# ENERGY CONSUMPTION THROUGH TIMBER TRANSPORTATION AND THE WOODMILES THE POSSIBILITIES OF THE WOODMILES INDEXES FOR EVALUTAION OF BUIELDING

**Takashi FUJIWARA Ph.D**[1]
Hideshi NODA Ph.D [2]
Takuya SHIMASE [2]
Satoshi TACHIBANA Ph.D [2]
Takuya TAKAHASHI Ph.D [3]

[1] Japan Federeation of Wood Industry Associations, 6F Nagatacho BLDG. 2-4-3 Nagatacho Chiyodaku, Tokyo, 100-0014, Japan, fujiwara@t.nifty.jp
[2] Forestry and Forest Products Research Institute
[3] The University of Shiga Prefecture

Keywords: woodmiles, woodmileage, $CO_2$, discharge, transportation, energy, consumption, timber,

## Summary

About one third of constructions in Japan have wooden structure, and timber is considered to be one of the important building materials. One of the features of timber as building materials is that very little amount of energy is consumed under its production processes. However it is pointed out that the energy consumption during transportation processes of timber from forests over seas to Japanese market is quite larger than the energy consumption during its production processes.

In order to shorten the transportation distance of the timber used for construction, and to promote a demand for locally produced timber, the Woodmiles Forum was launched in June, 2003. The forum is aiming at the development and promotion of the woodmiles indexes, including “the woodmileage for building” which represents a sum of the products between the volumes of wooden materials of a house multiplied by the corresponding actual transportation and “the woodmileage $CO_2$ for building” showing the quantity of carbon dioxide discharged in transportation processes.

This paper clarifies the possibility of the woodmiles indexes as a tool to evaluate environmental load in transportation processes of timber materials, through several evaluation case studies.

## 1. Introduction

In order to evaluate environmental load of buildings, sophisticated methods including various kinds of life cycle assessments are being developed. Up until now it cannot be said that methods developed have spread enough or that there has been enough reward from massive amounts of efforts. One reason as pointed out is the difficulty for users of such methods to interpret results from an evaluation despite methods such as LCA aiming to be quite comprehensive.

The woodmiles indexes, to be dealt in this paper, were developed by the Woodmiles Forum in Japan to evaluate some aspects of the environmental load of building materials. It may be limited because these indexes have a restricted range of timber transport distances if considering this index in regards to evaluations of the environmental loads from buildings. However, it could give us an opportunity for propagation, because

1) this index provides its users with a simple and clear index of environmental load and
2) this index provides a measurement for forming a network of supply of building materials.

In this paper we will explain the background the method of evaluation with the woodmiles indexes, and the possibilities and the assignment of them.

## 2. Timber Building Materials in Japan and its Sources of Supply

### 2.1 Timber as Building Material in Japan and its Evaluation of Energy Consumption

In Japan, 173 million $m^2$ of buildings were built in 2003, 63 million $m^2$ of them were wooden frame buildings. Timber itself is one of the most important building materials in Japan.

It is pointed out that one of the features of timber as a building material is its efficiency of energy consumption in production processes. Nakajima, S. and Okuma, M. reported that the quantity of carbon emitted from the production of one cubic meter of timber is fur smaller than that of other construction materials. (Table 1)

Table1 Energy Consumption and $CO_2$ Discharge in Production Process of Construction Materials

| Material | Fossil energy consumed | | $CO_2$-discharge | |
|---|---|---|---|---|
| | MJ/kg | MJ/$m^3$ | kg/t | kg/$m^3$ |
| Sawn timber air dried | 1.5 | 750 | 110 | 55 |
| Sawn timber kiln dried | 2.8 | 1390 | 205 | 103 |
| Plywood | 12 | 6000 | 799 | 440 |
| Particle board | 20 | 10000 | 1129 | 733 |
| Steel | 35 | 266000 | 2567 | 19507 |
| Aluminum | 435 | 1100000 | 31900 | 80667 |
| Concrete | 2 | 4800 | 183 | 440 |

Nakajima, S. and Okuma, M. 1991

### 2.2 Sources of Supply of Timber Used in Japan and the Environmental Load from Timber Transportation

In 2002, the demand for timber (sawn timber) for Japan was 34,856 thousand cubic meters (log equivalent basis). 70% was used as building materials. As to the sources of supply, domestic timber accounts for 32% of the supply and the others are supplied form foreign resources.. Main sources of imported timber of Japan are North America, South East Asia, Russia(Asian), Europe and New Zealand.

The Table 2 shows results of calculations that average the quantity of carbon dioxide discharged from distances of their transportation and its process of transportation, after analyzing routes of transportations of timbers from its origin.

Table 2 Distance and $CO_2$ Discharged of Transportation of Imported Sawn Timber

| Origin | Distance of Transportation (km) | | | | | | | $CO_2$ discharge ($kg/m^3$) |
|---|---|---|---|---|---|---|---|---|
| | Total | Sawn Product | | | Raw Log | | | |
| | | boat | truck | rail | boat | truck | rail | |
| North America | 8064 | 7710 | 254 | 0 | 0 | 100 | 0 | 160 |
| South East Asia | 5490 | 5736 | 254 | 0 | 0 | 0 | 0 | 131 |
| Russia | 6145 | 1921 | 254 | 3800 | 0 | 170 | 0 | 156 |
| Europe | 23274 | 22570 | 254 | 350 | 0 | 100 | 0 | 326 |
| New Zealand | 9770 | 9116 | 554 | 0 | 0 | 100 | 0 | 231 |

Fujiwara, T. and the Woodmiles Forum, 2005

Timber from Europe, the farthest major origins from Japan, travels 23 thousand kilometres. 326 kilograms of carbon dioxide per one cubic meter of timber is discharged from its transporting process. Fig.1 shows a comparison of this figure with the quantity of carbon dioxide discharged from the production process described in Table 1. It is clear that transportation of timber through long distances has more environmental load than the production process of the timber has.

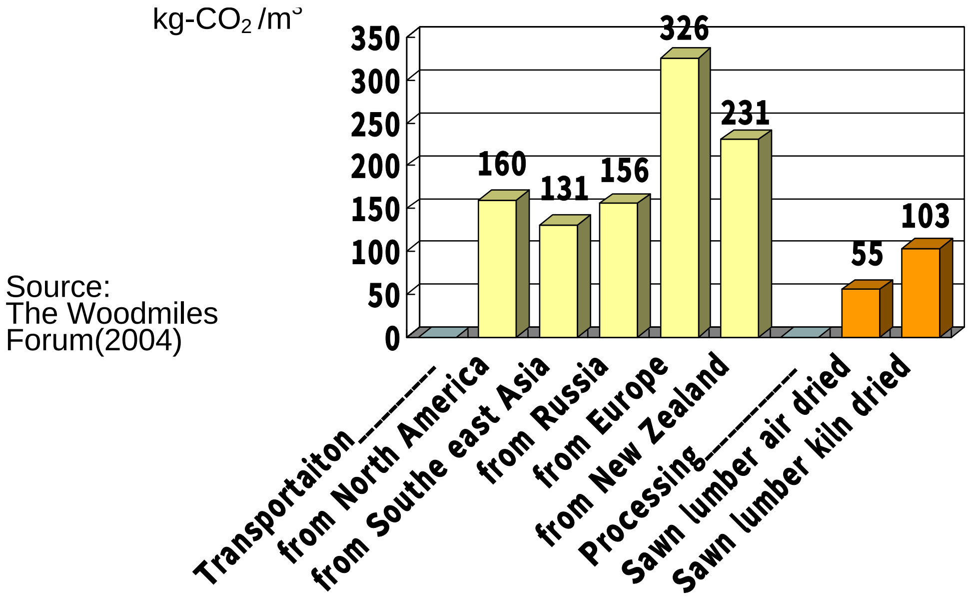


*Figure 1 $CO_2$ discharged on timber transportation to the Japanese market and timber production process (Source: Fujiwara, T. and the Woodmiles Forum 2005)*

### 2.3 Comparison of Timber Transportation Distances by Importing Countries

Further, Fujiwara, T. compared the transportation distances of timbers in importing processes for three countries Japan, U.S.A. and Germany, using the statistics of trading 2000 by the Food and Agriculture Organization. The U.S.A. imported the largest quantity of timber in the world and Germany imported largest quantity of timber in Europe. The Table 3 shows respective quantities of imported timber for each country by distances from the origins.

Table 3 Timber Importation Volume of Major Importing Countries by Distance form Origin

thousand cubic meters

| Distance from origin | Japan | | USA | | Germany | |
|---|---|---|---|---|---|---|
| Total import of timber | 52009 | 100.0% | 60357 | 100.0% | 22790 | 100.0% |
| -1000km | 0 | 0.0% | 55889 | 92.6% | 9378 | 41.1% |
| 1000-8000km | 33393 | 64.2% | 2845 | 4.7% | 13074 | 57.4% |
| 8000km- | 18616 | 35.8% | 1623 | 2.7% | 338 | 1.5% |

Fujiwara, T. 2002

If the distance of transportation is divided into three categories, U.S.A., which imported 93% from Canada depends the most imported timber on the nearest sources. Although U.S.A. has imported valuable timber such as *Mahogany* and *Teak* from South-East Asian countries more than 10,000 kilometres away, it only comprises 3% of the total amount of timber imported. On the other hand, Japan is one of the few countries that import substantial amount of timber from countries more than 10,000 kilometres away. If we introduce a concept of “Woodmileage” (total transporting distance that multiplies imported quantity of timbers and transporting distances), though the quantity of imported timbers for Japan would be less than that for U.S.A., the woodmileage for Japan would be more than 4 times as much as that of U.S.A. (Fig. 2)

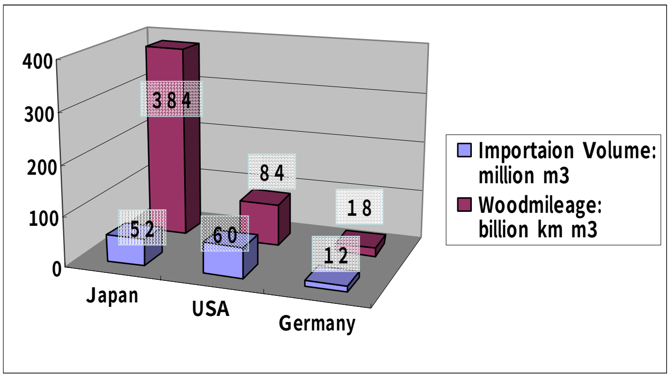


*Figure 2 Comparison of woodmileage of imported timber in major timber importing countries.*

## 3. Development of the Woodmiles Index

### 3.1 The Woodmiles Forum

As described above, the energy consumed for the transportation process of timber is a critical factor in environmental loads and it is especially an important problem to Japanese consumers. As this problem was brought to their attention the Woodmiles Forum ( here in after refereed as “the Forum”) was founded in June, 2003.

The purpose of the Forum is the development and promotion of the woodmiles indexes in order to shorten transportation distances of timber used for building houses and to revitalize local timber consumption. The Forum's goal is to contribute to realize the sustainable society by promoting the use of local resources in Japan.

### 3.2 The Woodmiles Index for Building and its Structure

To achieve the above mentioned objectives the Forum developed a manual to provide a reproducible and objective method of calculating the "Woodmiles Indexes for Building".

The manual revised in March 2005 defines the following four indexes for evaluation of building construction.

Building Woodmileage*(BWM)*

Actual distance covered in transporting timber of the applicable type used in the construction of a building (hereafter, applicable timber materials) from each place of harvest (timber type-specific woodmiles) multiplied by the respective volumes of timber transported from each place of harvest (unit: km $m^3$)

Building Woodmileage $CO_2$ *(BWMCO*$_2$*)*

$CO_2$ emissions equivalent to the energy expended in covering the above distances according to the types of transportation used (road, rail, sea, etc.) for each form of timber (unprocessed or processed) (unit: kg- $CO_2$)

Building Woodmileage L (L = linear)(*BWML*)

The linear distance from each place of harvest (timber type-specific woodmiles L) of applicable timber materials to the construction site, multiplied by the respective volumes of timber transported from each place of harvest (unit: km $m^3$)

Logistics Stops Knowledge Level(*LSNL*)

The degree, expressed as a proportion of total woodmileage, of applicable timber materials for which knowledge of processing and storage stops on the way from each place of harvest to construction site enables the calculation of an accurate woodmileage figure

### 3.3 Practical Meaning of the Woodmiles Index: Case Studies of the Large Scale Wooden Frame Domes

#### 3.3.1 Large Scale Wooden Frame Domes as Objects Used in Evaluation Studies

The building of large scale wooden frame domes has been increasing in Japan in recent years. They play role of symbol of promoting (local) timber utilization in each areas. We chose the largest three domes of the domes built since 1990 and compared the woodmiles indexes calculated from structural timbers used in these buildings. The building descriptions are shown in the Table 4.

Table 4 Building Description of the Dome

| Name | Izumo Dome | Odate Jyukai Dome | Konohana Dome |
|---|---|---|---|
| Location | Izumo City, Shimane Prefecture | Odate City, Akita Prefecture | Miyazaki City, Miyazaki Prefecture |
| Time of building | Oct.1990 to Mar.1992 | Jul. 1995 to Jun. 1997 | Dec.2002 to Mar.2004 |
| Building Areas | 16,277 $m^2$ | 21,911 $m^2$ | 10,966 $m^2$ |
| Height | 49m | 52m | 38m |
| Structure | Arch of glued laminated timber of Douglas fir | Arch of glued laminated timber of Japanese cedar | Arch of glued laminated timber of Japanese cedar |
| Timbers used for buildings | 2150 $m^3$ | 4273$m^3$ | 1381 $m^3$ |
| Type of timber | Douglas fir (*Pseudotsuga menziesii*) | Sugi (*Cryptomeria japonica*) | Sugi (*Cryptomeria japonica*) |
| Origin of Timber | North America | Akita Prefecture, Japan | Miyazaki Prefecture, Japan |


*Figure 3 Large Scale Wooden Frame Domes in Japan ( Photos are provided by the City Hall of Izumo City Takenaka Corporation/ Miyazaki Wood Techno Co.,Ltd.)*

3.3.2 Supply Process of timber and Outlines of the Woodmiles Indexes

All of these domes are large arch shaped structures comprised of glued laminated timbers used as the main structural material. Although the Izumo Dome which was built at an earlier stage used north American Douglas fir (*Pseudotsuga menziesii*) for its structural material, the other two domes that were built at the production centers for Japanese cedars *(Cryptomeria japonica)* in later stages used Japanese cedar supplied from their own prefectures.

Transportation and production processes of the timber used for the Dome are described in the Table 5.

Table 5 Production and Transportation Process of Timber Used for the Domes

| | Izumo Dome*1 | Odate Jyuaki Dome*2 | | Konohana Dome*3 |
|---|---|---|---|---|
| Harvest site | Bend, OR. | Yoneshiro Riv. Basin Akita Pref. | | Mimikawa Riv. Basin Miyazaki Pref. *4 |
| Transportation | 236km by truck | 30km by truck | | 40km by truck |
| Saw mill | Springfield, OR. | Yonesiro Riv, Basin | | Togo Town Miyazaki Pref. |
| Transportation | - | 50km by truck | | - |
| Dry kiln | ditto | Kazuno City Akita Pref. | | ditto |
| Ttransportation | 32km by truck | 710km by truck | 52km by truck | - |
| Laminating mill | Cottage Grove, OR. | Wada Village Nagano Pref. | Odate City | ditto |
| Transportation | 205km by truck | 741km by truck | 7km by truck | 93km by truck |
| Export port | Portland, OR. | | | |
| Transportation | 8543km by boat | | | |
| Import port | Kobe, Hyogo Pref. | | | |
| Transportation | 308km by truck | | | |
| Building site | Izumo, Shimane Pref. | Odate, Akita Pref. | | Miyazaki, Miyazaki Pref. |
| Total distance | 9272km | 1531km | 138km | 133km |
| $CO_2$discharge per unit | 246kg/ $m^3$ *5 | 286kg/$m^3$ *5 | 28kg/$m^3$ *5 | 27km/ $m^3$ *5 |
| | | 162 kg/$m^3$ | | |
| Timber Vol. | 2150 $m^3$ | 2356 $m^3$ | 2175 $m^3$ | 1381 $m^3$ |
| | | 4273 $m^3$ | | |
| Woodmileage | 19934 '000km $m^3$ | 3685 '000km $m^3$ | | 453 '000km $m^3$ |
| $WMCO_2$ | 529ton | 718ton | | 37ton*6 |
| $WMCO_2$ (sim.1)*7 | 529ton | 1052ton | | 340ton |
| $WMCO_2$ (sim.2)*8 | 58ton | 116ton | | 37ton |

*1 Source: Tanaka, S. Japan Lumber Importers' Association/ Watanabe, T. Government of Shimane Pref.

*2 Source: Shimizu, K. Government of Akita Prefecture

*3 Source: Jodo, H. and Hidaka, K: Government of Miyazaki Prefecture

*4 Some part of timber is from the other area in the same prefecture but most(85%) of total timber is from the Mimikawa River Basin

*5 The $CO_2$ emission units used to calculate woodmileage$CO_2$ are 0.18515kg-$CO_2$/km $m^3$ for truck and 0.01095kg-$CO_2$/km $m^3$ for boat. (The Woodmiles Forum "Manual for Calculation of Woodmiles Indexes for Building Version 2005")

*6 The figure includes that of the timber come from the other area than the Mimikawa River Basin.

*7 The figure calculated under the condition if the timber had been transported from oversea as the same condition as that of the Izumo Dome

*8 The figure calculated under the condition if the timber had been transported from local area the same condition as that of the Konohana Dome

For the Izumo Dome constructed in 1992, Douglas fir timber was harvested in the Cascade Mountains near Bent, Oregon. Logs are transported to a saw mill in Springfield OR. Processed and dried laminar was transported to a glued laminated timber factory located in Cottage Grove, OR. Possessed timber (Glulam) was transported via Portland OR. and Kobe, Hyogo Pref. to the construction site in Izumo City, Shimane Pref.

For the Odate Jyukai Dome constructed in 1997, Japanese cedar timber was harvested in the National Forest under the Akita Regional Forest Office, sawed in local sawmills and kiln dried in Kazuno City, Akita Pref. Originally, the timber was planned to be assembled into glued laminated timber at a newly constructed factory in Odate, Akita Pref., but because of restrict time schedule timber used in the early stages of the building was transported to Wada Village, Nagano Pref. 700km away, where an operational large scale laminated timber factory was running, and transported again to Odate City where a construction site was located. The other half of the timber was processed into glued laminated timber in the newly constructed factory in Odate City near the construction site.

For the Konohana Dome constructed in 2004, Japanese cedar timber was harvested in forests located in the Mimikawa River Basin, the north of Miyazaki Pref. and sawed dried and assembled into glued laminated timber at factories located in the same area. The possessed glued laminated timber was transported to the construction site in Miyazaki City, about 100km south of the factories.

These descriptions of timber supplying processes to the building project of big domes constructed at different time shows that, as the time goes on, timber supplying processes to large scale wooden framed dome in Japan had changed. Owing to the progress of infrastructure of supplying heavy timber for large scale construction in Japan, both the harvest location and the processed site had been getting nearer to the construction site. This kind of discussion shows the possibility of woodmiles study to analyze social aspect of circumstances around construction.

The result of calculation of woodmiles indexes are shown in table 5 summarized as follows.

1) As to the woodmileage, the figure of the Izumo Dome whose timber was transported from North America was the largest, followed by that of the Odate Jyukai Dome and the Konohana Dome in order.

2) As to woodmileage$CO_2$, the figure of the Odate Jyukai Dome whose timber had the largest volume and was traveled more than 1400 km in Japan by truck was the largest, followed by the figures of the Izumo Dome and the Konohana dome in order.

3) When compare unit $WMCO_2$ per $m^3$, the numbers line as the Izumo Dome> the Odate Jyukai Dome> the Konohana Dome. We can make simulation of construction of all domes with the same timber used in the Izumo Dome or the Konohana Dome. The result is listed in the Table 5 and outlined in the Figure 4.

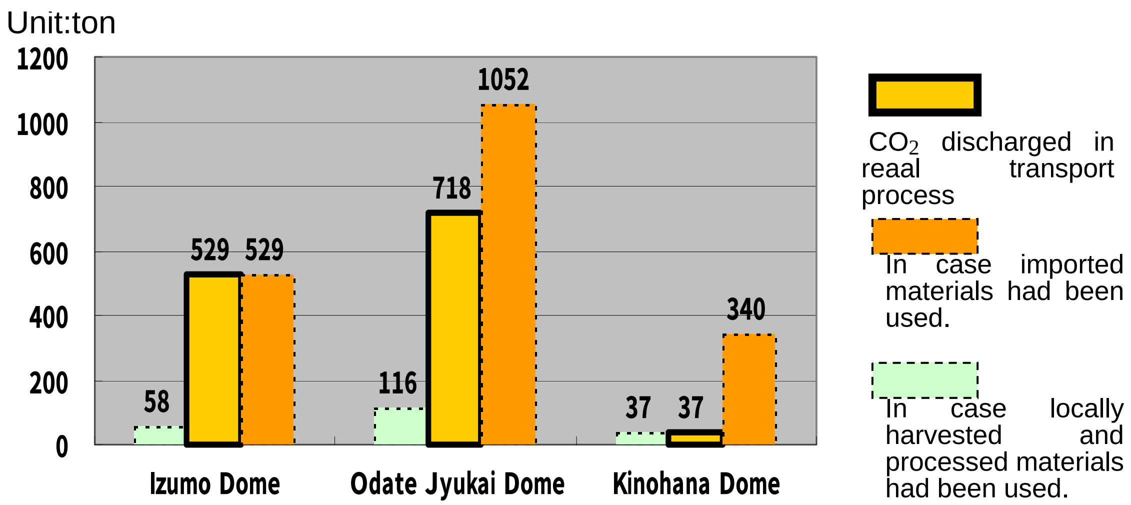


*Figure 4 Result of an estimate of the building woodmileage $CO_2$ from the construction of the three biggest wooden frame domes in Japan*

Figure 4 shows quantities of the building woodmileage$CO_2$, comparing those calculated if these building had been constructed with locally harvested and processed timber like the Konohana Dome and imported timber like the Izumo Dome .

A solid line shows an estimate of $CO_2$ in the real transport process, a broken line(right) shows the result from a simulation of the timber that had been imported, and a broken line (left) shows that of the timber that had been harvested and processed locally.

In case of the Odate Jyukai dome, for instance, a discharge of about 1000 tons of carbon dioxide had been cut down as the neighboring Japanese cedars were used for its building when compare with a case if it had been built with imported timber.

The forest absorbs the carbon dioxide in the air absorbing it into the wood. 1000 tons of carbon dioxide is equal to the same amount of carbon dioxide a forest the size of Odate Jyukai absorbs for more than 20 years.

## 4. Conclusion: the Possibilities and the Assignments of the Woodmiles

In the above sections we explained background of woodmiles, and processed and result of calculating woodmiles indexes. The case study of evaluation of energy consumption of timber transportation for the large wooden frame domes in Japan with woodmiles indexes shows that both processes and the result of woodmiles provide us with the following information.

1) The way of supplying timber for construction affect a lot for energy consumption through transportation processes.

2) Both location of harvest and processed site are important parameters affecting energy consumption through transportation.

3) Not only transportation distances but their measures (by truck, train or boat) are important factors for woodmiles indexes.

4) As large scale wooden frame constructions are expected to play role of symbol to promote local timber, evaluation of environmental load of these constructions with woodmiles indexes provides clear indicator to support local timber utilization.

Through these processes to evaluate woodmiles indexes, other than above mentioned energy issue, social aspect surrounding construction of buildings are also assessed. In recent years, capacity of heavy timber supply in Japan to construction of large scale buildings has greatly increased, and it would help improve energy efficient construction activities. This kind of discussion can be another possibility of study of the woodmiles indexes.

The following themes remain for further studies.

1) Further elaboration on a unit of transportation energy that indicates the relation between the transportation distances and the environmental loads are needed.

2) In order to increase numbers of case studies, it is necessary to develop more sophisticated and simple procedures and user-friendly tool to calculate woodmiles indexes.

3) It is necessary to develop sophisticated way of present implications of the figures of woodmiles indexes to be understood commonly.

4) The possibilities of contribution of woodmiles to more comprehensive method of evaluation of environmental load like LCA remains for a topic on future discussions

In Japan, green purchasing activities have been raised in both public and private sectors, recently. It would be getting more important to provide the consumers with reliable information related to the processes of production and transportation of each commodity. The concept of woodmiles would be one of the key words to evaluate the environmental load for building and transparency of the link between the consumers and the forests.

## References

Nakajima, S. and Okuma, M., 1991, Promotion of Wood Utilization for Mitigation of Global Warming, *Wood Industry*, Vol. 46, in Japanese

Fujiwara, T. 2002, Woodmiles and house constructed with local timber, *Wood Information*, Oct. 2002, Japan Wood Information Center in Japanese

The Woodmiles Forum, 2003, The Goal and Purpose of the Forum” http://woodmiles.net/gaiyou.htm in Japanese

The Woodmiles Forum, 2005, Manual for Calculation of Woodmiles Indexes for Building, Version 2005

Fujiwara, T. and the Woodmiles Forum, 2005, Average transportation distance and environmental load from them for ordinary distributing sawn timber in Japan, the Woodmiles study note #5, in Japanese