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ENERGY EFFICIENCY IN SPACE HEATING

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ABSTRACT

Buildings are the largest consumers of energy in the EU and the OECD countries, ahead of transportation and industry, consuming around 40% of the total energy consumption. Private households use over 80% of the required final energy for heating rooms and water but less the 20% is used for electrical devices and lighting. There is therefore, an enormous saving potential in the building heating sector.

Renovation of older buildings and more stringent building codes for new buildings is probably the most effective method of making the buildings more energy efficient. Other very important factors are to educate and involve the end user, the consumer, and make the energy selling and pricing methods important incentives to achieve responsible sustainable use of the energy source. Up to 50% savings in heat load can be expected by improving the insulation and windows of old buildings.

The Government or the Community has to be in the lead of improving the existing houses by giving grants or cheap loans to support improved energy efficiency of buildings. The Government should also promote the use of environmentally friendly energy.

In the near future many new houses will be built with the aim of “zero energy” consumption or close to it. These are now being tested in many OECD countries with success and can be foreseen to be a request in the near future.

1. INTRODUCTION

Buildings are the larges consumers of energy in the EU and the OECD countries, ahead of transportation and industry, consuming around 40% of the total energy consumption. Private households use over 80% of the required final energy for heating rooms and water but less the 20% is used for electrical devices and lighting.

The building sector has therefore enormous savings potential in energy consumption in the OECD countries and also in other countries where energy is used for heating and cooling by simply improving the energy efficiency in buildings and appliances.

Energy used for heating each unit area of floor in older Chinese residential buildings is estimated to be the double of similar houses in the new areas in China and OECD countries. The potential for energy saving in both urban as well as in older houses in rural areas of the colder regions in China is therefore enormous. Today coal is the main source of fuel for central heating systems and will continue to be so for the foreseeable future in China. Saving energy by simply improving insulation in houses is a method that should be considered thoroughly.

Now, when energy prices are increasing and the use of fossil fuels should be avoided as much as possible to cut down on CO_2 emission, one must try to save energy with all means, such as house renovation, improving the heating method, using different heating sources or re-using energy from the house or other sources. This is a simple, economical and very effective way of reducing heating cost.

One must look at all aspects along the “life cycle” of new and existing buildings. One should concentrate on areas with cold climate since the energy consumption is largest en those areas but in reality all areas need close attention. In areas where energy for heating is needed in the winter time and energy for mechanical cooling is used in summer time it is very important to design the buildings in an economical way to save and conserve energy both in the summer as well as in the winter.

"Energy Efficiency in Buildings" aims at producing economical and socially acceptable solutions, saving energy by insulation, re-using energy and adding comfort to those living in the buildings.

In this paper we will concentrate on the houses themselves, design, insulation etc, but not on the outside heating systems. Energy saving in simply improving the design of houses can be equally important as energy saving by more effective heating system.

2. MEASURES TO SAVE ENERGY

In the first oil crises back in 1973 when the price of oil went up from 10$/barrel to 40$/barrel in only one year a massive governmental support for reducing the use of oil was launched in Iceland. The government did among other things the following:

- They gave grants and aid for improving the insulation of all existing houses.
- They issued new and more stringent building codes on insulation and implementation of it.
- They gave grants and aid to communities for new investigations for geothermal water for house heating.

At that time more then 50% of all houses in Iceland were heated with oil, 5% with electricity and 45% with geothermal water. Many of the housed were poorly insulated and with single glass windows.

The government also started supporting geothermal investigations and drilling geothermal wells to enable smaller communities to find hot water and use it for house heating.

The issue at that time was not to reduce the CO_2 emission but to reduce the cost of heating houses and especially reduce the oil cost (Figure 1). Now some 30 years later more then 90% of all houses in Iceland are heated with geothermal water (the rest with electricity), still the quantity of 80°C geothermal water needed for heating houses has decreased from around 2.0 m^3 hot water/m^3 house/year to 1.3 m^3 hot water/m^3 house/year or by 35%. At the same time Iceland has completely eliminated the use of oil (no coal or gas is used for heating) for house heating and therefore also reduced CO_2 emission. The cost of geothermal heating is also much lower than heating with oil or any other energy source.

A similar situation is seen in the Scandinavian countries and Europe as whole. The building codes have been stringent, increasing the insulation and thus reducing the heating cost and CO_2 emission.

The official guidelines on insulating houses was improved in Iceland and called for much more insulation and double glassing in all houses. The implementation was very strict.

It is very important that each and every household owner has benefit of improving his house to save energy. It is also important that the local government assists and promotes some kind of energy saving program such as;

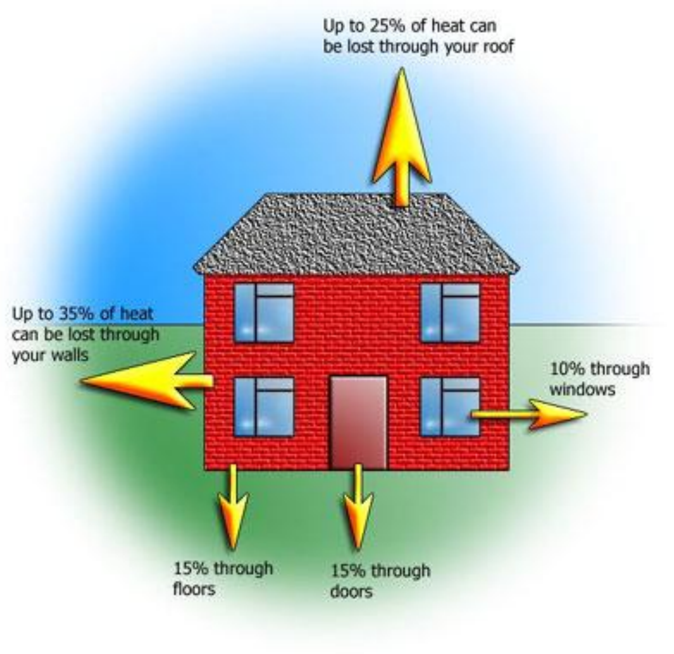

FIGURE 1: Energy loss from a typical building in percentages.

- Grant aid programs
- Building renovation programs
- Create a strong incentive for energy efficient construction and renovation

Ideas could include a "one stop shop" where homeowners, after receiving their energy ratings, could access grants and get quotes at the same time to carry out the improvements needed.

Subsidies should be available from energy suppliers to help fund the costs of insulation, and other energy efficiency improvements.

Improvements to save energy could amongst others be the following;

- Improve the insulations in outer-walls and roof, make the insulation thicker or of better quality.
- Improve insulations in windows, double glassing.
- To heat common household staircases
- Improve the heating system by placing radiator correctly,
- Improve the heating system control
- Enable the end-user to control the quantity of heat used and pay according to their consumption. This point should though be taken with care, as too detailed billing system often becomes too expensive in construction and operation to serve effectively. Metering energy consumption of one apartment is often unnecessarily detailed and expensive, while metering all connected apartments in one staircase can be very effective and fair.

Programs like these with governmental support have been ongoing in several counties like some OECD countries and also in China in places like Beijing and Tianjin.

It is important for the end users (consumers) to have easy access to technical help as well as aid or funds to improve their houses. New research shows that consumers want to know more about energy efficiency, with the majority supporting the idea of energy ratings.

The oil, gas and coal prices have nearly doubled over the last few years and no end seems to be in sight for the reduction of cost of energy. Improving insulation of houses and thus reducing energy bills becomes more and more feasible for all house owners, as less energy will be needed for heating.

3. EXAMPLES FROM BEIJING

To give a real example of potential energy saving in house heating we will look at a town close to Beijing and calculate house insulation in older buildings, measure energy consumption and compare with similar houses using insulation according to latest building code.

To determine the energy requirements of the area, two separate models were evaluated; one for older buildings with poor insulation and another for new buildings that confirm with more recent Chinese building standards. In addition, two different models were used for the evaluation, a static model and a dynamic one.

In order to obtain the heat load for the buildings (old and new), a five-storey block apartment with a net area of 500 m^2 per floor and 2.7 m height between floors was studied. A typical apartment was considered to be 70 m^2, housing 3.25 inhabitants. Dynamic simulations were made using BSIM, a software written by the Danish Building Research Institute. The resulting model is able to produce load duration curves for space heating, taking into account the sun load and the internal load. In addition, it enables to get an estimation of the expected energy consumption per square meter of building.

When evaluating space-heating requirements, the dynamic model takes the following into account:

- Hourly weather database for outdoor temperature, wind and sun radiations (based on data provided by the Meteorological Office in Beijing)
- Thermal characteristics of the building and its inertia (based on the Chinese code)
- Internal heat input (heating system, infiltration, people and eventually equipment)

The internal heat input represents the thermal energy given off by the dwellings inhabitants and their activities. This value is not dependant on the type of dwelling, i.e. it is the same whether the building is an old or a new one. The value obtained from an evaluation of the internal heat input is considered 5 W/m^2 of floor space.

A dynamic model was used to produce load duration curves from which the annual energy consumption was evaluated (Figure 2). The value for domestic hot water requirements from the static model, 5 W/m^2, was used for the evaluation.

Figure 2 depicts the load duration curves evaluated for both old and new buildings. They are the results of a computerized simulation for the year of 1991. Then, internal load is only considered during the heating period and domestic water is considered constant through the year. The load duration curves is depicted in cumulated hours for space heating and for domestic water usage, taking into account the internal heat input. The heating system is designed to maintain an indoor temperature of 18°C as requested by Beijing standard.

The heating period estimated by the dynamic model lasts 220 days (7.3 months approximately). The heating period is thus defined as occurring whenever the outside temperature falls below 15°C. According to the weather data, this happens approximately 223 days a year. In addition, the daily average outside temperature drops below 5°C approximately 150 days a year. The heating period estimated by the dynamic model is about one month longer than the current heating period which is 180 days per year in Beijing. From this, it can be deduced that at present no heating is supplied when the temperature outside is over 10°C.

In the future, the heating period is expected to increase. In addition the indoor temperature might also rise to the 20°C encountered in most European homes.

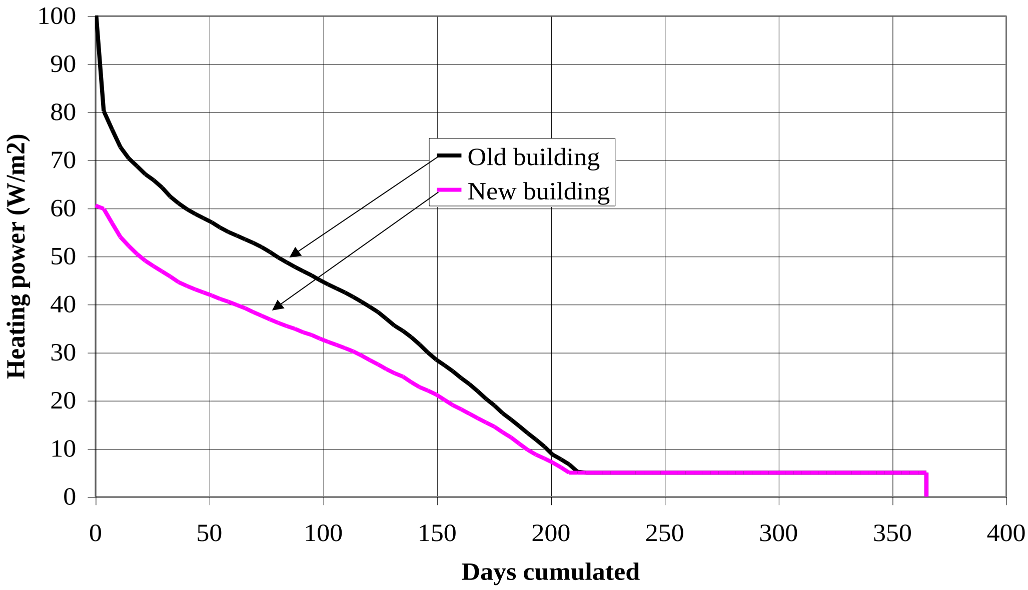

FIGURE 2: Load duration curves for new and old buildings

In Beijing, the calculated power and energy requirements for a new building are the following:

- Peak load power 60 W/ m^2 (including 5W/ m^2 for domestic hot water)
- Annual total energy demand 132 kWh/ m^2 for space heating (including 30 kWh/m^2 for domestic hot water)

This corresponds to utilization of the maximum power available for the duration of 2.930 hours annually.

The calculated power and energy requirements from the same model for an old building are as follows:

- Peak load power 97 W/ m^2 for space heating (including 5W/ m^2 for domestic hot water)
- Annual total energy demand 192 kWh/m^2 for space heating (including 30 kWh/ m^2 for domestic hot water)

This corresponds to utilization of the maximum power available for the duration of 2.310 hours annually.

The annual coal used for heating water for space heating in the same area was investigated. The energy consumption was approximately 35 kg of coal per m^2 of housing. The raw energy derived from burning coals is approximately 29 MJ per kg of coals, or 8 kWh/kg. Thus, the raw heat produced, solely for space heating, amounted to 280 kWh/ m^2 (35 kg/ m^2 x 8 kWh/kg).

The installed power made available by the boiler stations was 132 W/ m^2, a value that far exceeds the demand since it is 30% higher than the peak demand calculated, or 97 W/ m^2. Since the efficiency is highest when burners run at 60-70% of maximum capacity, this gives us reason to believe that the efficiency of coal burning in this area in Beijing in boiler stations is high. Up to 80% efficiency can be expected under such circumstances.

Assuming that this is the case in the boiler stations, i.e. a coal burning efficiency of 80% is taken into account and an estimated 10% heat loss from the distribution network, the resulting annual energy consumption for space heating is 200 kWh per m^2.

We have shown earlier that the energy consumption for space heating and domestic hot water heating should be 132 kWh per m^2 for new buildings and 192 kWh per m^2 in old buildings. This number takes into account fully controlled heating when the temperature falls below 15°C. The difference between the actual energy output, of 200 kWh per m^2, and the one derived from calculations, of 175 kWh per m^2, has led to speculations, namely that the insulation in the actual buildings is less than adequate, moreover that the boilers might not operate as efficiently as expected and that the ratio of old buildings to new might be higher than assumed. Another explanation could be that the consumer is actually keeping the indoor temperature higher than the regulated value of 16-18°C.

We have found similar numbers in several other cities in China (Xianyang). The required maximum power in older buildings is close to 90 W/m^2 and in new buildings around 50 W/m^2. The annual energy consumption is therefore around 200 kW/m^2/year for older buildings and 100 kW/m^2/year in new buildings.

By renovating old buildings in cold areas (better insulation, window improvement, heating system improvement and implementation of a suitable tariff system) the energy consumption can be reduced by up to 50%. The added building cost is of the range of 5 to 10% depending on buildings and is very cost effective over the lifecycle of the building. Renovation would also reduce the coal consumption and hence the CO_2 emission. No single method can save more coal and CO_2 emission than renovation of old houses in cold areas heated with coal.

4. GOVERNMENT AND COMMUNITY SUPPORT

To obtain energy efficiency in house heating the aim should be to reduce energy consumption by all means. This could include among other things the following issues;

- More stringent building codes for insulation and glassing in windows.
- Research on house improvement to reduce energy consumption.
- Education in schools, communities and smaller industry on energy saving.
- Metering systems and charging for energy use that supports energy saving.
- Improve insulation and glassing in older buildings

The households in colder regions use considerable amounts of energy and there is ample potential to lower the energy bill as much as 50% for most consumers. One of the primary objectives of each community (or government) is to provide consumers and public authorities with information in the field of energy efficiency and promote rational use of energy for space heating, putting emphasis on cold areas. In addition each community should create and promote educational material for schools and consumers, as well as small and medium size companies.

The Government or the Community has to be in the lead of improving the existing houses by giving grants or cheap loans to support added insulation, double glassing and other improvements. The effect should be visible for the consumer in form of lower heating bills, so the metering system has to reflect the consumption of energy, not as now, where it is common only reflecting the area heated.

The government should promote the use of environmentally friendly energy for house heating, such as solar-, wind-or geothermal energy, by some kind of support or subsidiary. This can be done through aid or reducing taxes on companies producing environmentally friendly energy.

CO_2 saving and refund from CO_2 international funds are also possible means of funding house improvement programs.

5. METERING ENERGY

It is very important to enable the consumer to control the quantity of heat used and pay according to consumption. This is the only way to make each and every consumer active in energy saving in house heating.

The billing for energy in China today is mostly based on a square meters price per year and has nothing to do with energy consumed or energy wasted. This billing method does not promote any house improvement such as added insulation, double glassing or keeping windows shut in cold periods. This must be changed in order to implement additional house improvement and energy saving.

By choosing a suitable charging method with respect to the energy source, one can establish an incentive for users to follow an applicable using pattern. The consumer has to have the choice to save energy by for instance adding insulation or selecting the indoor temperature and thus saving on energy and at the same time carry the burden of the price.

To minimize their energy bill, users could, for instance:

- Insulate walls further and put up windows with more layers of glass (double, triple, etc.).
- Choose to burn some kind of other energy media, natural gas from network, wood chops, etc. for heating instead of purchasing energy from the network.
- Choose to purchase heating for one room only (e.g. living room), or not at all.

A metering method is a combination of three types of fees. These are as follows:

- **One time connection fee:** This is a fee that an owner pays for connecting the house to the district heating grid. This fee is used to pay for parts of the installation cost of the heating utility. The remaining installation cost is paid by users with usage fees.

- **Fixed annual fee:** A fixed annual fee is nearly always used. This can be the only fee, or part of the fee depending on the charging method used. The fixed annual fee often pays for fixed maintenance costs of the heating network.

- **Variable fee:** A variable fee is used in many types of charging methods. This fee is often related to each user's consume, for instance as a proportion of incoming flow or used energy.

It is worth mentioning that the discussion and conclusions on each and one of the metering methods are based on authors' experience. Thus, the coverage is not complete and will probably never will be. Any specific feature that is desirable in one type of district heating network may be very undesirable in another location; different traditions in heating etc. may affect this wrap-up somewhat.

It is strongly emphasised that choosing an applicable metering method is extremely important to reach a goal of running an economical and practical (geothermal) district heating utility.

6. IMPROVING INDOOR CLIMATE AND QUALITY OF LIFE

Most of northern China has extreme temperatures that go as low as -20°C in winter and as high as 40°C in summer. Housing conditions such as cold indoor temperatures can result in adverse effects on human health. The minimum ideal comfort temperature for dwelling-houses is 18°C during winter, many western countries requiring 20°C as a standard or even higher (Figure 3).

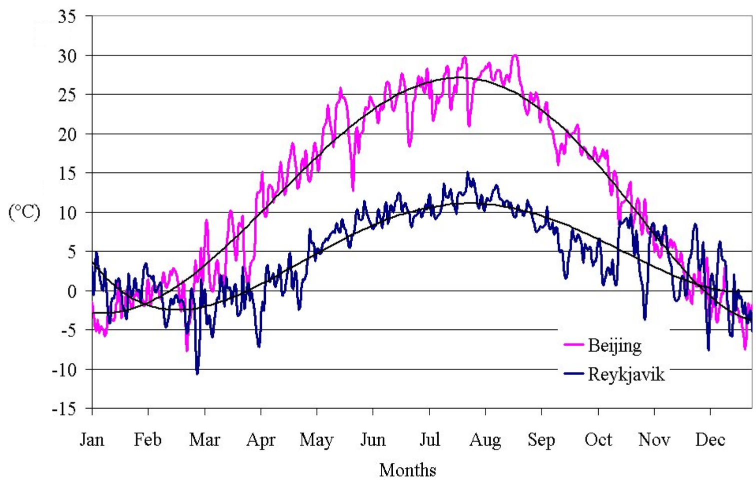

FIGURE 3: Temperature variation in Beijing (red) and Reykjavík (blue) for the year 1991.

Heating is usually required to sustain 18°C indoor when outdoor temperatures fall under 15°C. Outdoor temperatures in Tianjin, Beijing, Xian and Xianyang fall below 15°C during around 6 months. The current district heating system provides hot water for space heating 4 to 5 months a year, which means that the indoor temperature does not reach the ideal 18°C for about 1 to 2 months a year, in the fall and in the spring when the outdoor temperature is between 7°C and 15°C.

7. ZERO ENERGY BUILDINGS

A zero energy building is a general term applied to a building with a net energy consumption of zero over a typical year. Although zero energy buildings remain uncommon in developed countries, they are gaining importance and popularity. The zero-energy approach is promoted as a potential solution to a range of issues, including reducing carbon emissions, and reducing dependence on fossil fuels.

Zero Energy Buildings or buildings approaching zero energy use are definitely the future. Many countries are working on this solution and it is gaining momentum. This will not be done in one step but gradually. Different solutions are already used such as:

- Highly insulated enclosure
- Operable windows and natural ventilation
- Reuse of heat energy with in the house
- Daylight design
- Solar panels on roof
- Ground source heat pumps

Traditional home buildings are not adequately responding to the need for energy effective and resource efficient homes. The concept has to be redesigned. Japan and the European Community, faced with higher energy costs and high density housing conditions, have been leading the way globally with innovative ideas and financial incentives to produce better housing.

8. CONCLUSIONS AND RECOMMENDATIONS

An enormous amount of energy can be saved simply by improving the energy efficiency of existing houses (insulation, heating systems etc) and building new houses better in the future.
Improving the end-use energy efficiency is among the most economical issue to be tackled in the near future. This can start immediately and can be executed in as small or big steps as any community or government can handle.

The Government must give a clear message to the consumer (public) on how they want to see the improvement and energy savings in the future. To support energy saving the Government should;

- Support education in energy saving both in schools, in communities and in smaller industries.
- Support research and house improvements which reduce energy consumption, both in cold regions in the winter time as well as energy consumption in the summer time.
- Support rules improving the metering of energy used in house heating making the consumer active and responsible in energy saving.
- Give grants and aid to consumers to improve the insulation and glassing of existing (older) houses.
- Issue stringent building codes for insulation and implement them.
- Support the use of environmentally friendly energy (wind-, solar-, geothermal) by grants or by lower taxes.

The future is to build so called "Zero Energy Houses" where no outside energy is needed. The houses will be very well insulated, reusing the inside energy and using solar panels on roof, possibly geothermal or wind energy within the site. "Zero Energy Houses" are already constructed in various parts of the world but current cost structure prevents widespread adoption by contractors and consumers. The future work should be done by researchers in close collaboration with architects, engineers, builders, suppliers and building owners to promote a more sustainable approach to construction. The aim will be to produce houses that are self supporting in energy, not needing any or very limited energy from the outside.

The future “Zero Energy Houses” do not prevent us from saving energy by improving our houses today. This is a priority that saves enormous energy at an economical cost.

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