Research and Development of Energy Saving in Buildings of USA

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Abstract: The main purpose of this study was investigation research and development methods and implementation of them in United States of America. The United States is the second-largest energy consumer through the world. The building sector is one of the major energy-consuming sectors in USA; which energy consumption of the buildings in the country represents about 27% of the total energy consumption. Therefore, some NGos helped the USA government to implement an excellent plan to energy conservation in buildings section and individual domestic consumers controlled half of energy consumption. NGOs expanded best practices in building design, construction and made retrofitting result in homes that are profoundly more energy conserving than average new homes that includes insulation and energy-efficient windows and lighting. Part of results of this research showed that smart ways to construct homes such that minimal resources are used to cooling and heating the house in summer and winter respectively can significantly reduce energy costs.
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1. Introduction

Every year, much of the energy the U.S. consumes is wasted through transmission, heat loss and inefficient technology -- costing American families and businesses money, and leading to increased carbon pollution. Energy efficiency is one of the easiest and most cost effective ways to combat climate change, clean the air we breathe, improve the competitiveness of our businesses and reduce energy costs for consumers. The Department of Energy is working with universities, businesses and the National Labs to develop new, energy-efficient technologies while boosting the efficiency of current technologies.

The existing detached houses are being retrofitted for energy conservation. It is important to evaluate the energy-saving effect of retrofitting a non-insulated house and to show the importance of retrofitting to home owners by presenting reliable data to them.

The energy performance and consumption of a house were measured and analyzed after retrofitting. Cost-benefit analysis was conducted in each of the retrofitting measures. The following results were obtained from the experiments that were conducted on the test house: The total reduction in the heating energy requirement achieved by retrofitting was found to be 56.1%, and the payback period of the initial investment for retrofitting was estimated to be five to six years.

Fig. 1. Perspective of an existing detached test house

New Residential Houses

The energy conservation problems of residential houses have been viewed macroscopically and microscopically in every detailed field related to the design, construction, auditing, and maintenance of houses. Especially, studies on energy conservation in a newly constructed house clearly emphasize the need to consider energy savings from the initial stage of house design formulation.

Table 1. Before-and-After Comparison

	Pre-Retrofit [%]	Post-Retrofit [%]	Improvement Rates [%]
Boiler efficiency	79.8	85.2	5.4
Heating Efficiency	66.8	75.2	8.4
Piping Losses	13.1	10.0	3.1
Boiler Losses	20.2	14.8	5.4

The modified heating load of the A-type experimental model house was reduced to 7% compared with the B-type house, due to heavy insulation. In the case of the attachment of the insulated door, the difference between the indoor and outdoor temperatures was decreased to 2℃ compared with the case when an insulated door was not attached. The difference between the daytime and nighttime indoor temperatures in the former case was smaller than in the latter one. The indoor temperature in the southern direction was 1.89~1.99℃ higher than that in the northern direction.

Development of a Model House Using Energy-Efficient Design Methods

Since 2011, the results of researches have been used to establish energy-saving methods in residences. Model energy-efficient housing plans were prepared for the demonstration of energy-efficient design methods in residences to architects, clients, and constructors, and for nationwide dissemination. The objective annual heating consumptions in dwellings and the thermal-comfort criteria of indoor environments in Seoul were also estimated.

Model designs of energy-efficient residences, and their specifications, were made after investigating the applicability of the current energy-saving methods in dwellings. After this, the annual heating loads and annual heating energy consumptions, and the costs of the construction of these buildings, were estimated using the DOE-2 building energy analysis computer program for the Seoul climatic region. The objective annual heating load of the model houses for the Seoul climatic region can be achieved even with a 50 mm insulation thickness in each building envelope. In addition, a thermal insulating material should be attached to the basement wall to prevent surface condensation in summer.

A passive solar house was developed, with priority on the development and application of a passive technology for energy conservation in houses.

The principles of the Passive System (Trombe Michel Wall) are as follows:

– The thermal storage mass for the building is a south-facing wall of masonry or concrete with a glazed surface to reduce heat losses outside. Solar radiation falls on the wall and is absorbed by it and transferred by conduction from where it radiates, and heat is transferred by convection to the living spaces.

– Through the openings or vents at the top and bottom of the storage mass, hot air will rise and enter the living space, drawing cooler room air through the lower vents back into the collector air space.

– The solar wall may be used as a solar chimney in summer, when the continued air movement exhausts hot air from the solar wall and draws in cooler air from the north side of the house for ventilation.

The thermal performances of passive solar systems were evaluated through actual experiments, and the problems that can arise in relation to their implementation were discussed. Computer simulation programs were also developed for the theoretical performance prediction of passive buildings. The criteria were prepared by examining all the existing design schemes and synthesizing the performance evaluation methods that have been developed up to the present time. The solar-saving fraction was found to be 27.3%.

The concepts of active solar systems are well known to the public. Past experiences reveal, however, that this technology is not yet ready for massive commercialization in Korea, since it is not yet economical (has a high initial investment) and has difficult maintenance problems.

The 2012 project "Development and Improvement of the Active Solar-heating System," was conducted as a basic work to develop low-cost solar-heating systems, which are expected to show economical solar utilization as a low-thermal source of energy for use in space or water heating. To improve the chances of attaining its aim or objective, the work was divided into two parts: the software and the hardware aspects.

The scope of these studies includes the following four major works:

– Performance evaluation and formulation of a design method for liquid-type flat-plate solar collectors;

– utilization of a computer simulation program for designing active solar heating systems; Development of and Research on Energy-Saving Buildings in Korea 293

– Construction of a small-scale water-heating system and improvement of the existing active solar space-heating system for demonstration and performance evaluation; and

– Preparation of a test procedure, an evaluation scheme, and criteria for installation/ performance.

Super Low Energy Building

Residential buildings represent more than 70% of all the buildings in Korea. From this point of view, the spread of newly developed technologies and the carrying out of a demonstration project to prove energy savings as well as other parameters are essential for this study.

The project was carried out from July 2013 to December 2013. The focus of this study was the demonstration of the developed technologies that are not being used commercially in Korea, to promote them.

The scope of this study was divided into two categories: research work to provide detailed data for the design, and the discussion of the design and construction work with the project manager of six subprojects.

The contents of the study were as follows:

The design of a double-skin structure;

- A seasonal thermal storage System;
- Cool-tube-related technologies;
- A co-generation system;
- A vacuum tube solar collector for heating and cooling; and
- A PV for building application.

The super-low-energy office building was constructed in November 2014, with three stories and an underground floor. It was a reinforced-concrete type, with a total floor area of 1,102 m^2. It is now on the way to test operation.

74 kinds of elementary technologies were applied in the building: 23 kinds of energy load reduction methods through architectural planning, 35 kinds of mechanical-system-related technologies, and 16 kinds of electrical-system fields. The following are brief constructional descriptions of six of these major technologies.

Table 2. Comparison of major energy-saving tools

Major Technologies	Energy Savings [$Mcal/m^2 . y$]	Notes
Design of Double Skin Structure	22.9	Width : 1.5m, Height : 10.8m
Cool Tube Related Technologies	13.0	Length : 70m, Buried Depth:3m, Diameter of the Pipe : 30cm
Small Scale Co-generation System	56.4	Effective Area : 265m^2
Vacuum Tube Solar Collector for Heating and Cooling	26.0	Effective Area : 50m^2
Total	106.3	

Development of on the Green Building

A “green building” is a building that was designed, constructed, operated, and eventually demolished so that it would have a minimum impact on the global and internal environment.

Fig. 2. Exterior and interior of Green building

Sustainable development is the challenge of meeting growing human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting the environment quality and the natural-resource base that are essential for future life and development. The concept recognizes that long-term human needs cannot be met unless the earth's natural physical, chemical, and biological systems are also conserved.

Adopting green-building technologies into buildings will not only decrease the energy consumption of buildings but will also improve their environmental conditions.

The following are the contents of such technologies:

– Double envelope on the south section;
– An atrium for day lighting and natural ventilation;
– Movable shading devices on the west façade;
– A gray-water recycling system;
– A rainwater collection system;
– An energy-efficient HVAC system;
– Environmentally friendly building products;
– Solar collectors on the roof; and
– Solar cells.

Development of Zero Energy House

Both energy conservation and the use of an alternative technology must be applied for the construction of an energy-sufficient and zero-energy house. Zero-energy and solar technologies must be developed to overcome the energy crisis in the near future. This cannot be realized with the separate application of unit technologies because a building is an integrated system of several energy conservation technologies. As such, related energy technologies, including solar energy, must be developed and gradually adopted, considering the installation cost.

The objective of this project was to develop the net energy of 78% self-sufficient demonstration house in 3 years (January 2014 –December 2014), the commercialization in 6 years and 100% in 10 years.

From four years ago (January 2015), we started to research their integration something like the super-insulation and air-tightness, solar collector, heat recovery ventilation system and so on. The most important factors in superinsulated thermal envelope design are the low heat transfer, air leakage and moisture damage. Heat transmission coefficient of thermal envelope is under 0.15 (kcal/m2h℃).

It was selected exterior insulation system for Zero Energy House. The air/vapor barrier should be installed inside insulation and best material is 0.03~0.05mm polyethylene film. At the joint between two sheets of polyethylene, the two sheets should be overlapped by 50~150 mm.

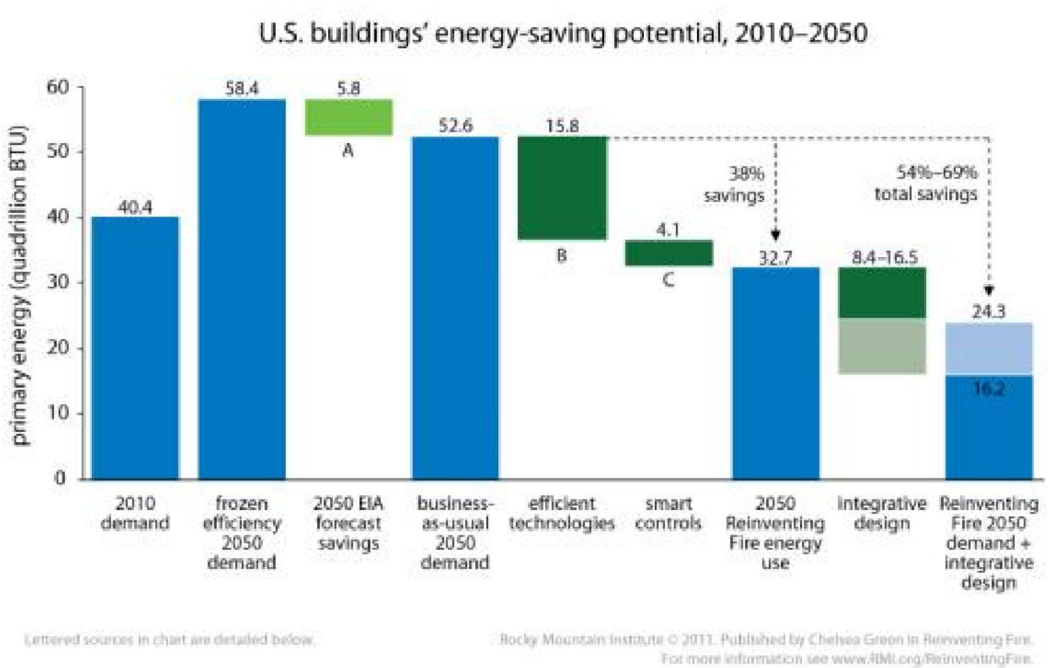

Fig. 3. U.S. buildings' energy-saving potential, 2010–2050

Conclusion

The energy consumption of the building sector in USA has been on the rise due to the growth of the USA economy. At the same time, the demand for a comfortable indoor environment is also increasing. It is thus very important to consider not only building energy conservation but also IAQ (indoor air quality).

Finally, by constructing, investigating, surveying, and testing experimental and model buildings, this study showed the criteria and measures for energy conservation in buildings (existing and new) and suggested the construction of "green buildings" to protect the environmental quality and the country's natural-resource base, which are essential for future life and development.

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