Building the BRI's Ideal Home

This month's installment of our series introducing the varied activities of Japan's Building Research Institute (BRI) focuses on the Institute's proposals for emissions reductions in housing. The article looks in particular at the BRI's seminal Design Guidelines, which specify the different approaches required to design low-energy residential buildings, and at the Life Cycle Carbon Minus (LCCM) house, a proposal for housing that minimizes CO_2 emissions at the construction stage.

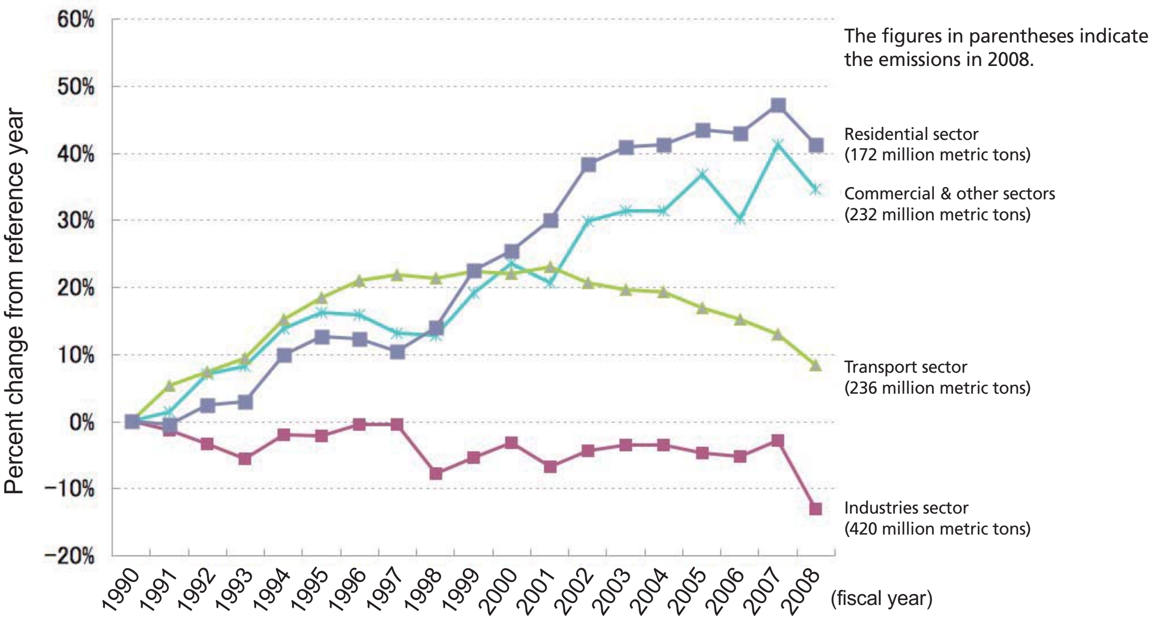
It is generally understood that global warming results mainly from an increase in carbon dioxide and other greenhouse gases due to huge consumption of fossil fuels. In view of that, the Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency (IEA) and other international organizations stress the importance of reducing carbon dioxide emissions from the residential sector.

Figure 1 shows the trend in carbon dioxide emissions by sector in Japan. It reveals that carbon dioxide emissions from the industries sector, the largest emitter in Japan, steadily declined to a level that is 13% below the 1990 level, whereas emissions from the residential, commercial and other sectors continued to rise until finally beginning to drop in 2008, when the emissions level was 30–40% higher than in 1990. In response, the Japanese government announced a New Growth Strategy, which was adopted by the Cabinet on July 18, 2010. It sets a long-term target of cutting greenhouse gas emissions by 25 percent from 1990 levels by 2020. The Ministry of Land, Infrastructure, Transport and Tourism expressed the importance of introducing an obligation to comply with the energy conservation criteria in a bid for energy conservation in all new residential and other buildings and commenced a study on imposing the obligation.

Low Energy Housing with Validated Effectiveness

Involved in research on energy conservation methods in residential houses, the Building Research Institute compiled the research findings to draw up the Design Guidelines for Low Energy Housing with Validated Effectiveness. Targeting Japanese regions with a relatively mild climate, including Tokyo, the Guidelines specify the different approaches required to design low-energy residential buildings and facilitate estimation of the energy conservation effect expected from a combination of these approaches. The degree to which energy consumption is reduced is based on the value of the effect observed in a test carried out with actual use of different facilities and equipment. The approaches suggested correspond to thirteen basic technologies listed below.

Figure 1: Trend in Carbon Dioxide Emissions by Sector



Source: Based on data from the National Institute for Environmental Studies

Figure 2: Covers of the Guidelines

1. Use and control of wind
2. Daylight utilization (Sunlight utilization 1)
3. Photovoltaic power generation (Sunlight utilization 2)
4. Solar radiation heat utilization (Solar heat utilization 1)
5. Solar water heating (Solar heat utilization 2)
6. Insulated building envelope planning
7. Solar shading method
8. Heating and cooling system planning
9. Ventilation system planning
10. Domestic hot water system planning
11. Lighting system planning
12. Introduction of high-efficiency consumer electronics
13. Treatment and efficient use of water and kitchen waste

They also show the ratio of energy consumption reduction by each approach. For instance, ventilation system planning is expected to cut ventilation energy consumption by 30% to 60% by:

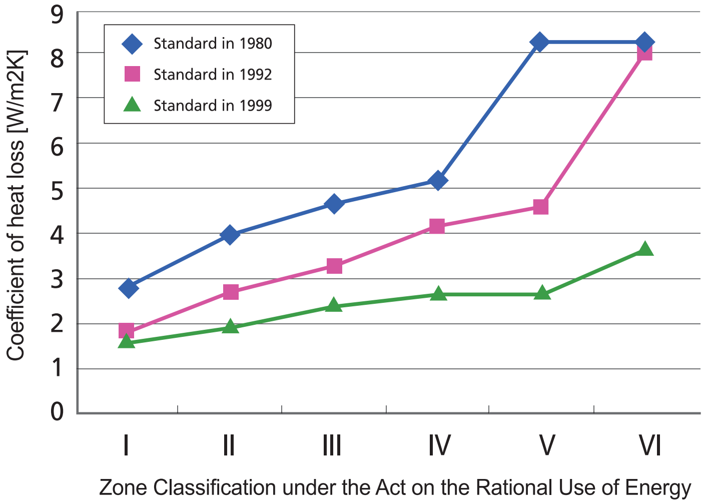
1. optimizing the duct diameter and the layout for minimizing a pressure loss in the duct ventilation;
2. introducing high efficiency motor and fan; and
3. adopting a hybrid ventilation system that capitalizes on the difference between indoor and outdoor temperatures.

A large number of seminars have already taken place with the use of these Guidelines mainly in target regions with mild climates. More than 10,000 people have to date participated in the seminars. After some called for guidelines for other regions, the Building Research Institute created a version for hot regions including Okinawa Prefecture, called the Hot Humid Region Edition. The climate in the region targeted by this edition is comparable with that of Southeast Asia. The version for regions where the climate is colder than in Tokyo and Osaka is being prepared. Foreign language versions of the Guidelines have also been created: specifically, a Chinese version of the mild region edition.

Energy Conservation Criteria for Residential Houses

Figure 3 shows the standard values of the coefficient of heat loss for different regions according to Japan's Act on the Rational Use of Energy. A smaller value for this coefficient means a higher level of heat insulation efficiency, and a region with a colder climate needs greater heat insulation. The diagram demonstrates that the standard value of the heat loss coefficient has been lowered each time the criteria are updated in order to gradually raise the insulation level of residential houses. **Figure 5** shows the breakdown of energy consumption in single-family residential houses in eight cities in Japan. It is common in this country to heat or cool a room only while the resident is present, except in regions with very cold climates like Sapporo. This means that energy consumption for heating and cooling is lower in Japan than in the West, where it is normal to constantly heat or cool the entire building. According to the diagram, energy consumption for heating is huge in Sapporo, accounting for more than half of the total energy used. In this city, the climate is so close to that in Canada and Scandinavia that uninterrupted heating of the whole house is widely practiced. In other regions, the share of energy consumption for heating is as small as about 25%. This implies that for the purpose of cutting energy consumption for an entire house in Japan it is necessary not only to lower the air conditioning load by improving the heat insulation properties, as prescribed in the Act on the Rational Use of Energy, but also to increase the efficiency of air conditioning equipment for dealing with the load and to use high-efficiency devices for hot water

Figure 3: Standard Value of the Coefficient of Heat Loss



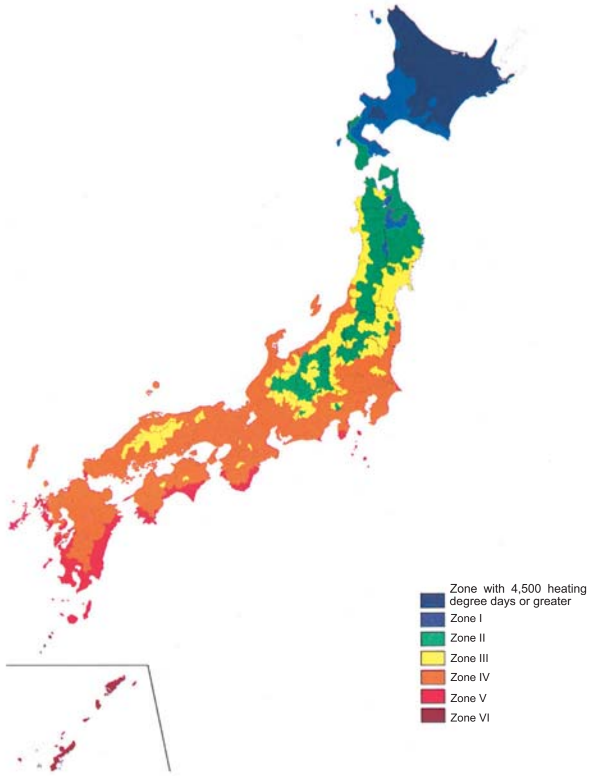


Figure 4: Zone Classification under the Act on the Rational Use of Energy

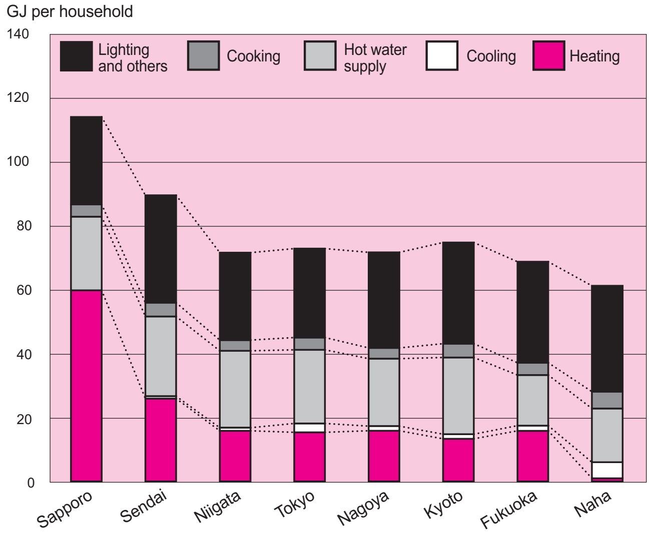


Figure 5: Current Status of Energy Consumption in the Residential Sector:
Comparison in single-family houses in eight cities

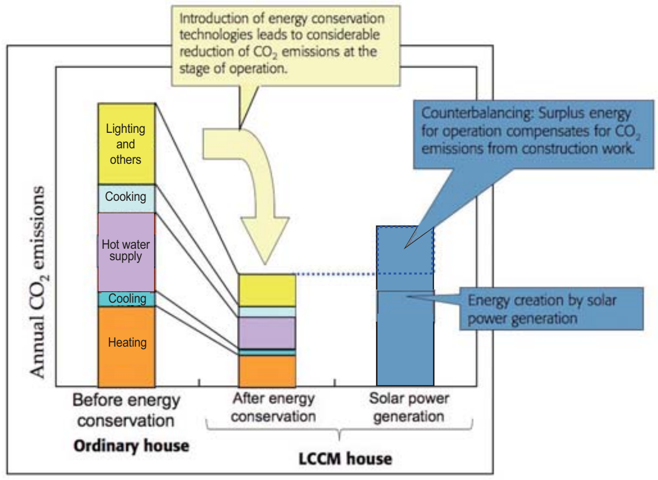


Figure 6: Energy Balance of the LCCM House

supply, lighting and other purposes involving energy consumption.

Applying to businesses that build a predetermined number of houses or more per year, the criteria for home building businesses under the Act on the Rational Use of Energy took effect in 2009. In light of the point discussed above, they stipulate that pre-installed air conditioning, ventilation, hot water supply, lighting and co-generation systems, and solar power generation equipment shall be assessed at the time of completion in addition to the heat insulation properties of the house. Specifically, the assessment is done by comparing the energy consumption for air conditioning, ventilation, hot water supply and lighting in the house with the standard value, which is determined at 90% of the energy consumption anticipated at the time of introducing air conditioning, ventilation, hot water supply and lighting equipment considered normal as of 2008 to a residential building with heat insulation performance equivalent to the 1999 standard value shown in **Figure 3**. For equipment that has yet to be installed at the time of handover, the value for equipment that is considered to have been commonly used in 2008 applies. As standard conditions for estimation purposes, housing attributes such as the form and neighboring conditions and the lifestyles of dwellers such as air conditioning durations and hot water demand are determined and adopted as given conditions. However, attention is paid to the climatic conditions depending on the building region. A schedule for calculating energy consumption according to different settings and conditions has been prepared. While it is possible to use this schedule, there is also a program for detailed calculation.

In the course of developing this assessment approach, much of the basic data studied for drawing up the Design Guidelines for Low Energy Housing with Validated Effectiveness were utilized.

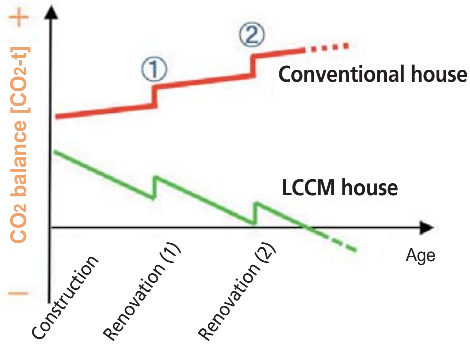


Figure 7: Schematic of CO_2 Balance throughout the Life Cycle

LCCM Houses

A Life Cycle Carbon Minus (LCCM) house has been proposed as a house for minimizing CO_2 emissions at the stages of construction, operation and scrapping in its long life span and for achieving a negative life-time CO_2 balance, including CO_2 emissions from building it, by making active use of renewable energy produced by solar and other power generation.

Specifically, energy consumption for operation will be slashed and solar power generation that exceeds the consumption will be introduced so that surplus energy for operation may be used for other houses. Power supply companies will minimize CO_2 emissions from power generation. This will counterbalance the CO_2 emissions in construction and other phases (see **Figures 6 and 7**). However, a drastic cut in energy consumption for operation will degrade health, safety, comfort and convenience and impair effectiveness. For the LCCM house to achieve widespread adoption, it is necessary to retain these elements to the maximum degree. As is shown in **Figure 7**, CO_2 emissions from conventional houses grow the longer they are operated. In contrast, CO_2 emissions from LCCM houses fall with the surplus energy for operation and decline below zero after the lapse of a certain number of years, although they do rise slightly at the time of renovation.

Based on this concept, a demonstration LCCM house was erected in the premises of the Building Research Institute in the city of Tsukuba, in Ibaraki Prefecture.

The potential of the LCCM technology was studied on the basis of the initial CO_2 emissions of this house at the time of construction and energy consumption for equipment operation (**Figure 8**). As far as this demonstration LCCM house is concerned, solar power generation volume is estimated to surpass the total of the initial CO_2 emissions and energy consumption for operation after approximately thirty years of use and to achieve the LCCM objective. Longer use will result in a greater amount of surplus energy.

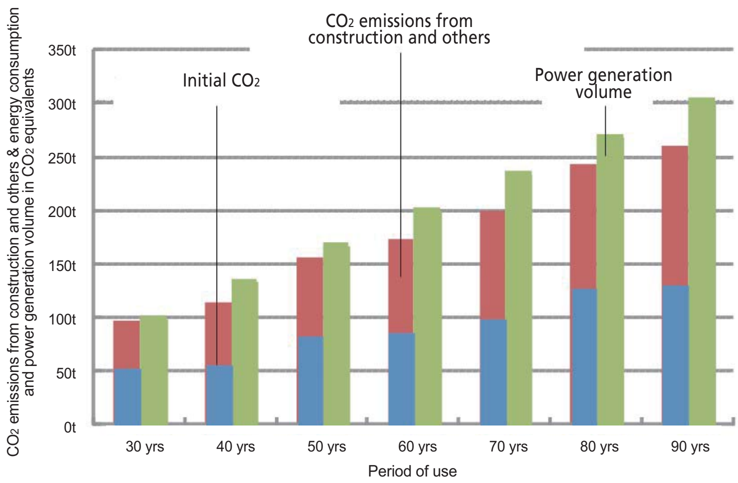


Figure 8: Trend in CO_2 Emissions and Power Generation Volume (Under the condition with the use of a solar thermal hot water system with natural refrigerant and with the unit CO_2 emissions of 0.418 kg-CO_2/kWh on average for all power sources)

Accurate initial CO_2 emissions from construction will be calculated with the use of measured data on the amount of waste emitted from the construction site of the demonstration LCCM house. Simulated living in this house will be carried out to measure the energy consumption for operation and to examine the LCCM technology. An LCCM house evaluation tool that covers various climate conditions and lifestyles in Japan will be developed with the use of the findings of this examination. In addition, the results will be used to authenticate LCCM houses with a view to accelerating the adoption of this energy-saving housing solution.

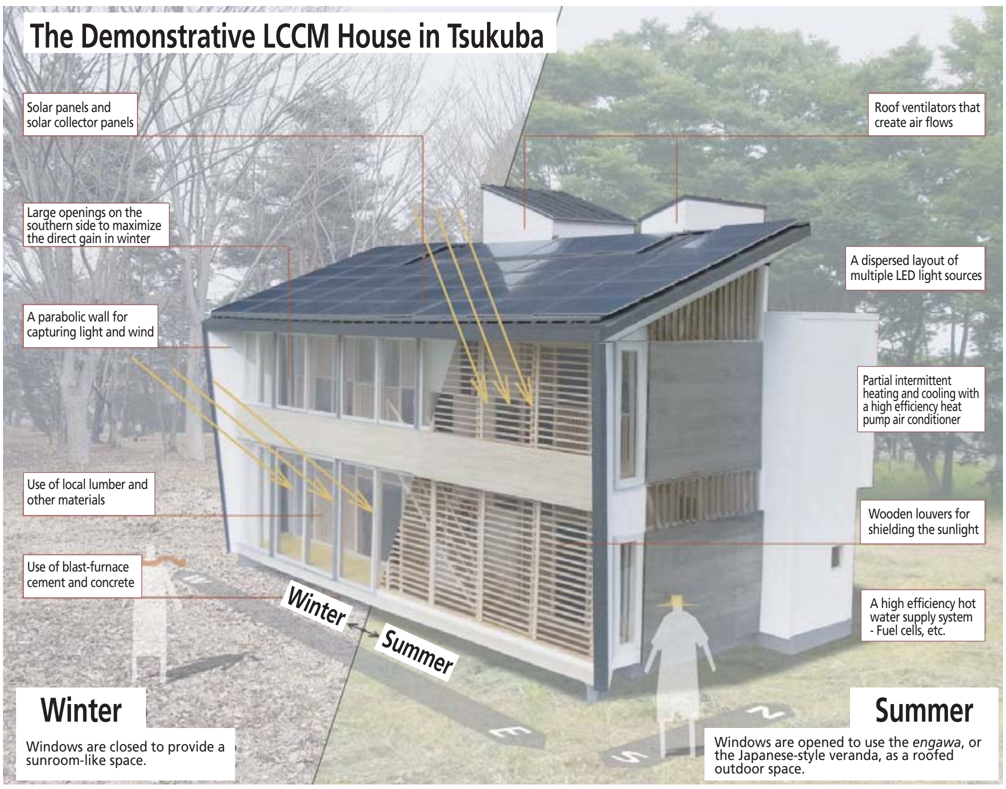


Figure 9: Overview of the Demonstrative LCCM House