Predicted Energy Conservation by Use of Common Areas in Cohousing

Hiromi Kido
Graduate School,
Kogakuin University
JAPAN
dm10027@ns.kogakuin.ac.jp

Yusuke Nakajima
Associate Professor
Kogakuin University
JAPAN
yusuke@cc.kogakuin.ac.jp

Summary

Recent investigations have concluded that hot water supplying seems less effective at energy-saving than heating, cooling, lighting, cooking or home electrical appliance. This study focuses on the co-housing (it is one of environmental symbiosis housing with a kitchen, a living room and the bathing facilities in common use), which can be rarely found in Japan. The survey was conducted to residents of an existing co-housing about how they try energy savings, and then the energy-saving effects of heating, cooling, hot water-supply, lighting, cooking and home electrical appliance in common space where residents gather were examined by simulation. Finally, Life Cycle Assessment was estimated on the co-housing partly made of natural materials such as domestic wood and bamboo. As a result, various advantages on energy and resource conservation were confirmed.

Keywords: Life Cycle Assessment, Energy Conservation, Lifestyle, Simulation, Cohousing

1. Introduction

Energy consumption in homes has increased over the past 20 years, so immediate steps must be taken to deal with this problem. Energy-saving technology is increasingly used in buildings, but some studies have cited the importance of steps by residents to reduce energy use as well as energy-saving structures and equipment. That said, there are limits to energy conservation in a single dwelling. Therefore, several families sharing areas like living rooms, kitchens, and bathrooms may lead to a new energy-conscious lifestyle.

Recent studies have found that conserving energy is harder with hot water supplying equipment than with heating, cooling, lighting, cooking, or home electrical appliances. Thus, this study focused on cohousing (collective housing that consists of private areas and common areas such as kitchens, living rooms, and bathrooms), which is rarely found in Japan.

Consequently, residents of existing cohousing were first surveyed regarding their approaches to conserving energy, and then a simulation was performed to determine the energy conservation of heating, cooling, hot water supply, lighting, cooking, and home electrical appliances in a building shared by residents. Finally, a life cycle assessment was performed on some of the natural materials, such as wood and bamboo, that were used to build the cohousing studied. Result confirmed that cohousing offers various advantages in terms of energy and resource conservation.

2. Simulation of energy consumption by cohousing

Individuals who plan to reside in cohousing were surveyed regarding their energy consciousness and anticipated lifestyles. Results of various simulations incorporating these data demonstrated that energy conservation is possible if individuals are energy-conscious of their lifestyles and reside together.

Table 1. Building overview

Site location	Sagamihara City Kanagawa Prefecture,Japan
Structure	two-story wooden house
No. of dwellings	4 houses+common space+warehouse
Number of persons per room	1–4
Architectural area	358.28㎡ (common space A :78.62 m^2 B : 71.21 m^2C : 74.52 m^2E: 63.55 m^2F: 68.99 m^2)
Hot-water supply equipment	Gas boiler
Environmentally friendly elements	Pellet stove, wood stove skylight for heat exhaust, Keyhole garden

Fig. 1 Exterior of the housing studied

2.1 Housing overview

In Japan, conditions in terms of space and cost prohibit larger private spaces in housing. The efficiency of housing can be improved by sharing spaces and facilities in common areas such as large living rooms, kitchens, and bathrooms. Moreover, such housing is intended to provide and environment that facilitates active communication between residents. This study focused on whether the sharing of spaces and facilities in cohousing can lead to energy conservation.
The housing studied is a complex of townhouses that consist of four residences (buildings B, C, E, and F), a shared building (building A), and storage (building D) in Fujino in the City of Sagamihara, Kanagawa Prefecture, Japan. Table 1 gives an overview of the housing studied. A photograph of that housing is shown in Figure 1. Figures 2 and 3 show the floorplan of the first and second floors. This building is a wooden structure employing the traditional method of Japanese construction involving clay walls with a bamboo lath underneath and extensive use of real wood (as opposed to laminates). Additionally, extensive insulation is planned.

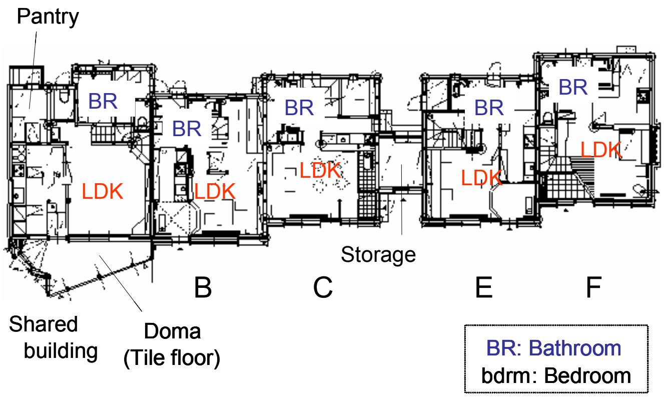

Fig. 2 1st floor plan

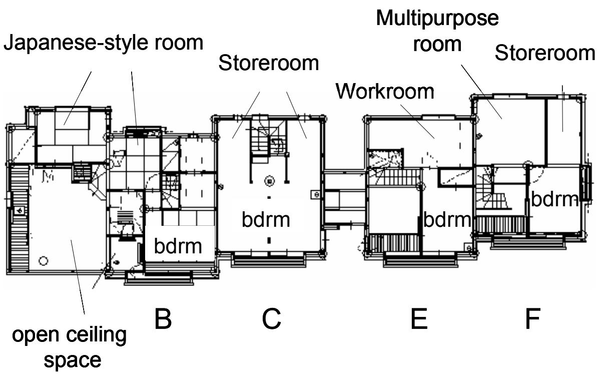

Fig. 3 2nd floor plan

2.2 Overview of heating and cooling load simulation

The heating and cooling load of cohousing were calculated using the software “SMASH for Windows Ver.2.13” (Institute for Building Environment and Energy Conservation). Table 2 summarizes simulation parameters. Three people live in building B. four people live in building C. One person lives in building E. Two people live in building F. A total of 10 persons live in this cohousing.
Figure 4 shows the number of people and four patterns of ways in which they use common and private spaces. Days and times were based on a group interview of individuals planning to reside in cohousing. When a common area was used, it was assumed that the area was used by all residents. Half of the residents were presumed to be out, e.g. at work, from 9:00AM–6:00PM. Rooms with air conditioning were the living room in the shared building and bedrooms and living rooms in private residences.

Table 2 Simulation parameters

Weather Data	Expanded AMeDAS Weather Data (Hachioji)
natural ventilation frequency	0.5 times/h
no. residents	B:3persons C:4persons E:1person F:2persons
schedule	conforms to Standard Problem Set of the Architectural Institute of Japan
air temperature	cooling26℃, heating22 ℃
heat exhaust ventilation	During cooling Air change rate 20times (room air temperature over28℃ external temperature below30℃)

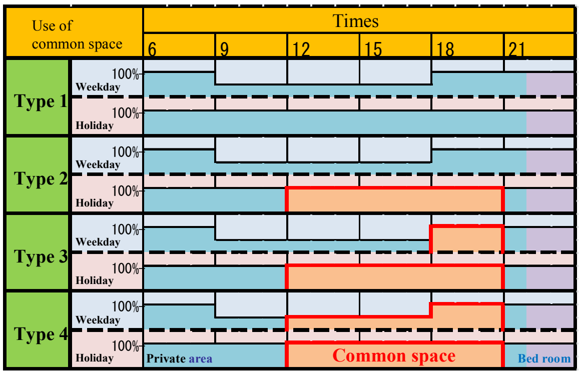

Fig. 4 Usage of common space

2.3 The results of heating load calculation

Figure 5 shows the results of heating load calculation. With Type 1 as the baseline, the load for Type 2 usage was 5% greater, that for Type 3 usage was 12% greater, and that for Type 4 usage was 10% greater. The load increased with all of the patterns. In living rooms of private residences, however, the total heating load for Type 4 usage decreased by 4% compared to that for Type 1 usage.
The heating load increased overall because residents used the common building when the outside temperature dropped; in the interim, the room temperature of private areas dropped substantially. Therefore, the start-up load increased in the living room of residences during the hour, 9:00PM–10:00PM, when residents returned from the shared building to their private residences. Consequently, there were few differences between this load and the load occurring with Type 1 usage during continuous operation. The overall heating load increases as a result of the load for heating the shared building.

2.4 The results of cooling load calculation

Figure 6 shows the results of cooling load calculation. Compared to Type 1 usage, the total cooling load decreased 16% with Type 3 usage and 37% with Type 4 usage. In contrast to the heating period, residents return to private areas when the outside temperature dropped led to a decrease in the cooling load. Looking specifically at the total cooling load for private areas alone indicates that the load decreased 54% with Type 4 usage in comparison to Type 1 usage.

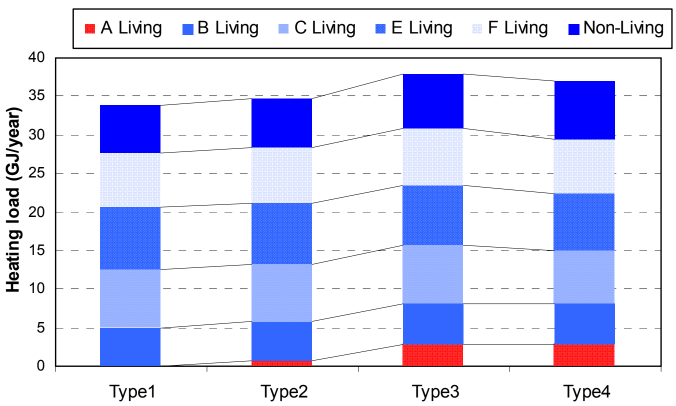

Fig. 5 Results of heating load calculation

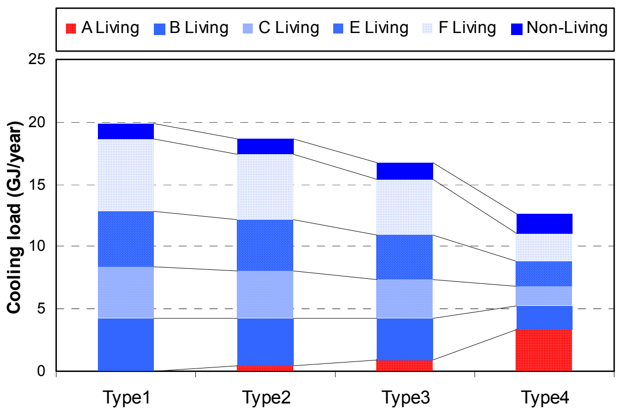

Fig. 6 Results of cooling load calculation

2.5 Calculated energy consumption depending on the usage of common areas

Based on the cooling load, energy consumption was calculated using the assumed average coefficient of performance (COP) (4.0) of air conditioners. Energy consumption for hot water supply and cooking was 13.9 (GJ/year), which was derived from previous studies of buildings similar to the housing studied. Moreover, energy consumption for lighting was calculated according to the lighting load schedule for cooling load calculation. Energy consumption for other consumer electronics was power consumed and the duration of use of general home appliances. The load for lighting and other consumer electronics used in the shared building was set to be larger than that for lighting and other consumer electronics used in private residences. Hot water supply for the shared building was twice the load for one private residence. Hot water supply for bathing was determined from the group survey of residents. Five of 7 residents responded that they would consider using the bathrooms in the shared building. In light of this fact, Type 2, 3, and 4 usage was calculated assuming that all residents would bathe in the shared building twice a week.
Figure 7 shows the results of the annual energy consumption. As previously explained, the heating load increased with usage of the shared building. However, the annual energy consumption along with cooling decreased 8% with Type 4 usage in comparison to Type 1 usage. In comparison to Type 1 usage, the energy consumed by lighting and other consumer electronics decreased 19% with Type 3 usage and 28% with Type 4 usage. A major reason for reduced energy consumption by consumer electronics was the result of sharing the rice cooker and television. Moreover, the energy consumed by bathing decreased substantially. If the bathrooms in the shared building are used twice a week, energy consumption can be reduced by about 10%. In comparison to Type 1 usage, overall energy consumption decreased 6% with Type 2 usage, 14% with Type 3 usage, and 21% with Type 4 usage. This finding indicates that use of common areas may help to substantially reduce energy use.

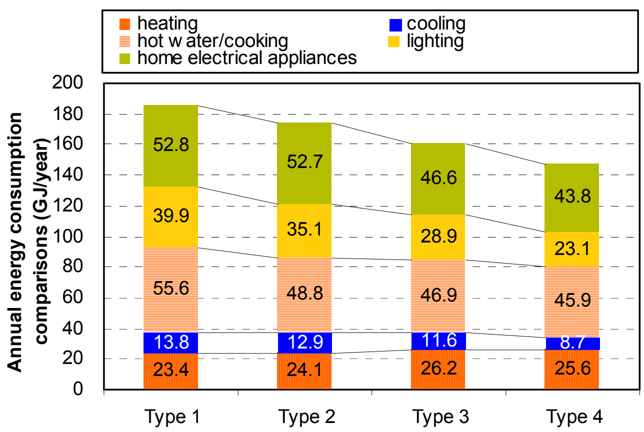

Fig. 7 Calculations for annual energy consumption

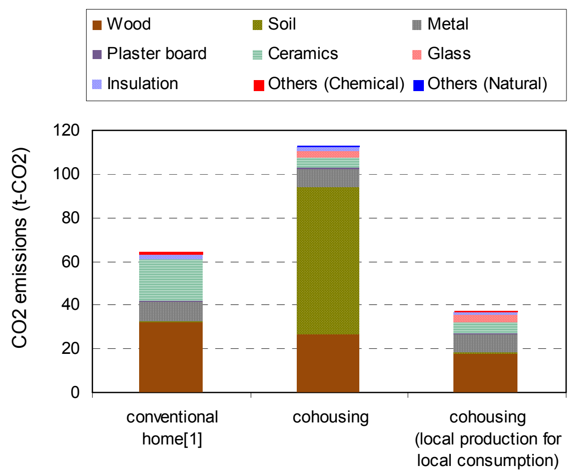

Fig. 8 Carbon dioxide emissions of cohousing during construction

3. Life-cycle CO_2 assessment of cohousing

Carbon dioxide emissions when cohousing was constructed were calculated using the CO_2 emissions intensity (inter-industry relations table,1995) according to the LCA guidelines for buildings (Architectural Institute of Japan). The life-cycle CO_2 of cohousing was assessed during construction and operation. The carbon dioxide emissions intensity for local wood (lumber) used and clay for clay walls was calculated based on previous studies and group interviews. The effects of using construction materials in accordance with local production for local consumption, the effects of using common areas, and the effects of using woody biomass (firewood and pellet stoves) were determined.

3.1 CO_2 emissions during the construction of cohousing

Figure 8 shows the calculations for CO_2 emissions during the construction of cohousing. The

average amount of materials used in 10 houses with a wood-frame structure, the amount of materials used in the housing studied, and construction of cohousing in accordance with local production for local consumption were taken into account. The carbon dioxide emissions intensity was calculated for wood (calculation included lumber but not plywood), the primary building material, and the soil used in clay walls and thatched roofs.
The carbon dioxide emissions intensity for wood was 45.7 (kg- CO_2 /m^3), which is the value for locally produced lumber harvested in Okutama-cho Tokyo, Japan. This value was divided by 0.38(t/ m^3), which is the density of Japanese cedar that is often used in the housing studied. The calculated value for locally produced and locally consumed wood used in the housing studied was 0.120 (kg- CO_2 /kg). The carbon dioxide emissions intensity for the soil was calculated based only on carbon dioxide emissions during transportation by truck and mixing. There were no carbon dioxide emissions during the process of producing soil and carbon dioxide emissions when soil was transported and mixed were 1.0 (t- CO_2).
When the housing studied was constructed in accordance with local production for local consumption, carbon dioxide emissions were reduced by 42% in comparison to a conventional home. Looking specifically at wood indicated that local production for local consumption allowed a 45% reduction in carbon dioxide emissions in comparison to a conventional home.

3.2 Carbon dioxide emissions during the operation of cohousing

Figure 9 shows carbon dioxide emissions with each pattern of use of the shared building. In comparison to Type 1 usage, carbon dioxide emissions decreased 8% with Type 2 usage, 15% with Type 3, and 22% with Type 4 usage. Carbon dioxide emissions were reduced by frequent use of the shared building.
Moreover, firewood and pellet stoves were used to heat the housing studied. Figure 10 shows carbon dioxide emissions during heating using woody biomass. The carbon dioxide emissions intensity for the pellet stove was an environmental load of 0.611 (kg- CO_2 /1,000kcal) during heating plus the carbon dioxide emissions intensity for the electric power consumed.
There are sites offering free firewood in the Fujino area. Fuel for a truck to collect the firewood was calculated based on the distance traveled by the truck and the number of trips the truck made each year to collect that firewood. The carbon dioxide emissions intensity for firewood stoves was the amount of truck fuel used in those trips (Truck fuel represented the carbon dioxide emissions of firewood stoves in order to determine the carbon dioxide emissions intensity for firewood. Truck fuel was the amount of fuel needed each year to travel to and from the firewood collection site (where firewood is available for free) and cohousing).
Figure 11 shows calculations assuming that pellet and firewood stoves are used in place of the heating energy used by air conditioning with Type 1 and 4 usage. When pellet stoves were used with Type 4 usage, carbon dioxide emissions decreased 4% percent in comparison to use of air conditioning. When firewood stoves were used, carbon dioxide emissions decreased 15%. Comparison of use of firewood stoves with Type 1 and 4 usage indicated that carbon dioxide emissions decreased 24% with Type 4 usage.

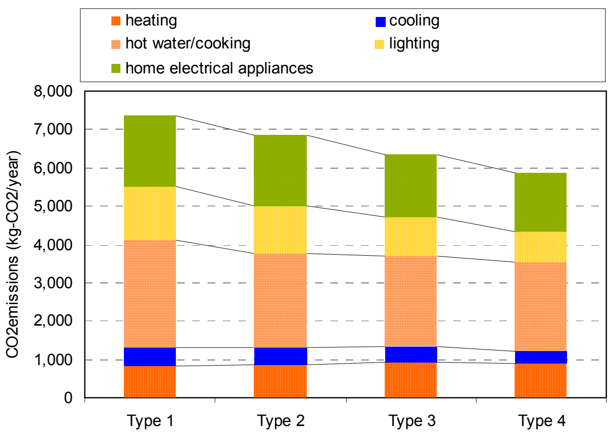

Fig. 9 Carbon dioxide emissions of cohousing during operation

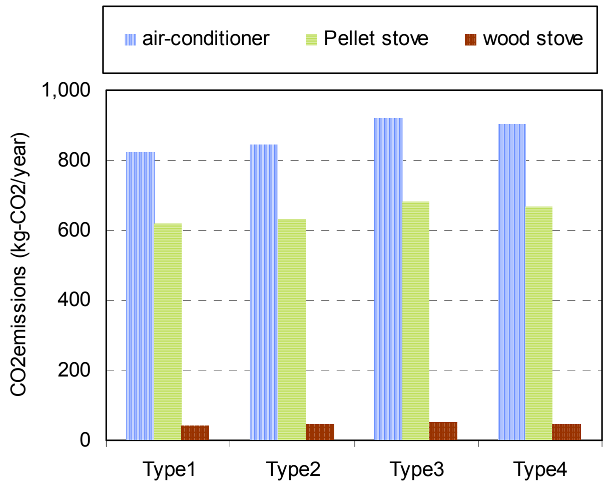

Fig. 10 Carbon dioxide emissions when woody biomass is used

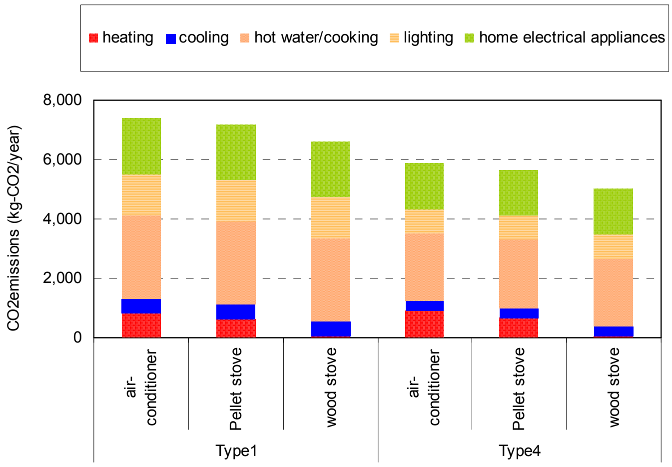

Fig. 11 Carbon dioxide emissions by heating energy source

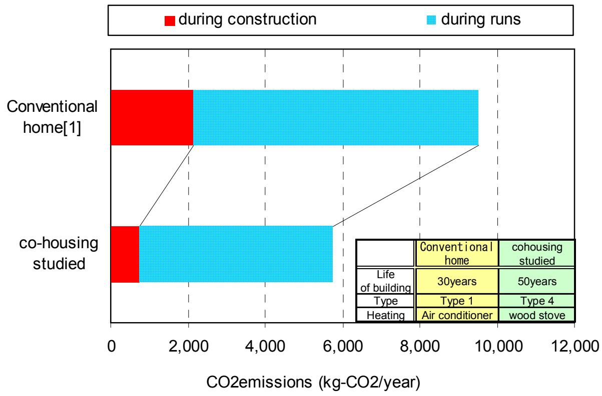

Fig. 12 $LCCO_2$ of housing studied

3.3 $LCCO_2$ of the housing studied

Figure 12 shows the $LCCO_2$ for the housing studied and for an average of ten houses with a wood-frame structure, i.e. a conventional home. One parameter was a building life of 30 years for a conventional home. Carbon dioxide emissions during operation were emissions for air conditioning and heating with Type 1 usage. The housing studied had a building life of 50 years. Carbon dioxide emissions during operation were emissions resulting from firewood stove heating with Type 4 usage. Results indicated that the housing studied had about 40% less $LCCO_2$ than did a conventional home.

4. Conclusion

This study examined energy conservation and reduced CO_2 emissions with a focus on cohousing. Results indicated that use of construction materials in accordance with local production for local consumption and use of woody biomass resulted in reduced CO_2 emissions. Additionally, living together offered the potential for energy conservation. Future research will study additional ways to use common areas. Living efficiently in cohousing must be considered.

Reference

[1] "PROJECT RESEARCH REPORT of National Institute for Land and Infrastructure Management", 2002, National Institute for Land and Infrastructure Management, MLIT, JAPAN, pp345-348