfied tenants' requirement. Such as permanent fresh and dry air coming to the apartment, which can prevent mold; Unnecessary to always open windows, which can reduce street noise and dusting.

For indoor heating, only depend on "Heating recovery", of course, is not enough. Gas still has to join in; what is more, the 150 m² solar collectors on the south-facing roof also can play a role, which can have a 17% contribution to space heating.

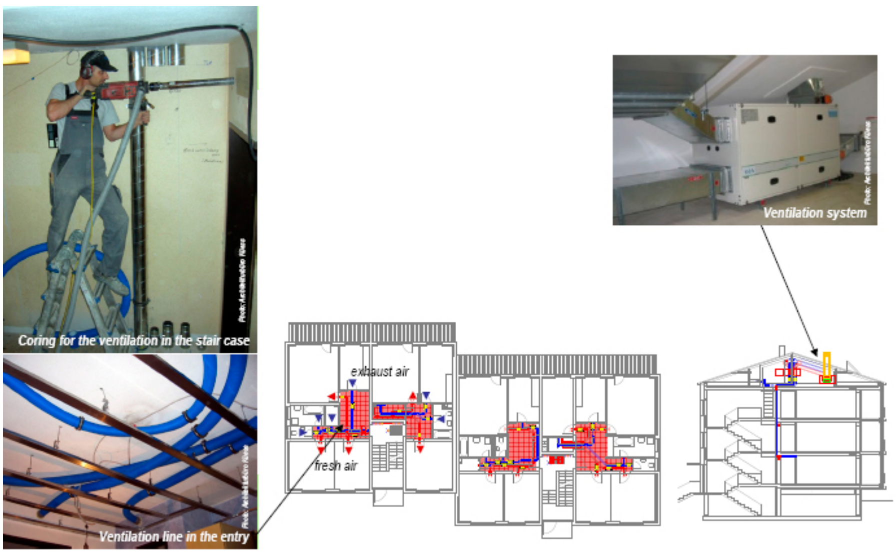

Figure 4.24: ventilation system function with heating recovery by air exchanger, which is set in attic. (Omoregie, 2008)

Non-tangible: Social, Cultural / Emotional

- Rigorous promotion policy

Vorarlberg has always been pioneer in the field of energy-efficient buildings. This is partly due to a very progressive housing subsidy policy that promote for stimulating sustainable construction activities in Vorarlberg. There is a scoring system ranks projects in three standards (levels 1, 2 and 3). The funding amount depended on the Level. (Figure 4.25)

Level 1	47 to 54 kWh/m^2/year
Level 2	40 kWh/m^2/year
Level 3	15 kWh/m^2/year

Figure 4.25: Maximum demanded energy for heating

This rigorous promotion policy is a great incentive for sustainable renovation. In the case of Fussenau, subsidy was received due to this project finally reach the "level 3". According to Hans-Peter Lorenz, managing director of Vogewosi, passive houses are encouraged; the funding policy is a strong incentive for sustainable renovation of low-energy buildings, depending on which level is achieved. The level 3 in the funding policy is about the passive house standard.

- Communication with the tenants

In this case, the renovation team was in close cooperation with the tenants. Through communication, the team knew well about how Fussenau looked before the renovation, and some problem of residence was revealed, i.e. the beige facade was stained, the red-brown windows and balconies bleached, the green awnings inappropriate. The tenants also can express their requirement for renovation to renovation team through communication, such like they wanted a renovation of the building appearance.

During the renovation process, the open information policy helped inhabitants to understand the remedial work and reached the consent of the residents within a very short time. The team also gained great appreciation from the tenants for their work, "*the workers in renovation team were rewarded with coffee and cake from the tenants constantly for their excellent work*." said project leader, which can increase workers' working enthusiasm.

4 Comparisons: before and after

The result of renovation reached the third level (15 kWh/m^2a) of funding policy. It improved the residence's performance and the living comfort of tenants.

By adding renovation measures such as additional insulation of the building envelope, changing the windows, the use of comfort ventilation systems, solar systems and replacement of heating system. To summary, the significant improvement through renovation is reducing quality energy consumption and increase living comfort. Table 4.7 lists some technical facts and the situation of the building before and after renovation.

Before	After
Constructions	
Outer wall U = 1.35 W / (m^2 K)	U = 0.12 W / (m^2 K)
Roof U = 1.85 W / (m^2 K)	U = 0.11 W / (m^2 K)
Window U = 2.1 W / (m^2K)	U= 0.8 W / (m^2 K)
Balconies- cantilevered balconies Massive heat bridges	Be enclosed as a buffer space. U = 1.0 W / (m^2 K)
Basement & ceiling U = 0.8 W / (m^2 K)	U = 0.19 W / (m^2 K)
Building technology	
Central ventilation systems	Central ventilation systems with heat recovery Recovery> 79%
Heating energy - Gas	Heating energy - Solar, gas, air exchanger
Heating demand	
250 kWh/ m^2a	15 kWh/ m^2a

Table 4.7: Some technical facts and the situation of the building before and after renovation

Besides the great improvement mentioned above, the architectural aesthetic improved as well. The start point for this renovation was the willing of tenants to improve the appearance of this building. After renovation, the former outdated outlooks have changed into a decent situation, i.e. façade was repainted and balcony was pocketed (Figure 4.26*).*

Figure 4.26: Façade before (left) and after(right) renovation.
(Architecture and sustainability, 2010, pp 39)

Enclosing the balconies not only solve the massive thermal bridge, but also enlarge the living area for residents and provide a energetic space for them. When answering the question of how it is like to live in the renovated residence, Hildegard Heinzle, a resident here, said that "*The winter garden is the best!*" We can spend much time there, she says - to chat with visitors, for handling work or just to look outside.

5 Successful factors & barriers or difficulties

This case was nominated for the State Prize 2010 for Architecture and Sustainability and VOGEWOSI was awarded the Energy Globe of Vorarlberg for its exemplary approach in the field of energy renovation of buildings in 2008. Both indicated that the result of renovation in this case is positive.

The focus of Fussenau renovation project is on the renewable resource usage, new ventilation system installation, façade changing, and improving insulation. So far, based on the figures and some reference, renovation result is good; these actives mentioned above can both reduce resource consuming and increase the living quality.

During the renovation process, the cooperation with tenants was successful. The requirement and feelings of the tenants were fully considered and fulfilled and the renovation work was high appreciated by the residents. The open information policy of VOGEWOSI played an important role in this cooperation, which is worthy to learn. Additionally, the funding policy in Vorarlberg positively influenced this case as well.

There are two main problems in this case. One is the material selection in this case had less attention to the embodied energy. For example, the balconies have been enclosed by using the aluminum construction which has a high embodied energy. We did not find the information on what kind of aluminum used. If aluminum was a recycled aluminum, the embody energy is about 34.3MJ/Kg, which is better than raw aluminum materials (201 MJ/Kg). The insulation material used in the top-floor ceiling and the basement ceiling is polystyrene, which also has a relative high embodied energy of 117MJ/ Kg.

The other problem is the monitoring after renovation is not that good. When we collected energy information about this residence, there are many versions of the renovation results found on the internet, such as follow:

Heating demand (5 versions):

- a reduction of the heating requirement by a factor of ten, that is, from 250 to 25 kWh/ m^2 a
- a reduction of the heating demand from 80 kWh/(m^2 a) to 16 kWh/(m^2 a)
- Heating energy: 23 kWh/(m^2 a), Data in accordance with passive house detection
- Heating energy: 15 kWh/(m^2 a), Data in accordance with national procedures
- In the end it was possible to reduce the requirement even to 11kWh/ m^2 a

Figure diversity reveals that the information collection after renovation especially some technical data collection is not precise. Under this situation, people may misunderstand the really condition of building due to receive incorrect data, and may set up unreal reference for future building.

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4.3 Case 3: Renovation and Extension of the House “Zeggele” in Silz

1. Background

The town of Silz

Silz is a municipality in Tyrol (Figure 4.27). Silz has a dying town center with many empty buildings. People prefer to set their homes in the new marginal area rather than staying in the old center. The Tyrol government, Department of Land Management and the Village Renewal Office has recognized this problem and launched the project of "town center revitalization". Several measures have been taken to promote the revitalization of the old center. A study of the vacant buildings has been carried out, checking for potential ones which are convertible to residential buildings (Figure 4.28). This study has also pointed out the advantages and special features for living in old structures. With the support funds from the Tyrolean housing subsidies, the project of revitalizing the old properties is performed. A special funding, which is primarily concerned citizens who are looking for a house, has been created to keep them staying in the center. In addition, information evenings, concerning for project planning, technical services, and energy recovery potential, were held to promote the cooperation among the specialist group, and between the specialists and citizens.

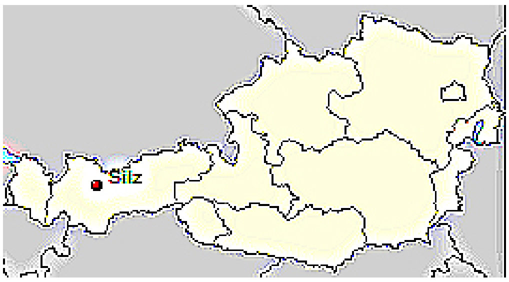


Figure 4.27: Position of Silz. (left). (Wikipedia, 2011). Figure 4.28: Study of the vacant buildings. (right) (Heiß et al, 2009)

The project

Our case, a farmhouse behind a large farm, is situated in the center of Silz (Figure4.29), and is one of the community’s oldest buildings, more than 600 years. The house has been vacant for 30 years and is in a state of decay.

The original part of this building was built in the late Romanesque / early Gothic (14th Century). Then it was expanded to the south in the Renaissance (late 16th century, early 17th century). Additional expansions and renovations (upstairs) were made in the 19th Century. An existing brick oven was also added in this period. A wooden-glass box is added to the west of the building in this renovation (Figure 4.30). The interior wooden floors and wooden beams are from the 19th Century without any insulation. The appearance of the house is determined by the superposition of building structures from various construction phases. The exterior walls in the ground floor are 50cm thick masonry walls. The walls of the upper floor are timber walls with a thickness of 20cm. Window and door openings are of various sizes, some with oblique window jambs, asymmetrically cut in the masonry. *(Culture reports from Tirol, 2006; 60 Monument reports of monuments in Tirol, 2006; Annual Report, November 2007)*

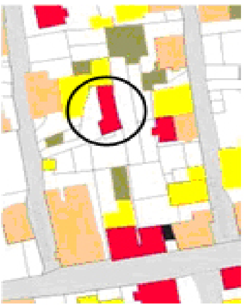


Figure 4.29: Position of our case.
Study of the vacant buildings. (Right)
(Heiß et al, 2009)

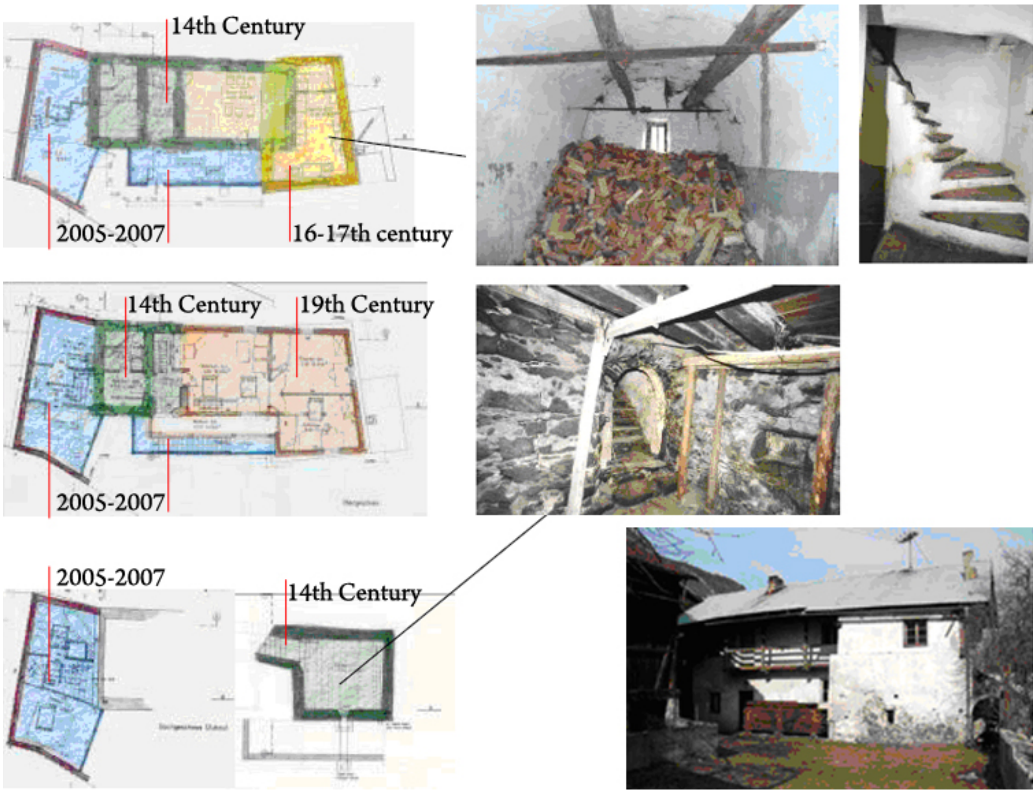


Figure 4.30: Different construction phases for the individual sections.
(Heiß et al, 2009)

Table 4.8 shows some basic information for this building.

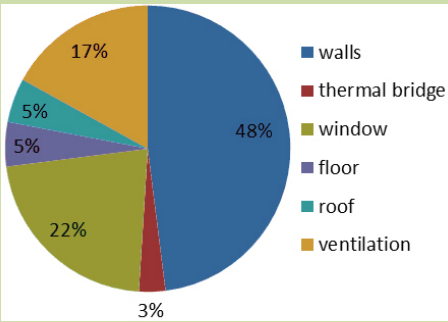
Basic information about House “Zeggele” before renovation	
Year of construction	14th century
Years of renovation	Spring 2005 - May 2007
Owner	Community Silz
Architect:	DI Dr. Peter Knapp
Other partners	Office of the Provincial Government village renewal office Energie Tirol
Layout	
Orientation	north-south
Number of stories	2 (with a basement)
Structure	Masonry & Timber
Energy	
Heated floor area	206 m² (only 80 m² for living)
Total heating energy	307 kwh/ m² a
Thermal insulation	
Envelope	Compare to other cases built in last few decades, whose envelopes are usually made of brick or concrete, envelope of this historic building is made of masonry and timber without insulation.
Transmission heat losses of the thermal envelope	

Table 4.8: basic information for this building

This case is the first time that tries to reduce the energy consumption of a historical building. After completion of the renovation works the charm of the small house that had been victim of decay over many years comes to light to its full extent. This project is nominated for Holzbaupreis Tirol 2007 in the category revitalization, and awarded from the Local Agenda 21 in Tirol in sustainability and green building in Energy Competition 2007. This case is supported by the funds from the Tyrol housing subsidies,

2. Why did we choose this case?

This case has a special background that it is part of the town center revitalization. This building serves as a model object for the center revitalization project of the Tyrol Government.

Another reason is that one interesting issue in this case is how to solve the contradiction between demand for preserving the existing appearance and the improvement of energy performance which needs to add insulation to the old envelope. Another issue is how to fulfill the needs of modern life in a historical building. This case shows that energy efficiency and modern needs in historical buildings are possible to achieve by careful consideration and planning.. The following issues are involved according to our checklist presented in the former chapter.

3. Renovation Activities

The overall goal of the renovation and extension project is to connect energy saving technology with the requirements of preserving the history. This project shows that historical value is possible to conserve at the same time with ensuring the comfort and modern needs. Several specific goals were set:

- To reduce energy consumption and increase thermal comfort
- To employ renewable energy.
- To increase living space
- To preserve the historical values.

These goals were achieved by measures marked in our checklist (Table 4.9).

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction • Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 4.9: renovation activities. The red-marked issues are relevant renovation measures involved in this case.

Tangible: Environmental, Architectural, and Technological

■ Envelope regard for energy and thermal issues

The renovated envelope has 3 factors: 1) a new built wooden-glass box; 2) OSB (Oriented strand board panel) inner insulation; and 3) new windows.

1) Figure 4.31 shows that the heat transmission through outer walls is the main reason for the heat losses due to the original non-insulated masonry and timber walls. Therefore, the outer wall is the key point for envelope renovation to reduce energy consumption and increase thermal comfort.

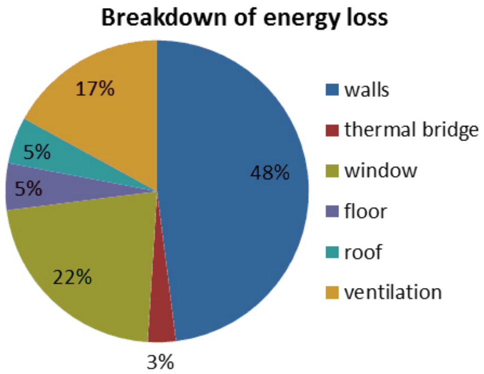


Figure 4.31: Breakdown of energy loss

Because of the requirement of preserving the original façade without great change, an important way to improve the thermal quality is a new wooden-glass box in front of the original building, a new element of the envelope. The function is not only as a new indoor living area, and as a shell that can protect the existing structure, but also a heat buffer (air log) for improving indoor climate. Moreover, from an architectural point of view, this glass box gives a new appearance of building (Figure4.32).

Figure 4.32: the new wooden-glass box. (Heiß et al, 2009)

2) OSB panel (Oriented strand board panel) is widely used as the inner insulation for the walls, ceiling of the basement and the truss of roof in this renovation (Figure 4 .33).

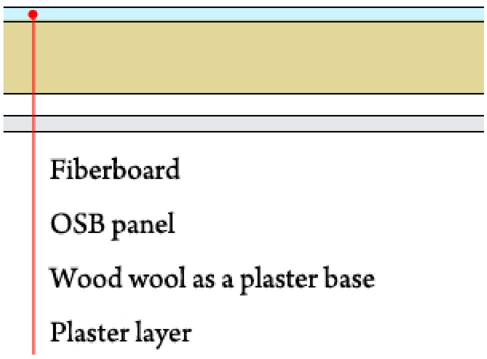


Figure 4.33: OSB inner insulation

OSB (Oriented strand board panel) panel is manufactured by compressing layers of strands of wood that are bound together with wax and water/oil-proof resin adhesives. The wood used to create OSB panels typically comes from fast growing species of trees such as yellow pine and bamboo. This compression process helps to avoid internal gaps which help to ensure a rigid, strong, air tightness and water-resistant panel and resistance from termites, mold, and fungus.

3) Windows are replaced with new ones which actually have two layers of window. In between, there is an air area, which can act as an air insulation to reduce indoor heat losses as well as a sound insulation (Figure4.34).

Figure4.34: The new windows
(Heiß et al, 2009)

- Heating System

After renovation, the heating area increased from 206 m² to 266 m². Energy generation for heating takes place in three levels. There is a wood gasification boiler placed in a fireplace. This wood boiler can provide heat for floor heating and radiator. Another natural resource to generate heat is gas (we found no information about what kind of gas used in this case). The hot water supply is depending on gas energy. Solar energy is also a resource for space heating in the wooden-glass box and act as an assistant for heating water. On the roof of the south, 10 m² solar collectors are mounted (Figure 4.35). Solar energy in this case plays an assistant role, associating energy from wood and gas to keep a comfort indoor temperature. The energy distribution has been adjusted to the building's structure and thermal quality. In the area of newly built barn, tube radiators inside of floor are used. In other room, heat is provided by both radiators and floor heating.

Figure 4.35: solar collectors. (Heiß et al, 2009)

■ Enlarge living space

Before renovation, the building has a living area of 80m². The owner wished to enlarge the living space to meet modern living needs. For this purpose, the original barn area has been rebuilt and converted into additional living area. The wooden-glass box added to the west, which is greatly improving the thermal performance of this building, serves as a new indoor area as well, connection to the old living area. A steel staircase was mounted in the box for a more comfort and safe vertical connection instead of the original steep spiral staircase (Figure 4.36).

Figure 4.36: the red line marked the new added part. (Heiß et al, 2009)

After renovation, indoor comforts are improved. Some measures carried out are:
- Internal wall was painted by plaster
- Maintain and replace the wood floor and all the wood floor are oiled
- Renovated the bathroom, a wood bathtub was set

The issues present above are some details which can give a comfortable feeling to residents.

Non-tangible: Social, Cultural / Emotional

■ Conserve the history

This project was primarily concerned with the preservation of the existing matter while energy part is in the second place. Careful measures were taken during the renovation process. To preserve the existing façade, the insulation was installed inside. The old windows have been replaced by replicas with an external single glazing and internal heat-resistant glazing. A window in the upper part inside the wooden-glass box was restored for nostalgic reasons. The quality of the window does not matter, since the thermal envelope is the wooden-glass box outside. The original front door was replaced by an old door from another old house in Silz. The original door to the kitchen has been restored. For the new built barn area, the external appearance is inspired by the local farm houses. After renovation, the façade has not changed very much, just use the plaster to repaint.

- Process

There is a careful and long process for this case, presented in Table 4.10, to achieve all the goals. All relevant specialists such as conservators, restorers, architects and constructors joined in this case and worked together during the whole process.

Time	Renovation Activities
Summer 2004	Preliminary work: the ceiling was exposed; inner walls were broken out to reveal a former window in the future kitchen; check the damage and carrying capacity of the upper floor structure; the plaster was blown down to reveal original visual of the bolts for damage. The architectural design was completed in autumn 2004.
May 2005	Recovery work: drain the stone wall; set up the foundation of the wooden-glass box.
Aug. 2005	Carpentry work: set up the new roof; replace all existing fireplaces by three new chimney structures; set up disruptions in the upper barn area; built the support structure of the connecting tract.
2005winter	Insulate the newly built barn area from the inside.
Mar. 2006	The window installation.
Apr. 2006	Restoration and repair of the facade. The cleaning work was awarded to a restorer. Restored and plastered the adjacent oven.
May 2006	The installation of heating and plumbing. Sewage pipes, heating pipes, solar pipes and water pipes were laid. The outside wall on the upper floor in the old part was provided with interior insulation. Completed facade restoration (plastering).
Jun. 2006	Installed the element in the kitchen.
Jul. 2006	Started the installations in the boiler room.
Aug. 2006	Complete the heating installations. Carpenter work which was carried out at the top and the bottom floor formwork was done.
Sep.2006	Install the bread oven for the shed roof, which will bear the solar system. Repair the old staircase in the historic part. Replace the doors. The electricians have started their work.
Oct. 2006	Interior restoration of the rooms.
Nov. 2006	Install the new glazing.
Dec. 2006	Suspended some radiator which could be turned on during the winter to dry he plaster. Install the solar panels.
Jan. 2007	Built the fireplace. The already plastered interior was painted and then plastered the former kitchen. The staircase was restored in the earth cellar. Began with the laying ground work.
Feb. 2007	Mounted the steel substructure of the stairs in the wooden-glass box. Insulate the floors and install the floor heating.
Mar. 2007	Finished the bathrooms. Mounted the new wooden stairs. All wood floors were oiled.
Apr. 2007	Complete the electrical installations. Installed a wooden tub.
May 2007	Installation of the skirting at the bottom and assembly the already selected lamps. Planted outside.









Table 4.10: the process of this project
(Heiß et al, 2009, pp 26-29)

4. Comparison: before and after

The renovation of this case has considered historical values and tried to balance the protection of historical issues while meeting current requirement. Thus, the renovation has not changed the outer facade, just a simple maintenance.

Inside the building, some changes have been made. Because one of the goals was to decrease the energy consumption and to improve the thermal comfort through insulation and involving solar energy, etc. Another goal was to improve indoor living comfort by enlarging living space and installed modern facilities. Table 4.11 shows the improvement after renovation.

component	before	after
Envelope	Masonry/timber walls and timber roof without insulation. Old traditional window with wood framework. 	Insulated with inner OSB panels; Replaced the original roof tile; Installed solar panels; Installed new windows with two layers 
Floor	Wooden floors without insulation	Maintain and replace the wood floor and all the wood floor are oiled
Staircase	  A steep spiral staircase connects the two floors, difficult to walk.	 Add a new staircase in wooden-glass box which is easier to walk. Keep the original spiral staircase for its historical values.
Barn Area	Only for storage	Changed into living area, and install heating equipment.
Basement	A weak point for heat loss	Insulated with inner OSB panels
Bathroom	No pictures for the original bathroom.	  A wood bathtub was installed.
Entrance		 A new wooden-glass box, more living

		area, and improve thermal quality. It is also an architectural element.
Floor Area	206 m²,only 80 m² for living space	266 m²
Heating energy	307 kwh/ m² a	116 kwh/ m² a 62% reduced, although it is still relative high.

Table 4.11: Comparison between before and after
(Heiß et al, 2009, pp 23)

5. Successful factors & barriers or difficulties

The focus of this project is to preserve the history as well as improve the energy performance. This project also contributed to the renewal of the town center. These renovation actives described above can revive the old building, reduce resource consuming and increase the living quality.

The good result of this case is due to the close cooperation among many people in different field, such as specialists of conservators, restorers, architects and constructors, and the stakeholders of local government, client, etc. There was a good cooperation with the research programs for the renewal of town center as well. Some studies had been carried out before starting this renovation in which the potential of this historical building to transfer to a residential building was explored and the users' demand was considered.

The careful measures of renovation also contributed to the good result. Renovation activities such as interior insulation, a new built wooden-glass box and the barn area, the solar system are carefully taken in order to not damage the old structure and preserve the historical part.

The experiences of other cases renovated for the town renewal were also helpful to this case. Since this project is a part of the town center revitalization in Silz, some similar projects carried out before. Those former cases provided the experience and guidelines for this case, communicating in the information evenings (mentioned in the earlier part of this article) or other occasions, to achieve a good result of renovation and the users' acceptance. This case also set an example for future projects.

So far, there are two main barriers in this case.
Firstly, all the renovation idea and concept for this building are all coming from architects, engineering, and archaeologist etc., and it is impossible to get the residents 'opinion. Because this residential building has already been empty for 30 years, there is no resident at all. In this case, it is hard to judge whether the result of renovation can satisfy the requirement of residents or not. If the some people move in

this building in future, new problem will probably be found. And we did not find if someone moved into this house yet.

Secondly, since this residential building is located in a mountain area, the household garbage transportation could be an energy consuming thing. Due to this situation, install a system that can use household garbage to generate electricity for building use could be considered in the future renovation.

Another observed barrier is that even after renovation, the energy consumed for heating is still high. One reason may be that the energy goal was set in the second place to preserve the existing façade. How to achieve high level of energy efficiency in a historical building is a challenge for the future projects.

References:

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Wikipedia, 2011, http://en.wikipedia.org/wiki/Silz,_Austria

4.4 Case 4: Renovation of residential buildings "Tschechenring" in Felixdorf

1. Background

The residential area "Tschechenring" was constructed in the late 19th Century, which is located in Felixdorf, Lower Austria, 50 kilometers away from Vienna. There is a direct train line connection to Vienna (Figure 4.37), and 30 min to the center of Vienna by car. The location makes the residential area to be an attractive choice for the tenants.

Figure 4.37: Position of Low Austria (left up), Perspective of "Tschechenring" (right up), Site plan (left bottom), Appearance of this building, (bottom) (Wohnhaussanierung "Tschechenring", 2008)

The type A Building is the renovation object (Figure 4.38*)*, and we choose it as the focus in this case study. "Type A" residential building was constructed in 1869, with more than 140 years' history. The story of this building are not always same, the part in the middle and two sides, the number of story is two; and the rest part of building, the story is three. In every floor, two flats are grouped around this staircase, and there are totally four apartments in each floor. The floor area before renovation is 1011 m^2.

The renovation project for "Type A" was launched in 2005, and last for two year, finally finished in 2007. During renovation, the occupiers have to move out. The triggers for the renovation were, firstly, it is necessary to change the poor condition of residence; secondly, the necessity to conserve the old residential building; thirdly, the good location of this residence is good, and through renovation, more tenants could be attracted.

Figure 4.38: section (left), plan (right). (Wohnhaussanierung "Tschechenring", 2008)

Some basic information of this building is listed in Table4.12.

Basic information about the House "Zeggele" in Silz	
Year of construction	1869
Years of renovation	2005-2007
Owner	Community Felixdorf
Architect:	Urban Planning mbH
Building physics	Buschina & Partner ZT GmbH
Building services	Christian Lebitsch
Layout	
Number of stories	3 (with a basement)
No. of apartment	12
No. of apartment in each floor and layout	4 apartments
Structure	Brick Wall
Energy	
Heated floor area	1.467 m²
Total heating energy	198 kWh / (m² a) , 290.466 kwh/a
Heat supply	By oil & gas
Hot water supply	By oil & gas
Thermal insulation	
Envelope	non-insulated exterior walls, floor structures and roof, Plastic windows need to be renovated
Cost for renovation	EUR 1,5 million € in total, 1.510 EUR / m^2 €

Table 4.12: Some basic information of this building

This case is an attempt to achieve high-quality of living environment, historical building protection and the requirements of modern residential market.

This renovation project is an ambitious renovation of an old building into a modern residence, but both consider of modern and old will arouse additional cost. Fortunately, money is not a barrier in this renovation. The renovation is funded with money from the province of Lower Austria and the community Felix village, funded by the FFG (Austrian Research Promotion Agency) and by a grant from the Federal Monuments Office. What is worth mentioned here is this project also planned to set an example for future projects of this kind of building.

2. Why did we choose this case?

The case had been selected due to the following reasons:

- This case employed a very different way of renovation on historical residential building compare with Case 3, in which renovation measures were carefully taken to preserve the history of the building, both the façade and the inside, while in this case, only façade has been conserved, and inside the old façade, the floors, walls and roofs was totally newly built.
- This case has a special focus on use of low environmental impact material, and considers the transportation distance of materials.
- Unlike the former cases which cover a wide range of renovation issues listed in our checklist, this case has an obvious emphasize particularly on tangible aspects.

3. Renovation Activities

The high demands of renovation of the protected area of residential buildings from the late 19th century requires a comprehensive approach in order to safeguard the historical characteristics, achieve a high environmental standard as well as satisfy the requirements of modern residential market. The owner set the following aims for the renovation:

- Living space expansion through loft conversion
- Optimization of the thermal envelope with interior insulation
- Keep original façade
- Renewable energy involving
- Use renewable materials
- Increase accessibility and security
- Maintenance after renovation

These goals were achieved by measures marked in our checklist (Table 4.13).

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction • Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 4.13: Renovation activities. The red-marked issues are relevant renovation measures involved in this case.

Tangible: Environmental, Architectural, and Technological

■ Envelope

The building had a solid brick wall without insulation and a cold roof before renovation. To achieve a better thermal performance, interior insulation of mineral panels has been fully adhered to the existing structures, without changing the outside of the old façade.

The original windows have been replaced by certified wood windows, with 2-pane insulating glazing (U-value: 1, 1 W / m² K, g-value: 0.58, light transmission: 80%) and interior blinds (Figure 4.39). The original roof was demolished and replaced by a new insulated roof. This kind of renovation method improved the thermal performance of the envelope (Figure 4.40), and some historical characteristics of the building are kept to some degreed due to unchanged façade.

Figure 4.39: windows

Figure 4.40: roof renovation. (Wohnhaussanierung "Tschechenring", 2008, pp 48)

■ Heating & Hot water, Ventilation

The heat and hot water is supplied by biomass fuels through a central wood chips heating system. The newly constructed boiler room is located in a small attached building. The heating period is determined by an outdoor temperature sensor connected to the controller of the boiler. Building is connected by heating pipes as well as hot water pipes in the ground. The use of wood reduces dependence on heating oil and natural gas which produces higher sulphur dioxide and hydrocarbon emissions than the burning of wood chips. The transportation and storage of wood chips poses little threat to the environment.

In combination with the central heating system, a controlled ventilation system with heat recovery is used, each installed in a suspended ceiling in the bathroom or the hallway. The cold fresh air is drawn in through the roof, goes to the heat exchanger and is supplied into the apartments with a temperature about 18-19 ° C. The exhausted air is taken from more polluted areas such as bathroom and kitchen. The intake and outtake valves are on top of the door frame.

To keep the noise as low as possible, sound insolation are installed in the intake and outtake pipes. The tenant can adjust the strength of the ventilation unit according to the specific ventilation requirements. All sanitary facilities are equipped with water-saving fittings.

- Outside the building

There is a high-quality preservation of existing green space enclosed in front of this residence, functioning as a semi-public recreational area. Due to the size of the green space, it also functions as the micro-climate for this area. A children's playground is formed in the green space as well. What is more, the addition of public area, such as bicycle storage room; garbage room etc. can give more convenient to residents.

- New interior layout

Inside the preserved old façade, structure is totally newly built, which means it is not possible for tenants to continue living in during renovation. Through renovation, interior wall, floor etc. was rebuilt. Attic is changed to be a part of living area for people who living in the 2 floor using through renovation, which increasing the floor area by approximately $250m^2$, 62.5 m^2 each apartment (4 apartments in the 2 floor). (Figure 4.41*)*

Figure 4.41: new interior layout. (Wohnhaussanierung "Tschechenring", 2008, pp 48)

After renovation, the sizes of all the apartments range from 72 to 108 m^2 in the building, at an average apartment size of about 84 square meters. 36-45 people are expected to use the flats. Around 28 square meters per person (depending on occupancy) are available.

■ Use of building materials from renewable resources

The material use principles in this case are based on the use of material from renewable resources. Table 4.14 lists the materials used in the project.

Description	Consum-ption in kg	Transport in km	Description	Consum-ption in kg	Trans-port in km
Reinforcing steel (rebar)	19.704 kg	40 km	Mineral. Insulation (recyclable)	19.017 kg	80 km
Concrete	591.248 kg	40 km	Expand. Polystyrene (recyclable)	2.115 kg	80 km
Plasterboard (recyclable)	40.362 kg	80 km	Wood building materials (timber board) (recyclable)	15.500 kg	80 km
Glass: heat resistant glass 2-fold (1.1 W / m² K) (recyclable)	150 m²	40 km	Compensation layer wood board (recyclable)	7.240 kg	80 km
Acoustic tiles (recyclable)	91.850 kg	40 km	Wood building materials (wood edging)	14.000 kg	80 km

Table 4.14: The materials used in the project.

.... km transport from the factory / dealer to the construction site, including empty return trips

Recyclable marterials is preferred in this project. And Products are selected mostly form local supplier to reduce the transportation distance, which reduce the transportation cost and negative environment influence.

Non-tangible: Social, Cultural / Emotional

■ Security and equity

Through renovation, new technical equipment and insulations etc. were installed, which improve the living quality. Beside these, a burglar-proof entrance doors was set in the main entrance of building, to increase the level of security. Moreover, in order to improve the accessibility and convenient for the disables, a small ramp was built in front of main entrance, instead of steps. Those changes made in the entrance can represent the security and social equity in the renovation design.

■ Historical value conservation

Because of the age of this building, more than one hundreds of years, historical value was necessary to be considered in the renovation. The renovation activities like protect the existent old green land in front of building and conserved the original façade of building etc. are the ways that taking old building conservation into account (*Figure 4.42*).

Figure 4.42: façade after renovation.
(Wohnhaussanierung "Tschechenring", 2008, pp 49)

Since this is a historical renovation project, more kinds of specialists have been involved, such as historian and Ancient architecture protection experts, and may be archaeologist. Under this background, with the help from Lower Austrian housing's assistance, a mixed team, include experts who focus on ecological high-quality and historic preservation and high modern living condition was formed. During the renovation, tenants should move out, which can give more free space for construction work.

■ Regular maintenance after renovation

Regular maintenance is always necessary for every building. After renovation, in order to keep the building in a good condition for a long period, a facility management company named "South Vienna" was hired and responsible for cleaning and maintenance of this residential building.

4. Comparison

The result of renovation is positive; Table 4.15 lists the aspects upgraded through renovation.

Items	Before	After
Floor area	1.011 m²	1.118 m²
Energy demand	198 kWh / (m² a)	53 kWh / (m² a)
kind of energy source used	Oil, Gas	Wood chips, Oil, Gas
Type of ventilation system	Mechanical ventilation	Mechanical ventilation with Heat recovery
water-saving fittings in sanitary facilities	no	yes
Window	Plastic window (previously renovated window)	Wood windows
Façade		 without big changing
Main Insolation material		Mineral wool EPS (expandable polystyrene) OSB (Oriented strand board) Ca-Si-panel
U-value	Outer Wall: 1,213 W/m²K Ground Floor: 1,460 W/m²K Top Celling: 1,113 W/m²K	Outer Wall: 0,456W/m²K Ground Floor: 0,225 W/m²K Top Celling: 0,159 W/m²K
Attic	Not a part of living area	A part of living area
Green land in front	Yes	Yes
Additional areas for public use		heating room garbage room Baby carriage room Bicycle storage room. Children's playground.
Entrance door	Simple Wood door	Burglar-proof entrance doors
Accessibility	Entry the main entrance through steps	Entry the main entrance through steps or ramp
Indoor space layout		

Bathroom renovation		

Table 4.15: Comparison between before and after
(*Wohnhaussanierung "Tschechenring", 2008, pp 49-50)*

Through renovation, in this building, in the aspect of energy, isolation, indoor living environment etc. are all updated. In consequence, this historical building can meet current needs.

5. Benefit and barriers

This renovation project trys to change the situation of this historical building and meet present needs for high quality of life. After renovation, through insultion installtion, new ventilation system setting, and renewable energy involving etc., the total energy consumption is reduced to a quarter compare with before, which is a great progress. Through attic renovation, living area was enlarged, and with renovation activities like redesign indoor layout, bathroom refurbishment etc. Living quality is dramatically increased. Through detail renovation, such as burglar-proof entrance doors installed and ramp instead of steps, social security and equity can be represented. What is more, the addition of public area, like playground, bicycle storage room; garbage room etc. can give more convenient to residents. Moreover, based on a lifespan perspective, maintenance is highlighted after renovation project finished, which can keep the building in a good performance in long period.

As historical building renovation, due to the consideration of historical conservation, façade of this residence is not changed too much, and the green land is also protected. Through these measures, historical value is conserved to some extent.

Although this renovation takes some consideration to historical building conservation, the effort is not enough. During the construction, the out wall (facade) was conserved in a good condition, but inside, almost all the structures were demolished include slabs and some beams etc., and, the roof is also reconstructed (Figure 4.42*).* In other word, only the shell of building is conserved, and based on the consideration of keeping the historical value, this project is not a good example. Because with taking off too many original elements, historical value is disappear gradually.

Figure 4.42: demolition during the renovation.
(Wohnhaussanierung "Tschechenring", 2008 pp 50)

In short, based on the consideration of satisfying current needs, this renovation project is successful; but based on historical building conservation, renovation should protect more original components rather than only façade and some pillars etc.

References:

2008, *Wohnhaussanierung "Tschechenring" Umfassende Sanierung einer denkmalgeschützten Arbeiterwohnanlage (1880) in Felixdorf. Interim report. Available from:* http://www.hausderzukunft.at/results.html/id4581. Accessed: 2011-05-30.

4.5 Case 5: A renovation and extension of a single-family house in Pettenbach

1. Background

The single Family house Werner and Gabriele Schwarz locates in Pettenbach, Upper Austria (Figure 4.43). The site, around 2,000 m², has a slight slope to the south. The northeast border of the site is directly linked with a forest. There is a narrow road on the southwest. The single-storey building with a floor area of 97 m² had an orientation of southwest, and located in the upper part of the site (Figure 4.44).

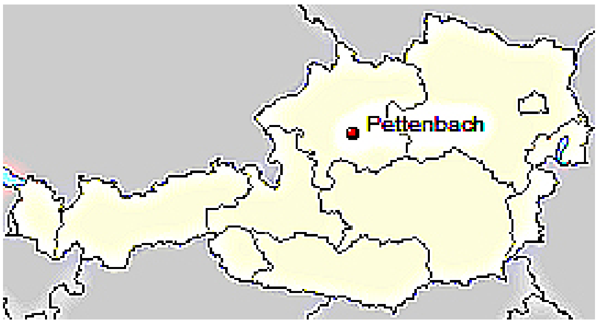

Figure 4.43: Position of Pettenbach
*(*Wikipedia, 2011)

Figure 4.44: Site plan (left), original façade (right).
(Lang, et al, 2007)

Some basic information about this case before renovation is shown in Table 4.16:

Basic information before renovation	
Year of construction	1962
Years of renovation	July 2004 - April 2006
Owner	Werner and Gabriele Schwarz
Architect:	DI Heinz Plöderl, PAUAT Architekten
Structure:	DI H.C. Obermayr, Obermayr wooden structures GmbH
Layout	
Orientation	southwest
Number of stories	1 (with a basement)
Number Of People	4
Structure	concrete
Energy	
Heated floor area	97 m²
Total heating energy	280 kWh / m²a
Heat supply	A central heating system with LPG (Liquefied Petroleum Gas). The boiler and a LPG tank were in the garden. In addition, two temporary electric radiators were in use.
Thermal insulation	
Envelope	Roof with a U-value of about 1.50 W / m² K.; Concrete walls with a U-value of 1.30 W / m² K; Small windows.

Table 4.16: Basic information about this case before renovation

The house, built in 1962, functioned as a weekend cottage originally. The space inside the house before renovation was small and dark, especially the rooms in the northeast with small windows because of the adjacent forest (Figure 4.45).

Figure 4.45: small and dark room before.
(Lang et al, 2007)

The existing envelope is in poor condition. The roof constructed with 2 cm of insulation with a U-value of about 1.50 W / m² K. The exterior wall constructed with 20 cm thick concrete blocks with a U-value of 1.30 W / m² K. The existing windows are no longer corresponded to today's standards and offered no comfort. The floors above the ground or the basement ceiling were not insulated and constructed with an 8 cm topping with a U-value of 2.65 W / m² K. The family determined to renovate the old cottage to satisfy modern living need and meet the energy standards. The children were eager for the renovation work (Figure 4.46).

Figure 4.46: The children were eager for the renovation work (Lang et al, 2007)

This project was subsidized by the province of Upper Austria. The following amounts were paid:
- Housing renovation funding annuity would do 40% subsidy for € 40.000,-
- Grant ventilation, hot water heat pump € 2.004,-
- Subsidy for PV system € 7.584,-on funding from the Land

2. Why did we choose this case?

This project is a renovation of a single-family house which represents 40% of the residential building type after the war in Austria. There is a large market for renovation of this kind of residence. The experience and knowledge gained in this project can be widely spread and set an example for the similar projects in the future.

The façade-integrated photovoltaic system used in this project was a new development by the Austrian manufacturer Ertex Solar GmbH, having multi functions and new architectural accents. The system in this project was the first time to present to the public and it awarded by the Energy Globe Vienna. This project provided experience of how to install and use this system and contributed to its development.

3. Renovation Activities

The owner set the following goals for this renovation:
- To reduce energy consumption and increase thermal comfort by improving the envelope.
- To improve the living comfort by means of better layout, enough daylight, better appearance of the house and better interior air quality.

- To use renewable materials
- To achieve an affordable renovation
- To establish new and innovative renovation procedures.

The goals were achieved by measures listed in our checklist (Table 4.17).

		Minimize Environment Impact	Maximize Comfort of Life
TANGIBLE	Environment	• Water consumption and reuse • Energy consumption • land use • reduce waste production and pollution • low impact material	• Increase air quality • Outdoor space (biodiversity etc.)
TANGIBLE	Technological	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Efficient appliances (tap, valves, electrical installation • Renewable technologies (biomass, PV, solar thermal, wind, Geothermal) • Maintenance to keep building system in good condition	• Technical system (Heating, Ventilation, Air-conditioning etc.) • Maintenance to keep building system in good condition
TANGIBLE	Architectural	• Better construction way • Space, function (Flexible layout, etc) • Building envelope	• Better construction way • Space, function (Flexible layout, etc) • Design for deconstruction • Architectural aesthetic
NON-TANGIBLE	Cultural & Emotional	• Reuse of the old buildings	• Neighborhood relationship • Historic value • Keep residents' memory maximum • Care about residents' feeling and demand for renovation
NON-TANGIBLE	Social	• Users' behavior • Planning process • No relocation of tenants	• Social equity (provision for disabled facilities) • Outdoor space (public space for social interaction) • Information data collection & popularization

Table 4.17: Renovation activities. The red-marked issues are relevant renovation measures involved in this case.

Tangible: Environmental, Architectural, and Technological

- Envelope

The new envelope has three factors including: 1) a prefabricated, load-bearing, "hook-in" timber wall construction; 2) high level of insulation and airtightness; and 3) 3-glazing windows with sun protection.

1) One motivation for this renovation is to add a storey to this house. The original walls are cantilevered on floor joists and could not take added weight. So, the addition was done with a prefabricated, load-bearing, "hook-in" timber wall construction (Figure 4.47). Key benefits by using the prefabricated timber wall construction are reducing construction time, improving the quality through strict factory quality control, scaffold-free installation, reduced noise and dust emissions, greatly reduced risk of accidents, minimized construction warehouse space, and convenient for future maintenance etc.

Figure 4.47: *Process for installing the pre-fabricated façade*
(Lang, et al, 2007)

2) High standard of insulation was employed to reduce energy consumption and increase thermal comfort. Insulation was carried out with cellulose blowing, making an easy separation to facilitate reuse. This kind of insulation was used for outer walls (Figure 4.48), roof, partitions, and the floor structure in the living and sleeping area.

Figure 4.48: Insulation. (Lang et al, 2007)

To insulate the ground floor, without reducing limited cellar head-room, 20 mm vacuum insulation panels were laid on the ground floor and new flooring installed above it. The air tightness concept was implemented. A bituminous adhesive foil seal to the wall was installed in the basement. The window also had an air-tight construction (Figure 4.49).

3) Original windows were replaced by the 3-glazing ones with a U-value of 0.8 W/m2 K (Figure 4.49). In order to achieve a comfortable room temperature in summer, an exterior sun protection was installed to avoid overheating in the southwest and southeast-oriented windows (Figure 4.49).

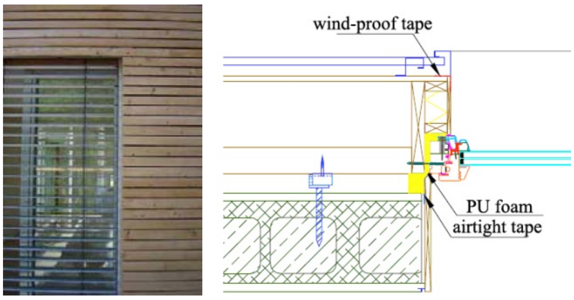

Figure 4.49: Sun protection (left), new window (right)
(Lang, et al, 2007)

- Domestic system (heating and ventilation) & Energy

Before renovation, a central heating system with liquefied petroleum gas was in use. There was a relatively high maintenance and repair cost for the gas boiler of an average of € 150, - /a and the costs of the gas tank of an average of € 180, - / a, as well as the high energy cost of LPG. Furthermore, there was potential risk of using LPG (Figure 4.50).

Figure 4.50: Preparations for removing the old heating system.
(Lang, et al, 2007)

After renovation, active solar energy and the ground are used for heating and cooling. 75% of the heat demand is covered by a 2.4 kWp photovoltaic system which is integrated into the façade, mounted in the window belt area. This façade-integrated photovoltaic system was especially developed for this project and was the first time to present to the public. A heat pump is used to heat water and air. A tank with 200 liters is used for hot water storage (Figure 4.51). A foam insulation ensures minimum heat loss.

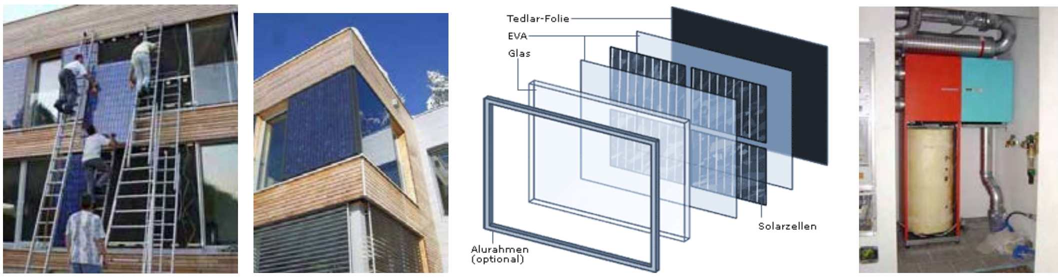

Figure 4.51: Façade-integrated PV-system and heat pump. Layers of the PV panel (front to back): 4mm toughened clear glass; Poly-or mono-crystalline solar cell, typically 156 x 156 mm; Encapsulation: EVA film (ethylene-vinyl acetate); Tedlar plastic film; Connector: Tyco socket (IP 65) to connector and 4 mm ² cables according to module width. (Lang, et al, 2007)

A ventilation device has been installed to create better air quality and to simplify the maintenance. A microprocessor in the ventilation device can control the speed of the fans and the operating condition of the heat pump. The fresh air was preheated in a 28 m pipe made of PE with a diameter of 20 cm. This pipe was installed underground in the garden, alongside the side wall of the new built cesspool, of which the higher temperature transmits to the soil and heat the pipe (*Figure 4.52*). In each room, at least one window is arranged to be open to get natural night ventilation.

Figure4.52: Pipes for fresh air
(Lang, et al, 2007)

To reduce energy consumption, the owner only uses the appliances with energy efficiency certification. 60% of all lamps are energy saving ones.

- Maximize living comfort through better layout, enough daylight and better appearance of the house

Living space is enlarged by adding a storey to the original house. A new interior concrete frame carries the 120/60mm wooden rafters of the new storey. All non-bearing partition walls were demolished to change the original narrow and dark rooms into open and bright space. In the south corner, the interior space expanded and integrated to the terrace and garden (Figure 4.53). For better access, there is a ramp in the entrance. An office room on the ground floor can be converted to a bedroom.

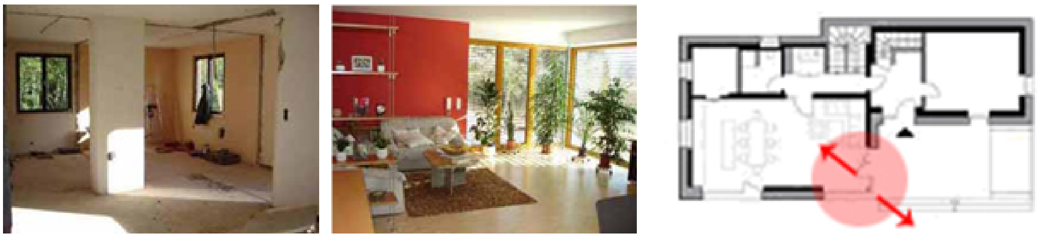

Figure 4.53: The south corner
(Lang, et al, 2007)

To get more daylight, all windows on the southeast and southwest were designed as floor to ceiling windows. The railings on the windows were made of transparent glass. There is adequate light in all rooms for pleasant psychological impression (safety, kindness, connection with nature) (*Figure4.54*). This also led to low energy consumption for artificial lighting.

Figure 4.54: New interior space with enough daylight
(Lang, et al, 2007)

Before renovation, the house had white plastered exterior walls since 1962. While after renovation, the house is distinguished by its simplicity with two cubes merging into each other. One cube, which is set back, is covered with gray metal panels contrasted with the other cube which is covered with wood (Figure 4.55). The house has a totally new character.

Figure 4.55: New façade
(Lang, et al, 2007)

■ Renewable material

This project aimed to cut the consumption of non-renewable raw materials. For example, wood is one main material in use. The windows were made of wood and aluminum. Doors were made of wood. All rooms were installed with wooden floors. And the exterior prefabricated walls are also made of timber

Non-tangible: Social, Cultural / Emotional

- Process

Table 4.18 presented the process of this project which lasted approximate one year.

Stage	Work	Time
Preliminary	Survey of the client's wishes; Set the environmental and comfort goals; Structural analysis of the existing building; Air tightness test prior to the demolition of old components.	July-September 04
	Detailed planning and design	Until November 2004
	Assessment of embodied energy and resource consumption; Presentation of design concepts, building services and material choice by the architects and constructors.	November 2004
Construction	Demolition of old elements	October 2004
	Exterior and interior construction, building system installation	By the end of April 2005
Test	PV modules test	March 2005
	Airtightness measurement with leakage detection - thermal camera	June 2005
	Documentation and presentation of the renovation by the renovation team.	Until August 2005
Usage	Move into the renovated passive house	August-September 05

Table 4.18: Process for the project

The process had four main stages: preliminary work, construction work, test and usage. A comprehensive preliminary work has been done before renovation. It can help the engineers and architects to have a deeper understanding of the building. Based on the preliminary job, good solutions can be offered to renovation project. Following is the construction stage which is less than 7 months due to the prefabricated technology and the good preliminary work. After the construction stage, the renovated house has been tested to check out the effect of renovation and document the data and experience of this project (Figure 4.56). The information is published in the series, and via the internet, which can be the reference for future projects. The clients moved into this house in August-September, 2005.

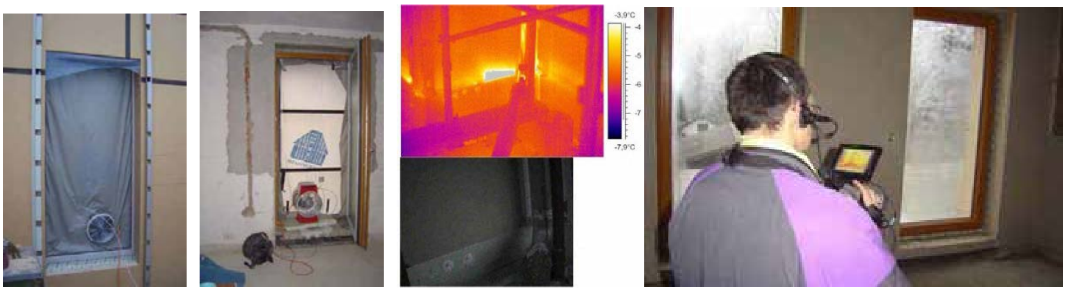

Figure 4.56: test for air tightness of window and interior temperature through thermo graphs. (Lang, et al, 2007)

4. Comparison

The result of the renovation/extension, in the energy aspect, is a reduction of heating demand by 95%, from 280 kWh / m² a to 14,6 kWh / m² a; and a reduction of overall heating demand from 27.100 kWh / year to only 3.170 kWh / year, a 88.6% decrease, despite of doubling the heated floor area from 97 m² to 217 m². (Figure 4.57)

The solar energy stands for a considerable part of heating energy supply for this residential building using, it covers about 75% of the need. The result of heating energy reduction will directly cause a dramatically fall down the volume of CO_2 emissions, from 9.2 t/a to 0.63 t/a, a 93% reduction (Figure 4.58).

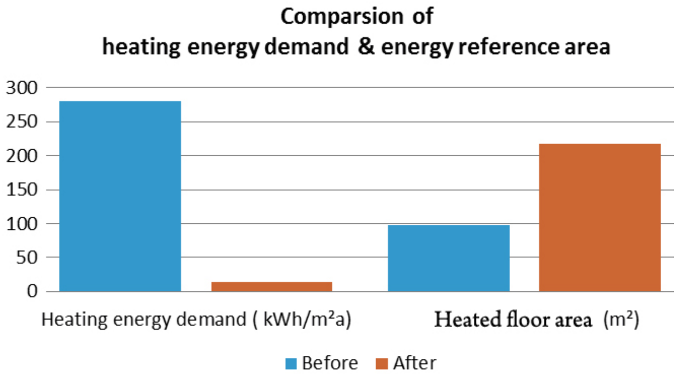

Figure 4.57: Energy demand for heating

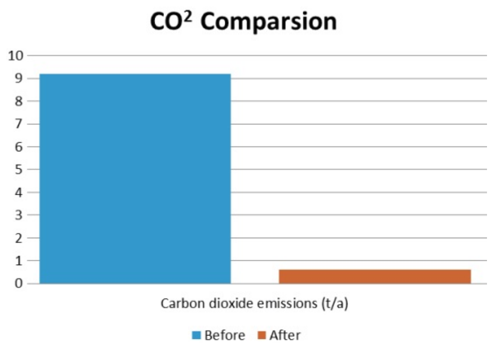

Figure 4.58: CO_2 emissions

Table 4.19 listed the improvement after renovation.

Component	Before	After
Heated floor area	97 m²	217 m² (1 storey added)
Heating demand	280 kWh/m²a	14.6 kWh / m² a
Total heating demand	27.100 kWh/a	3.170 kWh/a (88.6% reduction)
Energy source	Liquefied Petroleum Gas	Gas & solar energy
CO2 emissions	Ca. 9.200 kg CO2/a	630 kg CO2 / a
u-value of outer wall	1,30 W / m² K	0.11 W / m² K
U-value of Roof	1.50 W / m² K	0.09 W / m² K
U-value of the Floor above ground	2.68 W / m² K	0.12 W / m² K
U-value of Basement ceiling	2.68 W / m² K	0.13 W / m² K
Appearance		
Interior space		

Table 4.19: Comparison between before and after
(Lang, et al, 2007)

5. Benefit and barriers

This renovation project provided a good example of reducing the energy consumption and CO2 emission, increasing the living quality and achieving architectural aesthetic in an old house. In this project, architectural design was integrated into the overall concept harmoniously.

The well-organized process contributes to the success of this project. The comprehensive preliminary work is the basis for the success of this project. During the construction process, prefabricated timber construction minimized the impact on the environment and the residents, and shorted the construction period. Details of the project were carefully considered. For example, the thermal envelope was consisted of lightweight wooden support and cellulose insulation, which is easy to separate and reuse. This facilitates the future renovation if needed. After construction stage, test is carried out to ensure the quality of renovation and information and data is collected and popularized for future projects.

This single family house is designed for 4 people. In order to improve the living comfort, the living area increased from $97m^2$ to $217m^2$ through renovation. This result for residents is absolutely good, because spacious living area is available. But, $217m^2$ for 4 people means everyone has $54.25m^2$ living area, it seems a little bit large. The consequence might be that some area is seldom used but still need to be heated, and in this case, some energy is wasted. In Sweden, a house for 4 people is usually from 120 m^2 to 150 m^2, compared with 217 m^2. If the area can have a reasonable decrease, on one hand, the energy consumption can have a further reduce; on the other hand, construction materials can be saved.

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5. Conclusion & Discussion

In Austria, the main motivation for renovation of residences is to change the poor condition of current building; economic incentive is also an important assistance tool to promote renovation project.

In this thesis, five residential cases are selected to be research; and they can be divided into three types (Table 5.1), multifamily residence (case 1& 2 & 4), historical residence (case 3& 4), and single-family residence (case 3 & 5). Besides, cases 3, 4 and 5 are belonging to a program called "Demonstration project for the program Building of tomorrow", which is launched by the Federal Ministry of Transport, Innovation and Technology (BMVIT) in 1999, in order to research and development of sustainable technologies and solutions for sustainable building and living.

Single-family residence	Case 5	
	Case 3	Historical residence
Multifamily residence	Case 4	
	Case 1	
	Case 2	

Table 5.1 Classification of residence type of 5 selected cases

The renovation activities in these five projects contain plenty of aspects, such as environment friendly, new technology application, architecture redesign, culture conservation and focus on social issues as well. The targets of renovation are bringing the better and comfortable living environment to residents, and at same time, greatly reduce the negative impact to natural environment. And since the targets highlight comfortable living environment and reduce negative impact to nature, according the theoretical part ("minimize" and "maximize"), these five renovation cases take sustainability in to account.

In the following part, three types of residence, single-family residence, multifamily residence, historical residence will be discussed respectively; after that, several good sustainable renovation activities will be concluded; and suggestions about new buildings inspired by 5 cases will be briefly stated

5.1 Multifamily residential buildings

Residential buildings have many unique aspects affecting renovation:

- As we all know, one multifamily residence is designed for many residents living. When a multifamily residence renovation project is run, it is necessary to consider different kinds of residents' requirements. Unfortunately, it is hard to take all residents' requirements in to account. Due to financial limits, investors have to neglect some minor requirement while satisfying the majority of the residents' demand. As a result, investors can use reasonable spend to leave original residents and even attract new tenants, so that the investment can be quickly offset.

- The building volume and area of multifamily residence usually is large, plus, the condition of some building is poor, consequently, investment for multifamily residence renovation is normally bigger than other types of residence.

- In many multifamily residences, renovation costs were completely covered by the increasing of rental income through enlarging living area. And some tenants seem like willing to accept the additional rent, for example the situation in case 1. Based on a short-term perspective, it is a good way to deal financial problem; but based on a long-term perspective, it is not a sustainable financing; the next renovation cannot be paid in this manner, because the area is hard to be enlarged, and extra cost will be spent for the enlarged area in future renovation .

Accordingly, the typical actions taken in the multifamily residence renovation are:
- Increase the living area by changing balcony and attic into the indoor living area.
- Redesigning the layout of the district
- Replace the façade, in order to change the appearance and reduce energy loss
- Improve the U-value of envelope by adding insulation to the walls, roof and basement ceiling and replace the windows
- Use renewable materials
- Solar energy involving for heating and hot water.
- Add a multifunctional compact ventilation device with heat recovery
- Employ a prefabricated construction method
- A well-organized process
- Have communication with residents
- Study and guide of users' behavior after renovation

5.2 Historic residential building

Historic residential building unique in several aspects:
- Because often the building facades are protected cultural heritage, it is not allowed to add exterior insulation. The only alternative is interior insulation, if indeed the room walls do not have murals or ornaments. Interior insulation requires detailing care to minimize thermal bridges, prevent room moisture from getting in or behind the insulation and avoid rot if wooden floor rafters penetrate the bearing wall.
- The walls, window and door openings, floors and ceilings are unlikely to be even

or right angled, so fitting and finishing are more difficult. Several projects built a new wall inside an existing wall or installed new windows inside existing historic windows.
- If the envelope is tightened, mechanical ventilation with heat recovery may be especially important to prevent too high humidity and mold growth on walls which could not be insulated and remain cold.
- Such renovations upon completion are particularly striking, respecting historic, cultural heritage while providing modern comfort. The resulting apartments typically have a high market appeal, so it a modernization is likely an excellent investment.

Accordingly, some similar typical actions taken in the two historical projects are:
- Add interior insulation to the envelope and replace the window to improve the thermal performance as well as to preserve the historical value of the old façade.
- Use renewable energy for heating. In the case in Silz, gas and wood boiler was used for heating as well as solar energy. And in the case "Tschechenring", the heat is supplied by a central wood chips heating system.
- Use ventilation system with heat recovery
- Use renewable materials such as wood.
- Both of these two cases consider renovation in a larger context. In the case in Silz, the renovation project is a part of the town center revitalization. And in the case "Tschechenring", it has a special attention to a high-quality preservation of existing green space enclosed in the center of this residential area.

As to the inside layout of the old building, the renovation strategies are totally different in the two cases. In the case in Silz, the old interior layout is respected and kept. A wood-glass box and a barn are newly built, added to the old house to enlarge the living area, protect the old structure and function as a heat buffer zone. While in the case "Tschechenring", only the old façade is preserved. The old interior layout is torn down and rebuilt.

5.3 Single-Family residential building

Single-family residential buildings are unique in several aspects:
- For one Single-family residential building, compare with one apartment in a multifamily residence, the surface to volume ratio is very high. Accordingly, insulation, eliminating thermal bridges and air tightness are important.
- There is typically one owner or family, so decisions are not made by a committee or corporate headquarters, but by individuals, with very direct interest in the outcome.
- Design, aesthetics and living quality are decisive.

Accordingly, the typical actions taken in the project are:

- Increase the living area by adding a story to the old house.
- Introduce more natural light into the house.
- Improve the U-value of envelope by adding insulation to the walls, roof and basement ceiling and replace the windows.
- Use renewable materials
- Add a solar energy system for heating, and use the ground for heating as well.
- Add a multifunctional compact ventilation device with heat recovery.
- Use appliances with energy efficiency certification.
- Employ a prefabricated construction method.
- Comprehensive preparation work was done before renovation and has a well-organized process.

What is worth to mentioned here is, if compare these five cases, though renovation, both multifamily and single-family residence, the energy demand for heating is around 15 kWh/ m²a, which is a good result. But for historical residence “Tschechenring” and “Zeggele”, the energy demand for heating after renovation are 53 kWh / m²a and 116 kWh/ m² a respectively, which the figures are much bigger than multifamily and single-family residence. The reason is, in the historical building renovation project, historical value has to be considered, and as a result, the renovation activities such as conserve original façade, no insulation added in the external wall etc. was taken, in order word, the low energy demand made concession for historical value conservation.

5.4 What future renovation projects can learn from the cases?

Through the cases study, one thing we can stated here is although the types of residence is different, there are some common activities exist in the renovation. The common grounds are list below, which can be the reference for future renovation.

Firstly, all types of residence renovation focus on insulation renovation, new insulation materials with lower U-Value were installed to replace the former insulation, and installed insulation in the place that without any insulation in the past. In this case, the thermal performance is increase, and meanwhile, energy loss is reduced.

Secondly, multifunction of ventilation system was involved. New ventilation system is usually with air heat recovery function; consequently, ventilation system can supply warm fresh air rather than just transport fresh air from outdoor to indoor. Since the fresh air with comfortable temperature, the energy consumption for heating can be reduced.

Thirdly, renewable energy application, especially, solar energy involving for heating and hot water supplying, some of residence use wood chips to generate energy and even use the ground for heating. Renewable energy application can reduce traditional fossil fuse use, and positive to natural environment protection.

Fourthly, renewable materials, such as wood, are the priority selection as the construction material in the renovation project, due to the consideration of reducing impact to natural environment.

Fifthly, design team has communication with residents, and through communication, the residents' wishes can be known, and the problem of building can be easily found. Consequently, the result of renovation can be more satisfied for residents.

Sixthly, all of the renovation projects in this thesis are use prefabricated construction method, which can not only shorter construction period, but also reduce the negative influence to surrounding environment.

Seventhly, the renovation projects have a well-organized process. The pre-construction work, post-construction work and construction work are all well prepared and organized.

5.5 What new constructed buildings can learn from the cases?

The previous sections in this thesis have led to one clear conclusion that transformation is a much more environmentally efficient way to achieve the same result than are demolition and rebuilding. This raises the questions if and to what extent and in what way this should influence the design of new buildings? It is easier to achieve sustainability if the new-built building designed for further renovation. Before renovation, the life of a new building is similar to an old building had experienced, from designing, construction to usage. Lessons can be learnt in all these stages during the life of a new building.

In the design stage, lessons from these renovation projects suggest that maximum flexibility and adaptability are needed if they are to be successfully reused. For further renovation, transformation must be possible, which implies that the building must have a certain degree of flexibility and that it is worthwhile designing new buildings so they are flexible. This can be facilitated, in part, by using construction that does not depend on load-bearing inner walls, enabling the walls to be removed easily.

In some renovation projects, instead of the originally planned renovation with a conventional thermal insulation system, the thermal envelope was carried out with cellulose, making an easy separation in the future. This can be learnt in new buildings.

Improvements can be achieved by considering future demolition and disassembly of building elements at the designing stage of new buildings. Design for deconstruction or disassembly integrates waste prevention into the design process.

In the construction stage, a good management both on site and off site is essential to achieve the goal of less depletion of energy, natural and human resources, resulting in relatively low costs. Another consideration during construction is to minimize the impact on surroundings, both the nature and the neighborhoods. Good managerial methods are also a point we need to focus, which can increase productive in site, so that, time and cost can be saved to some extent.

In some renovation projects in this thesis, data collection focus both on the adoption of measures and what happens after measures have been installed. This provides knowledge and experience for future projects. It is worthwhile to have this kind of data collection in new buildings in the usage stage. It would be useful to have more annual data on the measures and quality of energy measures taken in new buildings. A database can be set for future projects.

5.6 Possible application in China

Sustainability is a global challenge, and in China, recently, it is a hot topic and paid more attention as well. The current situation is China has a large stock of existing residential buildings which are in poor condition that not satisfying the sustainable needs. At the same time, China has a high rate of constructing new buildings, maybe the highest in the world. In this case, if we can renovate the exiting stock to meet the sustainable standards, and to design and construct the new buildings in a sustainable way, it will contribute a lot to the sustainable issue. Since Europe is more advanced in the field of Sustainable building, some good measures and methods can be learned and taken in the future sustainable renovation projects or sustainable building construction in China. To borrow the sustainable building design ideas from European projects is one of the important motivations for us to do this thesis.

5.7 Conclusion

By presenting recent practice into sustainable renovation of residential buildings, we want to state that living comfort, energy saving and environmental protection are no contradiction, but the best way to increase living comfort, and finally secure the future. The environmental impact of life cycle extension in most cases is less than demolition and new construction. The conclusions of the studies are not conclusive and often related to specific cases. The debate about the environmental impact of interventions in the existing housing stock is not finished yet.

Today, the long necessary lifespan of the existing stock combined with rising energy prices and environmental measures could boost innovations and improvements in the field of sustainable renovation. Hopefully our work can contribute a little to the research in this field focus on sustainable renovation and provide knowledge and experience for similar projects in the future.

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