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Degree of Master of Science

ENERGY POVERTY AND CLIMATE CHANGE MITIGATION THROUGH THE PRISM OF LOW-ENERGY HOUSING SOLUTIONS

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AUTHOR'S DECLARATION

No portion of the work referred in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or institute of learning.

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ABSTRACT OF THESIS submitted by:
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Energy efficiency measures in the buildings sector, specifically the introduction of energy efficient buildings, can be an attractive way to reduce the future energy demand and decrease the GHG emissions. This paper explores the possible scenarios of energy poverty alleviation in developing countries, stricken by both energy poverty and climate change problems, through energy efficient, low-cost housing solutions, and in that way contributes to further systematic study of the energy poverty issue in the context of developing countries.

Based on the Mongolian case study analysis, the research has demonstrated that proper improvements in housing and wide application of low-energy, low-cost solutions not only help to reduce the GHG emissions and decrease the air pollution level, but also support the energy poverty alleviation, decreasing twice the amount of energy consumed, and similarly the energy/fuel costs in the Mongolian context.

Within the objectives of the research a cost benefit analysis has been carried out with an aim to determine the economic viability of high performance buildings in the Mongolian construction sector. According to the findings of the cost benefit analysis the overall costs and additional investments required for the construction of energy efficient houses have been twice as much as traditional houses. However, it has also been demonstrated that given the decreased fuel consumption, increased energy security, enhanced living conditions and positive environmental impacts the investments in low-energy housing options can become quite attractive in the longer run. It has been recommended that if energy saving buildings are to be promoted at larger scale, favorable socio-economic conditions should be created and energy efficiency financing and subsidy programmes should be promoted to encourage the purchase and construction of such houses in ger districts of Ulaanbaatar, where most often the vulnerable parts of the population reside.

Keywords: energy poverty, climate change mitigation, energy efficient houses in developing countries

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CHAPTER 1: *Introduction*

1.1.Background

In the face of climate change countries, both developed and developing, face enormous challenges in terms of reaching the lowest possible emissions by 2050 to prevent climate change cataclysms while improving the life standards of billions of people living in poverty and negligence throughout the world. There is a potential of substantial decrease in GHG emissions through the transformation of the buildings sector (IPCC 2007), especially the informal one where most often the poorest part of the population resides, towards more energy-efficient building technologies and services, sustainable private house insulation and energy efficiency financing mechanisms. Owing to recent advances in the buildings sector, specifically in design, know-how and technology it is now possible to decrease the building energy use significantly. High performance low energy buildings have been constructed in many parts of the world proving that energy efficiency is achievable in the buildings sector, and that buildings can become zero-net-energy users and zero-greenhouse gas emitters.

Energy efficiency improvements in the buildings sector go hand in hand with eradication of energy poverty, a problem that is common in many parts of the world. The lack of access to modern energy carriers as a result of inadequate basic infrastructure and low household income is often referred to as "energy poverty". Today nearly 1.4 billion people still live without access to electricity (IEA 2010), most of them living in developing or least developed countries in slums regions without any durable housing and infrastructure services. Lack of electricity affects their livelihood, impeding the development in the sectors of health, education, gender equality and agriculture, among other spheres.

According to Urge-Vorsatz and Tirado Herrero (2012), while low-income level and high energy prices are important drivers, the tendency of lower-income households to live in poorly insulated older buildings is a key factor in energy poverty. Low income households are the ones who are severely affected by fuel/energy poverty, which has a series of negative implications such as inadequate thermal comfort, increased mortality, a high risk of respiratory diseases and other detrimental consequences.

Highly energy efficient buildings can lead to a more energy sustainable future, being the most appropriate solution to both problems of energy poverty and increasing CO_2 emissions that contribute enormously to climate change. In addition to non quantifiable benefits such as improved health and indoor air quality, energy efficient buildings can offer benefits in monetary terms by reducing the amount of CO_2 emissions from the buildings sector and decreasing the operating cost of buildings at least twice (GEA 2012). IPCC (2007) calculations suggest that approximately 29% of the projected baseline CO2 emissions can be reduced by 2020 by application of cost effective energy efficient measures in the residential and commercial buildings.

Other benefits include, but are not limited to improved social welfare, energy security and sovereignty, new jobs and business opportunities, improved values for real estate, increased comfort, well-being, which all in turn lead to alleviation of energy poverty. Experience shows that improving a building's resistance to the elements through weatherization and building insulation and other energy efficiency improvements (e.g. water heater and piping insulation; replacing old and inefficient appliances, lighting and equipment) are effective in reducing fuel poverty. Investments in energy efficiency permanently lower energy use in low income households while reducing government and energy provider outlays on fuel assistance and social tariffs (GEA 2012). Thousands of households could be taken out of energy poverty with a combination of energy efficiency and renewable energy investments (insulation, boiler improvement, solar water heating).

However, cost effective energy efficient opportunities in buildings are not realized completely due to a wide range of barriers. Barriers are different, and vary enormously by country, climatic conditions, building type, as well as stakeholders involved. Mongolia, a country stricken with harsh climate and natural disasters, often aggravated by climate change, and where the energy poverty problem is most apparent in ger[1] areas of the capital city Ulaanbaatar among low income households, has been taken as an example to demonstrate the possibility of tackling both the energy poverty and CO_2 emissions problems through energy efficient housing solutions.

Even though energy poverty alleviation and climate change mitigation are closely connected issues, these have often been taken separately as distinctly disconnected fields of research and policy analysis. No sufficient research has been done to understand and analyze the energy poverty issue, particularly in the former Soviet Union countries and in Central and Eastern Europe, where the problem is considered to be widespread and requires urgent solutions (Buzar 2007, Boardman 2010). Even though many governments of developed countries such as the United Kingdom, the United States and New Zealand have already started tackling the problem through specific strategies and policies (Friel 2007) such as income supplementing fuel payments, reduced tariffs, investments in energy efficient appliances and housing solutions, it is still far from being a high priority issue for many developing countries. Only by addressing the two problems – reductions in GHG emissions and energy poverty eradication – in a more comprehensive way, and by joining the two policy goals would it be possible to tackle them properly.

Therefore acknowledging this research gap in this area the researcher will explore the possible scenarios of energy poverty alleviation in developing countries on the case of Mongolia, stricken by both energy poverty and climate change problems, through energy

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[1] Mongolian traditional dwelling

efficient, low-cost housing solutions, and in that way contribute to further systematic study of the energy poverty issue in the context of developing countries. The scale of the problem is enormous, and only by tackling the energy poverty jointly with such issues as climate change, poverty reduction and energy security, would it be possible to gain effective results in the longer run (GEA 2012).

A cost benefit analysis has been carried out with an aim to determine the economic viability of high performance buildings in the Mongolian construction sector. The overall costs and additional investments required for the construction of energy efficient houses in the Mongolian context have been analyzed in an attempt to determine whether low-energy housing options would be economically and environmentally attractive in the longer term as alternatives to traditional types of buildings.

1.2.The aims and objectives

The researcher's **main aim** is to look at the possibilities of integration of two different policy goals – poverty alleviation and climate change mitigation – through exploring ways of implementing wide scale energy efficiency improvements, most importantly in the buildings sector in developing countries that are severely stricken by the energy poverty problem.

Even though energy/fuel poverty alleviation and climate change mitigation have not been taken together as closely connected fields of research and policy analysis, alleviating this type of poverty through low energy housing technologies have strong synergies with climate change mitigation agendas for two reasons: (1) the buildings sector has the largest and lowest-cost climate change mitigation potential according to scientific estimates (IPCC 2007); (2) energy/fuel poverty can be eradicated through combined socio-economic and environmental efforts such as income supplementing fuel payments, improved quality of houses, and more efficient appliances (IEA 2010).

Therefore throughout the research project, the researcher explores the less studied relation between energy poverty alleviation and climate change mitigation measures, trying to fill in the research gap in this area, especially in developing countries. The research addresses a specific research question, which asks whether proper improvements in housing and wide application of low-energy, low-cost solutions will enable to reduce energy poverty and increase access to durable housing in developing countries that are prone to serious environmental problems, most often aggravated by climate change.

Within the main aim, the researcher will pursue **the following objectives**:

- Research best practices on low-cost low-energy buildings and assess their applicability and affordability to developing countries in the cold/temperate climate zones, especially Mongolia;
- Try to establish which prototypes of buildings could serve as low-energy, low-cost housing adequate for countries in cold/temperate climate zones like Mongolia;
- Conduct a cost-benefit analysis for the Mongolian case on whether the existing internationally known low-cost, low-energy options would be economically and environmentally attractive in the longer term as alternatives; find out how much extra funding would be necessary to subsidize the missing capital, save residents heating expenditures/costs, and make energy efficient, low-cost houses more affordable for low income households.

1.3.Methods and Data collection

For the thesis goal mostly qualitative methods of data collection and content analysis were applied for the processing of data and information gathered throughout the research, as well as making a variety of assessments based on the data accumulated. For data collection purposes the researcher carried out an extensive analysis of available documents and materials related to the research area through the methods of primary and secondary data collection.

Aiming to gain insight into the issue and determine what was known already and what new data were required, a secondary data research was done in the preliminary stages of research. General statistical data related to the buildings and energy sector of Mongolia, building types and technical characteristics, energy consumption patterns of households were obtained from a variety of sources. The most commonly used sources are the electronic and non electronic database including official reports and publications of the Government ministries such as of the Ministry of Mineral Resources and Energy, the Ministry of Roads, Transportation, Construction and Urban Development, related agencies and departments, namely the Energy Authority of Mongolia, the Energy Regulatory Commission and Ulaanbaatar Electricity Distribution Network Ltd. General information related to the physical size of houses of the residence, the available energy infrastructure, the design characteristics of buildings and the income level of households in ger districts of Ulaanbaatar were obtained through official publications in forms of project and programme reports of such international organizations as the United Nations Development Programme (UNDP), the Asian Development Bank (ADB) and the World Bank (WB) currently operating in Mongolia. The online database of the National Statistical Office (NSO) of Mongolia was useful in terms of obtaining required statistical data related to population and housing projections in Ulaanbaatar.

In order to gain a better understanding about the thermal performance of energy efficient, low-energy houses, it is important to analyze data related to thermal conductivity, thermal transmittance and thermal resistance of building components and materials. The online database of the Passive House Institute, the publications of other low energy building research centers and technical publications by L.D Danny Harvey, John Straube proved to be extremely useful, supplying necessary technical data.

The primary data was collected whenever possible through open ended face-to-face and online interviews with potential informants. According to Mack et al. (2005), one advantage of interviews in qualitative research is that the use of open ended questions gives participants the opportunity to reveal more about their attitudes and behavior and express themselves in a detailed way, in their own words rather than giving generalizations and being limited by fixed responses. Interviews held during the research helped to explore the gaps found in the existing literature, and in that way they proved to be quite important in depth understanding of the research problem. Interviews were carried out in an unstructured format to give greater flexibility to the interviewee, and to shape the interview structure according to the interviewee's responses. In that way it provided more opportunities to understand the complexity of the issue without any prior categorization. The list of the interviewees is attached hereto in Annex 1: Personal communications.

Face-to-face interviews targeted at construction sector specialists, including engineers and passive house specialists were conducted during a field trip organized during May 2-6th, 2012. The fieldwork was carried out in Hannover, Germany at the 16th International Passive House Conference, where the first class speakers in the passive housing field reported about the latest developments relating to energy efficient construction technologies. The focus of the conference was on the implementation and construction of low-energy passive houses in different climate zones, which made the conference much more interesting in terms of understanding and learning about the existing best practices on low-cost low-energy houses and assessing their applicability to developing countries in the cold/temperate climate zones.

Online skype interviews were carried out with senior officials of the Ministry of Roads, Transportation, Construction and Urban Development (MRTCUD) of Mongolia and some specialists at UNDP Mongolia. The main aim of interviews was to get the most up to date information regarding the policy developments in the energy and construction fields of Mongolia, identify the key challenges and barriers towards introducing energy efficient, low energy housing options, and finally to get to know their opinion about how to make existing internationally known low-energy housing options more economically affordable and environmentally attractive in the longer term for cold climate developing countries as Mongolia.

1.4. Limitations of the research

Through communication and interviews with international passive house construction experts and manufacturers, the researcher could acquire a good background knowledge regarding the low energy, passive housing technologies, and their adaptability in different climate zones. However, due to the limited scope of studies done in developing countries with cold climate and the comparatively high cost of passive houses, the proliferation process of highly energy efficient passive house technologies in developing countries is still slow. And although being specialists in their respective fields, mostly due to lack of appropriate information and data related to cold climate countries such as Mongolia, most of the interviewees could not give specific recommendations regarding the exact suitable options of low energy houses in Mongolia. Besides, most of the up-to-date policy and technological studies related to energy efficient housing technologies have been done in Europe and the US, and only a limited number of similar research is done in developing or transition countries.

Another limitation for research was the limited availability of data concerning the technical elements, as well as the actual cost of construction of energy efficient houses in Mongolia. The lack of sufficient time for research and the limited possibilities of having frequent field trips in Mongolia meant the lack of access to certain people and necessary information that otherwise could have been obtained on site from primary sources.

1.5. Organization of the research work

The thesis is split into 4 major sections and several subsections which are described in the Table of Contents. The Introduction part provides an overview of the research done and identifies the main aims and objectives of the research. The subsection of Methods and Data collection discusses the main research methods used. Also a detailed information regarding the data collection and data sources is included.

Chapter 2 provides a comprehensive review on the academic and policy literatures related to the thesis topic. The 1st subsection gives an overall definition of the energy/fuel poverty issue in its socio-economic and environmental context, discusses its interpretation in different country contexts and analyses the current situation and the severity of the problem in developing countries. The problem of growing energy consumption in the buildings sector and increasing CO_2 emissions that contribute enormously to climate change both on regional and global scales are explored in the 2nd subsection of the chapter. The last section gives an overall definition of energy efficient buildings and determines main principles and strategies applied in energy efficient houses based on the study of existing internationally known energy efficient housing options, their main advantages and drawbacks. A short summary about the cost of energy efficient buildings is also given at the end of the section, demonstrating the cost effectiveness and affordability of such buildings.

Chapter 3 describes the problem of energy poverty and air pollution in Ulaanbaatar, Mongolia through the current situation analysis and states the necessity and urgency of addressing the problems through low-cost, low-energy housing solutions. A cost-benefit analysis is conducted to determine whether the existing low-energy housing options would be economically and environmentally attractive for the Mongolian ger area residents, to find out how much extra funding and investment would be required to make energy efficient, low-cost houses more affordable for low income households. Lastly the research results are compiled and the implications of the results are examined in Chapter 4.

CHAPTER 2: *An overview of problems stated: energy poverty and climate change mitigation in the buildings sector through the prism of energy efficient houses*

2.1. Energy/Fuel poverty as a complex socio-economic and environmental issue (phenomenon)

This section gives an overall definition of the energy/fuel poverty issue in its socio-economic and environmental context, discusses its interpretation in different country contexts and analyses the current situation and the severity of the problem in developing countries.

2.1.1 What is energy/fuel poverty?

The problem of energy/fuel poverty is determined and interpreted differently depending on the country context and the way of addressing the issue. The International Energy Agency (IEA 2010) considers the term "fuel poverty" to be distinct from "energy poverty". In the context of developed countries there is a common definition that any household spending more than 10% of its annual income on energy is in fuel poverty (OECD/IEA 2011). The term "energy poverty" most commonly refers to the problem faced by developing countries and is determined as a lack of access to electricity as a result of inadequate basic infrastructure and lack of access to quality energy carriers (Urge-Vorsatz and Tirado Herrero 2012). In general, a household is in energy/fuel poverty when the household's basic domestic needs - particularly the adequate thermal comfort - are not satisfied due to its inability to afford a sufficient amount of energy required for that purpose or when the household spends a disproportionate share of its income on energy needs. For the purposes of this research, as it is mostly related to developing countries, the term "*energy poverty*" will be used more often as a broader concept including in itself all sorts of energy-related deprivation whether it be due to lack of access to modern energy carriers or the reliance on the traditional use of biomass due to low income of households.

Regardless of the definition, the incidence of energy poverty is growing around the globe (OECD/IEA 2011). Today, approximately 1.4 billion people, over 20% of the global population, lack access to electricity, and 2.7 billion people rely on the traditional use of biomass for cooking (IEA 2010) (see Table 1). According to the IEA projections the problem will deepen in the longer term: by 2030 1.2 billion people will still lack access to electricity, while the number of people relying on biomass will rise to 2.8 billion, 82% of them living in rural areas. Most of these people will be living in Sub-Saharan Africa, India and other developing Asian countries (excluding China).

Table 1: Number of people without access to electricity and relying on the traditional use of biomass by regions and countries, 2009 (in millions)

Regions and countries	**Number of people lacking access to electricity**	**Number of people relying on the traditional use of biomass for cooking**
Africa	587	657
Sub-Saharan Africa	585	653
Developing Asia	799	1937
China	8	423
India	404	855
Other Asia	387	659
Latin America	31	85
Developing countries*	1438	2679
World**	1441	2679

* Includes Middle East countries. ** Includes OECD and transition economies
Source: IEA World Energy Outlook 2010

While the problem of energy poverty can be conditioned by the lack of required infrastructure, the fuel poverty issue is affected by three different factors such as household income, energy prices and housing quality. Later on, in Chapter 3 it will be demonstrated that the both problems of energy and fuel poverty can be observed in the case of Mongolia taken as an example for this research. According to the 2010 IEA report, households stricken by energy poverty lack adequate financial resources to pay for energy bills as most of them tend to be low and middle income households without substantial sources of income. This is especially true for developing countries where the households in energy poverty are the most vulnerable groups of the population, residing in informal settlements where the unemployment rates are high and income levels are low.

Measures intended to provide sufficient energy access such as subsidized energy prices for the poor do not necessarily lead to positive consequences. Most often they provide wrong economic incentives for households, which do not encourage energy efficiency in equipment or houses, resulting in highly inefficient infrastructure and poorly insulated building stocks. Many former Soviet Union countries, as well as formerly communist countries of Eastern and Central Europe have found themselves in energy poverty when after communism subsidized energy prices got removed and instead market based energy prices were introduced (GEA 2012).

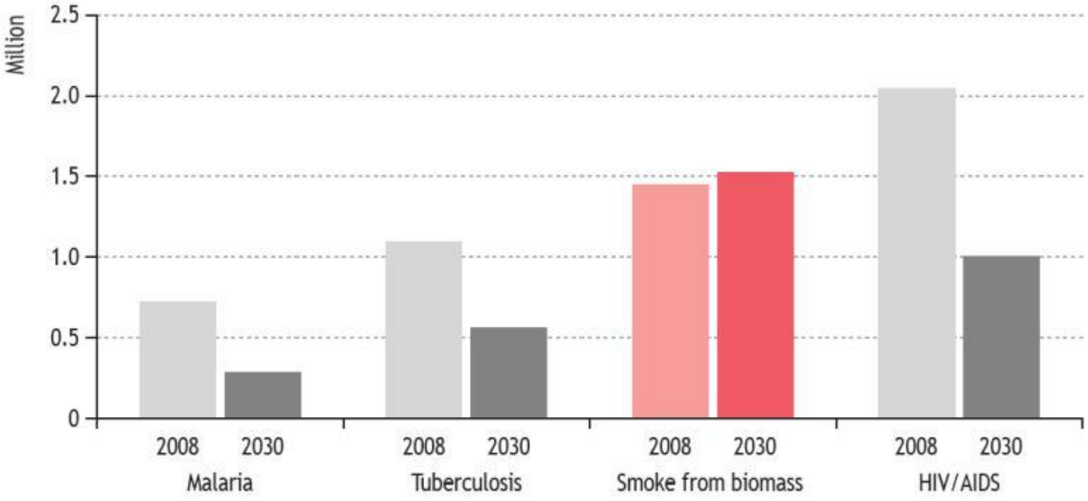
As pointed out by Urge-Vorsatz and Tirado Herrero (2012), while low-income level and high energy prices are important drivers, the tendency of lower-income households to live in poorly insulated older buildings is a key factor in energy poverty. Positive results are achievable through improving a building’s resistance to the elements through weatherization and building insulation and other energy efficiency improvements (e.g. water heater and piping insulation; replacing old and inefficient appliances, lighting and equipment).

2.1.2 Socio-economic and environmental implications of energy poverty

Low income households are the ones which are severely affected by energy poverty, which has a series of negative implications such as inadequate thermal comfort, poor indoor quality, increased morbidity and mortality, poor educational outcomes and a high risk of respiratory diseases among other things.

The use of traditional biomass for cooking well illustrates the negative consequences of the energy poverty problem for people’s health, economic development and the environment (IEA 2006). Traditional biomass in its solid unprocessed form such as firewood, agricultural waste and dung accounts for about 10% of global total primary energy use (IEA 2008). The most commonly used devices for cooking with biomass are three stone fires, traditional mud, cement or brick stoves without efficiently operating chimneys or hoods. Air pollutants emitted by stoves are extremely toxic, and as a consequence the indoor air pollution level is very high. According to World Health Organization (IEA 2010) estimates indoor air pollution due to the use of biomass combustion in inefficient stoves results in more than 1.45 million premature deaths per year (see Figure 1). This number is expected to grow reaching 1.5 million (over 4000 per day) in 2030, greater than estimates for premature deaths from malaria, tuberculosis or HIV/AIDS (IEA 2010). It is also demonstrated that inadequate indoor temperature associated with poor housing quality can be the cause for excess winter mortality, and high incidence of cardiovascular and respiratory diseases among the elderly and children (Healy 2004).

Figure 1: Premature annual deaths from household air pollution and other diseases globally /2008; 2030/



Source: IEA World Energy Outlook 2010

Young children and women in developing countries who spend many hours indoors inhaling the toxic substances from cook stoves are most at risk (IEA 2010). In developing countries heavily reliant on traditional biomass for cooking and heating, women and children are generally responsible for fuel collection. Due to this laborious and time consuming task, less time is left for education or job, and women and children can suffer physical damage or even be subject to human assault.

Inefficient biomass combustion practices also have serious implications for the environment such as land degradation, local and regional air pollution, deforestation, if only to name few. In places where households rely a lot on wood for cooking and heating purposes, the level of deforestation and related land degradation and soil erosion is high in the surrounding area (IEA 2010). The soot or black carbon that is emitted as a result of incomplete combustion in household stoves contributes a lot to the global and regional warming. As reported in the World Energy Outlook (2010), this warming issue appears to be especially evident in the Asia's Tibetan Plateau, where most of the population is highly reliant on fuel wood, and where summer melt-water from glaciers provides drinking water to more than one billion people.

It is hard to quantify exactly the reduction in GHG emissions due to introduction of advanced and cleaner biomass technologies as there are a variety of factors involved, including the type of fuels and stoves, and whether new plantings are done and that a sustainable forestry management programme is in place or not. But it is widely acknowledged that health risks and environmental problems related to biomass combustion can be significantly reduced by introducing chimneys, more efficient stoves, or by increasing access to clean modern fuels such as biogas, liquefied petroleum gas, and electricity (GEA 2012). Increasing the house ventilation through larger space, open windows and doors can also contribute to reducing indoor air pollution. Taken altogether and in accordance with each other all these measures can result not only in health and social benefits, but also bring in wider economic and environmental benefits that can be demonstrated in the long run.

2.2. Unsustainable energy consumption in the buildings sector as a driving force of climate change

As solutions to the problem of energy poverty go hand in hand with sustainable energy goals in buildings, this section explores the problem of growing energy consumption in the buildings sector and increasing CO_2 *emissions that contribute enormously to climate change both on regional and global scales.*

2.2.1 Increasing energy consumption in the buildings sector

At the global level almost 60% of the world's electricity is consumed in the buildings sector, including both residential and commercial buildings (IEA 2008a). Biomass is considered as the most important energy carrier for energy use in buildings, followed by electricity, natural gas, and petroleum products.

At the national level, buildings consume 20 – 40% of an individual country's total final energy use (see Table 2), with the world average being 31%. There is a significant difference between developed and developing regions of the world in terms of per capita final energy use. In developed countries with cold/temperate climate such as the United States and Canada, the per capita final energy use in buildings is 5-10 times higher than in developing regions with a warm climate such as Africa or Latin America.

Table 2: Contribution of the buildings sector to the total final energy demand globally and in selected regions, 2007

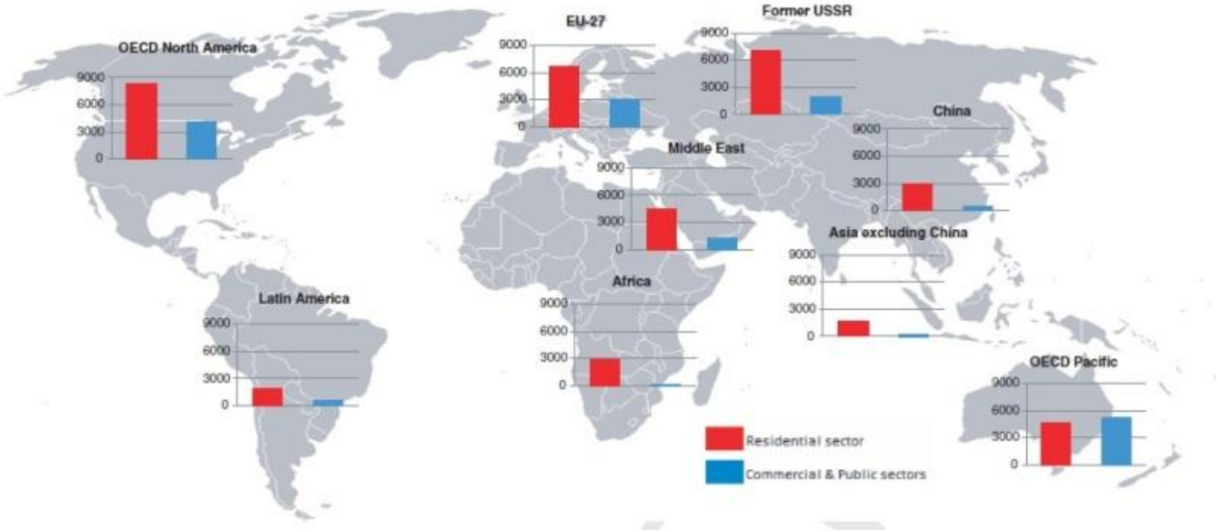
World regions	Share of the residential sector in %	Share of the commercial sector in %	Share of the buildings sector in %	Residential and commercial energy demand per capita, MWh/capita-yr.
USA and Canada	17	13	31	18.6
Middle East	21	6	27	5.75
Latin America	17	5	22	2.32
Former Soviet Union	26	7	33	8.92
EU 27	23	11	34	9.64
China	25	4	29	3.20
Asia excluding China	36	4	40	2.07

Africa	54	3	57	3.19
World	23	8	31	4.57

Source: GEA 2012

The demand for energy services in buildings differ by region. It varies by geography, climatic conditions, culture and economic development of a country. One can also notice a difference in energy demand in buildings of different type, location and age (e.g., residential or commercial, new or existing, rural or urban, etc.) (Chakravarty et al. 2009). The final energy use in buildings per capita in different regions of the world are shown in Figure 2below.

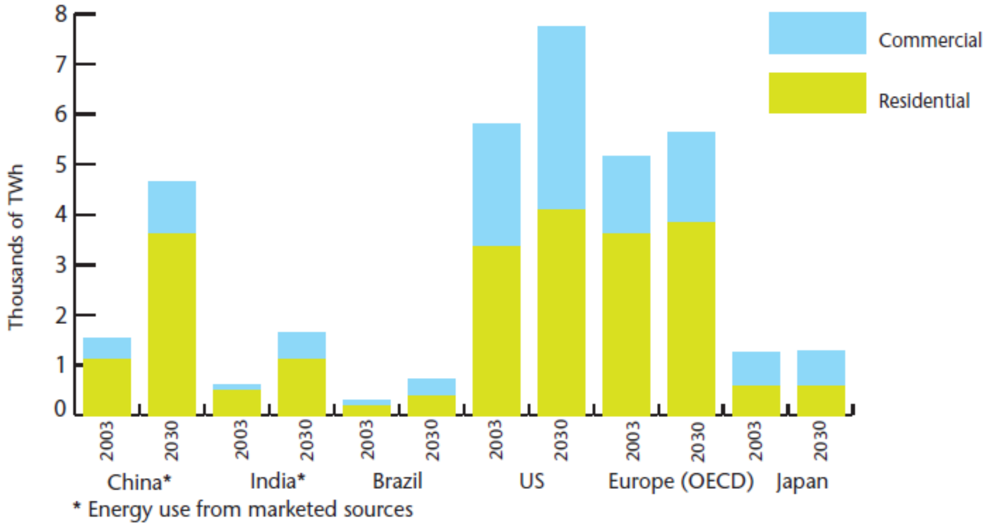
Figure 2: Total annual final energy use in the residential and commercial/public sectors, building energy use per capita by region and building type in 2007 (kWh/capita/yr)



Source: GEA 2012

Today the energy use in the construction sector is significantly higher in the US than in other regions, and this trend is likely to continue (see Figure 3). Consumption in other regions will grow, but the growth rate is substantially high in China and India, while in Western Europe and Japan it is relatively low. Apparently China’s building energy consumption will be approaching Europe’s by 2030, and India can potentially overtake Japan, especially in the residential sector.

Figure 3: Building energy projection by region 2003/2030

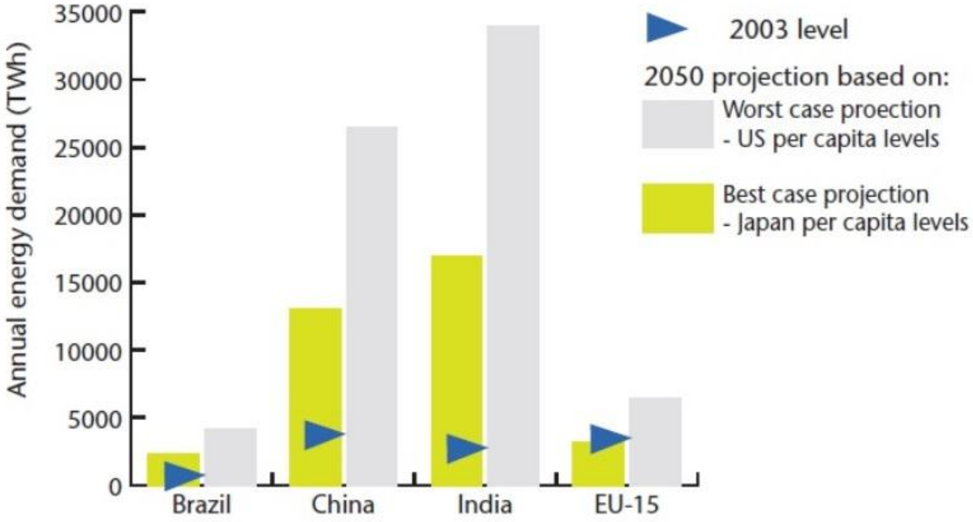


* Energy use from marketed sources

Source: WBCSD 2007

There is a projection of a dramatic increase in energy consumption in the building sector both in developed and developing countries (WBCSD 2007) by 2050 if no major energy efficiency improvements are done in this sector. Figure 4 shows the annual energy demand for different countries based on Japanese and US levels in the year 2003 taken as the best and worst case scenarios. The energy demand in buildings is increasing significantly due to the construction boom in China and other developing countries of Asia. If the energy use in buildings in China and India grows to current US levels, China's and India's consumption will be four to seven times more than they are today.

Figure 4: Best and worst case projections of site energy demand by regions /2050 projection/



Source: WBCSD 2007

2.2.2 Increasing CO2 emissions in the buildings sector

The increasing energy consumption of the buildings sector contributes significantly to global greenhouse gas emissions and finally to global warming. The buildings sector is responsible for approximately one-third of energy-related CO2 emissions, two-thirds of halocarbon, and approximately 25–33% of black carbon emissions, and the emissions are projected to be growing in the future reaching 15.6 Gt CO2 emissions in 2030 unless effective preventive measures are not taken (GEA 2012).

The total amount of emitted CO2 from the buildings sector, including the emissions from electricity use was 8.6 Gt CO2 (IPCC 2007) in 2007, almost a quarter of the global total energy related CO2 emissions (IEA 2008a). CO2 emissions from buildings grew by 2% annually during the period from 1971 to 2004, and the trend is likely to continue. The annual growth rate of CO2 emissions for the residential and commercial buildings sectors during that period were 1.7% and 2.5% respectively (IPCC 2007). According to the 2007 IPCC report, CO2 emissions varied by regions: the largest increases for both residential and commercial buildings were from developing Asia accounting for 30% of increase in the commercial buildings sector and 42% for the residential sector. Regional increases in CO2 emissions for commercial buildings in North America and OECD Pacific were 29% and 18% respectively.

The emission of halocarbons (HFCs, CFCs and HCFCs) covered by the Montreal Protocol, account for more than 15% of the total 8.6 Gt CO2 emissions from buildings (IPCC 2007). The total amount of halocarbon emissions due to use of such agents for cooling, refrigeration and insulation purposes in buildings was 1.5 Gt CO2-eq in 2002.

2.2.3 The impact of climate change on the buildings sector

Besides being aggravated by GHG emissions from buildings, the climate change itself has its own implications on the buildings sector worldwide. Due to the rising temperature, the cooling demand increases in some hot and arid parts of the world, making such passive cooling approaches as overnight ventilation or shadowing less effective, and obliging to rely more on active cooling systems. However, in cold zones the heating demand decreases, which allows to achieve the required indoor temperature more easily and cost effectively. In regions with a temperate climate impacts on both winter heating and summer cooling demand can be observed.

It is likely that due to climate change the electricity and primary energy demand will increase in most developing and developed countries, with some exception of some temperate industrialized countries, where such demand may remain small. The electricity demand of households may rise due to additional cooling required to adapt to the warming temperature, increasing the need for more power generation (Hunt and Watkiss 2011). As noted by Mansur et al. (2005) the switching from fuels to electricity in buildings in the United States may increase the overall primary energy demand. In general, buildings will have to be designed to allow greater comfort in the changing climate, incorporating advanced knowhow in building construction, building heating and cooling performance necessary to avoid negative implications of climate change on buildings. In order not to get locked in the set of short term inefficient technologies, it is required to make use of innovative buildings solutions such as passive ventilation, passive buildings, cooling by absorption technology, shadowing by building elements and trees, white roofs and surfaces, vegetation in urban areas, etc. (IPCC 2007).

2.3. Energy efficient buildings

The section gives an overall definition of energy efficient buildings and determines main principles and strategies applied in energy efficient houses based on the study of existing internationally known energy efficient housing options, their main advantages and drawbacks. A short summary about the cost of energy efficient buildings is also given at the end of the section, demonstrating the cost effectiveness and affordability of such buildings.

As climate change impacts are more evident, there is an increasing necessity to design and construct buildings in a way to ensure a healthy and thermally-comfortable indoor environment for inhabitants. According to the GEA building experts (GEA 2012) the following principles are essential for the construction of energy efficient buildings:

- energy efficiency (incorporating passive solar design and other possible energy saving technologies)
- bio-climatic design (greening buildings and integrating them into their natural setting rather than setting them apart from their surrounding) (Yeang 1994)
- adaptability (designing for simple retrofitting to enhance resilience to environmental climatic challenges) (Graham 2005)
- cost efficiency (affordability and cost effectiveness in the longer term).

According to different scenarios designed and suggested by GEA building experts, a reduction of global energy consumption by up to 40-46% is achievable through the joint application of the above mentioned principles in the buildings sector and proliferation of best practices of high performance energy efficient buildings, their design, construction and operation techniques and technologies (GEA 2012). Increased amenity and thermal comfort in buildings can be achieved without interfering with economic and population growth, and can lead a way to alleviate climate change and eradicate energy poverty.

2.3.1 Definition and main strategies for energy efficient buildings

Recent advances in building design and know-how have demonstrated that it is possible to decrease the energy use in buildings through high performance low energy and passive building technologies already available nowadays. The incorporation of on-site renewable energy generation sources such as active solar technologies (photovoltaic, solar thermal) can enhance the overall performance of buildings making them zero-net-energy or zero-greenhouse gas emitters in the long run.

According to the recent 2012 GEA report, energy efficient buildings that use 10-40% of the total energy for heating and cooling of conventional new buildings offer cost effective housing solutions in many parts of the world. Retrofits made through holistic approach can result in 50-90% final energy savings in thermal energy use in buildings, with the remaining energy needs possible to be achieved through community level energy supply or renewable energy sources.

Although it is commonly agreed that buildings' energy use and environmental impact must be reduced, there has been a lack of consensus on the proper means and ways of achieving this. Owing to that, there are various terms and definitions of high performance buildings used in different countries. Bio climatic house, carbon/emission free house, eco/green building, energy saving house, low energy house, passive house, zero emission house, etc. – are all terms used to identify high performance buildings in many countries around the world. Notwithstanding the varying definitions among countries, the main goal of constructing and designing such buildings is to reach the lowest possible energy demand and associated greenhouse gas emissions. High performance buildings are performance based buildings, and therefore the definition of such buildings should not limit the technological options that can be used to meet performance requirements (EPBD 2011).

This section briefly reviews the basic technological and know-how strategies that are commonly applied for energy efficient buildings, and their performance in terms of energy consumption, indoor climate, environmental impact, and cost are provided accordingly. Design strategies for energy-efficient buildings include reducing both heating and cooling loads, utilizing systems that make the most effective use of available energy sources and using efficient equipment and effective control strategies.

Utilizing Integrated Design Processes

First of all, an integrated design approach is required for energy efficient houses to ensure that the architectural elements and the engineering systems work effectively together. In order to achieve high energy efficiency performance, it is crucial to analyze the building as an integrated system rather than focusing on improvements of individual energy using devices (Harvey 2008), which do not give effective results.

A new approach to building design, the Integrated Design Process (IDP) examines the building as an entire system and requires setting ambitious energy efficiency goals at the very beginning of a project, involving all members of the design team, including designers, architects, engineers and others (GEA 2012). IDP can result in improved building performance with lower costs and fewer disruptive changes during the later project stages.

As Harvey (2006) discusses, the main steps of IDP are as follows:

- consider building orientation, form, thermal mass;
- determine necessary measures to reduce heating and cooling loads in order to achieve a high performance building envelope;
- get a maximized use of passive heating, cooling, ventilation, and daylighting;
- install efficient systems to meet remaining loads;
- ensure that individual energy using devices are as efficient as possible and properly sized; and
- ensure the systems and devices are properly commissioned.

Designing energy efficient houses according to the steps identified above can bring in desired results: by taking into consideration the building form and a high performance envelope it is possible to minimize heating and cooling loads and maximize the daylighting opportunities, and in that way reduce energy demand and associated costs. The generated cost savings can offset additional costs for high performance building envelope and other high efficiency equipment and appliances installed. Energy savings of 35-50% is achievable in new buildings thanks to these steps alone, and even higher energy savings in the order of 50-80% are possible if more advanced technologies are utilized (IPCC 2007).

Reducing heating, cooling and lighting loads

Simple strategies which are commonly used in energy efficient buildings for reducing heating loads are to use high levels of insulation in walls, roof and basement; ensure thermal bridge free and airtight building envelope, which prevents structural damage and increases the level of comfort; use high quality windows and doors with well insulated frames and install heat recovery ventilation system which reduces the level of indoor air pollution and improves the health of occupants. This approach is most appropriate for cold climates, whereas a bit different strategy is used in other climates. In milder and hot climates rather moderate levels of insulation can substantially reduce heating energy demands, as well as reduce summer cooling energy use by a factor of two or more (Florides et al. 2002).

The cooling load is reduced through proper orientation, self shading, use of highly reflective building materials, increased insulation and vegetation on building surfaces to reduce ambient air temperature through evapotranspiration (IPCC 2007). Both internal cooling and lighting loads are reduced in energy efficient buildings through the use of highly efficient lighting and household appliances and electronics. However, increasing the efficiency – by reducing the number and size - of household appliances may at times increase heating loads, but only in lesser amounts.

By reducing the heating, cooling and lighting loads it is possible to gain substantial energy savings. For example, in Austria a building may be considered as a low energy house if its annual heating demand is equal or less than 17 kWh/m2 (Mahdavi et al. 2010). For passive houses this benchmark should be equal or less than 15 kWh/m2 per year, and the primary energy use must be equal or less than 120 kWh/m2 per year. This means a saving of up to 90% of energy in relation to the average consumption in existing buildings (iPHA 2010).

Utilizing active solar energy and other environmental heat sources

Low energy buildings use active solar energy systems for electricity generation, hot water and space conditioning purposes. Some low energy buildings use other renewable energy generation methods, using the ground, ground water, aquifers and air as heat sources or sinks, either directly or by using heat pumps. Space cooling techniques such as evaporative and radiative cooling, earth pipe cooling are used to dissipate heat directly to natural heat sinks without the use of refrigeration cycles.

Considering building form, orientation and related attributes

Urban design influences energy use by buildings through building form, orientation, self-shading, height-to-floor-area ratio and other related attributes. Decisions related to the building design affect the effectiveness of passive ventilation and cooling. Many countries have incorporated effectively the traditional building design techniques into energy efficient building design in order to reduce heating and cooling loads. For instance, in the hot climate of India traditional narrow streets with tall and compact houses with thick walls and small openings help to keep heat out of buildings.

Building shape, its width, length and depth and form can also have a significant impact on heating and cooling loads. In temperate climates, for example, the optimal orientation for buildings would be a long axis running east-west, which helps to maximize passive solar heating during winter time and minimize the solar heat gain in warm season. Other urban design solutions such as clustering or mixing different building types influence the operation, location and cost of district heating and cooling systems.

Improving maintenance and quality control

In order to improve the actual performance of a building, it is important to ensure quality control through building commissioning, which includes in itself design review, testing and monitoring of energy consumption of systems and devices, and clear documentation of maintenance and operation. Continuous monitoring and diagnostics are crucial for effective operation and maintenance of energy efficient high performance buildings in particular.

In general, energy efficient houses are performance based buildings. Therefore all the technologies identified above are not necessarily to be applied always. Only the most adaptable, affordable and suitable for the local climate should be used to meet the specific building performance needs. For instance, although controlled ventilation system mostly used in passive houses clearly contributes to better indoor air quality and lower levels of CO2 concentrations, it is not always required if user-operated natural (window) ventilation is more desirable or affordable for a specific location and the inhabitants are satisfied. Higher energy efficiency measures could be achieved through other measures.

2.3.2 Benefits in terms of climate change mitigation and energy poverty alleviation and others

Highly energy-efficient buildings can bring in not only monetizable benefits in terms of the reduction of buildings operating costs, but also non-quantifiable or non-monetizable benefits in many respects. One of the most important future benefits is the reduction of the building sector contribution to climate change. IPCC (2007) calculations suggest that approximately 29% of the projected baseline CO2 emissions can be reduced by 2020 by the application of cost effective energy efficient measures in the residential and commercial buildings. Moreover, in addition to that, at least 3% of baseline emissions can be avoided at costs up to 20 US/tCO2 and 4% more for up to 100 US$/tCO2. These estimates are equal to reductions of approximately 3.2, 3.6 and 4.0 billion tonnes of CO2-eq in 2020 at zero, 20 US$/tCO2 and 100 US$/tCO2, respectively.

Other benefits are: elimination or reduction of indoor and outdoor air pollution, related mortality and morbidity; other health improvements and benefits; alleviation of energy poverty and improvement of social welfare; advances in energy security and sovereignty; new business opportunities, and job creation; improvement in skills of building professions and experts; enhanced real estate values; and increased comfort, well-being, and productivity. The benefits that are most commonly attributed to energy efficient buildings are summarized below.

Reduction in local/regional air pollution

Through energy efficiency measures in the residential and commercial sectors, it is possible to alleviate local climate change impacts and improve local or regional air quality, particularly in large cities. It then contributes to improved public health, resulting in increased life expectancy, reduced attacks of respiratory diseases, and consequently reduced hospital visits and productive working days. For instance, in China, providing district heating through large boiler houses is more effective rather than using residential coal burning, and it has the largest abatement benefits per ton of CO2 reduction, if to take into account the health benefits from improved ambient air quality (Mestl *et al.* 2005). Other studies (Mirasgedis et al. 2004) found out that the economic benefits of the reduction of GHG emissions in the buildings sector can be substantially increased by up to 80% if the co-benefits of improved air quality are accounted for.

Improved health, quality of life and comfort

Improved indoor air quality along with the reduced indoor air pollution is one of the most important co-benefits of energy efficient measures in the buildings sector in developing countries (IPCC 2007). One of the biggest challenges in developing and least developed countries, where traditional biomass is used for heating and cooking purposes, is to tackle the problem of indoor air pollution and focus on the health related benefits of clean domestic energy services. Today approximately three billion people use biomass for cooking and heating energy needs (ITDG 2002), and the indoor air pollution resulted from the incomplete combustion of biomass in inefficient traditional stoves threatens the health and wellbeing of these people. As WHO estimates (IEA 2010), due to burning of biomass, the rate of respiratory infections is high among young children, whereas adults are more vulnerable to obstructive pulmonary diseases. Over 2.2. million deaths occur annually due to indoor air pollution, and over 98% of such incidences are in developing countries (IPCC 2007). Energy efficient houses equipped with clean-burning cooking stoves not only reduce substantial amounts of GHG emissions, but can also be a solution to prevent many of these health problems thanks to improved indoor environment.

Improved health at the same time leads to increased productivity. There is an interesting correlation between the well designed, energy efficient building and the occupant's productivity and health (Fisk 2000). In developed countries, the proliferation of energy efficient techniques and technologies in the construction sector can improve the quality of life for inhabitants and increase the value of real estate. According to Jakob (2006) there are several co-benefits of energy efficiency measures such as improved thermal comfort indoors, reduced level of outdoor noise infiltration into the buildings due to the high level of insulation and high quality doors and windows. Moreover, thanks to better insulation of buildings, it is possible to avoid thermal bridges and eliminate moisture related problems that can otherwise potentially shorten the lifespan of buildings.

Energy poverty alleviation

Improved energy efficiency helps poor households to reduce the economic burden of paying energy bills, and in that way increase the affordability of adequate energy services (IPCC 2007). In former communist countries and in other developing countries of Asia and Latin America, where the energy subsidies were removed after the collapse of communism and market driven energy prices were introduced, energy expenditures are a major burden for households (Urge-Vorsatz *et al.* 2006). Energy programmes in such countries should be oriented towards more energy efficiency in the buildings and energy sectors instead of focusing on short term energy bill subsidies (Urge-Vorsatz and Miladinova, 2005). Through energy efficient technologies and low energy cost effective building design, it is feasible to achieve up to 20% of reduction in energy expenditure. This can result in more availability of adequate energy services for more low income households (Goldemberg 2000).

The energy/fuel poverty problem which was identified in earlier sections is also found in wealthy, developed countries. In the UK, for example, in 1996 about 20% of households were considered to be living in energy/fuel poverty. There are estimates that annual excess winter deaths are largely due to inadequate heating at home (Boardman 1991). Improving energy efficiency in these households is a major strategy to combat energy/fuel poverty, and eliminate the associated social and health related problems. Development strategies aimed at improving the social welfare of a country can go hand-in-hand with energy efficiency development needs.

New business and employment opportunities

Many studies have shown that energy efficiency improvements create new employment opportunities along with economic savings on energy costs (Jochem and Madlener, 2003). The energy services sector is considered to be a rapidly growing and very promising business worldwide. Experts see some profitable business opportunities thanks to energy efficiency, for instance, ranging from 5-10 billion euro in energy service markets in Europe (IPCC 2007).

Energy security

According to IEA (2004), improved energy security is one of the important co-benefits of energy efficiency measures. Improving end-use energy efficiency is among the top priorities on the European Commission’s agenda to increase energy security, with the recognition that energy efficiency is likely to generate additional macro-economic benefits because reduced energy imports will improve the trade balances of importing countries (European Commission 2003).

In summary, it is worth noting that energy efficiency improvements both in the residential and commercial buildings sectors and associated renewable energy investments bring in substantial benefits in a number of ways, and not always limited to the value of saved energy or reduced GHG emissions. Combined and implemented in consistence with other policy goals in fields such as employment, social and economic welfare, health and environment, energy efficiency measures result in broader climate change mitigation efforts, and reduction of associated costs (IPCC 2007).

2.3.3 Cost effectiveness of high performance buildings

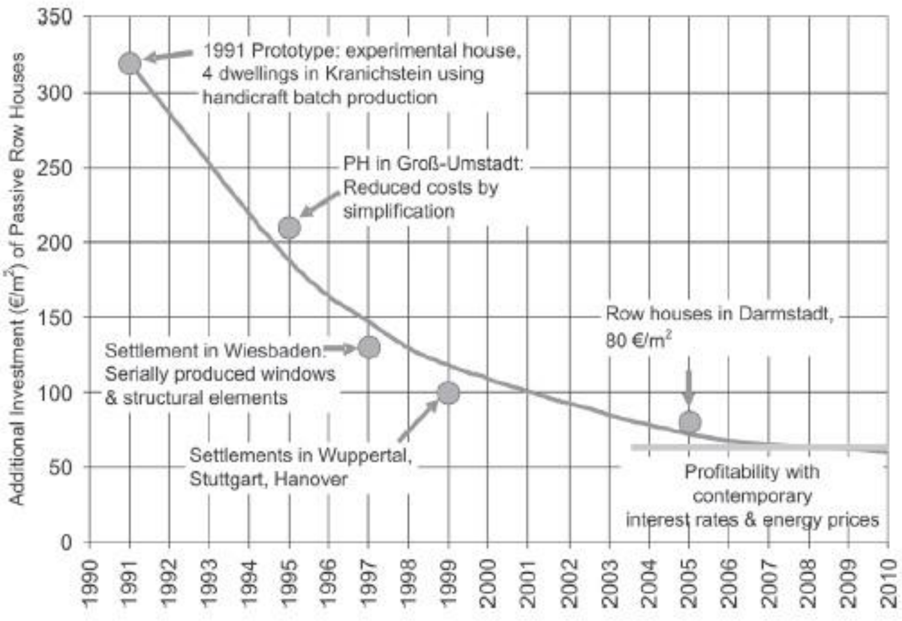
Financial considerations are important when it comes to decide on real estate or property investments. Although it differs by country, financial pressures play a significant role in decision making, particularly due to the increasing value of real estate and the growing investment in it alongside equities and bonds (WBCSD 2010). Investors are interested in short term revenues, rather than in longer term benefits. Moreover, the decline in the number of owner-occupied buildings impedes energy efficiency investments in buildings for a longer term perspective. Too much consideration is given to the "first cost", the initial investment required rather than life-cycle cost assessment and return on investment calculations (WBCSD 2010). These and other financial concerns do limit the advance of new technologies, especially of energy efficiency.

Advances in the building technology, materials and know-how have made it possible to construct energy and cost effective buildings that use 10-40% of the final heating and cooling energy of conventional buildings (GEA 2012). Comprehensive retrofits can also be cost effective, at times exceeding the investments, and resulting in 50-90% final energy savings in thermal energy use in buildings. The remaining energy needs can be met by decreasing both energy consumption and production rates, on and off site renewable energy generation or by community level distributed energy sources or energy imports.

Cost of new energy efficient buildings

The additional cost of energy efficient buildings in Central Europe has been declining steadily over the past decades. In North America and some other developed countries where the passive house technology has penetrated there are sometimes no additional costs or even cost savings compared to traditional conventional buildings. For instance, the cost of passive houses, which use four to eight times less energy for heating than conventional houses, is in the range of 5-8% of the standard construction costs (GEA 2012). Figure 5 shows the decline in the additional investment in passive houses in Europe, when costs fall to the point where incremental cost can be justified.

Figure 5: Curve showing the progressing decrease in the incremental cost of meeting the passive house standard for the central unit of row houses in Germany, 1990-2010



Source: GEA 2012

According to calculations made by Schnieders and Hermelink (2006), the additional average cost for 13 passive houses built in Germany, Sweden, Austria and Switzerland was 8% of the conventional house cost. When amortized over 25 years at 4% of interest rate and divided by the amount of saved energy, the cost of saved energy averages 6.2 eurocent/kWh, which is more than the cost of natural gas for households in most European countries, which ranges between 2-8 eurocent/kWh. Audenaert et al. (2008) estimate extra costs of 4% for low-energy houses and 16% for passive houses in Belgium, having energy savings of 35% and 72%, respectively, relative to current standard houses in Belgium. The result of numerous studies conducted by the US Green Building Council suggest that the cost of reaching certification under its Leadership in Energy and Environmental Design (LEED) standards system is between zero and 3%. The highest level of LEED (platinum) comes at a cost premium of less than 10% (WBCSD 2010).

The extra costs incurred for the construction of high performance houses are usually offset by reduced operational and maintenance costs (GEA 2012). In order to offset the costs, for example, the construction of Passive Houses is often financially assisted through low interest rate housing loans offered in many countries and regions. For instance, a housing loan from the German KfW bank (50 000 euro at a rate of 2.45 to 3.05% per year as of 2010) is available to anyone who builds a passive house, regardless of personal income (iPHA 2010). Moreover the reduced energy costs, increased comfort and less concerns about structural damage – all more than compensate for a great part of the additional expenditure, increasing the value of the property (iPHA 2010).

Basically, in developed countries and the places where the required construction materials are widely available and competitively priced and the know-how technology of high performance energy efficient buildings is familiar, the costs are not necessarily higher than conventional houses. Besides as energy efficient houses are mostly performance based houses, there are ways to design and construct such buildings in a more cost efficient way than average new buildings.

Extra costs will continue to decrease as architects and building engineers gain more experience in the construction of energy efficient houses. The awareness of climate change, its negative consequences for development, rising energy costs and dependence on imported fuels will certainly attach more importance to energy efficiency. A McGraw-Hill study showed that “greener buildings” might increase in value by 7.5% over conventional buildings with a 6.6% return on investment (WBCSD 2010). In the US, high performance, energy efficient buildings are becoming more financially attractive due to the expanding market for renewable energy and energy efficiency credits.

CHAPTER 3: *Case study analysis (Mongolian case)*

This chapter describes the problem of energy poverty and air pollution in Ulaanbaatar, Mongolia, through the current situation analysis and states the necessity and urgency of addressing the problems through low-cost, low-energy housing solutions. A cost-benefit analysis is conducted to determine whether the existing low-energy housing options would be economically and environmentally attractive in the longer term as alternatives for the Mongolian ger area residents in order to find out how much extra funding would be necessary to subsidize the missing capital, save residents heating expenditures/costs, and make energy efficient, low-cost houses more affordable for low income households.

3.1. Tackling the problem of energy poverty and air pollution in Ulaanbaatar, Mongolia: current situation analysis

3.1.1. Background information

Since 1990, when Mongolia shifted from a centrally planned economy into a market economy, there has been a major increase in urbanization, particularly in Ulaanbaatar, Darkhan and Erdenet cities, where around 55% of the population resides. The increase in urbanization was mostly due to changed macro-economic situation in the country and a series of severe winters, known as zud, after which many low income families from rural areas migrated into cities. The population of Ulaanbaatar has increased from around 600 thousand in 1989 to around 1154 thousand in 2010 (NSO 2010b).

This ‘from rural to urban’ migration pattern has led to an unprecedented expansion of ger areas in Ulaanbaatar, and the sustainable development of these areas is one of the critical development issues in the country. The ger area residents are now estimated to make up about 60% of the total population of Ulaanbaatar (NSO 2010a).

New urban residents coming from rural provinces are mostly settled in ger areas that surround the already built up ‘downtown’ of Ulaanbaatar. Most of the families live in scattered arrays of fenced property in very poorly insulated gers and small private houses. Basic heating, electricity, water and sanitation services are very limited or even non-existent in some ger areas. Most of the ger area households are not connected to the central heating system, and approximately 85% of them use wood or coal burning stoves for heating purposes (WB 2010). The provision of public services is quite costly given the low density in ger areas and extreme weather conditions of Ulaanbaatar, particularly during winter time. This lack of access to basic services results in serious environmental degradation of the surrounding area, including air, water and soil pollution and substantial health risks for inhabitants.

Ulaanbaatar is located in high lands with strong winds, and is considered to be one of the coldest capital cities in the world. It has an 8 month heating season, and winter temperatures fluctuate between -15^{0}C to -30^{0}C and can drop to even -40^{0}C at night. Therefore, heating is the primary Mongolian building energy demand (UNDP 2009). In apartments space heating is provided by hot water radiator systems, whereas in ger districts houses are heated with highly inefficient stoves, as most of the households are not connected to basic service networks.

Coal is widely used for heating purposes in stoves in ger districts. With estimated reserves of 150 billion tons, according to the Ministry of Mineral Resources and Energy (2010), coal is likely to remain as the main and most accessible heating fuel for households. In order to cope with the harsh Mongolian winter, ger area households that mostly live in under heated, poorly insulated dwellings, can spend up to 60% of their annual income on the purchase of required amounts of coal and firewood. This clearly demonstrates how deep the energy poverty problem is in Ulaanbaatar ger districts, and how much financial burden it can be on the household's budget, given the fact that mostly low and middle income households reside in this area.

Besides the energy poverty problem, there is a severe air pollution issue in the city, especially during the winter time. The combustion of coal adds a significant amount of carbon dioxide (CO_2) to the atmosphere per unit of heat energy, more than the combustion of other fossil fuels does. According to the National Air Quality Office of Mongolia, national air quality standards of SO_2 are exceeded by a factor or two. In fact, Mongolia has the extremely high per capita fossil fuel use (WB 2009).

Figure 6: Ulaanbaatar under a blanket of smoke[2] (WB blogs 2010)

Particulate Matter (PM) is also relatively most severe air pollution component in Ulaanbaatar. According to several air pollution assessments, the estimated amount of ground level air pollution in terms of PM10 during the winter time was 3 to 6 times higher than the levels recommended in Europe and North America, and 10 to 20 times more than the World Health Organization standards (WB 2011). Although it is found to be most appropriate for rural gers to use lightweight steel stoves for burning of dried dung and wood, it is not the case with gers and small private houses in urban ger districts where raw coal of low efficiency and high particulate concentration is used.

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[2] http://blogs.worldbank.org/eastasiapacific/ulaanbaatar-s-air-pollution-crisis-summertime-complacency-won-t-solve-the-wintertime-problem - World Bank blogs, East Asia and Pacific

These stoves tend to be poorly sealed, and this leads to inefficient and expensive firewood and coal use. Almost 90% of winter air pollution is caused by such stoves.

It is well known that particles such as PM_{10}, $PM_{2.5}$ and others can seriously damage health when inhaled by people (WB 2011). Respiratory diseases are becoming common among the urban residents; children are obliged to live in a smoky and dusty town where one can hardly find any clean and safe place to play. The Public Health Institute (PHI) study has shown “a strong correlation between the increase in heart defects among infants and higher concentrations of nitrogen dioxide and sulfur dioxide that were released by coal burning in the city” (Pearley 2011).

Improved energy efficiency in the buildings sector, especially in the informal sector in ger areas, would contribute to reducing local environmental problems, such as urban air pollution due to inefficient use of fuel for heating purposes, and the deforestation problem because of excessive use of wood for heating and construction. Moreover, it would be one of the ways of reducing the urban energy poverty that is mostly evident in ger areas, where the majority of poor urban families reside. Improved insulation materials and energy saving initiatives could lead to lower energy consumption, heating and fuel costs, alleviating the burden of low income families currently trapped in energy poverty.

3.1.2. Socio-economic characteristics of ger areas

General information

For reasons of socio-economic characterization, ger areas in Ulaanbaatar can be nominally divided into 3 major parts (WB 2010):

a. The City Center *Ger area that* borders the existing urban area of Ulaanbaatar and is partially connected to basic infrastructure and service networks. It has been gradually converted into an apartment area.

b. The Mid-tier *Ger area*, bordered on all sides by other *ger* areas, where most of the residents have acquired the title over their land and plan to stay there for a longer term. The households are provided with the standard level of public services currently available for ger area residents. According to World Bank, a progressive improvement in housing and public services is required in this area.

c. The Fringe *Ger* area, where the migrants from rural areas reside. It usually lacks the standard level of public services, as the area is poorly connected to infrastructure networks.

The socio-economic differences between the *ger* and apartment areas are quite significant. G*er* area households tend to be larger, younger, less educated, poorer, and more reliant on social services than households in apartment areas.

Income and employment

There is a considerable income gap between ger and apartment areas. The average annual income (including cash, in kind) of ger area households in Ulaanbaatar is 2496 thousand MNT (1665 USD) (WB 2010), which is 43% lower in comparison with apartment area households. Average monthly income in City center ger area is higher than in Mid-tier and Fringe gers at 223 USD per month. The income level in other two ger areas is only about 50% of apartment areas' income level (see Table 3). There is also a big contrast between ger and apartment areas in terms of assets and liabilities. For instance, in the Fringe ger area the total reported assets are only 30% of the apartment residents.

Table 3: Household assets, liability, monthly income and savings /2010/ (in thousand USD)

	Illiquid assets (property)	Liquid assets (cash, stocks, cars)	Total	Monthly income	Monthly savings
City center ger area	21.92	4.38	26.19	0.22	0.07
Mid-tier ger area	13.52	0.93	14.45	0.15	0.014
Fringe ger area	8.95	0.31	9.26	0.16	0.005
Apartment	26.44	1.36	27.8	0.31	0.021

Source: World Bank 2010

Rates of unemployment vary by districts and data sources available, but they are usually higher than in apartment areas. According to the HIES survey (NSO 2008), almost half of ger area residents are unemployed, with only 51% having worked during the previous 12 months.

Land and housing in ger areas

In ger areas private ownership of land plots and houses is generally high, with nearly 99% of families owning their dwellings in long established ger areas. The ownership rate is lower (around 80%) in fringe ger areas, where new immigrants from rural areas usually settle down (WB 2010).

The most common dwelling types in ger areas are traditional gers and detached houses. Gers are traditional nomadic dwellings made from a wooden frame and insulated with wool felt. Ger has been used by Mongolians for centuries as it has been the most convenient dwelling type for nomads, easy to transport and assemble. Though gers have advantages of being a mobile dwelling, it is no longer suitable for the modern urban lifestyle, which requires more comfort and amenity. In Ulaanbaatar gers are generally used by poor families with limited income sources to afford larger private houses. Gers usually have limited space, on average only one room of 28 m2. Private houses constructed in ger areas tend to be of smaller size, and of poor insulation, mostly with wall stoves installed in buildings. Stoves used both in gers and private houses for heating and cooking purposes are not efficient and are usually considered as a source of bad indoor air quality due to incomplete combustion.

In the City Center ger area, more than 50% of residents still live in gers (WB 2010), as the area is still being expanded by settlements in the hilly sides. In the Mid-tier ger area, which was established a relatively long time ago, more than 70% of households live in detached houses, and 30% in gers. In the Fringe Ger area more than half of the residents live in gers because this is a newly established and still growing area.

In all three types of ger areas the average land plot size is less than 700 m2, to which individual households are entitled by law, and the average size ranges between 470 – 590 m2 (see Table 4). For gers, the average number of walls is fairly uniform, just under five. As for private houses, the closer to the city center the bigger the average land plot and house size, with the average number of rooms ranging between 2.3-3.5. In the Fringe ger areas the size of land plot and dwellings are slightly smaller than in other two types of ger areas, and most of the families pay rent.

Table 4: Average size of land and houses in three ger areas

	Gers		**Detached houses**		
	Land size (m2)	# of walls	Land size (m2)	House size (m2)	# of rooms
City center ger area	535.7	4.8	593.5	76.5	3.5
Mid-tier ger area	589.3	4.9	546.8	55.4	2.9
Fringe ger area	469.2	4.8	501.3	54.0	2.3

Source: World Bank 2010

Heating in Ger areas

Ulaanbaatar is one of the coldest capitals in the world, therefore supplying households with reliable and affordable heating, especially during winter time when temperature can drop as low as -40^{0}C, is vital for the livelihood of its inhabitants (UNDP 2009).

In general, there are four types of heating systems in Ulaanbaatar: centralized (or district) heating system, small heating systems for groups of buildings (heat-only boilers or boiler houses), individual heating systems (water heaters), and household stoves (WB 2010).

Indigenous coal or wood is used in all of these heating options, which greatly contributes to the worsening ambient air quality in Ulaanbaatar.

Centralized (or district) heating system has a number of advantages over decentralized heating options, especially when it is applied in areas of high heat load density. Centralized heating systems mostly use Combined heat and power (CHP) production, which offers possibilities of increasing the efficiency of the use of primary energy and in that way positively impact the ambient air quality. There are significant economic benefits such as low production costs and fuel savings due to economies of scale and high heat load density. However, connecting individual households in ger areas to district heating system is not cost effective, mostly due to sparse settlement of households and low heat load density per km of network, which is about 40-50 times lower than for apartment buildings (WB 2010). Because of the unplanned development of ger areas, it is technically almost impossible to provide district heating. Besides, individual connections would not be efficient enough without proper building insulation measures. On average, traditional gers lose 4-5 times and private houses about 2-3 times as much heat as the national standards (WB 2010).

Coal-fired water heaters are quite common in ger areas, and are usually installed in small businesses and shops. The disadvantage of such heaters is that they use significant amount of raw coal and in that way contribute a lot to Ulaanbaatar city air pollution. *Heat-only boilers* are used mostly to heat one or several schools, kindergartens and hospitals. *Heating stoves* are the most common heating and cooking facility in ger areas and are used in a number of ways and in variety of forms. Stoves can be used directly for space heating, or a heating wall is attached to the stove for better heat distribution. In scope of programs and projects to improve the efficiency of stoves in ger areas, different modifications of improved stoves have been developed and tested to increase the consumption of cleaner fuels instead of raw coal for heating and decrease related CO2 emissions (WB 2010).

For better determination of the energy poverty problem, the estimation of the household expense on fuel has been made based on annual consumption volume and household annual income. In households of the City center ger areas the fuel consumption is the highest - 11,930 tons of coal and 2,550 tons of firewood annually (WB 2010) (see Table 5). In Mid-tier ger areas households use 7,044 tons of coal and 1,510 tons of firewood annually, spending about 1217.7 thousand MNT for fuel use, which is approximately 48% of their annual income. In Fringe ger areas the heat loss in houses is almost the same. Households consume about 10 tons of coal and 2.3 tons of firewood per year, which results in 1760 thousand MNT.

Table 5: Cost of fuel consumption and its % in annual household income in ger districts of Ulaanbaatar /2010/

	Fuel consumption /annually in tons/		**Fuel cost[3] /annually/**			**Average annual income[4] (thousand MNT)**	**% of annual income**
	Coal	Wood	Cost of coal (thousand MNT)	Cost of firewood (thousand MNT)	Total fuel cost (thousand MNT)		
City center ger area	11,93	2,55	1550.9	510	2060.9 (1472 USD)	3746.4 (2676 USD)	~55.0
Mid-tier ger area	7,044	1,51	915.72	302	1217.72 (869 USD)	2587.2 (1848 USD)	~47.1
Fringe ger area	10	2,3	1300	460	1760 (1257 USD)	2755.2 (1968 USD)	~63.9

In Europe, a common definition of fuel poverty is that any household spending more than 10% of its annual income on energy is in fuel poverty (Boardman 2010). In ger districts of UB households can spend up to approximately 60% of their annual income for purchase of coal and firewood for heating purposes, which demonstrates the severity of the energy poverty problem in this area. As it can be seen from Table 5, an average household in the City center ger area can spend up to 55% of its annual income for fuel purchase, whereas in

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[3] Fuel cost estimates has been done using retail prices: 1 ton of coal cost is 130 thousand MNT per ton; 1 ton of firewood is 200 thousand MNT per ton.

[4] For estimation purposes the following rounded average monthly income values were used: City center ger area household income – 312.2 thousand MNT; Mid-tier ger area household income – 215.6 thousand MNT; Fringe ger area household income – 229.6 thousand MNT.

the Fringe ger area households are obliged to spend approximately 64% of their income for purchase of coal and firewood for heating purposes.

3.2.Sustainable housing options in the cold climate in ger areas in Mongolia

As the ger districts are expanding rapidly, there is an urgent need to address the housing issue in this area. As it was mentioned earlier, the ger area households mostly live in under-heated, poorly insulated gers and private houses. The Mongolian houses are significantly less air tight (there is twice as much air leakage) than houses in other cold climates countries (UNDP 2004). The majority of houses built in ger districts does not meet the Mongolian building standards for thermal insulation, and are generally built by homeowners or a group of local homebuilders.

The problem of air and soil pollution and the lack of key infrastructure and social facilities have become a major concern of ger area residents and are usually the main reasons for being dissatisfied by their living environment. Due to these factors, many residents, especially those living in the city center ger area or in the remote areas of ger districts, would like to live in more comfortable apartment areas. However, the mid tier ger area residents want to stay in their long settled land plots, but to improve their current living conditions through better housing and infrastructure solutions (WB 2010).

Given the current level of expansion of ger districts and the ever increasing socio-economic and environmental problems in the area, it is worth to explore new sustainable housing options that can meet the needs and requirements of ger area residents and which can be developed in conformity with the City Municipality ger area development plans. According to Urge Vorsatz (GEA 2012), ‘the key to achieving sustainability in the building stock is to reduce the energy requirements in operating buildings … while maintaining indoor air quality and avoiding hazardous chemicals’. Hence, it is important to promote sustainable housing through energy efficient building technologies that can substantially reduce the energy needs. Measures and techniques to decrease energy consumption in buildings that can be adopted either in the designing or the maintenance phase of buildings should be investigated and applied in the construction of houses.

Currently there are various types of energy efficient building technologies available on the market. The research and analysis on the existing high performance buildings have demonstrated that dramatic reductions in the energy use in buildings are possible through enhanced building envelopes; more efficient heating, cooling and daylighting through the maximized use of passive solar heating; efficient ways of combining different HVAC components; through better use and supply of hot water; and finally, through more energy efficient household/office appliances and devices (Harvey 2010). However, the success of each energy efficient technological measures depends on the climatic condition, the overall energy demand in different countries and the applicability and affordability of the suggested measures. It is not always necessary to make use of all technologies, as sometimes substantial results can be achieved through a handful of very simple measures that are suitable for the chosen conditions.

Out of different energy efficient housing technologies available, the German passive house technology, the gold standard for housing in cold climates, is of great interest, as it can offer households high levels of thermal comfort conditions during both winter and summer without traditional heating systems and without active cooling. Passive houses are buildings with an annual heat demand of no more than 15 kWh/m2/yr and a total energy consumption of no more than 42 kWh/m2/yr (Harvey 2010). Typically this includes very good insulation levels, high airtightness of the building and a mechanical ventilation system with highly efficient heat recovery. Thus, passive houses offer a reduction in heating energy use by a factor of 15 to 25 compared to the average of existing building in Europe (Harvey 2010).

However, the passive house experiences gained in Central Europe, where the passive house technology is getting popular, are not directly applicable in the harsh cold climate of Mongolia, where the winter temperature can be as low as -40^{0}C. According to a preliminary research, the energy demand is going to be higher than the corresponding demand in Central Europe (Ayurzana Ts. in personal communication 2012). More insulation thickness in exterior walls, the roof and the floor, and high performance windows would be required to fulfill the cold climate requirements for a passive house. Therefore, the economic viability of such houses may seem to be rather low in Mongolia. Besides, many of the specific conditions in cold climates, for instance the frosting/defrosting conditions which require special attention to thermal insulation in foundations, have not been well tested or provided with appropriate instructions. Further research and simulations should be done if the concept can be adapted to the Mongolian construction practices.

Based on the research done regarding the low energy building practices, a certain set of options for achieving reductions in the energy intensity of buildings in the Mongolian construction sector is presented below. The measures are quite general for cold climates, however, some specific measures which can be applied in the Mongolian context are also included. The measures suggested can be applied separately, but taken together can yield more benefits and bring in higher energy reduction results.

- *High levels of insulation and air tightness*: In cold climates it is important to reach a high performance envelope through a thermal insulation over the entire building to reduce heating and cooling loads (GEA 2012). High levels of insulation of walls, ceiling and basement along with a high degree of airtightness shall be achieved. Good quality thermal insulation of the building envelope can save a significant amount of energy, particularly in the heating season, as the heating season in Mongolia is quite long, almost 8 months annually (UNDP 2004). Especially the insulation of external walls and roof can provide robust and considerable energy savings given the climatic conditions of Mongolia.

- *High performance windows:* Most ger district houses in Mongolia have double pane wood framed windows that are commonly built on-site using Chinese glass and wet wood. These windows tend to be of very low quality as they have poor air and water seals (UNDP 2004). Therefore, minimizing the heat loss through windows is extremely important in this case. Energy-efficient, condensation resistant windows with extra layers of glazing and low emissivity coatings shall be introduced to achieve greater reductions in heat loss. Argon gas fill and triple pane systems are already available from custom window manufacturers in Mongolia. Other advanced window manufacturing technologies should be assessed for feasibility in the Mongolian market.
- *Reduced rates of air leakage:* In buildings in cold climates up to half of the heating requirement is to heat the outside air that comes to replace the inside air (Harvey 2010). Therefore, an installation of a continuous impermeable barrier inside the interior wall and ceiling is required, with all the breaks and joints between walls, windows, doors and floors carefully sealed. This can reduce the rates of air leakage by a factor of 5 – 10 compared to standard practice in North America, Europe and the cold climate regions of Asia (GEA 2012).
- *Mechanical ventilation system:* In buildings with very low air leakage a mechanical ventilation system is required that circulates fresh outdoor air through the building and then exhausts. A carefully planned and installed mechanical ventilation system with heat recovery ensures a good indoor air quality and can substantially reduce the risk of respiratory diseases. Up to 95% of the available heat in the warm exhaust air

can be transferred to the cold incoming air in winter using a heat exchanger (Harvey 2010).

- *Weather barrier on the exterior of a building:* Given the extreme weather conditions of Mongolia, this shall be used to protect the exterior components of the building by preventing water and wind from blowing into the wall cavities and reduce the effectiveness of the thermal insulation by causing mold and mildew (Ayurzana Ts. in personal communication 2012).
- *Maximized use of passive solar energy for efficient heating and cooling:* An increased use of passive solar energy through sun facing glazing, use of solar energy collectors, airflow windows and others should be promoted for daylighting, heating, cooling and ventilation purposes (GEA 2010). In Mongolia there are 250 sunny days available annually, and solar radiation penetrates windows causing an immediate solar gain which is good in cold winter times.
- *Low toxicity high quality building and insulation materials:* Choosing the building and insulation materials carefully can help avoiding poor indoor air quality and other related problems that can potentially have serious health implications for inhabitants. Instead of importing low quality construction materials from neighboring countries, the production and use of locally available good quality materials should be promoted.
- *Efficient and safe appliances and lighting:* In order to complement the rest of the system and improve the energy efficiency levels, the most efficient energy using devices and appliances should be used.
- *Building shape (the relative length, width and depth), form (small scale variations in the shape of a building) and orientation:* The Mongolians have been nomads for centuries, and the most commonly used dwelling is the portable round shaped ger, a

structure comprised of a crown or roof wheel supported on posts by roof ribs which are connected to the lattice wall. Although there is an influence of round shaped buildings on the modern architecture, most of the buildings have acquired a rectangular shape due to the simplicity of construction. In order to maximize the passive solar heating in winter and minimize the solar heating in summer rectangular shaped buildings are usually oriented with a long axis running east to west (Harvey 2010).

- *Building size:* The house size is an important factor in total energy use. The bigger the size, the lesser the surface to volume ratio, which means that the thermal losses relative to floor area would be less. However, the total energy use will increase unless the building envelope is sufficiently improved (GEA 2012). The average housing size in ger areas in Mongolia is considerably small, ranging between 35 – 75 m2. There are a number of strategies to make efficient use of small space (Wilson and Boehland 2005). Some of them which might be useful for the Mongolian case are as follows: to design multiple uses into rooms; to make use of attic spaces by insulating the roof; to design windows and doors to increase the visual connection to the outside; to provide visual, spatial and textual contrasts to make spaces feel larger than they really are; to provide natural daylight; to design for flexibility and change (so that houses are not built big just to allow for changing needs in the future).
- *Building type (multi unit versus single family housing):* Mostly due to the sharing of walls and the reduction in the roof area, multi-floor, multifamily housing is more energy efficient than one-floor, single family housing (Harvey 2010). According to a World Bank survey (2010), most of the ger area residents in Mongolia expressed their willingness to live in low rise, multi-family buildings rather than in high rise apartment complexes. Low rise multi-family buildings can be a suitable option for

them, as the income level of most of the households is not enough to purchase apartment buildings. Besides, close family bonds in the Mongolian culture allow to promote multi floor, multifamily housing in ger districts, as it can give a substantial boost to the development in this area through advantages such as: the reduced heat loss, more opportunities for passive ventilation, the protection of the lower floors from solar heat gain, and more material and cost savings due to reduced surface to volume ratio and consequently a reduced building cost per unit of floor area. Moreover, the multi-unit housing can facilitate the connection to district heating and cooling grids, which are currently not accessible to many of the ger area residents, making it economically and environmentally justifiable.

3.3. A cost analysis

3.3.1. Overview of the cost analysis

Although it is commonly acknowledged that investments in the building sector can have the most efficient and biggest impact on energy consumption and CO2 emission reductions worldwide (GEA 2012), energy efficiency measures are not popular enough in many developing countries around the world. This is mainly due to the high amount of initial investment needed for energy efficient houses in comparison with conventional buildings. However, it should be noted that the initial investment in energy system optimization and energy efficient improvements in buildings pays off in the longer term, and reduced energy costs more than compensate for a great part of the additional expenditure (iPHA 2010). Besides, in order to offset initial costs, the construction of EE houses is often financially assisted through low interest rate loans and housing subsidies in many countries worldwide.

As larger amounts of investments are required to reach higher levels of energy savings, the aim of this study is to perform an economic analysis in order to determine the economic viability of high performance buildings in the Mongolian construction sector. In this study the potential of standard houses and energy efficient (EE) houses will be compared from an economic investment point of view. Conventional or standard houses can be defined as buildings constructed according to the common construction practice of a specific country, using standard design and materials with no energy saving measures included, whereas low energy or energy efficient houses refer to buildings that are constructed in conformity with special requirements to reduce the building energy demand (Sartori and Hestnes 2007).

Cost estimates for the construction of EE houses vary greatly across countries, regions and climate zones. This variation in cost makes it difficult to determine the amount of additional investment required for the construction of EE houses. This study analyzes the overall costs and investments[5] for the construction of EE houses in the Mongolian context, and attempts to determine whether low-energy housing options would be economically and environmentally attractive in the longer term as alternatives to traditional types of buildings.

3.3.2. <u>Aims and objectives</u>

This analysis aims to provide some insight into the investment requirements and cost effectiveness of energy-efficiency investments in the buildings sector demonstrated on the Mongolian case. Through the analysis, the researcher addresses the following questions:

- How much extra funding would be necessary to construct EE houses?
- How much energy cost savings it can offer? How does the energy cost change over time?
- What is the payback time for EE houses given the energy costs saved?
- How can the extra funding be obtained? What mortgage scenarios are more favorable for ger area households willing to construct EE houses?

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[5] This study does not examine the costs of specific types of building or insulation materials, appliances or construction methods, which can be the subject of another analysis.

- How to make energy efficient houses more affordable for low income households in the longer run?

3.3.3. Samples

Type: Average wooden and brick masonry houses built in ger districts in Ulaanbaatar were taken as samples for conventional houses. As for EE houses, the cost of timber framed, brick masonry and structural insulated panel houses built according to the National energy efficiency standards were chosen for analysis. Timber framed and brick masonry houses are quite common in Mongolia, whereas the structural insulated panel technology is relatively new, and recently introduced into the construction market. All sample houses are single family houses. Multifamily EE houses are currently not constructed in Mongolia. Only some preliminary drawings are made at the UNDP Building Energy Efficiency Project (Buyan, M. in personal communication 2012).

Size: Two different floor areas, 35 m2 and 65 m2, were chosen to represent small and middle sized detached houses commonly constructed in Ulaanbaatar ger areas.

3.3.4. Input data

Cost of houses:

Cost comparison of traditional and EE buildings in Ulaanbaatar ger areas (the targeted area of the research) was not easily available in the literature. Due to the shortage of detailed data on housing situation in ger areas, it was quite difficult to make generalizations based on small sample size taken for the analysis. However, open sources of such international organizations such as World Bank and UNDP Mongolia, governmental organizations and agencies such as the National Statistical office of Mongolia were highly useful in determining the average cost of traditional and EE houses. Also skype interviews and personal communications via email were used to get and verify related data (The list of interviewees can be found in Annex 1: Personal communications).

There are two major cost categories examined in this study: EE and traditional building costs. Costs are broken down into minimum and maximum subcategories with two different floor areas: 35 m2 and 65 m2. Table 6 below shows the average and total costs for both traditional and EE houses built in Ulaanbaatar (see Table 6). As there are certain variations in the cost of traditional and EE houses depending on location, building materials' availability and cost, it was decided to take for the analysis purposes both the average minimum and the average maximum prices of houses offered on the market.

Table 6: Cost of traditional and EE houses in Ulaanbaatar ger areas /2010-2012/

	Average cost per m2 (thousand MNT)		**Total cost (thousand MNT)**			
			35 m2		65 m2	
	min	max	min	max	Min	Max
EE house	584.4 (436 USD)	828.1 (618 USD)	20455.4 (15265 USD)	28984.3 (21630 USD)	37988.7 (28349 USD)	53828.1 (40170 USD)
Traditional house	324.9 (242 USD)	449.9 (335 USD)	11372.9 (8487 USD)	15748.6 (11752 USD)	21121.1 (15762 USD)	29247.4 (21826 USD)

Source: UNDP 2012; WB 2010

Note: Exchange rate effective 1 USD =1340 MNT (as of July 2012)

The cost of traditional houses was based on the market price of private detached houses that are commonly constructed in different zones of ger areas in Ulaanbaatar. The traditional detached houses do not necessarily meet formal EE requirements and are often built by homeowners themselves. The cost of EE houses is twice as high as the cost of conventional houses. The minimum and maximum cost of such houses was determined based on the average price offered by small and middle sized local construction companies, currently operating on the construction market. Although the performance and quality of EE houses built on the market do not answer the high standards of construction, they are planned and constructed according to the EE requirements set up in national building norms and standards, namely the Thermal performance code BNbD 23-02-09 (2009).

After determining the total cost of houses, the additional investment costs for constructing EE houses were calculated for each subcategory by subtracting the total cost for traditional houses from the total cost of EE houses (see Table 7).

Table 7: Additional costs to be incurred for the construction of EE houses in Ulaanbaatar ger districts /2010 – 2012/

35 m2 (thousand MNT)		**65 m2 (thousand MNT)**	
Min	Max	min	Max
9082.5 (6778 USD)	13235.7 (9877 USD)	16867.6 (12587 USD)	24580.7 (18343 USD)

Fuel consumption/Energy costs

As most ger area households are not connected to district heating services, they heavily rely on coal and firewood[6] for heating and cooking purposes. Therefore, the calculation of the energy cost for sample houses is based on the amount of fuel (in this case coal) used for heating (see Table 8). Fuel cost estimates have been done using retail price of 130 thousand MNT (97 USD) per ton of coal. All the analysis was performed at constant energy costs.

Table 8: Fuel/Energy cost in Ulaanbaatar ger areas /2010/

	Annual fuel consumption (tons)		**Cost of annual fuel consumption (thousand MNT)**	
	35m2	65m2	35m2	65m2
EE house	3.08	5.26	616 (459 USD)	1052 (785 USD)
Traditional house	7.44	11.52	1488 (1110 USD)	2304 (1719 USD)

Source: Ayurzana, Ts. in personal communication, 2012

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[6] Coal and firewood - the main primary energy sources in Ulaanbaatar ger areas

Mortgage terms and conditions

Mortgage terms and conditions of several commercial banks operating in Mongolia were analyzed (see Table 9).

Table 9: Housing mortgage terms and conditions offered by commercial banks currently operating in Mongolia /2012/

	Loan amount (million MNT)	**Down payment (%)**	**Interest rate (monthly)**	**Duration (years)**
XacBank	up to 100 (up to 74626 USD)	20 - 50	1.5 - 1.75	10
Khan Bank	30-50 (22388 – 37313 USD)	30-50	2.0 - 2.2	5
Khadgalamj Bank	10 – 50 (7462 – 37313 USD)	30-50	2.2 - 2.5	5

Source: XacBank – http://www.xacbank.mn/; Khan Bank – https://www.khanbank.com/; Khadgalamj Bank - http://www.savingsbank.mn/

The terms and conditions of a private house mortgage offered by XacBank seem to be the most favorable in terms of offered loan amount, down payment scheme, interest rate (being the lowest) and the loan duration. Therefore, the XacBank mortgage conditions were used as the base to estimate the attractiveness of investment in EE houses through banking loans for both the cash flow and sensitivity analyses.

3.3.5. Analysis structure

The cost analysis consists of 3 different types of analyses, namely:

- Break even analysis
- Cash flow analysis
- Sensitivity analysis

Each of them will be briefly discussed below with relevant results and conclusions.

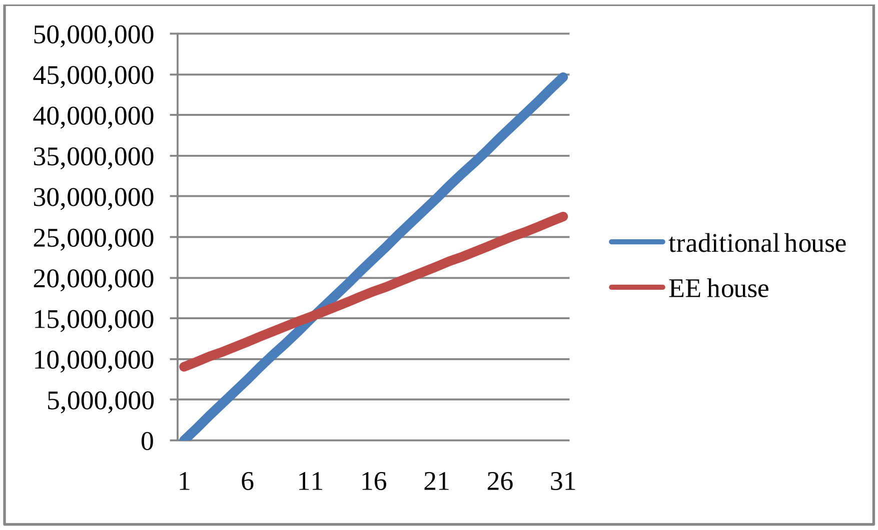
A. Break even analysis

This analysis was used to show the time needed to recover the net costs for constructing a new EE house given constant energy prices. 4 different scenarios were analyzed for 8 different samples taken: minimum and maximum cost scenarios for 35 m2 of traditional and EE houses, and also minimum and maximum cost scenarios for 65 m2 of traditional and EE houses.

The charts below start with the net additional cost required for the construction of EE houses, and then adds every year the corresponding energy costs. The total amount of fuel/energy cost savings were taken into consideration in order to observe how the investment needed to construct EE houses changed over time. The break even time shown in charts and tables is the year the total costs of the second house type are lower than the first given the amount of energy costs saved.

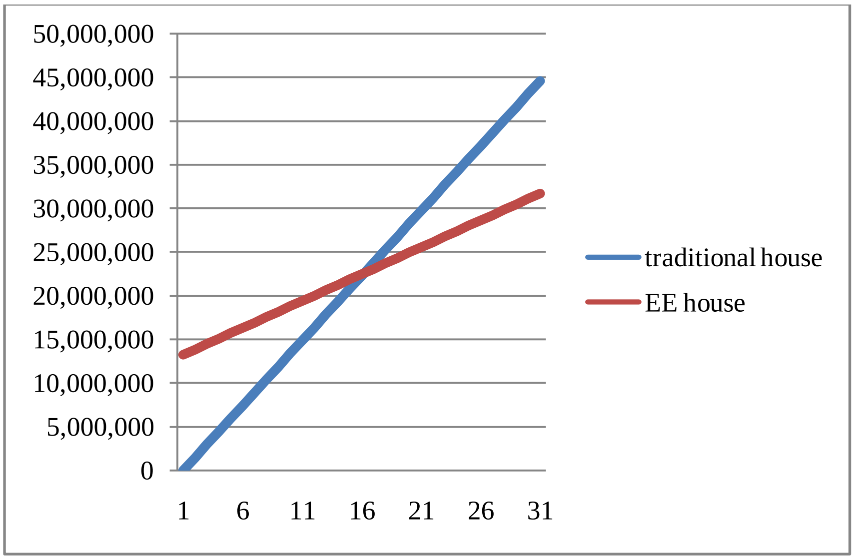
Figure 7 shows the break even time for the EE house compared to the conventional house of the same size of 35 m2 at the minimum cost of construction of EE houses offered on the market. The break even time is 11 years.

Figure 7. Break even time /35 m2 houses at minimum cost/



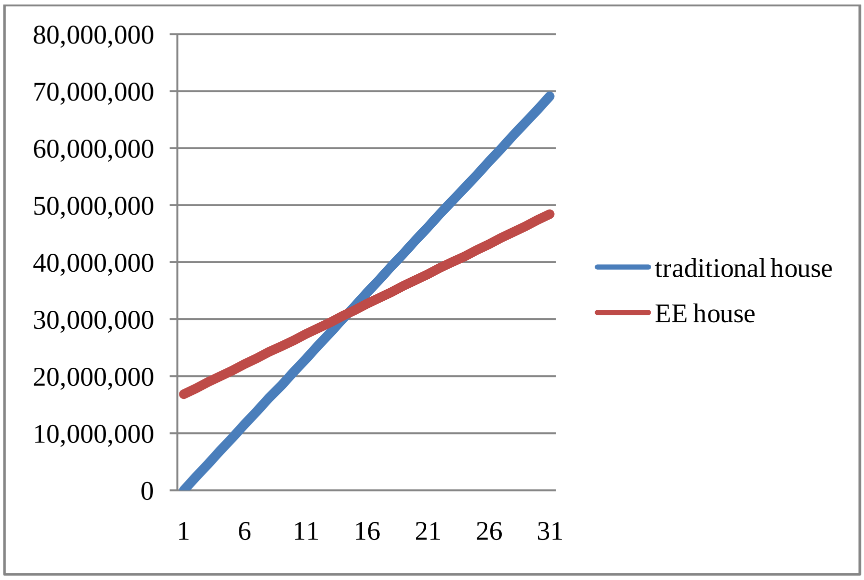
As for the EE houses with a total floor area of 35 m2 and that are constructed at the maximum price available on the market, the break even time equals 16 years. In other words, the net costs required for the construction of such houses will be recovered only after 16 years, given the total energy cost savings.

Figure 8. Break even time /35 m2 houses at maximum cost/



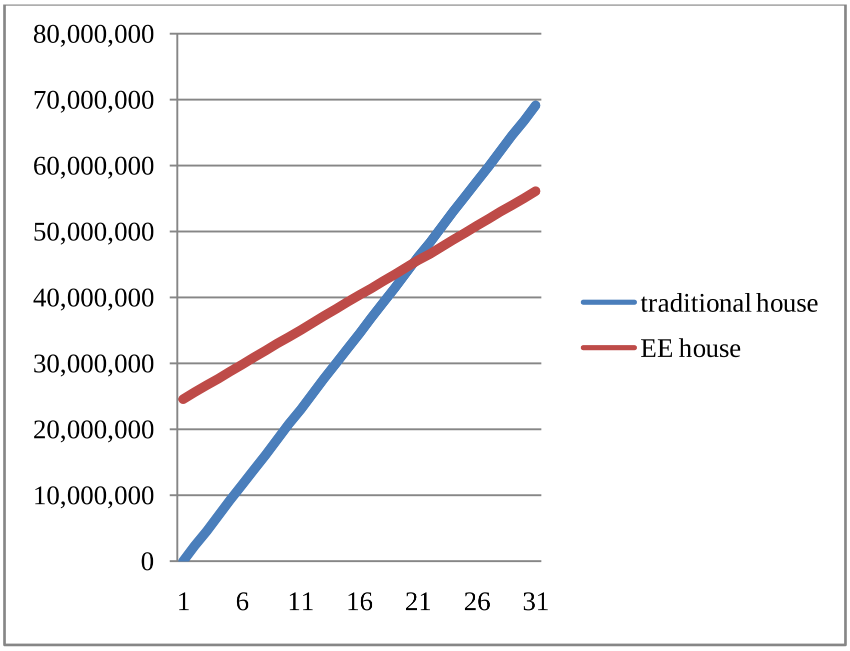
According to Figure 3, after 14 years the EE houses of 65 m2 constructed at minimum market prices will become an attractive investment if to take into account the cost savings offered by such houses.

Figure 9. Break even time /65 m2 houses at minimum cost/



As it is shown in Figure 10, the EE house of 65 m2 built at the maximum cost starts paying off after 20 years only, compared to standard houses of the same size. The cost for construction of such houses was the highest among all the samples taken, and the payback period is the highest as well.

Figure 10. Break even time /65 m2 houses at maximum cost/



Summary

According to the break even analysis, it can be concluded that the time the EE houses need to have a positive impact on the family budget becomes smaller when the cost of houses decreases. In the first scenario the EE house of 35 m2, built at the minimum price offered on the market, needs 11 years to have a positive impact on the budget. As for the EE houses of 35 m2 built at the maximum price, 16 years will be required to recover the net costs, even though EE houses offer almost two times less consumption of fuel/energy. As the total floor area and the cost per m2 of houses increase, the payback period becomes longer. For the third and forth scenarios, when houses of 65 m2 were analyzed, the initial cost of construction could be paid off after 14 and 20 years, respectively. But given the fact that residential houses are commonly considered to be life time investments for Mongolian households, the resulted payback periods are acceptable, as they are within the range of 11-20 years.

B. Cash flow analysis

This analysis assumes a mortgage of 10 years, based on terms and conditions offered by XacBank, a local commercial bank offering low interest rate housing loans. The bank's terms and conditions were chosen after a careful analysis of housing loan terms and conditions offered by several other commercial banks currently operating in Mongolia. The cash flow analysis is done to show the possible mortgage burden on the family budget and to estimate whether the investment made to construct EE houses can be more desirable than the investment in traditional houses given the current mortgage conditions and the energy cost savings. Two different types of scenarios were analyzed depending on the required down payment amount and the offered interest rate: first scenario looks at a soft track with more favorable mortgage conditions /down payment of 20% and annual interest rate of 18%/ and a hard track with less favorable loan requirements /down payment of 50% and annual interest rate of 21%/.

Scenario 1: Soft track

The mortgage finances 80% of the total cost needed for the building of EE houses. The current annual interest rate of 18% was chosen to perform the analysis. Based on the amount of loan to be taken, the monthly and annual mortgage payments were calculated through mortgage payment calculation programs available online (Transbank 2012). Table 10 shows the total amount of loan, monthly and annual mortgage payments.

Table 10: Total amount of loan, monthly and annual mortgage payments

	loan amount (80%) (thousand MNT)	**mortgage payment (monthly) (thousand MNT)**	**total mortgage payment (annual) (thousand MNT)**
1.1. 35 m2 (min)			
EE house	16364.3	294.8	3538.3
traditional house	9098.3	163.9	1967.2
1.2. 35 m2 (max)			
EE house	23187.5	417.8	5013.6
traditional house	12598.8	227	2724.1
1.3. 65 m2 (min)			
EE house	30391	547.6	6571.2

traditional house	16896.8	304.4	3653.4
1.4. 65 m2 (max)			
EE house	43062.5	775.9	9311
traditional house	23397.9	421.5	5059.1

After determining the total amount of mortgage to be paid by households, the difference in mortgage payments and energy costs were calculated to find out whether the investment in EE houses was attractive or not in the given scenario (see Table 11).

Table 11: Difference in mortgage payment and energy costs

	difference in mortgage payment (annual) (thousand MNT)	**difference in energy costs (annual) (thousand MNT)**	**total yearly difference (thousand MNT)**
35 m2 (min)			
EE to standard house	1571	-872	699
35 m2 (max)			
EE to standard house	2289.4	-872	1417.4
65 m2 (min)			
EE to standard house	2917.7	-1252	1665.7
65 m2 (max)			
EE to standard house	4251.9	-1252	2999.9

Scenario 2: Hard track

For the hard track scenario, the mortgage finances 50% of the total cost of construction and the annual interest rate equals 21%. As in the previous track analysis, the monthly and annual mortgage payments were calculated (see Table 12) along with differences in mortgage payment and energy costs (see Table 13).

Table 12: Total amount of loan, monthly and annual mortgage payments

	loan amount (80%) (thousand MNT)	**mortgage payment (monthly) (thousand MNT)**	**total mortgage payment (annual) (thousand MNT)**
2.1. 35 m2 (min)			
EE house	10227.7	204.4	2453.8
traditional house	5686.4	113.6	1364.2
2.2. 35 m2 (max)			

EE house	14492.1	289.7	3476.9
traditional house	7874.3	157.4	1889.1
2.3. 65 m2 (min)			
EE house	18994.3	379.7	4557
traditional house	10560.5	211.1	2533.6
2.4. 65 m2 (max)			
EE house	26914	538	6457.1
traditional house	14623.7	292.3	3508.4

Table 13: Difference in mortgage payment and energy costs

	difference in mortgage payment (annual) (thousand MNT)	**difference in energy costs (annual) (thousand MNT)**	**total yearly difference (thousand MNT)**
35 m2 (min)			
EE to standard house	1089.5	-872	217.5
35 m2 (max)			
EE to standard house	1587.7	-872	715.7
65 m2 (min)			
EE to standard house	2023.4	-1252	771.4
65 m2 (max)			
EE to standard house	2948.6	-1252	1696.6

Summary

As it can be concluded from Tables above, at present both soft and hard tracks, none of the investment patterns can prove to be attractive. At the soft track, even though the offered mortgage terms and conditions are considered to be more or less favorable for households given the present banking sector situation in Mongolia, the investment in EE houses through the current mortgage terms and conditions is not appealing for ger area households.

The average monthly income of households residing in ger areas vary, being 215.6 thousand MNT (154 USD) in mid tier ger areas and 312.2 thousand MNT (223 USD) in city center ger areas (see Table 14). According to the cash flow analysis undertaken, for both soft and hard tracks, the monthly mortgage payments for loans taken with a purpose to construct

EE houses range between 204.4 thousand MNT (152 USD) – 775.9 thousand MNT (579 USD). Due to the huge influence of hidden (underground) economy in Mongolia, the actual amount of income of ger area households could be higher than indicated in the source. However, it can clearly be seen that loans at current mortgage terms and conditions would be a tough burden on ger area households' monthly budget, and it even can be concluded that the households might not be eligible for such loans.

Table 14: Income of households in ger area zones, 2010

	monthly income (thousand MNT)	**annual income (thousand MNT)**
city center ger area	312.2 (223 USD)	3746.4 (2676 USD)
mid tier ger area	215.6 (154 USD)	2587.2 (1848 USD)
fringe ger area	229.6 (164 USD)	2755.2 (1968 USD)

Source: World Bank Mongolia, "Enhancing policies and practices for ger area development in Mongolia" report, 2010

Note: Exchange rate effective 1 USD = 1400 MNT (as of January 2009 indicated in the above source)

As it was mentioned above, the cash flow analysis was carried out with a purpose of estimating whether funding of additional costs for EE houses through mortgage loans at current terms and conditions could be an optimal option or not. After having demonstrated that it cannot be an effective way of funding suitable for ger area households, attempts were taken to determine the most favorable loan duration, interest rate and down payment conditions, at which the actual investment in EE houses could become attractive. For that a sensitivity analysis was carried out.

C. Sensitivity analysis

A sensitivity study analyzing the influence of interest rate and the duration of obtainable loans was carried out to investigate at what mortgage terms and conditions investments in EE houses could be appealing and profitable for home owners.

Various scenarios of mortgage with different interest rates and loan durations were tested. To consider the influence of interest rates and the overall loan duration, scenarios are simulated at interest rates of 6%, 10% and 18% and loan duration of 10, 15 and 20 years. 6% has been taken as the lowest possible annual interest rate for housing loans currently offered in Mongolia, and 20 years as the most feasible loan duration. The results of the sensitivity analysis are presented in Tables below.

Table 15: Scenario 1 - Down payment 20%, loan duration 10 years

Interest rates	**Total yearly difference (thousand MNT)**			
	35 m2 (min)	35 m2 (max)	65 m2 (min)	65 m2 (max)
6%	96	538.6	545.7	1367.8
10%	280.2	807.1	887.9	1866.4
18%	699	1417.4	1665.7	2999.9

Table 16: Scenario 2 - Down payment 20%, loan duration 15 years

Interest rates	**Total yearly difference (thousand MNT)**			
	35 m2 (min)	35 m2 (max)	65 m2 (min)	65 m2 (max)
6%	-136.2	200.2	114.4	739.2
10%	64.9	-	-	-
18%	-	-	-	-

Table 17: Scenario 3 - Down payment 20%, loan duration 20 years

Interest rates	**Total yearly difference (thousand MNT)**			
	35 m2 (min)	35 m2 (max)	65 m2 (min)	65 m2 (max)
6%	-247.4	38.3	-91.8	438.5
10%	-30.5	-	310.6	-
18%	473.6	-	-	-

Summary

EE houses can have a positive impact on the family budget only if mortgages with more favorable conditions than the ones offered currently by the commercial banks in Mongolia, are made available for ger area households. The longer the loan duration, the lower the interest rates, the lesser the burden on the family budget. As for the Scenario 1, when a mortgage of 10 years was analyzed, it could not prove to be efficient for any of the cases tested. Mortgages of 15 years in the Scenario 2 offered at interest rates of 6% resulted to be attractive for households, as they offer savings starting from the 1st year. Lastly, out of the three cases studied, Scenario 3, when the lenders require 20% down payment, but at the same time offer a loan of 20 years and an annual interest rate of 6-10%, turned out to be the most favorable. For instance, a household that purchased an EE house of 35m2 at the minimum cost offered on the market can save up to 247.4 thousand MNT (184 USD) annually even after paying for both the mortgage and the energy. Note here that this household pays almost 2.5 times less for the energy, as the EE house reduces the overall energy consumption of the household.

Out of curiosity a simulation was done for a mortgage of 30 years, annual interest rate of 3.05% with no requirement for down payment, currently offered by the KfW bank of Germany for energy efficiency measures. According to calculations made, the family would greatly profit from the low interest loan, getting an annual savings of 569.2 thousand MNT (424 USD).

Overall conclusion

For the study purposes the minimum and maximum costs of two categories of houses were analyzed: energy efficient and traditional houses with a total floor area of 35 and 65 m2. Based on the current use and cost of coal, corresponding energy demand and energy costs of houses were determined. All the data obtained were used to perform a cost study consisting of three different analyses: break even analysis, cash flow analysis and sensitivity analysis.

The break even time was calculated comparing the total amount of actual construction costs and the energy cost savings for different samples of buildings. The break even time for EE houses with lesser price and a smaller amount of floor area was considerably shorter than the break even period of bigger houses with higher costs. Out of four scenarios analyzed, EE houses in Scenario 1 with 35 m2 of area, built at the minimum price offered on the market, needed 11 years (the shortest period out of all cases studied) to have a positive impact on the family budget. The EE houses of a total floor area of 65 m2 and constructed at maximum costs resulted in the highest break even time of 20 years.

The cash flow analysis calculated the impact of the choice of housing type on the family budget. The results show that at both soft and hard tracks analyzed, none of the investment patterns can prove to be attractive. At the soft track, even though the offered mortgage terms and conditions are considered to be more or less favorable for households, given the present banking sector situation in Mongolia, the investment in EE houses through the current mortgage is not appealing for ger area households.

Therefore, attempts were taken to determine the most favorable loan duration, interest rate and down payment conditions, at which the actual investment in EE houses could become attractive, through sensitivity analysis. EE houses can have a positive impact on the family budget only if mortgages with more favorable conditions than the ones offered currently by the commercial banks in Mongolia, are made available for ger area households. The longer the loan duration, the lower the interest rates, the lesser the burden on the family budget. Out of the 3 cases studied, the Scenario 3, when the lenders require 20% of down payment but at the same time offer a loan of 20 years and an annual interest rate of 6-10%, turned out to be the most favorable.

CHAPTER 4: *Conclusion*

4.1. Relevance of the research to the energy poverty and climate change mitigation agenda: some specific conclusions and recommendations

In the face of increasing effects of climate change and the growing energy demand, the developing countries shall address both the climate change and the energy security issues through development focused long term policies that are guided by domestic priorities. Pursuing energy efficiency in new buildings is vital for developing countries as the construction sector can offer the largest potential for cost effective GHG mitigation and energy poverty alleviation in the next coming decades. Throughout the paper, it has been demonstrated that a long-term and sustainable solution to climate change and energy poverty problems lies in the buildings sector, specifically in the introduction and promotion of EE houses and replacement of inefficient building stocks by high-efficiency ones.

According to different scenarios designed and suggested by GEA and IPCC experts (GEA 2012, IPCC 2007), a reduction of global energy consumption by up to 40-46%, and decrease of approximately 29% of the projected baseline CO_2 emissions by 2020 are achievable through the proliferation of best practices of high performance energy efficient buildings, their design, construction and operation techniques and technologies. The quantifiable or monetizable benefits of highly energy efficient buildings in terms of the reduction of buildings operating and other related energy/fuel costs can be a significant factor in alleviating the livelihood of thousands of households currently stuck in energy poverty. Investments in energy efficiency permanently lower energy use in low income households while reducing government and energy provider outlays on fuel assistance and social tariffs (GEA 2012). There are also non-monetizable benefits in many respects such as the elimination or reduction of indoor and outdoor air pollution, related mortality and morbidity, other health improvements and benefits, advances in energy security, and increased comfort and well-being of households.

Addressing the main aim of the research, Mongolia - a country stricken with harsh climate and natural disasters, often aggravated by climate change, and where the energy poverty problem is most apparent in ger[7] areas of the capital city Ulaanbaatar among low income households - has been taken as an example to demonstrate the possibility of tackling both the energy poverty and CO_2 emissions problems through energy efficient housing solutions.

Ulaanbaatar can be largely characterized by the growing peri-urban ger areas, which have existed for decades and that consist of unplanned settlements of low and middle income households. Ger districts remain to be the only place of settlement for rural migrants, yet highly unplanned and polluted, hugely populated. The low efficiency of the heat supply system, lack of proper heat and power distribution mechanisms, high consumption level of low quality raw coal by the majority of ger area households along with long cold winter days have greatly contributed to the problems of air pollution and energy poverty in Ulaanbaatar ger districts. In order to cope with the harsh Mongolian winter, ger area households that mostly live in under heated, poorly insulated dwellings, can spend up to 60% of their annual income on the purchase of required amounts of coal and firewood (WB 2010). This clearly demonstrates how deep the energy poverty problem is in Ulaanbaatar ger districts, and how much financial burden it can be on the household’s budget, given the fact that mostly low and middle income households reside in this area.

Besides the energy poverty problem, there is a severe air pollution issue in the city, especially during the winter time. According to the National Air Quality Office of Mongolia, national air quality standards of SO_2 are exceeded by a factor or two; the estimated amount of

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[7] Mongolian traditional dwelling

ground level air pollution in terms of PM_{10} during the winter time was 3 to 6 times higher than the levels recommended in Europe and North America, and 10 to 20 times more than the World Health Organization standards (WB 2009). Living standards, livelihoods and well-being of ger area residents will continue to deteriorate if immediate steps are not taken to address critical issues such as the use of inefficient stoves in poorly insulated houses, the growing problem of air pollution, subsidization through the provision of low-cost energy, the impact of fluctuations in energy prices, the widening gap between the income and housing level of households in ger and apartment areas.

The research has explored the less studied relation between energy poverty alleviation and climate change mitigation measures, and in that way filling in the research gap in this area, especially in a developing country like Mongolia. Based on the Mongolian case study analysis, it has been demonstrated that proper improvements in housing and wide application of low-energy, low-cost solutions not only help to reduce the GHG emissions and decrease the air pollution level, but also support the energy poverty alleviation, decreasing twice the amount of energy consumed, and similarly the energy/fuel costs.

The following findings are the most relevant to the research **objectives** formulated in previous sections:

- Given the current level of expansion of ger districts and the ever increasing socio-economic and environmental problems in the area, it is worth exploring new sustainable housing options – low cost, low energy buildings - that can meet the needs and requirements of ger area residents and which can be developed in conformity with the City Municipality ger area development plans.
- The research and analysis on the existing high performance buildings have demonstrated that dramatic reductions in the energy use in buildings are possible through enhanced building envelopes; more efficient heating, cooling and daylighting

through the maximized use of passive solar heating; efficient ways of combining different HVAC components; through better use and supply of hot water; and finally, through more energy efficient household/office appliances and devices. However, it is worth to be mentioned that all the energy efficient technological measures currently available in some developed countries, are not directly applicable in the harsh cold climate of Mongolia, where the winter temperature can be as low as -40^{0}C. Therefore specific energy efficient housing technologies adaptable and affordable for the cold climate of Mongolia should be explored and developed in the longer run.

- Energy efficient housing measures should be produced at an acceptable cost for the targeted beneficiaries. In the case analyzed, the challenge has been the affordability issue of EE houses to the Ulaanbaatar ger area households whose average monthly income is not always high enough in comparison with apartment area households. According to findings of the cost benefit analysis (for more detailed results see Chapter 3), carried out with an aim to determine the economic viability of high performance buildings in the Mongolian construction sector, the overall costs and additional investments required for the construction of energy efficient houses in the Mongolian context have been twice as much as traditional houses. However, the annual fuel consumption could decrease by a factor of two to three, and the normal payback period for houses of 35-65m2 ranged between 11-20 years. Given the fact that for Mongolian households a family property, especially private residential houses are considered to be a major life time investment, the EE houses can be quite an attractive investment in the longer run. However, most of the ger area households are low income, and they are willing to see their investment paid back soon, in a relatively short period of time, and therefore often sacrifice the long term benefits in favor of short term priorities.

- Although from an individual household perspective, investments in EE houses cannot be considered as an attractive one, from a public policy perspective high performance, energy efficient houses are beneficial solutions to many of socio-economic and environmental issues. Monetizable and non-monetizable benefits of energy efficient buildings in terms of increased energy security, enhanced living conditions and positive environmental impacts are much more significant and valuable than short term agenda items. This demonstrates that low-energy housing options would be economically and environmentally attractive in the longer term as alternatives to traditional types of buildings.
- Currently in developed countries and the places where the required construction materials are widely available and competitively priced and the know-how technology of high performance energy efficient buildings is familiar, the costs of EE houses are not necessarily higher than conventional houses. Further advances in the building technology, materials and know-how, and practical experience with planning and construction of energy efficient houses can facilitate the market penetration of such houses in developing countries, and consequently decrease the initial construction costs. Besides as energy efficient houses are mostly performance based houses, there are ways to design and construct such buildings in a more cost efficient way that is suitable and affordable for a specific country or region. Extra costs shall continue to decrease as architects and building engineers gain more on site knowledge and experience.
- As it can be concluded from the case analysis, given the current economic situation and the existing mortgage market in Mongolia it is hard to demonstrate the attractiveness of investment in EE houses over traditional houses especially when offered to households of low and middle income. Only through innovative policy

portfolios, measures and financing schemes it will be possible to remove the financial barriers in order to capture the cost effectiveness and energy conservation potential of energy efficient buildings in the Mongolian context. When energy saving buildings are to be promoted at larger scale, favorable socio-economic conditions should be created to encourage the purchase and construction of such houses in ger districts of Ulaanbaatar, where the most vulnerable parts of the population reside.

Based on the results of the cost analysis, the following recommendations can be drawn:

- ➢ Adopt effective policies and programs on a Government level to encourage energy efficiency financing in new construction. Development of a sustainable housing in Ulaanbaatar ger districts should become a priority for decision makers. Institutions like the Mongolian Housing Finance Corporation[8], Development bank of Mongolia[9] and other related financing organizations should be active in developing and implementing larger scale housing programmes in ger areas in accordance with the current projects such as the "100 000 households housing" project[10], recently being initiated by the Government.
- ➢ To support the programs, the Government should develop financing options to help lower the cost of constructing EE buildings. For that purposes the Government may cooperate with energy services companies, construction companies, energy efficiency organizations, home owners and others to share information and leverage existing efforts. All stakeholders may assist to design, develop, and market energy efficiency financing programs and policies.
- ➢ As the energy poverty issue can be solved jointly with other environmental issues, special public funds dedicated for environmental priorities can be merged with funds

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[8] http://www.ossk.mn/ossk/

[9] http://www.dbm.mn/mn

[10] 100 00 households housing project is a newly developed housing project implemented in Ulaanbaatar city with an aim to provide city residents with wider opportunities to purchase new apartments through low interest rate loans (annual interest rate of 6%, down payment 10%, loan duration 20 years). The programme refers to only apartment building purchases.

for socio-economic issues, such as energy poverty, and in that way broaden the financing opportunities in both directions.

- The Government should be well aware of the unique requirements and conditions of the targeted ger area residents while pursuing to develop appropriate housing financing schemes. The Government should coordinate with local municipalities, commercial banks, and other financing partners to determine the range of financing needs and the most favorable terms and conditions of mortgage loans for ger area households. EE houses can have a positive impact on the family budget only if mortgages with more favorable conditions than the ones offered currently by the commercial banks in Mongolia, are made available for ger area households. The longer the loan duration, the lower the interest rates, the lesser the burden on the family budget. If deemed necessary, the Government should aid with larger subsidies to make EE houses more attractive and profitable to households in the longer run.
- There is a high need to explore opportunities to decrease the actual cost of high performance buildings, but at the same time to improve the quality of EE houses offered on the market, making use of the most up to date, cost effective construction technologies and building materials, that could be well adapted into the extreme climatic conditions of Mongolia. Pursuing so, the Government has to assist the currently operating construction companies that incorporate energy efficiency into their building practices, encouraging them through discounted permit fees, reduced taxes and other forms of subsidies.
- Advance the construction of EE houses in conformity with the ger area and urban development plans determined by the City Municipality and other city planning institutions.

- Increase the general awareness about energy consumption and energy efficiency measures among the public, promote the advantages that EE houses can offer in terms of increased indoor and outdoor air quality, enhanced thermal comfort and amenity, and other health and environmental benefits. Encourage the construction and purchase of EE houses, by providing financial incentives and bonuses to interested households.

The capacity of poor people to change their energy consumption patterns, reduce energy expenditures, and at the same time to enhance their living conditions, creating healthy surrounding environment with clean air is critical for Ulaanbaatar's future development. Further analysis on how to promote energy efficiency in the construction sector, while addressing the most important socio-economic and environmental problems on the national agenda, should be fostered for better policy responses to urgent development issues.

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ANNEXES

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