Passive Houses in Korea

Schuetze Thorsten[1, a], Lee Pil-Ryul[2, b]

[1]Faculty Architecture, Department Urbanism, Chair of Environmental Design,
Technical University Delft, Berlageweg 1, 2628 CR Delft, Netherlands
[2] Department of Culture and Art, Korea National Open University, Seoul-Si, Korea, 110-791
[a] t.schuetze@tudelft.nl, [b] prlee@knou.ac.kr

ABSTRACT

Passive Houses are buildings with a very low service energy demand. The total primary energy demand of certified domestic European Passive Houses may not exceed 120 kWh/m² per year (103,200 kcal/m² per year) for heating and cooling, hot water production and household energy consumption. Furthermore the maximum heating and cooling load is minimized to a value of 10W/m² which allows the passive tempering of such buildings (hence the term passive is used). The average energy demand for the tempering of Passive Houses is approximately only 10 percent of the existing building stock in Germany and Korea. Hence they contribute significantly to the reduction of fossil energy consumption and the related green house gas emissions. In Europe the passive house concept is very successful and many buildings have been already built. Passive Houses can be built in Korea with less constructive effort than in Germany, primary due to the local climate and the specific local architecture. But so far passive houses haven't been built in Korea. In the framework of the described research it is investigated how the Passive House principle can be adapted to Korean residential buildings. This is done by the analysis and evaluation of specific climate conditions, architecture, building practice as well as specific comfort criteria. The monetary and constructive efforts for the construction of Passive Houses in Korea are investigated on the basis of calculations (e.g. heating and cooling energy demand, heat and cool load as well as cost estimation). Passive Houses can be realized in Korea with a comparable low additional effort compared to the common building practice according to the first research findings. The completion of the described research is estimated for summer 2007. On the basis of the research results it is planned to start with the construction of the first residential Passive House in winter 2007/ 2008.

KEYWORDS: architecture, energy efficiency, CO2 emissions, insulation, health, sustainability

1. INTRODUCTION

The building sector in Europe as well as in Korea is responsible for a big part of the total energy consumption and economical activity. In Europe it implies a portion of more than 42% [1] of the total final energy consumption and 12.5 percent of the total economic activity [2]. In global average the building sector is providing in average 5 - 10 percent of national employment and 5 - 15 percent of gross domestic product (GDP). Approximately 80 percent of energy consumption occurs during a building's operational phase (i.e. heating, cooling, and lighting). The service of building, including amongst others heating, cooling, ventilation and lighting, is in average worldwide responsible for approximately up to 40 percent [3] of the total primary energy consumption (including e.g. transportation, industrial and agricultural production as well as the service of infrastructures). The building sector is therefore responsible for a big part of the global green house gas emissions, but it implies also a significant potential for the reduction of energy consumption and related CO2 emissions.

The most significant end user demands for energy use in building are the heating of space and water, air conditioning, lighting, refrigeration and the service of building equipment, such as domestic appliances, computers, lifts and office equipment. Figure 1 illustrates the average breakdown of energy consumption by end uses across the building sectors throughout the European Union (EU). The most significant differences between the energy consumption in domestic and commercial buildings are the additional demand for other uses, cooling and the smaller demand for water heating.[2]

The portion of the specific energy uses are corresponding with the international averages: Most residential energy is consumed for space heating and cooling (60%), followed in order by water heating (18%) and domestic appliances like refrigeration (6%) and cooking (3%); other uses (e.g. ancillaries) account for 13%. However there are substantial variations, even across OECD member countries, especially regarding the portion for heating and air conditioning, which are mainly caused by differences in climate and culture; in Japan, for example, the share for space heating is as low as 28%.

It is remarkable that the use of electricity is growing very strongly in all OECD regions. While the overall final energy consumption in the residential sector grew by 14.6% between 1973 and 1991 and is expected to grow at a lower rate in the future, electricity consumption grew by almost 100% over the same period. [4] Concerning the CO2 emissions this is a much undesired development because the primary energy demand for the production of 1 unit electric energy (e.g. 1 kWh) compared with other forms of end energy is significantly higher. In Germany this factor is 3 (3 kWh of primary energy are needed for the production of 1 kWh of electric energy). Due to the low average portion of renewable energy at the global energy production, the consumption of electric energy is related to very high greenhouse gas emissions. The portion of nuclear energy is worldwide less than 7% of the total energy production and is expected to decline in the future [5]. It can therefore not contribute significantly to a CO2 neutral energy production.

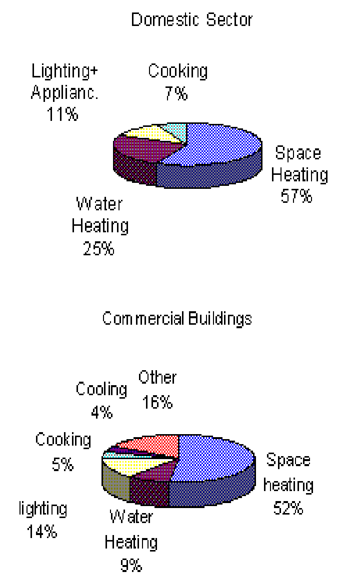

Figure 1. Breakdown of Energy Consumption by end use in the Domestic Sector (above) and for Commercial Buildings (below) [2]

If we want to stabilize the concentration of CO2 in the atmosphere to 475 parts per million (ppm), we have to reduce the global CO2 emissions in future significantly. The necessary measures would cost the mankind approx. 3% of the total GDP. By exceeding the above mentioned CO2 concentration in the atmosphere we would face significant changes in the world climate with unpredictable effects on the global ecosystem as well as the global economy and the human living conditions.[6] In opposed to these perspectives, it is expected that the world fossil energy consumption will rise by 50% compared to the amount of 1990 until the year 2030, with a related rise in CO2 emissions of 56%.[5] In that event, it is expected that fossil fuels will remain the primary sources of energy and will meet 90% of the increase in demand to 2030.[7]

By the extended use of nuclear and renewable energy, renewable fuels, and energy efficiency, the expected rise of CO2 emissions can presumably only be limited from 56% (see above) to 32%. A stabilization of the greenhouse gas emissions can only be achieved by the extended use of renewable energies, the construction of new buildings according the passive house standard and the maximum rational implementation of measures to reduce the energy efficiency of existing buildings. By the utilization of passive house technology in the natural cycle of component replacement and building renovation the necessary measures can be realized in an economical feasible way, while reducing the energy demand for the heating and cooling of buildings significantly, by approx. 90%. If only the technology for so called low energy (see also figure 2) houses would be used (whose requirements are comparable with the present building code in Germany), a stabilization of the CO2 emissions can presumably not be achieved.[8]

Due to the described situation it is not only important to reduce the service energy demand of buildings for heating, cooling and the production of warm water to a minimum, but also to reduce the electric energy consumption in buildings for domestic and commercial use (e.g. building service, household appliances, lighting and technical appliances like computers).

2. RESULTS AND DISCUSSION

2.1 Definition of Passive Houses

Passive Houses are buildings with a very low service energy demand. The total primary energy demand of certified domestic Passive Houses (according to Feist, W., Passive House Institute in Darmstadt) may not exceed 120 kWh/m² per year (103,200 kcal/m² per year) for heating and cooling, hot water production as well as household energy consumption. Furthermore the maximum heating and cooling load is minimized to a value of 10W/m² which allows the passive tempering of such buildings (hence the term passive is used). For middle European Passive House constructions (e.g. in Germany) an average annual heating demand of less than 15 kWh/m² per year is required (see also figure 2). The annual average heating demand is a climate dependent factor. For north European countries (above latitude of 60º) the annual heating requirement hence maybe exceeded to a limit of about 30 kWh/m² per year.

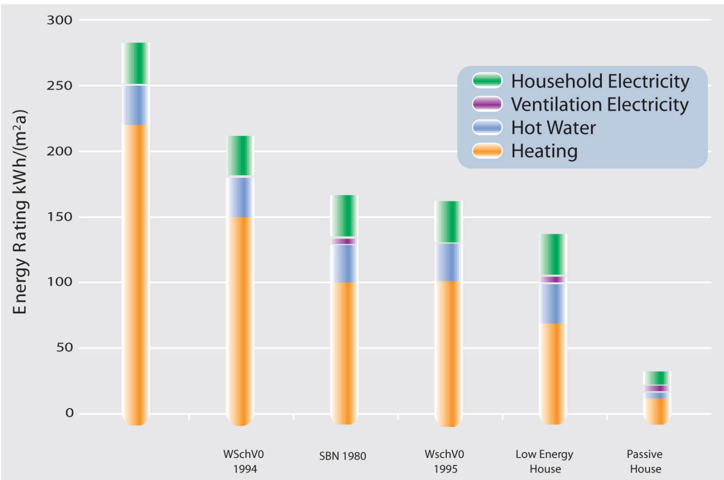

Figure 2. Comparison of different energy ratings of homes. The average rating of German building stock is displayed far left and for Passive Houses far right. (WSchVO = German Heat Protection Regulation. SBN = Swedish Construction Standard). [9]

The average energy demand for the tempering of Passive Houses is approximately only 10 percent of the existing building stock in Germany and Korea. The total energy consumption of a Passive House is less than the average energy demand in European homes for electricity and hot water alone. Hence Passive Houses can contribute significantly to the reduction of fossil energy consumption and the related green house gas emissions.

The minimization of the heating and cooling energy demand is achieved by a good insulation of the building skin, the appropriate use of internal heat sources (like persons, lighting and domestic appliances) and solar radiation as well as the controlled energy efficient ventilation with a high heat recovery rate. Furthermore an appropriate surface to volume ratio of the specific building, the avoidance of thermal bridges and the reduction of heat losses by uncontrolled ventilation are crucial for meeting the required low energy demand. Uncontrolled ventilation has to be avoided by the realization of an airtight building skin. During the construction the air tightness of the building has to be proved, by a so called “blower door test” which allows the estimation of the proportional leakage surface. The energy efficient controlled ventilation with heat recovery can be also defined as comfort ventilation. Due to the fine-filtering of the outdoor air before entering the building and a defined air exchange rate, a healthy indoor air with low contamination (emitting from furniture, building materials and components) can be guaranteed in Passive Houses. The well insulated airtight building skin guarantees also very comfortable and stable indoor temperatures which are basic for human well-being.

2.2 Construction of common buildings in Korea

In the Republic of Korea according to the present building practice most residential buildings are massive constructions made out of reinforced concrete. This is true for the structural as well as the room building elements (walls and slabs) which are connected frictional. The buildings are constructed on site and no prefabricated concrete components are used. The insulation (in general expanded polystyrene) with a required minimum thickness of 10 cm is fixed to the inner surface of the outside walls and ceilings (cellar and roof). The insulation is generally covered with gypsum boards. They form the final indoor layer of the constructions and are generally covered with wallpaper. It is remarkable that the requirement for the minimum insulation thickness was only 5 cm until 2004. The inside insulation of the building envelope includes a lot disadvantages. Among others it limits the durability of the building structure because it is exposed to significant thermal fluctuations. These are causing cracks in the concrete surface and are leading to further destructions, e.g. by penetrating and freezing water. Indoor insulation reduces the thermal storage capacity of the indoors which are important for keeping a stable indoor temperature and implies thermal bridges, e.g. between the joints of outside walls with indoor walls and slabs. High-rise apartment buildings with a compact building shape have a portion more than 80% of the domestic building stock. The staircases consist in general of a stairway and an elevator and are integrated in the building structure. The present building practice in Korea includes the staircase as part of the building structure. It is either full or partly integrated in the building and the components are connected frictional with each other.

2.3 Comfort Criteria for Passive Houses in Korea

The comfort temperature in Korean apartments is approx. 24°C due to own experiences and research findings of the authors (interviews with individuals and experts). Due to the fact that older persons require even higher comfort temperatures, it is expected that the heating systems for Passive Houses should allow heating the individual apartments up to a temperature of 25 – 26°C. Hereby the humidity of the air is not taken into account. The air during the winter in Korea is generally quite dry. Hence also the indoor climate generally is very dry. By humidifying the indoor air the comfort temperature could be lowered and the indoor climate could be optimized. According to the Korean culture only apartments equipped with a floor-heating system (ondol) are accepted by the users. Therefore the application of other heat distribution systems is not further investigated in the framework of this research. Even though the cooling energy demand can be reduced significantly in Passive Houses compared with other buildings, it is expected that the application of dehumidification and cooling systems of the indoor air are crucial to guarantee a comfortable indoor climate throughout the year.

2.4 Design and energy demand of a selected residential building in Korea

The residential building selected for the research was designed by the Nodd Design Group for the Korea District Heating Corporation. The building site is located 40 km south of Seoul in Jungwon-Gu Seongnam-Dong 3292, Seongnam City, and is surrounded by high buildings, also on the southern side. Hence the potential use of solar radiation for passive heating is very limited but exemplary for the urban structure in Korea. The building purpose is residential, for senior citizens. The building can be divided in three parts (see also figure 3), part 1 and 2 are for residential purpose while part 3 consists of the staircase, elevator and corridor to access the apartments. Originally all three parts are integrated in one spatial and thermal structure. While part 1 and 2 are designed with 5 storeys, part 3 only has two storeys. According to the common building practice and building code, the envelope has to be minimum insulated as described subsequently. The standard windows have an U-value of 2.8 W/m²K. Walls, ceiling and base-plate have to be insulated with 10 cm insulation material. The lambda value of standard polystyrene for insulation is 0.04 W/(mK). For the insulation of entrance doors and the ventilation type of the building no special requirements are made in the regulations. The heating energy demand of the building has been calculated on the basis of the described physical values of the specific building parts as well as their size and orientation and for a comfort temperature of 20°C. For the whole building, consisting of all three building parts, it is approx. 190 kWh/m²a. By dividing the building in three structural and thermal separated parts and only insulating the parts 1 and 2, the heating energy demand can be reduced to 116 kWh/m²a for part 1, respective to 128 kWh/m²a for part 3. The total primary energy consumption including warm water production and electricity consumption would be 239 kWh/m²a for part 1, respective 249 kWh/m²a for part 3. It is remarkable that the total energy savings of the separated designed buildings are even higher compared with the single building because the heated floor area is reduced by the corridor area.

2.5 Design and energy demand of a selected residential Passive House building in Korea

The construction of staircases for passive houses can be realized principally in two different ways: The construction of staircase and corridor inside the thermal insulated building skin (the staircase has indoor temperature of the apartments) or the construction of staircase and corridor outside of the thermal insulated building skin (the staircase and the elevator will have outside temperature). If the staircase is not part of the insulated building it has to be thermally separated from the insulated building part. The easiest way is the construction of staircase and corridor as a self sustaining building structure which is not structural connected to the insulated building but allows the access of people by physical connections. As described in chapter 2.4 it is possible to reduce the heating energy demand of the building per square meter by the separation of the building in three parts. Therefore also the Passive House design, based on the above described building will be separated in three parts. The buildings 1 and 3 will be structural and thermal separated from the building 2, staircase (including elevator, corridor and void). The buildings will be insulated from outside, primarily to avoid thermal bridges but also to guarantee a high thermal storage capacity inside the buildings and to protect the load bearing structure from building damages (see chapter 2.2).

The described Passive House building was designed as described subsequently, based on the common building practice in Korea as well as to the locally available materials, components and technical appliances. The chosen windows and entrance doors have an U-value of 1.3 W/m²K. The outside walls are insulated with a thermal insulation composite system, with 20 cm expanded polystyrene (lambda-value = 0.034 W/(mK)). The roofs and base-plates are insulated with extruded polystyrene (lambda-value = 0.031 W/(mK)). The thickness of the roofs and base-plates is 30 cm for building 1 and 35 cm for building 3. Even though a higher insulation thickness is used for building 3, the heating and primary energy demand is higher than that of building 1. This is primarily caused by the inferior surface volume ratio but also by the shading through the buildings 1 and 2 during the heating period. For the ventilation of the building a mechanical ventilation system with a heat recovery rate of 75% for building 1, respective 85% for building 2 is used.

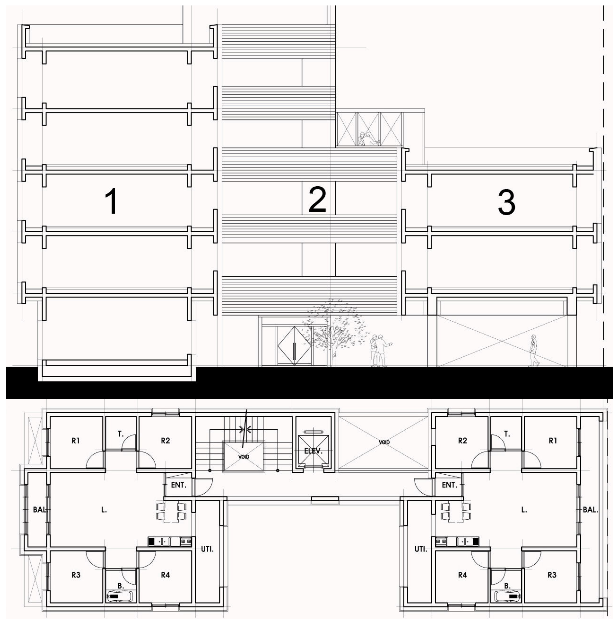

Figure 3. Exemplary floor plan (bottom) and section (top) of the selected residential building in Seoul; the building parts 1 and 3 will be insulated according to passive house standard, while part 1 will be not heated and constructed separately.

The heating energy demand of the building has been calculated on the basis of the described physical values of the specific building parts as well as their size and orientation and for a indoor temperature of 20°C. The heating energy demand for building 1 is 16 kWh/ m²a while it is 21 kWh/ m²a for building 2. The total primary energy consumption would be 140 kW/m²a for part 1, respective 142 kW/m²a for part 3. The described buildings can be identified as Passive Houses even though the primary energy demand exceeds the limit for European certification. This is true because the primary energy was calculated according to German standard and will be adapted to the Korean situation in the framework of the ongoing research.

Additional measures to lower the heating and primary energy demand of the described buildings include a thicker insulation of the outside walls with 25 or even 30 cm, the installation of ventilation systems with a more efficient heat recovery rate of up to 95%, the optimization of the surface volume ratio of building 3 and the optimized use of the solar radiation for passive heating. Furthermore the utilization of renewable energy could contribute significantly to the reduction of the primary energy demand, which is not taken into account yet.

3. CONCLUSIONS

This paper examined the planning and construction of Passive Houses in Korea on the basis of the design and planning for a new residential building. According to the findings Passive Houses are realizable in Korea already at present with local available components and comparable low constructive and monetary effort. Their realization can contribute not only to a sustainable energy management and independency from foreign energy sources but also to a strong national economy due to value enhancement in the field of construction materials, components, technical appliances and labour. Furthermore the application of the Passive House concept for both new and old buildings is crucial to limit the destructive effects of global warming by cutting CO2 emissions significantly. Due to the difficult basic conditions of the described building, Passive Houses based on Korean Apartments, could be realized with less constructive effort.

Only immediate and strong efforts to reduce greenhouse gas emissions by energy efficiency and the use of renewable energy can lead to a stabilization of the green house gas emissions and limit the damages for the global economy. The application of Passive House Technology in the framework of upcoming renovation measures of existing buildings and the construction of all new buildings according to the Passive House standard can contribute significantly to the reduction of greenhouse gas emissions without negative impact on the GDP.

REFERENCES

Global Insight, SA (Paris, France), IWW (Karlsruhe, Germany) for European Communities, 2006. The Annual Energy and Transport Review for 2004, December 2005.

European Commission, Directorate General for Energy and Transport, Information and Communication, 2001. Improving the Energy Efficiency of Buildings. Short presentation of the Commission’s proposal for a Directive.

United Nation Environment Programme, Division of Technology, Industry and Economics, Sustainable Consumption and Production Branch, 2007. Buildings and Climate Change, Status, Challenges and Opportunities.

European Commission, Directorate General for Energy and Transport, Atlas Project, 1997. Building Sector Characteristics & Energy Figures.

International Energy Agency (2006). World Energy Outlook. Available on internet at: www.iea.org

Intergovernmental Panel on Climate Change, IPCC, UNEP, WMO, 2007. Climate Change 2007. Available on internet at: http://www.ipcc.ch/

International Energy Agency (2006). 30 Key Energy Trends in the IEA & Worldwide. Available on internet at: www.iea.org

Feist, W., 2007. Let’s Get Energy Efficient. Conference Proceedings International Conference on Passive Houses 2007, pp. 37-44.

Passive House Institute, 2006. Darmstadt, Germany. In [3]