Case Study of An Environmental Residential Building System For Hokkaido, Japan
Akira Yamaguchi† and David Cohen‡

ABSTRACT
As green building becomes increasingly important examples from around the world will provide some of the directions for improving not only our buildings but also the impact they have on our global environment. An example from the North Island of Hokkaido, Japan is presented. Some design and construction considerations are similar to green building concepts in North America others are relatively new and thought provoking. Environmental considerations are only some of the ethos that this building system considers, this holistic model does provide avenues of exploration for North American designers of wood buildings to consider. The authors develop a model to interpret much of the normative reality of environmental design and building that has produced over 16,000 houses to date. This model is compared to some of the current North American models of “green building” and then each component is discussed in more detail.

INTRODUCTION
The importance of buildings, both residential and non-residential, on the environment is significant. Buildings account for one-sixth of the world’s fresh water withdrawals, one-quarter of its wood harvest and two-fifths of its material and energy flows (Roodman and Lenssen, 1995). Not only do they require resources to construct and maintain but up to 30% of new and renovated buildings suffer from “sick building syndrome”, subjecting occupants, many who spend up to 90% of their time indoors, to unhealthy air (Lowe, 1991). The need to ensure that sustainable building practices are adopted on a global scale is becoming widely accepted. There is growth in organizations or groups like the Association for Integral Biological Architecture or the Green Building Council throughout the nineties. Their objective is to stimulate and educate professionals and the public in environmental techniques, technologies and products. This paper discusses a house building company with a strong environmental ethos constructing wood frame residential houses in Japan.

Kinoshiro Taisetsu “(KST)” is the name of a company in the business of building houses in the northern island of Hokkaido Japan. It is a company founded on a fundamental commitment to building homes designed and constructed specifically for the environmental realities of this northern region with six months of winter annually. Fundamental to the company is a strong commitment to environmental and social ethics. A complete building system has been developed specifically to suit the climactic realities of the North Island of Japan, Hokkaido within a global concern for environmental impacts – a positive and practical example of thinking globally but acting locally. This system incorporates many factory-built components as well as traditional construction techniques from historic Japanese temple construction (Cohen et. al, 1996).

Through most of the twentieth century housing design and construction techniques in Hokkaido were imported from the southern island of Japan (Honshu). These styles were based on traditional Japanese house design which was much better suited to living conditions free from snow (Yamaguchi, 1994). The fundamental focus in the design and construction of these types of houses was on creating a comfortable living environment for the hot and humid summer season (Onobayashi, 1965). The evolution of the KST building design was developed to ensure comfort during a long and relatively harsh winter season. This dramatic shift in the fundamental design focus allowed the firm to include many other radical features such as year round construction, a flat roof system, larger houses more suitable for multi-generational families and many environmental considerations. The building system is based on traditional Japanese temple design, traditional Japanese timber-frame construction techniques used in residential housing and the use of modern engineered wood products. In addition, construction includes the use of high quality factory built components. The system is a unique blend of tradition with the modern. The KST Total Housing System has been responsible for

† Founder and owner of Winter Research Institute Corporation and KST-Hokkaido
‡ Associate Prof. Department of Wood Science, University of British Columbia
building over 16,000 houses in the past several decades and much more focussed on doing rather than discussing (Cohen et al, 1996). This paper outlines various environmental aspects, which were considered in the design, construction and use of unique timber frame house.

The philosophical underpinnings of the KST housing system include social, economic, environmental and cultural parameters. These philosophical foundations are extremely complex marrying antithetical concepts on a normative and practical plane (McQuillan and Preston, 1998). However, the marriage of opposites such as technology and ancient craft is best left to a more suitable venue, as are other innovations in the design, sales, construction and use of the KST house. This paper focuses on the environmental aspects of the KST housing system.

ENVIRONMENTAL PARAMETERS

The environmental concerns can be grouped into four broad but often interlinked characteristics. These were derived post hoc from observing the complex interactions of many perspectives, which are reflected, in the actual physical structure of the house. One of the most interesting and significant differences between much Western environmental thought and that presented here is the role of humanity. In the fundamental environmental considerations, the family, representing humanity, is at the core. Many of the more radical environmental philosophies subordinate the role of humanity to that of parasite.

Over the past several decades, an important concern for many human activities has been their ecological impact or footprint. This concept has emerged as the science of life cycle analysis or the philosophical perspective of “earth friendly” structures or sustainable activities and/or development. This concept measures the ecological footprint over time of alternative actions and decisions. It can be applied to housing and is a keystone in the design, material selection and construction of the KST house.

A second important environmental consideration is the health of the residents of KST houses. This can be negatively impacted due to poor indoor air quality as well as low comfort levels through the harsh winter season in a society with little central heating and high costs for energy.

A third environmental component is the energy use and carbon sequestering. This has become increasingly important during the past decade given scientific concerns regarding global warming. The Kyoto meetings on global warming and the international agreement to reduce greenhouse gas emissions were hosted by Japan partially due to the country's commitment to improving this aspect of environmental degradation.

The fourth environmental aspect that has strongly guided the design and construction of KST houses is the longevity of the structure. This directly impacts material usage over the generations and the ability to ensure renewable and natural resources such as wood are used in a sustainable fashion. In addition increased longevity can contribute to decreased material requirements over time as well as increased importance placed on quality. This is of particular concern in Japan where the average house lasts less than 30 years and in some cases less than 20 years (Anonymous, 1998). These four environmental categories are shown graphically in Figure 1.

These four environmental characteristics correspond to the groupings developed by Wolley et al (1997) for green building principles. Those groupings included

1) minimizing external pollution and environmental damage (corresponds to sustainable material selection and life cycle analysis),
2) minimizing internal pollution and damage to health (corresponds to minimizing negative health impacts to residents),
3) reducing embodied energy and resource depletion (corresponds to both longevity and life cycle analysis) and,
4) reducing energy in use (corresponding to energy use and carbon sequestering).

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3 Much of the information regarding the KST philosophy has been gathered during numerous visits and interviews between the authors. In addition, much information was collected during interviews between Dr. Cohen and managers, employees and customers of KST and Fuyosoken (the Winter Research Institute) from 1995 until the present.

Ecological Footprint

Much attention continues to be given to material selection based on the impact these materials will have on the environment. Often the selection of materials will impact not only embodied energy but also energy use over time. KST has approached this objective through several avenues. First, there is a strong commitment to using natural and renewable materials such as wood for structural purposes, wool and wood for floor coverings and cotton for wall coverings. There is strong support in the literature for wood use due to superior environmental properties, relative to alternative structural building materials using various life cycle analysis tools (Marcea and Lau, 1992; Koch, 1992; Buchanan, 1993 and Arima, 1993). Life cycle analysis examines the environmental impact of the production of all materials used in construction from resource extraction, to material production to maintenance and finally demolition and reuse or disposal. This ecological impact information can be combined with environmental impacts resulting from using and renovating the building. For example the requirement for both embodied energy (all energy required to construct and demolish the building) can be added to the “energy in use” requirements to create a complete energy measure, often an excellent surrogate for overall ecological impact. Life cycle analysis is new and developing field of study and there is still much discussion over the “accuracy” of many of the measures for factor such as energy use. However key concerns regarding energy consumption, heat transfer during use, water consumption during material manufacture and other factors indicate that wood has some environmental advantages over alternative materials other than the fact that it is renewable.

One of the most complex aspects of life cycle analysis and trying to measure the ecological footprint is the time frame for the ecological audit. For example what is the environmental trade-off between creating a larger ecological footprint to build a structure if the structure would last twice as long as an alternative which had a smaller initial footprint? These concepts will be discussed in the section on longevity. However, this dilemma becomes apparent when unpublished results of a carbon cycling study of KST houses and alternative houses in Hokkaido are examined. The houses built by KST use substantially more wood than typical houses built in Hokkaido on an area basis. However, the KST houses require less energy to heat and should last a substantially longer time period. The energy break-even point is seven years. Thus in seven years the energy saved due to a very efficient heating system as well as increased use of materials is equal to the increased energy required to make the materials in a KST. The implication and value of the trade off between increased material use to both extend longevity and increase energy efficiency would require a separate paper in itself.

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5 personal communication from Dr. Jack Spengler regarding unpublished results from Harvard School of Public Health
At KST there is an additional corporate commitment to move towards increasing usage of local natural materials to ensure not only regional social sustainability but to minimize environmental transportation costs. Commitment to using natural and renewable materials takes a very long view of material consumption and recognizes that increasing populations and economies ensure depletion of non-renewable resources even with increased recycling (Zeiger, L., 1996). While the impact of sourcing materials locally is still a matter of some debate, the approach of using regionally supplied raw materials from renewable and sustainable sources seems imminently logical, particularly for use on an island substantial distance from alternative material supplies (Malin, 1996). One of the environmentally beneficial consequences of this “bioregional” policy has been the development and use of laminated lumber products from regional timber thinnings. This has contributed to improved forest management practices through intensive silviculture by converting previous wood waste to a raw material supply for both structural and non-structural building components.

The last factor that will be presented in this paper regarding the ecological footprint is the concept of ecological footprint per person using the house and not per unit area. This is not a common perspective. However, by keeping the family at the core and designing a house that encourages multi-generational living, the KST house compensates for their increased size by focusing on area per inhabitant. The result is often less area per person despite more area per house. This contributes significantly from an environmental perspective for the same reason that “reduce” is the first in the hierarchy of the three R’s due to continued population growth.

**Indoor Air Quality**

For all products in the house there has been an active avoidance of the selection and use of materials, which off-gas potentially irritating chemicals. Chemical sensitivity, particularly for formaldehyde is of great concern to the majority of Japanese consumers (Cohen and Gaston, 1998). This has led to material selection, which favours natural materials over those that are synthetic. An avoidance of plastics as well as chemically based materials ensures that once the initial off-gassing due to surface finish has been vented there is little long term omissions of toxic chemicals.

In addition, the house is designed to facilitate slow leakage of air ensuring air transfer between the indoor air and the relatively unpolluted air of Hokkaido. The heavy use of wood and the use of wood on wood connections ensure slow air leakage. In addition, the intentional omission of a vapour barrier contributes to continuous air leakage. The building envelope has received special consideration to produce a “breathable” skin suitable to a climate with a six-month winter and substantial snow levels. This in turn has required the use of innovative products such as a breathable backing on fiberglass insulation. The backing on the insulation includes many perforations as specified by KST. This ensures slow air transfer without condensation and associated wood-water problems. In addition, traditional joins are used to connect the walls to the floors and corners. These are wood on wood connections where the wall can move since it fits within a sleeve which is part of the wall or floor where the connection is made. This allows some movement as materials adapt to different winter and summer conditions and swells and shrink with changing humidities. It also facilitates the slow air transfer between the interior and exterior portions of the building envelope. The use of a breathable envelope is significantly different from trends in building construction techniques in North America. It is designed specifically for indoor air quality as well as to increase the longevity of the building.

Incorporating a natural air exchange without the need for mechanical air exchange not only reduces energy requirements to facilitate air exchange but ensures that air exchange occurs even during interruptions of power. The environmental cost of this leakage should be increased energy requirements to heat the house. However, in a KST house this is not the case as is explained in the following section.

**Energy Use**

All KST houses follow the basic design of a rectangle. This shape is the most efficient in terms of energy use in cold climates since it minimizes the number of both horizontal and vertical planes separating the controlled indoor environment and external weather. Only unheated portions such as decks, stairs and driveways protrude from this basic box shape which contributes to efficient energy use. By maintaining this basic shape and minimizing the number of environmentally controlled protrusions, the energy consumption of any house is minimized.

The house is heated by a Russian “Petchka” kerosene heater. The exhaust is directed through a horizontal coil of pipes encased in concrete and brick prior to being vented outside. This not only captures almost all of the heat, but also creates a heavy mass of concrete and brick suitable for radiant heat transfer. By combining a central, low-rise stair system with a
radiant heating system fueled by a small kerosene heater, the actual cost of energy is less than the average modern airtight house in Hokkaido. Use of radiant heat ensures heat transfer regardless of the availability of energy to run fans for air circulation in a centrally heated house. The heavy mass of concrete and brick becomes a feature of the main floor for each KST house and becomes the core for the design of other rooms. Electronic fans can be used to ensure adequate heat transfer to the far corners of rooms on the second floor.

The house is well insulated and designed for slow air transfer for indoor air quality. It is also designed to prevent drafts. In-house, as well as independent studies verify that energy consumption on either a square foot basis or a cubic volume base is less than averages for other modern houses in Hokkaido. Another unique feature, which contributes to improved energy use, is the flat roof, which is separated from the main structure i.e. a cold roof. This roof stores snow throughout the winter reducing problems associated with snow falling from sloped roofs in an area with high snow loads along with small building lots and dense housing. It also contributes to providing a relatively quiet air space above the heated portion of the house reducing heat loss. By preventing snow from falling from the roof and laying against the exterior walls of the house, a common sight in Sapporo, the largest city in Hokkaido, the heat efficiency of the house is also increased. No longer does the house wall have to heat the snow that leans against the walls and sunlight can reach the majority of windows located on the southern walls to provide some passive solar heating. This also contributes to longevity since removing this snow reduces condensation and associated decay, mildew and structural degradation. The windows are made up of two sets of two panes of sealed glass and third set of single glass. The enables occupants to adjust heat levels by sliding one or more of window sets up and avoid having to adjust the heat of the large concrete and brick mass, a slow process.

Longevity
Houses in Japan last less than 30 years on average. This is due to the historic construction of temporary houses with movable bedding and furniture due to the need to replace houses after fires resulting from frequent earthquakes. Traditionally houses have been considered durable goods (similar to a washing machine in North America) while the land is what had permanent value. To this day, there exists only a very small market for second hand houses. It is Japanese tradition to replace a house if the land is sold or if the next generation moves onto the family land (Cohen et. al, 1996). One result of this practice is a life span for an average wood house less than half than that achieved in Europe of North America (Anonymous, 1998).

Recently there has been growing awareness in Japan that there is a tremendous environmental and social cost in replacing houses every 25 years. In 1994 the Japanese Ministry of Construction included in its policy revision the objectives to reduce life cycle costs and increase longevity of new housing (Japan MOC, 1994). The KST house has been designed to greatly expand the longevity of housing in Hokkaido. Some of the activities that have already been presented that increase longevity include the flat roof system, a breathable envelope and movable joints to prevent splitting and cracking. However, there are several other design and construction processes that contribute to increased longevity for a KST house.

The design of KST houses borrows from traditional Japanese temple construction by using oversized structural support members to provide structural redundancy. Lessons from wood buildings that have lasted millennia indicate that over-design and building has structural redundancies, which ensure increased longevity and the ability to repair major structural supports rather than replace the entire building. Thus if there is minor decay or other factors which reduce the load bearing capabilities of main structural supports the overall strength of the house does not decrease below safe standards. Repairs can be made which do not have to bring the house back to its original strength parameters resulting in repair often being more financially attractive than replacement.

An additional factor, which increases the longevity of the KST house compared to others, is the consistent quality in assembly of components. Most components are produced in a single factory with rigorous quality control. By centralizing the construction of components, simplifying their fabrication and ensuring high quality throughout their manufacture, the finished product has few if any weaknesses that contribute to reduced longevity. In addition, the

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6 ibid
7 Research is underway both at the University of British Columbia and Harvard School of Public Health that examines different aspects of this rather unique roof system.
company produces as much of the materials and sub components in-house as is possible. By sawing the logs to produce lumber and then drying their own lumber, not only is waste minimized but also quality is guaranteed. The firm produces its own plywood, laminated lumber, lumber, posts, beams, joinery, mouldings, windows, doors, cabinets and much much more. This integration ensures consistent quality of each and every component which contributes to increased longevity.

SUMMARY

As green building design matures and grows, the global nature of various solutions can provide meaningful illumination of not only problems but also the variety of solutions available. An examination of some of the factors considered by a builder with a strong environmental ethos was examined based on the principles considered. As a relatively new field of design and construction, it is critical to continually examine new approaches and holistic solutions. The design and construction by Kinoshiro Taisetsu in Hokkaido provides much food for thought for wood engineers and architects interested in green design and construction.

REFERENCES


McQuillan, Allan and Ashley Preson, 1998. Globally and Locally: Seeking a Middle Path to Sustainable Development (pages 199-252). University Press of America, Maryland USA 449 pages


