IMPACT OF THE ZERO-ENERGY MASS CUSTOM HOME MISSION TO JAPAN ON INDUSTRY EDUCATION TOWARD COMMERCIALIZATION

Masa Noguchi [1] and Jun-Tae Kim [2]
[1] MEARU, Mackintosh School of Architecture, The Glasgow School of Art, Glasgow, United Kingdom
[2] Department of Architectural Engineering, Kongju National University, Cheonan, South Korea

In response to global warming issues, homebuilders today are becoming keener on the delivery of zero-energy housing than ever. To stimulate homebuilders and housing researchers around the globe, knowledge transfer study visits to Japanese housing manufacturers were initiated in 2006. The event was later called 'Zero-energy Mass Custom Home Mission to Japan' and continuously executed in 2007 and 2008. As part of the mission results, 3 industry participants were transformed successfully from conventional housing suppliers to champions of net zero-energy/carbon homebuilders in their local contexts. This paper unveils the mission contents and examines the response from the industries.

Keywords: zero-energy sustainable housing, industry education, pre-fabricated housing, commercialization

INTRODUCTION

There is a tendency for homebuilders to rarely adopt or buy new products and/or services that to some extent interrupt their business operation that is often based on routine [1]. In general, homebuilders tend to restrict their information search to the programmed decision, since the search for information for non-programmed decisions take too much time, money and effort. Thus, to open the gate for conventional homebuilders (and housing manufacturers) to consider future commercialization of zero-emission or -energy sustainable homes, the 'Zero-energy Mass Custom Home Mission to Japan' was organized by the first author in collaboration with CanmetENERGY-Varennes, Natural Resources Canada, from 20th to 23rd February, 2006, and with the Centre for the Built Environment in the UK from 3rd to 5th September, 2007, and from 10th to 12th September, 2008. The mission delegates were given opportunities to examine on every hand the product quality of low to zero-energy industrialized mass-customizable homes in Japan. The participants could learn about the successful business operations in order that they can follow or newly develop design, production and marketing strategies for the delivery of innovative marketable green homes (Fig.1).

Fig.1. Typical net zero-utility-cost house in Japan (Source: SANYO Homes Co.)

In Japan, a total of 1,093,485 houses were newly built in 2008 and among them, 154,271 homes, or 14.1%, were estimated to be prefabricated [2]. Moreover, the housing manufacturers have been successful in commercializing their industrialized houses that are often equipped with a photovoltaic (PV) power generation system, as a standard feature, rather than optional one. In fact, between 1994 and 2003, the number of domestic PV installations in Japan drastically increased from 539 to 52,863 houses (Table 1).

Table 1. Number of residential PV installations in Japan: 1994-2003

YEAR	ANNUAL NUMBER OF HOUSES EQUIPPED WITH PV SYSTEMS	ANNUAL INSTALLED CAPACITY (MW)
1994	539	1.9
1995	1,065	3.9
1996	1,986	7.5
1997	5,654	19.5
1998	6,352	24.1
1999	15,879	57.7
2000	20,877	74.4
2001	25,151	91.0
2002	38,262	141.4
2003	52,863	201.4
TOTAL	168,628	622.8

To alleviate the eccentric appearance of their contemporary PV homes, Japanese manufacturers tend to well integrate the cells into the roofing and façade materials (Fig.1). Although the country has been experiencing the negative fluctuation of housing starts over the last few years, the PV solar home suppliers in Japan express their confidence in the increase of their sales for years to come [3]. For instance, in 2006, Sekisui Chemical Co., one of the largest housing manufacturers in Japan, reported that the company already sold over 50,000 PV solar homes as of July 2006 and they would strengthen even more the production of their net zero-utility-cost PV homes by increasing the ratio of the contracts from 17% in FY 2005 to 30% in FY 2008 [4].

In response to the societal needs for zero-energy housing, CANMET Energy Technology Centre (called *CanmetENERGY* today) of Natural Resources Canada organized the *Japan Solar Photovoltaic Manufactured Housing Technical Mission 2006*, where the first author was appointed to be the coordinator. The mission was aimed at offering

Canadian homebuilders, housing manufacturers, building component suppliers, architects, academics, and government officials an opportunity to visit the state-of-the-art production facilities of four leading net zero-energy housing manufacturers in Japan such as Sekisui Chemical Co., Misawa Homes Co., PanaHome Co., and Sanyo Homes Co. They also visited the sales centre, or *housing park*, that is comprised of a number of displayed PV model homes [5]. In addition, the mission program was also extended to the visit to a new solar housing community in Kobe that PanaHome constructed. The solar community is composed of total 100 homes and all units are equipped with PV systems. At the time of the visit, 50 PV solar homes were already completed and the 19 mission delegates were allowed to scrutinize the qualities of the houses that are actually in use. This paper describes the mission contents and examines the response from the industries.

MISSION OBSERVATION

In order to meet market demands for the design customizability of housing and the societal needs for sustainable development, Japanese manufacturers tend to produce high cost-performance housing [6]. Their commercialization approach to PV solar houses reflects their *cost-performance* marketing strategy [3]. Japanese housing manufacturers may use the money saved from lowering production costs through mass-production to equip homes with more standard housing components of high quality—this, in turn, upgrades housing quality and distinguishes their houses from conventionally built ones. In fact, Japanese housing manufacturers today install a variety of amenities including a PV system as a *standard feature* rather than *optional* one and emphasize that they have been producing better-quality homes for *about* the same price as conventional ones.

The housing manufacturers' communication approaches derived from their cultural context, in which *customer satisfaction* is of utmost concern, based potentially on the theory of consumer behavior [6]. Prior to entering into a contract with the client, the manufacturers offer an extensive amount of information in order to motivate the client to learn more about the company's products and services during the buying decision-making process. Consumer involvement during such a process accords with the consumer's motivation. However, the level of consumer involvement generally increases with such factors as the cost, the consumer's interest, the degree of perceived risk in buying the product, and the social visibility [7]. To enhance consumers' motivation to purchase high cost-performance housing, in which a PV system is often installed as standard equipment, the manufacturers have been practicing three principal communication approaches to deal with potential homebuyers:

a. Advertisement: encouraging clients by advertising the company's products
b. Education: helping clients to understand the value of their high cost-performance products
c. Value assurance: reducing the degree of buying risk perceived by clients by offering long-term warranties, as well as maintenance and communication services

In 2007, Japan Prefabricated Construction Suppliers and Manufacturers Association indicated that 17% of the homebuyers, who preferred to purchase prefabricated homes, answered that they were well convinced of the value of innovative housing. Their communication techniques are applied to each stage of their marketing efforts and are proven to be influential in the enhancement of customer satisfaction.

Japanese housing manufacturers produce *marketable* and *reproducible* PV solar housing, where the design customization cannot be negligible. In fact, the housing manufacturers tend to produce low to zero-energy *mass custom homes* that aim to meet the wants and needs of individuals as well as society [3]. The *mass custom design* approach may theoretically achieve a high level of standardization of housing components that homebuyers can directly select in planning their new home, while the user choices of the mass-producible standard components paradoxically increases a level of design customizability [8]. The application of the mass custom design approach may have potential to reduce production costs by achieving the *economies of scope* (based on standardization of housing components), while helping totally customize homes in response to the wants and needs of homebuyers [9].

As for the societal needs for green products, Sekisui Chemical Co. demonstrates that by installing a 3kW PV system on the rooftop of a house, the CO_2 emissions can be reduced by 36.2% and the annual electricity cost by 49.7% in comparison to their conventional product (Table 2). The results indicate that the installation of PV systems helps to create environmentally friendly housing that addresses to some extent the negative environmental impacts of conventional homes, as well as the reduction of long-term operating costs [10].

POST-MISSION INDUSTRY RESPONSE

As per the post-mission feedback, most delegates who participated in the past Zero-energy Mass Custom Home Mission to Japan expressed their positive impression on Japanese manufacturers' systematic way of commercializing low to zero-energy homes [4]. A number of the participants admit that Japanese housing manufacturers, which they visited, were all large-scale enterprises and might be able to invest heavily in systemizing their design, production and marketing approaches to their industrialized homes equipped with luxurious renewable energy technologies. The feedback led to an argument that small- or medium-sized homebuilders and housing manufacturers, such as mission industry delegates, may hardly apply Japanese housing manufacturers' commercialization approach without scaling down the extent.

Table 2. Impact of PV applications on annual CO_2 emissions and energy costs

HOUSING TYPE *	ELECTRICITY CONSUMPTION (kWh/Year)	ELECTRICITY GENERATION (kWh/Year)	NET ELECTRICITY COST (A) (JPY/Year)	NATURAL GAS CONSUMP-TION (m^3/Year)	NATURAL GAS COST (B) (JPY/Year)	ANNUAL CO_2 EMISSION (kg/Year)	TOTAL ENERGY COST (A+B) (JPY/Year)
A	5,814	0	143,712	527	70,790	1,036	214,502
B	5,814	3,125	72,247	527	70,790	661	143,037
C	5,814	3,125	72,247	317	47,050	526	119,297

* Typical prefabricated housing model equipped with HVAC systems, Tokyo: 158 m^2 in total floor area
Type A: Without PV system
Type B: With 3kW PV system
Type C: With 3kW PV/thermal solar hybrid system

Despite the remaining concern over the applicability of costly renewable technologies, one of the 2006 mission industry participants, Alouette Homes, considered the actual production of PV solar housing immediately after the mission. In fact, receiving support from external zero-energy housing experts including the first author as the housing design lead and Prof. Andreas Athienitis as the engineering lead, the manufacturer developed its own near net zero-energy house prototype, later called 'ÉcoTerra house' (Fig.3).

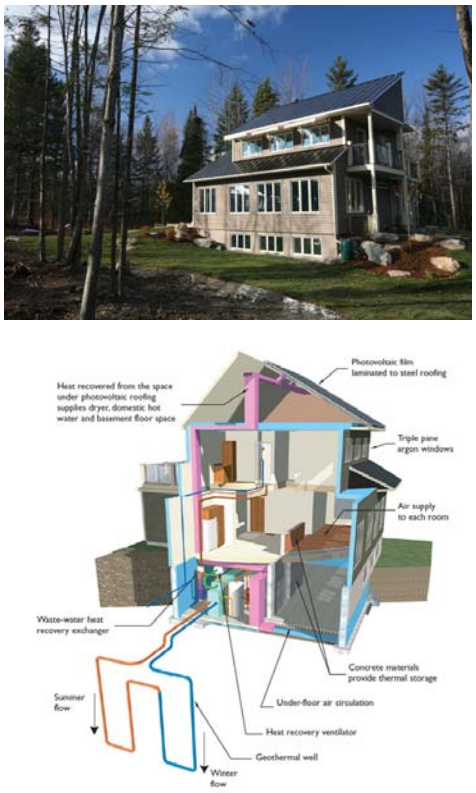

Fig.3. ÉcoTerra house by Alouette Homes in Canada
Top: South-facing façade appearance
Bottom: Service equipment schematic diagram
(Source: Alouette Homes)

The company also entered the housing prototype in the EQuilibrium sustainable housing competition that had been run by the Canada Mortgage and Housing Corporation (CMHC). On 13th February, 2007, CMHC unveiled the finalists of the competition. In total, 12 homebuilder teams were originally selected out of 72 entries and the Alouette Homes' ÉcoTerra house was also included in the list of the winning projects. On 9th November, 2007, the grand opening of the ÉcoTerra house was held at the construction site in Eastman, Quebec, where the Honorable Christian Paradis, Secretary of State, made the inaugural address and congratulated Alouette Homes on the successful completion of Canada's first net zero-energy house built and commercialized through the federal government's EQuilibrium sustainable housing initiative.

Following the 2006 mission delegate's project success, Aberdeen-based Tenants First Housing Co-operative, who attended the Zero-energy Mass Custom Home Mission to Japan twice in 2007 and 2008, took the initiative for construction of zero-carbon (or emission) affordable homes with due consideration of the housing social, economic and environmental sustainability (Fig.4).

Fig.4. Donside Zero-carbon affordable homes' initial unit arrangement and landscape image, Tenants First Housing Cooperative (Source: MEARU)

This £1.5million zero-carbon affordable housing project being carried out in partnership with MEARU, Mackintosh School of Architecture was launched on 27th May, 2009. It has been supported partially by the UK government through the Knowledge Transfer Partnership program. In view of the Code for Sustainable Homes Level 6 scheme, 10 zero-carbon mass custom homes will be constructed initially in Aberdeen, Scotland, by 2012.

Moreover, Robertryan Homes, the delegate who attended the Zero-energy Mass Custom Home Mission to Japan in 2007, is also carrying out the company's first net zero-energy housing project today. The house aims to optimize passive solar gains whilst heated mechanically using low CO_2 emission energy source. The design innovation extends to the installation of a PV/thermal heat recovery system with the aim to maintain fresh air heated by PV cells so as to reduce the total space-heating load. The prototype will be constructed in West Kilbride, Scotland, in the middle of 2011 (Fig.5). In order to analyze the value mismatch between the as-designed energy simulation and the as-built housing performance, post-occupancy evaluation will be carried out in due course.

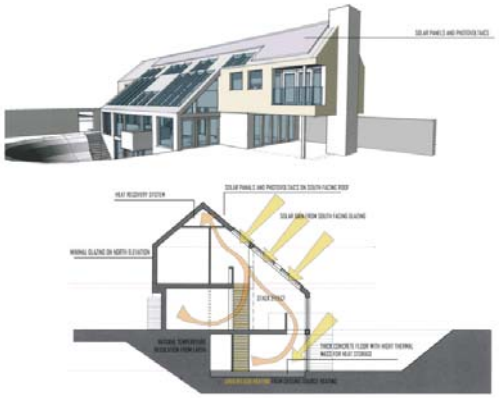

Fig.5. West Kilbride zero-energy house conceptual design image, ROBERTRYAN Homes
(Source: ROBERTRYAN Homes)

CONCLUSIONS

Homebuilders' business operations often develop into routine. To change housing suppliers' perception to zero-energy homes, which correspond with societal demands, builders (and housing manufacturers) should be given educational opportunities that help them understand not only readily available low-energy sustainable housing design techniques accompanied by zero-carbon renewable energy technologies, but also the marketability of such homes. The Zero-energy Mass Custom Home Mission to Japan was carried out successfully in 2006, 2007 and 2008 and helped transformed at least three industry participants in North America and Europe to date from conventional housing suppliers to early adopters or champions of low to zero-energy homes in their local contexts.

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