Wood Miles:
A Canadian Situational Analysis (Japan)
Discussion Paper



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Confidential

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Summary

This report addresses the validity of Japan's "Woodmiles" metric and its technical strengths and weaknesses. The report also provides alternative Canadian cases for log and lumber exports to Japan in the context of Japan's Woodmiles metric, a situational analysis of Japan's net wood products trade balance and the inherent domestic forest situation in Japan.

Key findings:

- There are significant technical errors in the methods used for the Woodmiles metrics. It is therefore unsuitable for serious use in setting trade policy.
- Nonetheless, the Woodmiles contention that domestic wood has less of a transportation-related CO_2 impact than imported products is true.
- In fact, if the Woodmiles approach were corrected for its errors, the environmental edge for Japanese domestic wood is even larger.
- However, Japan does not have adequate domestic capacity for its wood demand. So where will it get the additional wood, and in what format, for the best CO_2 choice?
- The Woodmiles method indicates that Canada (North America) has less transportation impact than several competing regions (Europe, South America and New Zealand).
- Two other regions (Russia and SE Asia) have lower Woodmiles, however one could argue that Canada compensates with a better record for sustainable forestry.
- One serious consequence of the errors in the Woodmiles method is an underestimation of the CO_2 due to importing logs. The CO_2 impact of shipping lumber is far less than for shipping logs, yet Woodmiles shows the two to be fairly close in impact. This represents somewhat of a bias towards logs, when the opposite should be the case.
- Japan also should consider that if Woodmiles discourages importing wood, one alternative scenario is an increase in demand for locally supplied non-wood products. The net CO_2 impact of that choice over imported wood is almost certainly poor.
- The CO_2 impact of transportation of goods to Asia is tempered by the fact that trade imbalances between Asia and N. America mean that many containers and ships are returning back to Asia empty anyway. The full CO_2 impact of the ocean-crossing to Asia is therefore not accurately applied solely to the exported Canadian wood products.
- The Woodmiles Forum suggests that doubling Japan's self-sufficiency in logs would have a positive impact on CO_2 effects. A faster solution for the same CO_2 reduction would be to shift some of Japan's imports from logs to lumber.

Acknowledgements

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1 Objectives

The overall objective of this work is development of information to help mitigate the potential damage to wood products trade between Canada and Japan due to "Woodmiles." Specifically:

- Investigate and verify the technical underpinnings of the Woodmiles metric using a life cycle analysis approach;
- Determine Japan's domestic wood supply and demand situation from a Woodmiles perspective to better gauge Japan's overall response capability should the notion of Woodmiles be used to underpin Japanese trade policy;
- Provide alternative Canadian cases for log and lumber exports to Japan in the context of the Woodmiles metric; and
- Determine if there are other extenuating transportation metrics or overriding trade patterns with implications for Canadian wood products trade with Japan in an environmental context.

2 Introduction

Japan established its Woodmiles Forum in 2003. This is a voluntary, government-supported forest sector organization with an intention of reducing transportation distances involved in the use of wood and energy consumption due to transportation, as well as increasing consumption of domestic wood products. The rationale for these objectives is a reduction in the environmental burdens associated with transportation of wood materials. Similar to the popular notion of "food miles," the idea is to "buy local" for environmental reasons. However, both wood miles and food miles are viewed by some as trade barriers, with an environmental rationale that is not necessarily clear or accurate.

The Woodmiles Forum uses research conducted by the Japanese Forestry and Forest Products Research Institute to develop and promote environmental data related to wood transportation. The Forum defines "woodmileage" as the total kilograms (kg) of carbon dioxide (CO_2) emitted per cubic meter-kilometer (m^3-km) of wood transported. This is calculated by multiplying wood volume (in m^3) by the distance (in km) between wood product manufacturing and the point of consumption, applying specific CO_2 emission factors (CO_2 kg/m^3-km) for each relevant transportation mode, and then summing the individual transportation mode results across the supply chain to arrive at a total.

According to the Woodmiles Forum, Japan's wood mileage is about 4.6 times higher than that of the United States, although its wood import volume is less. In other words, Japan consumes much more energy per unit in transporting wood than the US, due to the far greater distances involved when Japan sources non-domestic wood compared to the US (Figure 1). The Forum also states that Japan could cut about 500,000 tons of carbon dioxide emissions annually if the current volume of wood consumed was supplied by local forests instead of imports. These potential savings, in the context of the 1.4 billion metric tons (tonnes) of greenhouse gas emitted by Japan in 2008, represents about .04% of that country's total emissions.

Nonetheless, the Forum contends that importing offshore wood products into Japan carries a significant transportation energy-use component and consequently a higher greenhouse gas component than domestically-produced wood products. Under the guise of both advocating domestic forest stand improvement and utilization and helping to meet Japan's Kyoto Protocol commitments, the Forum is calling for international trade restrictions with a preference for the use of domestically-derived wood products.

This report addresses the validity of the Woodmiles metric and its technical strengths and weaknesses. The report also provides alternative Canadian cases for log and lumber exports to Japan in the context of Japan's Woodmiles metric, a situational analysis of Japan's net wood products trade balance and its inherent domestic forest situation.

Figure 1 Major Supply Routes to Japan

Source: Woodmiles Forum web site. http://www.woodmiles.net/english/e021-enkakuka.htm

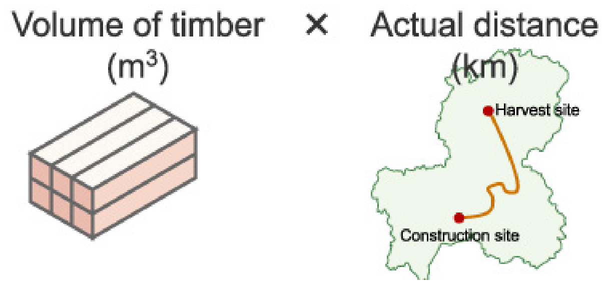
3 The Woodmiles Metric Explained

The Woodmiles Forum has established a calculation method in an attempt to quantify wood product transportation distances and the consequent CO_2 emissions for wood products used in the construction of Japanese houses[1]. This calculation method includes four different measures, or "indices": 1) Building Woodmileage; 2) Building Woodmileage CO_2 ; 3) Building Woodmileage L (linear); and 4) Knowledge Level of Logistics Steps. These are described in more detail below.

[1] Our discussion here is drawn from the latest available "Manual for Calculation of Woodmileage Indexes Ver.2005" - available on the Woodmiles Forum website (http://woodmiles.net/cgi-2008/e-cgi-jirei/gallery.cgi?no=2) and also attached to this report as an appendix.

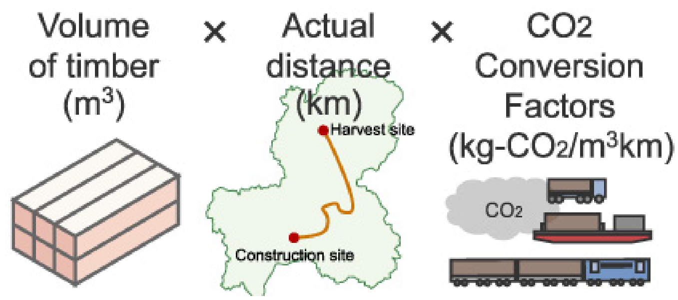
Building Woodmileage

- Expressed in km-m^3, this is the sum, for each step in the transportation modal chain, of the actual distances that a material is transported multiplied by the volume of the material transported.



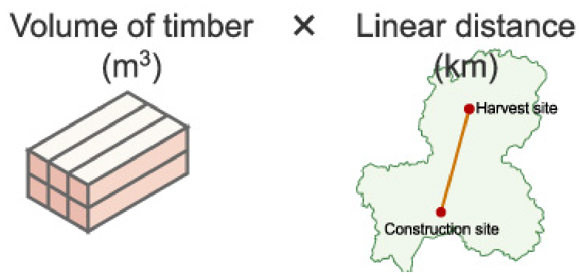
Building Woodmileage CO_2

- Expressed in kg CO_2, this is a sum of the CO_2 emitted in the transport of each material, by each transportation method used (road, rail, coastal shipping, bulk oceangoing shipping and container oceangoing shipping).



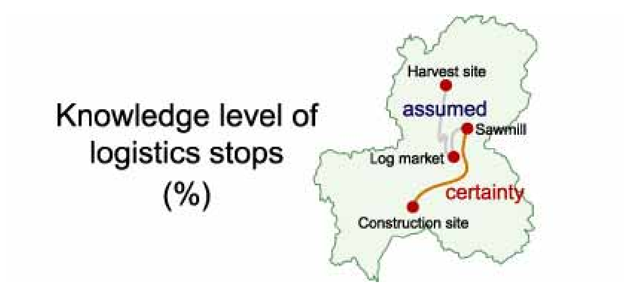
Building Woodmileage L

- Expressed in km-m^3, this is the sum, for each step in the transportation modal chain, of the linear distances that each material is transported multiplied by the volume of each material transported.



Knowledge Level of Logistics Steps

- This is a measure of the accuracy of the data which is used in calculating the Woodmiles indexes.



Source of graphics: the Woodmiles Forum web site:
http://www.woodmiles.net/english/e051-kanren-shihyo.htm#e051-04

Building Woodmileage and Building Woodmileage L are both derived solely from the volume of material transported and the distance that it is transported. These metrics are a way of establishing a basic distance scale to facilitate comparisons of different forest product transportation scenarios. It is an assumption-laden scale and therefore somewhat arbitrary. The Building Woodmileage L index seems especially specious since it assumes straight-line distances between steps in the transportation supply chain, and has little relation to the real logistical distances involved in transporting materials.

Knowledge Level of Logistics Steps is a ratio of the distances traveled that are known to be correct, divided by the total distances that are used in the Woodmileage calculation. For example, a user may know for certain that the distance from the mill to the construction site is 60 km, but may be uncertain about the distance from the harvest site to the mill and estimates that to be 40 km. Using the Forum's method here, the "knowledge level" is 60 ÷ (60+40), in other words, 60%. The outcome is a somewhat artificial data quality indicator that has little bearing on the actual calculated environmental impact of a particular transportation chain scenario.

The Building Woodmileage CO_2 index is the only index that produces any "real" output that may be used to compare results from project to project or location to location. However, this index is based on the *volumes* of materials transported, while transportation analysis would typically emphasize the *mass* of materials transported. In general practice, most energy-use and greenhouse gas transportation data is expressed on a per tonne-km basis (energy or greenhouse gas emissions associated with moving a tonne of material one km) for and by various modes, making it quite simple to calculate energy use and/or CO_2 emissions. The volume-based Woodmileage CO_2 index presents an oversimplification of the transport system, and it tends to use one mass for all products. Additional analysis of the Woodmileage CO_2 index indicates that it is based on emission data on a per tonne-km basis and simply multiplies that data by the material's specific gravity or density (kg/m^3) to arrive at values on a per m^3-km basis. There are many conflicting values and sources for CO_2 emissions associated with different transportation modes, and it is difficult to determine with confidence which one(s) may or may not be valid for any given scenario[2], but converting mass values using specific gravity conversions, especially for dissimilar forest products, only introduces another level of uncertainty that is unnecessary.

Further, the specific gravity used in the Woodmiles calculations is 0.529 (529 kg/m^3) for all wood, but the index is a sum of all the steps in the process, each of which may have a different material mass and hence a different specific gravity (mass) on a dry or green volume basis, and different modes of transport for each step. Using only one specific gravity produces results that don't reflect the reality of the material in question (logs or lumber) at each step in the transportation supply chain. This inherent conversion from mass to volume is a considerable weakness of the Woodmiles metric calculation.

[2] It should be noted that we were unable to locate and assess the stated sources for the Woodmiles energy and CO_2 intensity values used in the development of the Woodmiles index.

4 Woodmiles Method Verification

If intended to justify a reduction in the use of imported wood on environmental grounds, then the Woodmiles approach is successful, because the calculation is simplistically based on distance. When looking only at distance traveled, the advantage of *not* transporting forest products 7,710 km from North America to Japan is all too obvious. For example, compare a Canadian shipment of 10 m^3 of lumber delivered to a Japanese construction site 200 km from a port of entry with a similar load of 10 m^3 of Japanese domestic lumber used 200 km from the harvest point. The Building Woodmileage index for Canadian lumber would be 10 m^3 x (7,710+200) km = **79,100** m^3-km versus an index result of **2,000** m^3-km (10 m^3 x 200 km) for Japanese domestic lumber. On a simple distance scale, the Japanese case is obviously superior. However, this distance index is only one component in a calculation of the real environmental impacts. For instance, using the Forum data for CO_2 emissions for road and bulk shipping of 0.18515 kg/m^3-km and 0.0058 kg/m3-km respectively, over a distance of 1000 km, the truck journey will produce 185.15 kg CO_2/$m^3$of cargo, and the bulk carrier will produce only 5.8 kg CO_2/m^3 of cargo. Put another way, 1 km of truck travel is equivalent to 31.9 km (0.18515/.0058) of ocean travel on a bulk carrier. Clearly, a consideration of distance alone, without assessing other factors such as mode of transportation, can easily lead to incorrect conclusions about total transportation CO_2 impacts.

The Forum promotes the notion that wood is an environmentally-friendly material – except when it is transported long distances. Using the Woodmiles method, the Forum reports CO_2 impacts of importing wood products to Japan from various global sources. See Figure 2 for this data. The figure shows CO_2 emissions per cubic meter of lumber due to transportation from other countries, as well as for two different transportation scenarios within Japan for domestic lumber. In addition, the graph shows CO_2 emissions from the process of manufacturing lumber, for the purpose of comparing the emissions due to these two stages of the lumber lifecycle (manufacturing and transportation). The graph is intended to demonstrate that, in all cases for imported lumber, the climate change impacts from transportation outweigh the impacts from manufacturing.

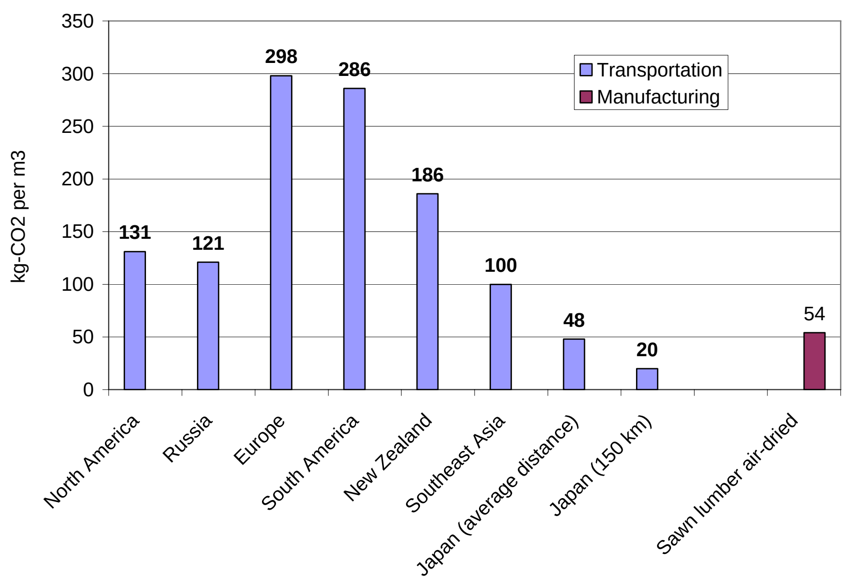


Figure 2 CO_2 Emissions for Wood Transportation from Various Sources

Source Woodmiles Forum website http://www.woodmiles.net/english/e023-yunyuzai-yusou.htm

In order to check the accuracy of the Forum's CO_2 data, we attempted to reproduce the values reported in Figure 2. The chart indicates that **131** kg CO_2/m^3 are emitted in the transport of North American wood to the Japanese market, and 20 kg CO_2/m^3 are emitted for 150 km of transportation within Japan. Using Forum Tables 1 and 2 on pages 6 to 7 of their manual (see appendix), we note that they assume a linear 100 km road journey within N. America for roundwood and a 7,710 km ocean journey for sawn lumber. Their implied emission factors for road travel and oceangoing container shipping are therefore 0.18515 kg CO_2/m^3-km and 0.01095 kg CO_2/m^3-km, respectively. Using these stated distances and the modal CO_2 emission factors, we calculated the combined road and ocean legs at **103** kg CO_2/m^3 (100 km x 0.18515 kg CO_2/m^3-km + 7710 km x 0.01095 kg CO_2/m^3-km).

Our 103 result is short of the 131 value in the above graph. We concluded that the Forum calculation of 131 must be including transportation within Japan (from port to building site) not clearly stated in the Forum documentation, and, working backwards, found the missing 28 with a truck distance of 150 km (150 km x 0.18515 kg CO_2/m^3-km = 28 kg CO_2/m^3).

Note that our use of the Forum's own emission factors for 150 km of truck transport yielded **28** kg CO_2/m^3, but for the same distance, the Forum reports a value of **20** in the above chart for truck transportation of Japanese domestic lumber. This is likely a simple typographical error by the Forum[3]. However, we also had difficulty duplicating all the reported values for other regions in the chart even when correcting for the typographical error. We essentially matched the Forum's numbers for Europe and Russia using 28 kg CO_2/m^3 for transport within Japan but were unable to duplicate results for the other regions.

Another way to try to reproduce the 131 kg CO_2/m^3 value is to consider only the sawn timber transportation value of 7,710 km and the Japanese Average number of 48 kg CO_2/m^3 in the above graph. This calculation yields 132 kg CO_2/m^3 (7710 km x 0.01095 kg CO_2/m^3-km + 48 kg CO_2/m^3)

Both methods produce values very close to the chart above for the European, Russian and North American values, but do not reproduce the New Zealand or South American values. The first method does not reproduce the South East Asia value, but the second method does. These inconsistent results made for a very challenging validation exercise, because there is no obvious clarity on the exact procedures and assumptions involved with the Forum method.

We then back-calculated the distance used for the stated "Japan (Average)" for transportation of Japanese domestic lumber of 48 kg CO_2/m^3 and came up with 259.2 km (48 ÷ 0.18515 kg CO_2/m^{3-}km). With an average of 259 kilometers, the rationale for the 150 km case (also shown in the chart) is unclear. For the sake of consistency in our analysis, we chose to use the Forum average distance figure of 259. Thus, later in the report when comparable scenarios are developed, it is assumed that forest-to-mill distance in Japan is 109 km and the remainder of 150 km is the average distance from the mill or port to the building site.

[3] We sent an email to the forum requesting clarification regarding the values reported this chart but received no reply.

4.1 Verification Detail for Stated Variable Values and Assumptions

Our attempt to duplicate the Forum results highlighted some potential problems with the Woodmiles calculation method, suggesting that a deeper investigation into the underlying data values and assumptions governing the Woodmiles methodology was required.

First we examined the factors used to calculate CO_2 emissions by transportation mode (ship, truck, rail). See Table 1 for CO_2 transportation data by mode on a per tonne-km basis from Woodmiles and from the Athena Institute, as well as from a third source for comparison: the European Commission's Eco Label program[4]. This table demonstrates both the diversity and similarity of transportation LCA data. With respect to rail transport, Athena and Woodmiles values are very close to each other, but the Eco Label program value is 2.5 times greater[5] than the Woodmiles figure. For ocean shipping, Athena's Super-E program[6] uses an average value for both container and bulk shipping, while Woodmiles differentiates between the two carrier types, with a higher CO_2 emission factor for container shipping and a much lower emission factor for bulk shipping[7]. Generally container ships are smaller (typically having half the load capacity of dry bulk carriers) and operate at faster speeds than their dry bulk ship counterparts, which leads to the higher CO_2 emission levels per tonne-km for container shipping. However, container shipping typically involves a one-way haul leg as they are continually reloaded at the port of entry or along the adjacent seaboard before heading back across the ocean. Conversely, dry bulk carriers are dedicated ships (e.g., wheat is not transported in iron ore carriers and potash is not transported in coal carriers), and therefore they invariably arrive empty at a port of call, where they are loaded and returned full and thus typically involve a water ballasted empty backhaul leg[8]. The Woodmiles calculation methodology fails to acknowledge or account for these empty backhaul legs when applying container and bulk dry transportation distances. The Eco Label source uses an even lower average CO_2 emission value for shipping, which we believe may only reflect intercoastal shipping in Europe given the limited geographical focus of that calculation tool. Overall, the shipping CO_2 emission values, although different from each other, all seem to be within the same order of magnitude, but there is an issue with accounting for empty dry bulk shipping backhauls in the Woodmiles methodology.

For the trucking CO_2 emission values, however, dramatic differences were uncovered. The Athena and Eco Label program values are virtually identical, but the Woodmiles value is almost five times larger. We suspect this value is erroneous or is accounting for some other operational factor (e.g., truck size) which hasn't been made explicit in the Woodmiles calculation handbook methodology.

[4] http://ec.europa.eu/environment/ecolabel/carbon_en.htm - See the "Excel-based Toolkit."
[5] This likely due to the greater use of electric rail in Europe (70%) and the consequent higher CO_2 emissions traced back to, and associated with, electricity generation and distribution.
[6] This is a software tool that addresses lifecycle environmental footprint of houses built overseas using imported Canadian lumber.
[7] As part of the literature review for this investigative study, the Institute was unable to locate the Woodmile's reported sources for these data.
[8] Personal correspondence, Mr. Bob Lassig, North American Logistics Manager, Maersk Shipping.(973-222-1767).

Table 1 CO_2 Emissions by Transport Mode, in kg CO_2/tonne-km

	Athena [a]	Woodmiles [b]	Eco Label [c]
Container Shipping	0.0166	0.0207	0.007
Bulk Shipping	0.0166	0.0096	0.007
Trucking	0.0743	0.35	0.075
Rail	0.0191	0.02	0.05

Source notes:

a) Athena Institute values: Super-E transportation model derived from various Life Cycle Inventory databases (e.g., US LCI database (www.nrel.gov/lci) and the Ecoinvent database: Ecoinvent Centre, Data v 2.0 (2007), Swiss Centre for Life Cycle Inventories, Dubendorf.

b) Woodmiles Manual: http://woodmiles.net/cgi-2008/e-cgi-jirei/gallery.cgi?no=2

c) European Commission Eco Label program: derived from various European LCI databases http://ec.europa.eu/environment/ecolabel/carbon_en.htm

Next, we examined the data related to wood mass, as transportation impacts are partially a function of the mass of the material transported. See Table 2 for basic wood, log and lumber specific gravities[9] (densities) at different moisture contents, i.e., different phases of the process from harvest to end-use. Woodmiles specifies only one specific gravity for wood, and uses this same value to convert all wood masses to a per m^3-km basis. The values listed under the Athena column reflect the basic density of the Spruce-Pine-Fir (SPF) species group at various moisture contents (MC) for both lumber and roundwood. The 60% MC roundwood value would be typical of wood transported by truck to a mill, while the 80% MC roundwood value would be typical of wood transported via barge or tug with boomed storage at the Vancouver log market port prior to shipment. As is evident, product mass can vary significantly depending on the product and the method of roundwood transport.

Table 2 Specific Gravities of Wood at Various Moisture Contents

	Athena	Woodmiles
Oven Dry Wood	0.392	0.529
Lumber MC 17%	0.459	0.529
Roundwood MC 60%	0.627	0.529
Roundwood MC 80%	0.706	0.529

Source: Personnel correspondence with Dr. Jim Wilson
Oregon State University (CORRIM values for the US PNW) - see CORRIM LCA Protocol www.corrim.org

Next, we examined the impact of both mass and mode on transportation CO_2 emissions. Table 3 shows the conversion of LCA data from a per tonne-km basis to a per m^3-km basis as in the Woodmiles methodology and with the Athena transportation and moisture contents considered. It is simply the

[9] Specific gravity is a dimensionless measure sometimes called relative density. It is the ratio of the density of a material to the density of water. The higher the moisture content of wood, the more water it contains and the closer its specific gravity approaches 1.

product of the transportation modal kg CO_2 values reported in Table 1 and the specific gravities in Table 2, using Athena and Woodmiles source data. Essentially, Table 3 indicates that containerized shipping of lumber is lower using the Athena data as opposed to the Woodmiles data, and when the moisture content is included for roundwood, the bulk shipping values increase using the Athena methodology but remain constant when using the Woodmiles calculation method. The Woodmiles calculation assumption of constant specific gravities across all products, with no adjustment to account for varying moisture, is too simplistic. One specific outcome of this methodological shortcoming is an erroneous calculation for transportation of roundwood versus lumber. Woodmiles underestimates the CO_2 emissions for 80% MC roundwood and overestimates the emissions for lumber, masking the differences between the two. This is a serious error, discussed further in this report.

Table 3 CO_2 Emissions, by Mode of Transport and Density of Wood, in kg CO_2/m^3-km

	Lumber MC 17%		Roundwood MC 60%		Roundwood MC 80%	
	Athena	**Woodmiles**	**Athena**	**Woodmiles**	**Athena**	**Woodmiles**
Container Shipping	0.0076	0.0110	0.0104	0.0110	0.0117	0.0110
Bulk Shipping	0.0076	0.0051	0.0104	0.0051	0.0117	0.0051
Trucking	0.0341	0.1852	0.0466	0.1852	0.0524	0.1852
Rail	0.0088	0.0106	0.0120	0.0106	0.0135	0.0106

Lastly, we investigated assumptions about yield rates. Woodmiles reports a roundwood-to-lumber yield factor of 66% for Japanese sawmills; in other words., 66% of the incoming roundwood is converted to lumber. Both FPInnovations-Forintek and CORRIM have determined that N. American mills attain a yield of about 50%[10]. This assumed higher yield rate for Japan would suggest that Japanese sawmills are either better at recovering lumber or they process a superior resource than their N. American counterparts, or both. There is no evidence to suggest this is true, and, in fact, the opposite has been suggested: Japanese sawmills have been characterized as small and inefficient, using out-dated technology.[11] In addition, Japanese sawmills typically cut pieces larger than N. American 2x4s for their common post-and-beam construction systems. Finally, the Japanese resource is widely acknowledged as poor quality, meaning yield rates would be low. Later in this report, the 66% yield factor is scrutinized to determine the sensitivity of Woodmiles results to both a 66% and 50% yield factor.

[10] (CORRIM) Milota, R.H, C. D. West and I. Hartley (2005) Gate-to-Gate Life Cycle Inventory of Softwood Lumber production. Wood and Fibre Science (37) pp 47-57. (Forintek) Meil, J. et al, 2009, Status of Energy Use in the Canadian Wood Products Sector.

[11] Eastin, I. (2008) Review of the Japanese Green Building Program and Domestic Wood Program" by Center for International Trade in Forest Products (CINTRAFOR), University of Washington (WP111).

4.2 Validation Summary

In summary, this validation exercise yielded a number of problem areas for the Woodmiles method, calling into serious question the accuracy and applicability of this tool:

- The Building Woodmileage index (km-m^3) is based on linear distances. While certainly a simplifying assumption, it is not necessarily correct for all mode and distance elements in the supply chain. However, the reported N. American distances are essentially in agreement with Athena's own LCA work on B.C. forest products and the Athena Super-E transportation model.
- The basic data (per tonne-km energy-use, and CO_2 emissions) underlying the Building Woodmileage CO_2 index for truck and ocean shipping differs significantly from Athena and other source data. The truck transportation data is an order of magnitude larger than reported by other sources we have reviewed. The Woodmiles ocean-going container and bulk dry transportation energy and CO_2 emission factors are generally in the right order of magnitude for these varying modes – Athena's value represents a combined average which is in-between the values reported for these two modes. However, empty backhauls are not considered in the Woodmiles results, which is a major oversight in the case of dedicated trucks and dry bulk carriers transporting roundwood.
- The reported specific gravity values for wood and lumber appear to be particularly limited as they do not take into consideration the wet weight of logs to be shipped via bulk carrier or truck.
- The mass to volume conversion, based on a single specific gravity for all products, is particularly spurious and represents a biased oversimplification in favour of roundwood imports over lumber imports.
- The stated conversion yield for logs to lumber of 66% seems unduly high and unlikely to be the case especially when processing the acknowledged poorer quality Japanese plantation grown roundwood.

5 Japanese Forests and Forest Products Trade

This section is based on various statistical sources as well as a detailed 2008 CINTRAFOR study[12]. That study provides a thorough review of the regulatory steps taken in Japan to preferentially treat domestic wood consumption in the proposed CASBEE-Sumai green home building program[13] and as a consequence further protect what is referred to in the CINTRAFOR report as the "inefficient" Japanese sawmilling industry from international competition. In some respects, the Woodmiles Forum and the development of its Woodmiles indices is supporting these preferential domestic trade policies.

Although two-thirds of its land area is covered in forest, Japan has a considerable wood deficit; its domestic wood resource meets only 20% of its wood demand (Figure 3). Figure 4 indicates that this has not always been the case. In 1960, Japan's wood self-sufficiency rate was 85% but has been declining ever since, due to demographic shifts and increased demand for wood housing. New regulatory initiatives

[12] Eastin, I. (2008) Review of the Japanese Green Building Program and Domestic Wood Program" by Center for International Trade in Forest Products (CINTRAFOR), University of Washington (WP111).
[13] CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) is a Japanese program for sustainable design.

in Japan to double its self-sufficiency include: 1) providing preferential treatment for domestic wood within the proposed CASBEE-Sumai green home building program; 2) using subsidies at the prefectural level to increase the share of domestic wood used in post-and-beam wooden homes to at least 50%; and 3) using subsidies at the national level to increase the market share of domestic wood used in the post-and-beam industry from the current 30% to 60% by 2015 (Eastin, 2008).

Japan's self-sufficiency rate is considerably better in terms of lumber. While 80% of Japan's total wood supply is imported, much of that is in the form of logs which Japan then processes into lumber. This means Japan need only import about 40% of its softwood lumber (60% lumber self-sufficiency, see Figure 5). However, the Japanese domestic lumber industry is characterized by declining production volumes as thousands of smaller, less efficient sawmills have closed down since the industry was hit hard by the Asian economic crisis in the mid to late 1990s. These sawmill closures resulted in large declines in productive capacity, and between 1990 and 2006 domestic lumber production dropped from 29.8 million m^3 to 12.7 million m^3, while lumber imports increased only slightly from 7.6 million m^3 to 8.1 million m^3. The combination of declining domestic production and increasing imports indicates that Japan's lumber self-sufficiency declined from 76.3% in 1990 to 60% in 2006.

The past decade has seen a tremendous shift in the structure of softwood lumber imports into Japan (Figure 6). The Canadian share of the Japanese lumber market, which averaged 53% during the period 1990-1998, declined to 43% during the period 1998-2006. Meanwhile, imports from Europe increased from essentially zero in 1992 to a 31.9% market share in 2006. Similarly, imports from Russia increased from 3.5% to 13% between 1992 and 2006. These increases were largely at the expense of the US, whose share of the Japan market plummeted from 27.8% to 1.1% between 1990 and 2006.

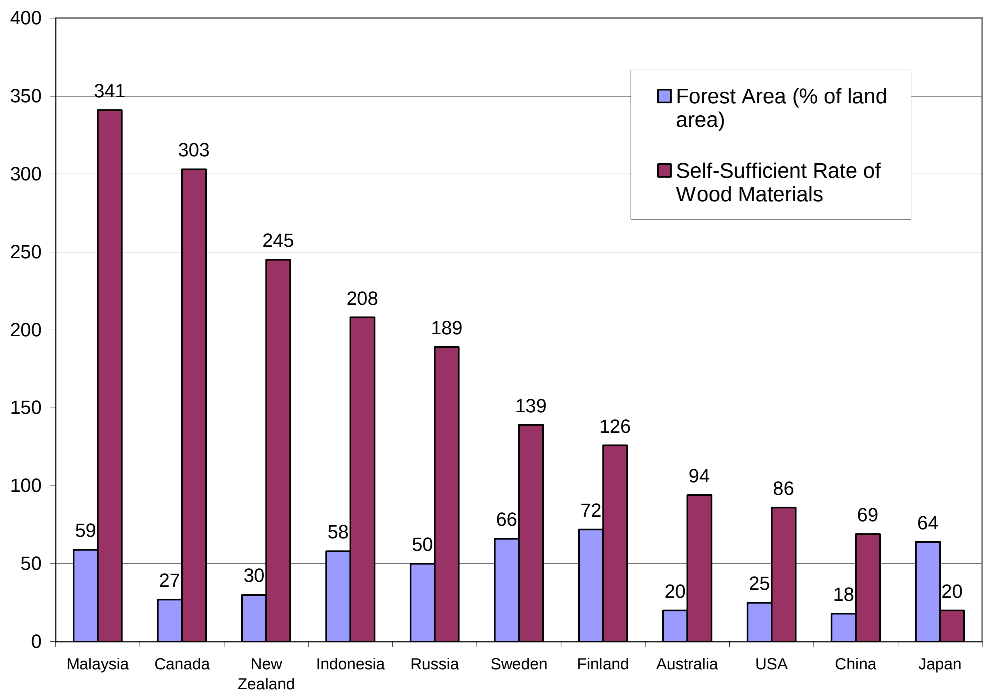


Figure 3   Forest Area (% of land area) and Self-Sufficiency Rate of Wood Materials

Source: Woodmiles Forum web site http://www.woodmiles.net/english/e013-chikuseki.htm, citing FAO State of the World's Forests, various years.

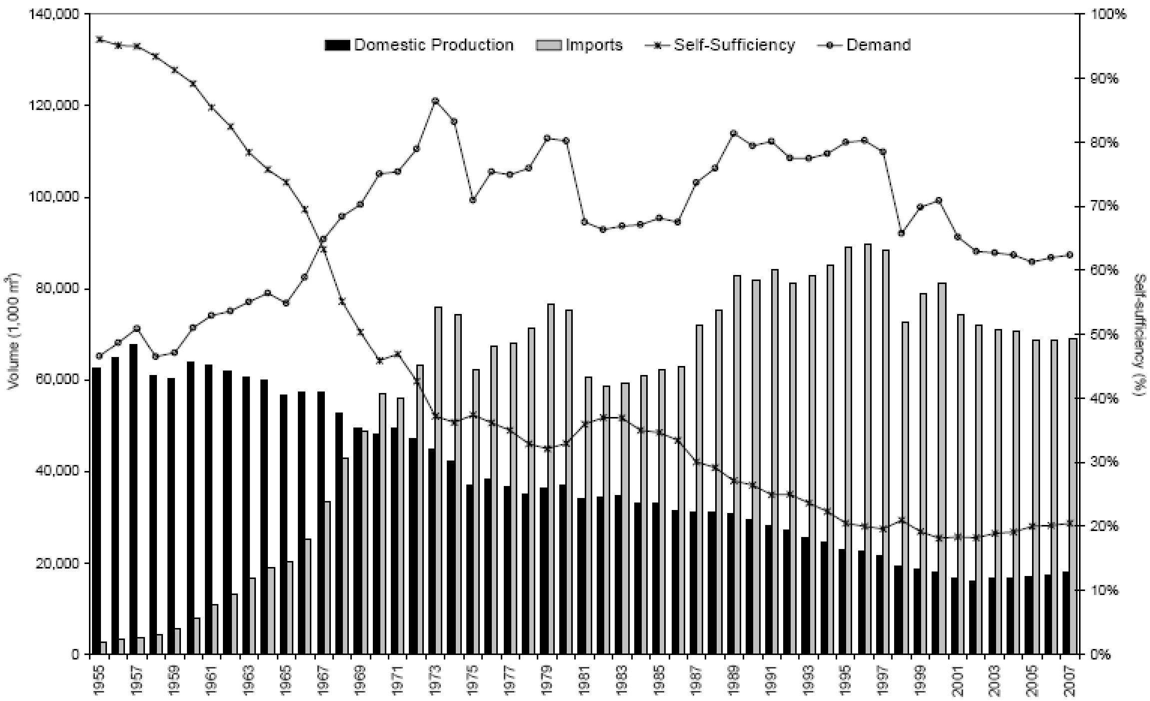


Figure 4 Trend in Wood Supply, Demand and Self-Sufficiency in Japan

Source: Eastin, 2008, citing the CINTRAFOR database.

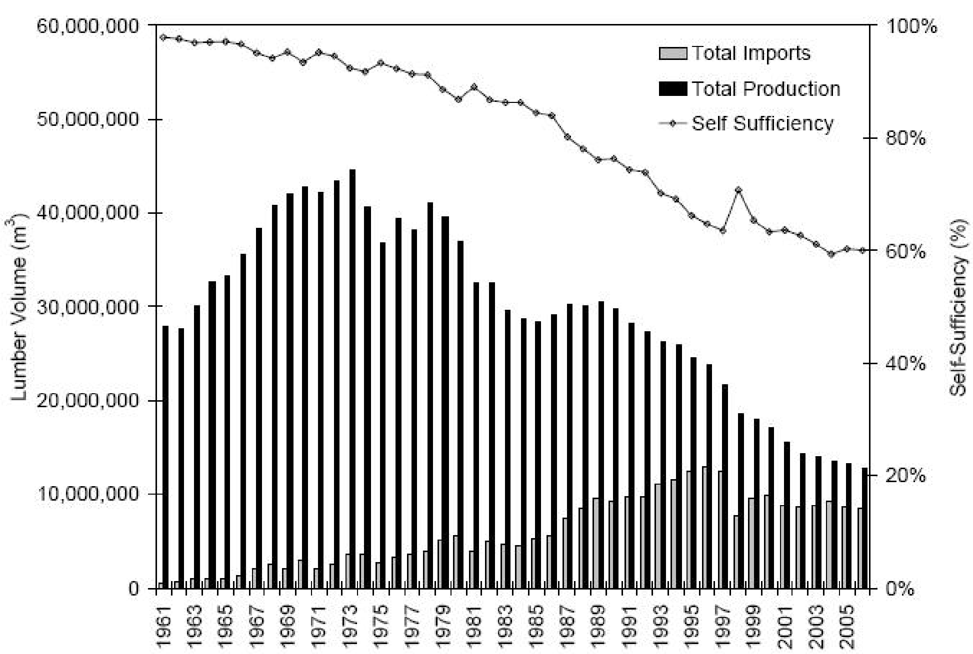


Figure 5 Trend in Japanese Total Lumber Production, Imports and Self-Sufficiency

Source: Eastin, 2008, CINTRAFOR.

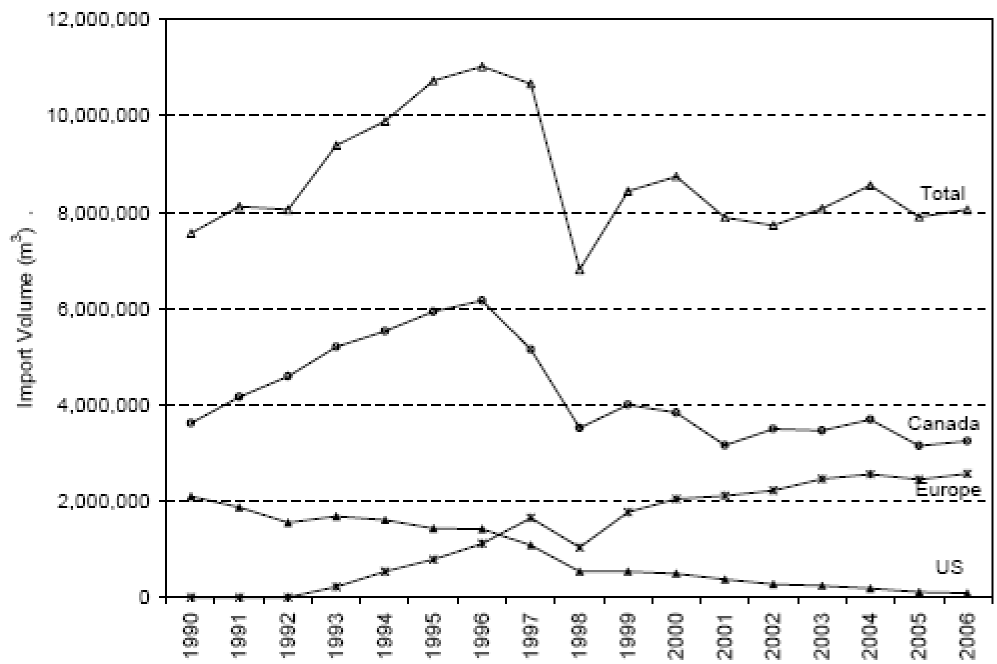


Figure 6 Japanese Softwood Lumber Imports by Source, 1990-2006

Source: Eastin, 2008, citing Japan Customs Association, various years.

Note that the discussion in this section on Japanese log and lumber trade and production is not meant to be thorough but rather is intended to provide brief context only. For greater detail on this subject, refer to Eastin (2008). Statistics described in the text here and shown in the graphs may not be adequately capturing a full picture; for example, distinctions between hardwood and softwood imports and the fate of by-products of sawmilling are not provided.

6 WoodMiles – Alternative Scenarios

Given some of the shortcomings and over-simplification of the Woodmiles calculation method, this section provides alternative transportation scenarios for logs and lumber imported from Canada as well as for Japanese lumber production based on processing their domestic resource. In these scenarios, the Woodmiles calculation method is contrasted with our preferred method (developed by the Athena Institute), to provide a side-by-side comparison of these two different approaches to calculating transportation impacts. Finally, this section ends with a comparative summary for logs and lumber based on current Japanese softwood log and lumber imports; Japanese production and consumption compared with a factor two increase in use of the Japanese domestic resource (self-sufficiency increasing from 20% to 40%); and the effect of this on Japan's overall CO_2 emissions profile for wood products.

6.1 Canadian Lumber Model

This scenario begins with the Canadian transport of roundwood from the forest to the sawmill by truck, including an empty return (backhaul) of the truck. The empty return truck leg is a significant fraction of the total journey, likely accounting for 75% of the fully loaded truck CO_2 emissions, but for ease of calculation it is assumed that the empty truck will use the same amount of fuel and emit the same amount of CO_2 as a full truck. This is referred to as a backhaul factor (multiplier) of 2; i.e. twice the one-way distance. The total amount of roundwood to be transported depends on the yield rate of the sawmill. A yield rate of 50% would require 2 m^3 of roundwood to net 1 m^3 of lumber. Both CORRIM and Athena life cycle inventory studies of US PNW and BC lumber production report about a 50% yield rate for softwood lumber mills and hence, this figure is used here.

From the mill, kiln-dried sawn lumber is assumed to travel to the port using a commercial trucking service. We expect the commercial truck would pick-up another load at the port to haul elsewhere, and hence no backhaul is assumed (i.e., a backhaul multiplier of 1).

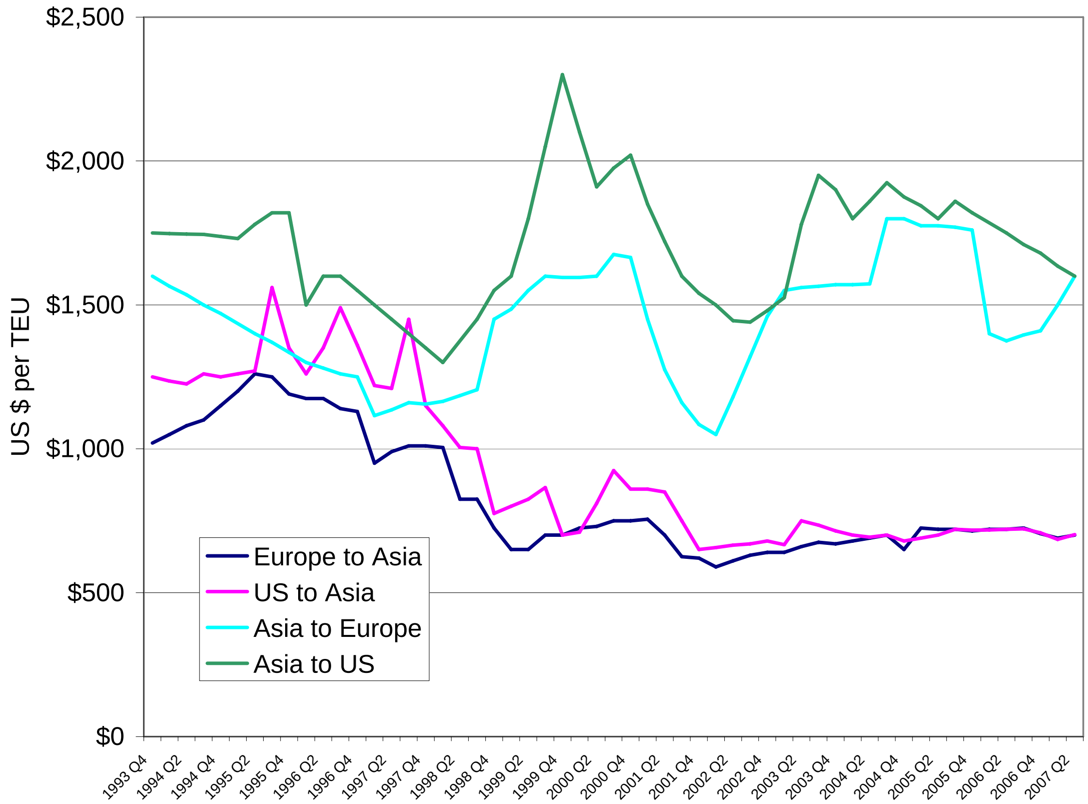
From the port to Japan, the kiln-dried lumber will travel in containers on a container ship. Container shipping in theory has no backhaul effect, as the containers just get forwarded on to somewhere else, fully loaded. However, in reality, empty containers do get repositioned from time to time. According to recent research (Rodrigue, undated)[14], approximately 20% of all containers are regularly repositioned empty due to trade imbalances within and between regions – note that Canada has a significant trade imbalance with Japan[15]. International repositioning of empty containers is typically back to net exporting countries; for example, containers are repositioned back to Asia as opposed to N. America, given the trade imbalance between the these two regions. In this scenario we account for empty container repositioning as follows: a container arrives in N. America full of goods from Asia, and lumber is then sent to Asia in a container that 20% of the time would go back empty anyway. In other words, the empty weight of every fifth container sent back to Japan is netted out of the CO_2 emissions for the transport of a container containing lumber on its way to Japan. This yields a backhaul multiplier of 0.8, which is applied to the mass of the container only.

Backhauls are the reason that container rates to Asia are lower than to N. America or Europe (Figure 7). The Rodrigue report shows about a 50% containerized shipping cost differential between Asia and North America – that is, if it costs $1,700 to ship containerized goods from Asia to North America, then it would only cost $850 to ship North American goods to Asia, so by corollary, it could be argued that 50% of containers are returning to Asia empty; in that case, it may be more appropriate to credit the empty weight of every *second* container returned to Japan, for a backhaul factor of 0.5. We examine both these cases below. A similar repositioning case could be applied to container ships themselves, as these ships also need to be repositioned according to the trade imbalance. Hence, every second or fifth trip from North America to Asia would be a repositioning trip for the container ship, and the N. American lumber would travel CO_2 free (or close to it), as the ship would need to return to Asia anyway. This is not an assumed case in the scenario developed here, but if it were, it would certainly have a large impact on the results.

[14] Rodrigue, Jean-Paul, undated, Hofstra University. See http://people.hofstra.edu/geotrans/eng/ch5en/appl5en/ch5a4en.html

[15] Exports to Japan in 2007, one of Canada's main trade partners, slipped to $9.2 billion, the first decline since 2003. Imports from Japan increased slightly to 15.5 billion in 2007 – Statistics Canada cat. 65-208-XIE International Merchandise Trade, Annual Review 2007

Figure 7 Primary Oceangoing Routes Container Rates



Source: Rodrigue, J-P, Hofstra University, http://people.hofstra.edu/geotrans/eng/ch2en/conc2en/maritimefreightrates.html, citing UNCTAD, Review of Maritime Transport, Various Years. TEU (Twenty-Foot Equivalent Unit) is a standard measure of shipping flows and capacities; one 40-foot container is 2 TEUs.

From the Japanese port to the building site, the scenario assumes the lumber will travel 150 km by commercial trucking. We expect the commercial truck would pick-up another load nearby to haul to the port or elsewhere, and hence no backhaul is assumed (i.e., a backhaul multiplier of 1).

The following is a description of the calculation of the port-to-port leg of the Canadian Lumber Model as depicted in Table 4. A recently-completed mass balance analysis for Canadian lumber[16] determined a density of 392 kg/m^3 for SPF lumber, and with a moisture content of 17% it would have an overall mass of 459 kg/m^3 (392 x 1.17). The table shows various CO_2 emission data values for different modes of transport used by both Athena and Woodmiles on a per tonne-km basis. Woodmiles chooses one specific gravity for all wood and applies this to convert their emission factor to a volume or per m^3-km basis. The Athena method applies different specific gravities according to the type of roundwood or lumber transported at each stage. As an example, containerized transport of one cubic meter of lumber (port-to-port) would emit 0.0166 kg CO_2/tonne-km, which converts to 0.00762 kg CO_2/m^3-km (0.459 x 0.0166). Therefore, transporting Canadian lumber from Vancouver to Japan would result in the emission of 58.75

[16] Meil, J. et al, 2009, Status of Energy Use in the Canadian Wood Products Sector, FPInnovations-Forintek.

kg of CO_2 (7,710 km x 0.00762 kg CO_2/m^3-km x 1 m^3 of lumber). In addition, the calculation should account for the mass of the container the wood is shipped in. A high cube container weighs 4.12 tonnes and has a capacity of 76.6 m^3. Assuming a full container and a 80% backhaul factor (i.e. 20% of all containers return empty anyway), then the container-shipping portion applicable to 1 m^3 of lumber is 5.5 kg CO_2 (7,710 km x 0.0166 kg CO_2/tonne-km x 4.12 tonne x 1 m^3 of lumber ÷ 76.6 m^3 of container space x 0.80 backhaul factor). Thus, the total CO_2 emitted during the port-to-port transport of lumber is 64.3 kg (58.75 + 5.5).

Table 4 shows overall CO_2 emissions by transport leg according to the Woodmiles methodology (noted in the table as J for Japan) and the Athena calculation methodology (noted as C for Canada). The Woodmiles CO_2 emission for lumber transport is at least 43% higher than the Athena result. Half of the difference can be traced to the Woodmiles use of a higher specific gravity value for N. American lumber. The other half of the difference can be traced to the Woodmiles emission factor for trucking, particularly in Japan from port to site. It is our contention that the Woodmiles trucking value is incorrect. While oceangoing transport is the most efficient method of transport on tonne-km basis, the long distance traveled from the port of Vancouver to Japan makes it the largest contributor (70%) to the overall transport CO_2 emissions calculated for Canadian lumber.

Table 4 Scenario 1: Canadian Lumber Shipped to Japan

Transport Leg (C-Canadian data, J-Japanese data)	Distance (km)	Emission Factors by Mode kg CO_2/m^3-km	Assumed Specific Gravity (Mass)	Yield Rate	Backhaul Factor	Total kg CO_2/m^3
Forest to Mill C	100	0.04659	0.627	50%	2	18.6
J	100	0.18515	0.529	100%	1	18.5
Mill to Port C	80	0.03410	0.459	100%	1	3.0
J	0	0.18515	0.529	100%	1	0.0
Port to Port C	7710	0.00762	0.459	100%	0.8	64.3
C	7710	0.00762	0.459	100%	0.5	62.2
J	7710	0.01095	0.529	100%	1	84.4
Port to Site C	150	0.03410	0.459	100%	1	5.1
J	150	0.18515	0.529	100%	1	27.8
			Canadian Total (0.8 Backhaul)			**91.1**
			Canadian Total (0.5 Backhaul)			**89.0**
			Japanese Total			**130.7**

6.2 Japanese Canadian Log Import Model

This scenario involves a 100 km trip for roundwood from BC forested land to the port of Vancouver by dedicated logging truck; the backhaul multiplier for the truck is 2. The logs will then wait in the Vancouver log market for loading onto a bulk carrier. While stored in a boom, it is estimated that the moisture content of the logs will rise to 80% (see Table 2). Invariably, bulk carriers return empty, ballasted with water, so a ship backhaul factor of 2 is assumed. After the ocean journey to Japan, the logs are milled, the lumber is kiln-dried and then sent by truck 150 km to a building site. It is believed that the vast majority of Japanese large-scale lumber mills with kiln-drying facilities are located adjacent to or very near a port, and therefore a truck leg from the Japanese port to the sawmill is ignored. The yield rate has also been adjusted down to 50% from the assumed 66% used in the Woodmiles methodology.

Table 5 calculates the overall CO_2 emissions by transport leg for Canadian roundwood imported by Japan according to the Woodmiles methodology (noted as J for Japan) and the Athena methodology (noted as C for Canada). The Athena (C) total of 232.8 kg of CO_2/m^3 of roundwood is 1.6 times higher than the Woodmiles result with no backhaul (J1), but only 13% higher than that calculated using the Woodmiles methodology with an assumed empty backhaul (J2). The small difference in the Athena result relative to the second J2 scenario serves to underscore the significance of an empty dry bulk carrier backhaul.

But this near alignment between the J2 total and the Athena total is merely an averaging-out of major discrepancies for each leg of the log's journey. The Athena results are a factor of three lower for the forest-to-port transportation leg, almost a factor of two higher for the port-to-port leg, and a factor of five lower for the port-to-mill-to site truck transportation leg. The reasons for these individual transportation leg differences are many. For example, the Athena methodology uses a lower CO_2 emission factor for truck transportation, but a higher wood mass for roundwood and accounts for an empty backhaul. More importantly, the Woodmiles method does not account for the required empty bulk carrier backhaul and therefore is missing some of the emissions from the largest component (the ocean leg) of the calculation.

Table 5 Scenario 2: Japanese Log Import

Transport Leg (C-Canadian data, J-Japanese data)	Distance (km)	Emission Factors by Mode kg CO_2/m^3-km	Assumed Specific Gravity (Mass)	Yield Rate	Backhaul Factor	Total kg CO_2/m^3
Forest to Port C	100	0.04659	0.627	50%	2	18.6
J	100	0.18515	0.529	66%	2	56.1
Port to Port C	7710	0.00678	0.706	50%	2	209.0
J1	7710	0.00508	0.529	66%	1	59.3
J2	7710	0.00508	0.529	66%	2	118.6
Port to Site C	150	0.03410	0.459	100%	1	5.1
J	150	0.18515	0.529	100%	1	27.8
			Canadian Total			**232.8**
			Japanese-no backhaul-J1 Total			**143.2**
			Japanese-with backhaul-J2 Total			**202.5**

6.3 Japanese Domestic Roundwood & Lumber Scenario Model

This scenario consists of a 109 km truck journey for roundwood (at a moisture content of 60%) within Japan from the forest to a mill, on a dedicated logging truck that returns empty (backhaul factor equals 2). The lumber is milled and kiln-dried to a moisture content of 15%, and then transported via commercial truck 150 km to a building site, where the truck picks up another load in the vicinity (backhaul factor equals 1).

See.Table 6. Using the Athena emission factor for truck transportation and assuming an empty forest-to-mill backhaul results in values that are half the values calculated using the Woodmiles methodology (J1), which assumes no backhaul of the empty logging truck. Adding in the empty backhaul for the Woodmiles calculation (J2) to better match the Athena assumptions makes the difference worse; the Woodmiles total is then more than three times higher than the Athena result. Obviously, this particular scenario hinges on the emission factor used for truck transportation and it is believed that the Japanese factor is incorrect (a factor of five larger than other LCA sources).

Table 6 Scenario 3: Japanese Domestic Resource

Transport Leg (C-Canadian data, J-Japanese data)	Distance (km)	Emission Factors by Mode kg CO_2/m^3-km	Assumed Specific Gravity (Mass)	Yield Rate	Backhaul Factor	Total kg CO_2/m^3
Forest to MIl C	109	0.0466	0.627	50%	2	20.3
J1	109	0.1852	0.529	66%	1	30.6
J2	109	0.1852	0.529	66%	2	61.2
Mill to Site C	150	0.0341	0.459	100%	1	5.1
J	150	0.1852	0.529	100%	1	27.8
			Canadian Total			**25.4**
			Japanese-no backhaul-J1 Total			**58.4**
			Japanese-with backhaul-J2 Total			**88.9**

7 Discussion

The Athena and Woodmiles transportation carbon dioxide emission calculation methodologies lead to very different results. The differences can be traced to a number of factors: the use of varying roundwood and lumber masses at various transportation stages along the supply chain (Athena) as opposed to a single specific gravity for all wood materials (Woodmiles); the use of different emission factors for the transportation modes; whether empty backhauls for the modes are accounted for (Athena yes, Woodmiles no); and to a minor degree whether the methodology includes or excludes the weight of a container in the calculation process (Athena yes, Woodmiles no).

In general, the results by any method indicate that the use of domestic Japanese roundwood, converted into lumber and delivered to a building site, would result in lower CO_2 emissions per m^3 of lumber when compared to scenarios involving imported wood (given the ground transportation distances as used in this study). The next best choice to minimize carbon dioxide related transportation emissions (according to our calculations), is to import Canadian lumber (91 kg CO_2/ m^3) as opposed to Canadian logs for milling in Japan (233 kg CO_2/ m^3) for a 2.5 fold difference.

This is a substantial CO_2 difference that strongly supports the environmental favourability of importing lumber versus logs. To properly understand environmental impact of transportation, it is critical that specific gravity (i.e., density or mass) be included in the calculation. Because the Woodmiles approach fails to account for varying specific gravities of wood products, it significantly underreports the CO_2 impact associated with shipping logs. Specifically, Woodmiles shows only a 9% greater impact due to shipping logs versus lumber, making the log import scenario look far more attractive than it actually is. The Athena method shows a 155% increase in CO_2 emissions when shipping logs versus lumber.

Our synopsis of the Woodmiles Forum tool is that it is too rudimentary and misrepresents the actual transportation logistics to such a degree that its results are misleading and can lead to grossly misinformed conclusions. If the intent is to use such a tool to better inform or develop a wood products trade policy on the basis of meeting Japan's Kyoto Protocol obligations, than the tool needs to be of a higher rigor to withstand international scrutiny.

Table 7 below summarizes the CO_2 impacts for Japan's log and lumber scenarios, based on 2006 data[17]. Japan's total demand for softwood lumber is approximately 20.25 million m^3 per year. At 60% self-sufficiency in lumber, Japan domestically produces 12,150,000 m^3 of sawn lumber and imports the remaining 8.1 million m^3 of lumber to meet this demand. For the domestically-sawn 12,150,000 m^3 of lumber, Japan requires 24,300,000 m^3 of roundwood (50% yield rate: 12,150,000 x 2). Japan is only 20% self-sufficient in wood resources, so a large portion of that roundwood needs to be imported. Thus, 4,860,000 m^3 (0.2 x 24,300,000) is derived from its own forests and 19,440,000 m^3 (0.8 x 24,300,000) is imported logs.

The Forum identifies a goal of doubling Japan's wood self-sufficiency, which would mean an increase from 20% to 40% (4,860,000 m^3 becomes 9,720,000 m^3) of the roundwood required from domestic forests and a subsequent reduction in the amount of roundwood Japan imports to 14,580,000 m^3.

About three megatonnes of CO_2 is emitted annually in the process of transporting all the wood resources and products necessary to meet Japan's current softwood lumber consumption, and about 74% of this CO_2 can be traced to imported logs. Increasing the amount of domestic wood used in the production of softwood lumber to 40% would certainly reduce Japan's dependence on imported logs and would reduce total transportation-related CO_2 emissions by about 0.5 megatonnes, assuming all other variables are held constant. However, increasing the use of domestic wood resources in Japan is a complex and long-term goal

A more immediate reduction in greenhouse gas emissions associated with the transportation of wood resources and products (assuming current softwood lumber consumption levels remain the same or higher) could be achieved with a shift from log imports to sawn lumber imports. The same 0.5 megatonnes of CO_2 could be saved by increasing softwood lumber imports by 44% to 11,664,000 m^3 and consequently, decreasing Japanese log imports to 6,220,000 m^3 of equivalent lumber or by 36% of the current log import quantity. In other words, there is good environmental rationale for Japan to reduce imports of logs intended for domestic manufacturing into lumber and replace this portion of lumber supply with an increase in imports of sawn foreign lumber.

[17] See Figure 5 and the CINTRAFOR reference for this data.

Table 7 Japanese Log and Lumber Scenarios Using Athena Calculation Methodology

Current situation	Total demand =	20,250,000 m^3 lumber	
	Sourced from:	60% domestic mills =	12,150,000 m^3 lumber
		40% overseas mills =	8,100,000 m^3 lumber
	Domestic production =	12,150,000 m^3 lumber =	24,300,000 m^3 roundwood
	Using logs from:	20% domestic forests 2,430,000 m^3 lumber =	4,860,000 m^3 roundwood
		80% imported logs 9,720,000 m^3 lumber =	19,440,000 m^3 roundwood
	CO_2 impact	3.1 megatonnes CO_2 24% due to imported lumber 74% due to imported logs 2% due to domestic lumber	
Option: Double Japan's resource self-sufficiency	Total demand =	20,250,000 m^3 lumber	
	Sourced from:	60% domestic mills =	12,150,000 m^3 lumber
		40% overseas mills =	8,100,000 m^3 lumber
	Domestic production =	12,150,000 m^3 lumber =	24,300,000 m^3 roundwood
	Using logs from:	40% domestic forests 4,860,000 m^3 lumber =	9,720,000 m^3 roundwood
		60% imported logs 7,290,000 m^3 lumber =	14,580,000 m^3 roundwood
	CO_2 impact	2.6 megatonnes CO_2 29% due to imported lumber 66% due to imported logs 5% due to domestic lumber	
Option: Shift imports from logs to lumber	Total demand =	20,250,000 m^3 lumber	
	Sourced from:	42% domestic mills =	8,586,000 m^3 lumber
		58% overseas mills =	11,664,000 m^3 lumber
	Domestic production =	8,586,000 m^3 lumber =	17,172,000 m^3 roundwood
	Using logs from:	28% domestic forests 2,366,000 m^3 lumber =	4,732,000 m^3 roundwood
		72% imported logs 6,220,000 m^3 lumber =	12,440,000 m^3 roundwood
	CO_2 impact	2.5 megatonnes CO_2	

Notes:

- For the sake of illustrating the examples, this table assumes all imports are from Canada.
- 50% yield factor is assumed in the roundwood calculations (lumber volume x 2 = roundwood required).
- Emission factors are as presented elsewhere in this report, and as shown below:
    - Canadian lumber transported to Japan: 91.1 kg CO_2/m^3
    - Japanese lumber from domestic resource: 25.4 kg CO_2/m^3
    - Japanese lumber from imported logs: 232.8 kg CO_2/m^3

Appendix: Woodmiles manual for calculating indices

June 11, 2005
Woodmiles Forum

Manual for Calculation of Building Woodmileage Indexes
Version 2005

1. Fundamentals

1-1 Purpose

The purpose of this manual is to provide a reproducible and objective method for the calculation of "building woodmileage indexes" concerning the distance covered while transporting timber used in the construction of a building. The aim of these indexes is to reduce the distance covered and thus the amount of energy consumed while transporting timber, as well as to stimulate demand for locally grown timber.

1-2 Conditions

The indexes must fulfill the following conditions: (1) They should be precise and reproducible in order to ensure that they are fair when compared with each other. (2) They should elicit sufficient interest so as to serve as an incentive for investigating the origins and logistics of the timber concerned (in principle, calculations should be based on data obtained from factual investigation such as hearing). (3) They should be sufficiently simple such that anyone with a certain level of interest and effort can perform the calculation (through the provision of standardized data such as woodmileage and woodmileage CO_2 values for different types of imported timber, etc.).

2. Procedures for revision of the manual

This manual shall be revised as required, in accordance with the Provisions for the Revision of Woodmiles-Related Index and Tools.

3. Types and definitional formulae of indexes to be created

3-1 Types of indexes

The following indexes shall be created.

Building woodmileage

An index representing the sum of actual distances covered in transporting timber the applicable type of timber used in the construction of a building (hereafter, applicable timber materials) from each place of harvest (timber type-specific woodmiles), multiplied by the corresponding volumes of timber transported from each place of harvest (unit: $km \cdot m^3$)

Building woodmileage CO_2
An index representing the volume of 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, namely unprocessed or processed (unit: kg-CO_2)

Building woodmileage L (L = linear)
An index representing the sum of the linear distances between each place of harvest (timber type-specific woodmiles L) of applicable timber materials and the construction site, multiplied by the corresponding volumes of timber transported from each place of harvest (unit: $km \cdot m^3$)

Knowledge level of logistics stops
The number, expressed as a proportion of total woodmileage, of applicable timber materials for which accurate information is available with regard to processing and storage stops between each place of harvest and the construction site

3-2 Definitional formulae
Building woodmileage
$= \Sigma(Vi) \times (Dri + Dpi)$

Building woodmileage CO_2
$= \Sigma(Vi) \times (((Drci) \times (Ec) + (Drri) \times (Er) + (Drbi) \times (Eb))/P + ((Dpci) \times (Ec) + (Dpri) \times (Er) + (Dpbi) \times (Eb)))$

Building woodmileage L (L = linear)
$= \Sigma(Vi) \times (Ddi)$

In the above equations,
Vi = Volume of applicable timber materials transported via route i
Dri = Distance transported as roundwood
Drci = Distance transported by road as roundwood
Drri = Distance transported by rail as roundwood
Drbi = Distance transported by sea as roundwood
Dpi = Distance transported as timber products
Dpci = Distance transported by road as timber products
Dpri = Distance transported by rail as timber products

2

Dpbi = Distance transported by sea as timber products
Ec = Road transport CO_2 emission units
Er = Rail transport CO_2 emission units
Eb = Sea transport CO_2 emission units
P = Processing yield rate
Ddi = Linear distance from place of harvest

Knowledge level of logistics stops
$= \Sigma((Vje) \times (Drje + Dpje)) / \Sigma((Vi) \times (Dri + Dpi))$

where
Vje = Volume of timber material of which transportation routes are known
Drje = Confirmed distance transported as roundwood
Dpje = Confirmed distance transported as timber products

In the case of n stages of processing being used:
Building woodmileage CO_2
$= \Sigma(\Sigma(Vi \times Dk \times Ek/Pk))$
<The former sigma is for k and runs from 1 to n; the latter sigma is for i.>
here,
Dk = Distance transported from points k to k-1(km)
Ek = CO_2 emission units for each type of transportation from points k to k-1 ($kg/m^3 \cdot km$)
Pk = Processing yield rate at point k

4. Applicable timber materials and their classification

4-1 Applicable timber materials
In principle, all building materials derived from timber should be regarded as applicable timber materials.

4-2 Classification of applicable timber materials
(1) Structural materials
(2) Sheathing, backing materials
(3) Millwork materials
(4) Finish materials
(5) Door materials
(6) Built-in cabinetry materials
(7) Exterior materials

5. Transportation distances

5-1 Basic approach

Maximum possible identification of the processing and storage stops between places of harvest and the construction site, along with precise measurement of distances between stops, the form of the timber transported (roundwood, processed timber), and types of transportation used (road, rail, coastal route, oceangoing) for each stage

5-2 Domestic timber

5-2-1 If actual distances are known

If distances between places of harvest and the various stops for processing and storage are known (or if the processors or transporters can provide reliable woodmileage figures based on the use of prescribed procedures), these distances may be used.

5-2-2 If actual distances are unknown

If distances between places of harvest and the various stops for processing and storage are unknown, the following methods shall be used.

(1) Distances transported by road

Use Internet resources to obtain the distance between points.

(View the Mapfan Web Route Map at http://www.mapfan.com/routemap/index.html)

(2) Distances transported by rail

Use the distances provided by railway operators in fare calculation tables prepared in accordance with the requirements of Article 13 of the Railway Enterprise Law.

(Distances between two stations are available at the following URLs.

Yahoo Railway Route Information: http://transit.yahoo.co.jp/

Jorudan Train Connection Information: http://www.jorudan.co.jp/norikae/norimap.html)

(3) Distances transported by sea

Use the distances between ports published by the Japan Coast Guard and other agencies.

(Japan Coast Guard Maritime Traffic Department distance tables etc.)

5-2-3 If places of harvest and logistics stops are unknown

Create as accurate a picture as possible of places of harvest and logistics stops by making enquiries among suppliers, and estimate the mileage in accordance with the methods described above.

5-3 Imported timber

5-3-1 Distance transported in producer country and import distance

If the processors or transporters can provide reliable woodmileage figures for distance transported in the producer country and distance to port of entry based on the use of the prescribed procedures, these distances may be used. If such figures are unavailable, the figures provided in Table 1 may be used provisionally.

5-3-2 Distance transported in Japan

For domestic timber, calculate the distance transported within Japan from the port of entry in accordance with the methods described in 5-2 (replacing place of harvest with port of entry).

6. Other coefficients

6-1 CO_2 emission unit

CO_2 emission units used to calculate woodmileage CO_2 for each form of transportation are listed in Table 2.

6-2 Processing yield

Processing yields used to calculate woodmileage and woodmileage CO_2 are shown in Table 3.

7 Miscellaneous

7-1 Composite materials

In the case of a material composed of timber from more than one place of harvest, calculate indexes based on the volume of each raw material and its corresponding transport route distances equivalent to the proportion of each component in the total.

7-2 In cases wherein this manual's explanation is unclear or when unforeseen calculation problems arise, the Forum will decide on a provisional solution based on the Fundamentals listed in Section 1. The Forum will disclose the contents of and grounds for such decisions to assessors certified under "The rules for certifying assessors of woodmiles-related indexes" (hereafter, Assessors). and apply the contents and grounds to further editing of the manual.

7-3 When one uses and interprets this Manual, calculation results in which Assessors calculate and published shall be referred.

Table 1: Data for Imported Timber

Provisional distances (km) of imported timber to port of entry

			Sawn timber transportation			Roundwood transport		
	No.	Producer country/region	Sea	Road	Rail	Sea	Road	Rail
Roundwood imported	1	North America	0	0	0	7710	100	0
	2	Russia	0	0	0	1700	200	4200
	3	Chile	0	0	0	18235	100	0
	4	New Zealand	0	0	0	9116	100	0
	5	Southeast Asia/South Pacific	0	0	0	4920	100	0
Sawn timber imported	6	North America	7710	0	0	0	100	0
	7	Russia	1921	0	5000	0	500	0
	8	Europe	22570	0	350	0	100	0
	9	Chile	18235	300	0	0	100	0
	10	New Zealand	9116	300	0	0	100	0
	11	Southeast Asia/South Pacific	4820	0	0	0	0	0
Plywood imported	12	Indonesia	4820	0	0	0	100	0
	13	Malaysia	4920	0	0	0	100	0
	14	North America	7710	0	460	0	100	0
	15	New Zealand	9116	300	0	0	100	0

Note (1) When the species of timber indicates that the timber originated in the Russian Far East (Khabarovsk Krai; Primorsky Krai), Table 1-1 may be referred to.
Note (2) When the Russian export port and domestic import port can be identified, data sources such as *Distance Tables for World Shipping* by the Japan Shipping Exchange, Inc. may be referred to. (Table 1-2 provides provisional figures.)

(As of May, 2005)

Table 1-1: Provisional figures for transport distances by rail for Russian roundwood in Russia (Unit: km)

Species	Assumed places of harvest	Assumed collection point	Transport distance by rail	Export port
Picea jezoensis/ Abies sachalinensis	Khabarovsk Krai	Komsomolsk	450	(Wanino)
			1270	Nakhodka

Table 1-2: Provisional figures for transport distances for Russian roundwood (Unit: km)

Export ports	Import ports

6

	East to Tokyo, on the Pacific Ocean	East to Toyama, on the Sea of Japan
Northern Primorsky Krai	1921	1400
Southern Primorsky Krai	1700	811

Table 2: CO_2 conversion factors

		CO_2 emission units per m^3	CO_2 emission units per ton	Specific gravities of timber
No.		$kg/m^3 \cdot km$	$kg\text{-}CO_2/ton \cdot km$	
1	Road	0.18515	0.35 *1	0.529
2	Rail	0.01058	0.02 *1	0.529
3	Coastal shipping	0.02116	0.04 *1	0.529
4	Oceangoing bulk shipping (roundwood imported)	0.00508	0.0096 *2	0.529
5	Oceangoing container shipping (sawn timber imported)	0.01095	0.0207 *2	0.529

*1 Central Environmental Council (July 2001) "Working Group on Scenarios for Achieving the Targets, Division for the Global Environment: Interim Report."

*2 Ship & Ocean Foundation (June 2001) "Report on Reduction of Green House Gas (CO_2, etc.) Emissions from Ships."

Table 2-1: Specific gravity of timber

	Figures	Notes	Sources
Specific gravity of bone-dried timber	0.46	Specific gravity with zero moisture content	*3
Moisture content of air-dried timber	15%	Specific gravity in equilibrium with normal temperature and humidity	*4
Specific gravity of timber employed in this Manual	0.529		

*3 Tonozaki, Mario, et al (2000) "Evaluation of Carbon Sequestration Capacity" in Forestry and Forest Products Research Institute (ed.) *Anthropogenic Effects on Carbon Budgets in Forestry and Wood Sectors.*

*4 Forestry Research Station (ed.) (1982) *Handbook of Forest Products Industries (3rd Revised Version)*, p. 105.

Table 3: Yields

	Yields	Conversion factors for converting to	Sources

7

		roundwood	
Roundwood	100%	100%	
Sawn timber	66%	152%	*5
Plywood	60%	167%	*6
J panel	40%	250%	*7
Try-wood panel	40%	250%	*8
Trapezoidal laminated timber	30%	333%	*9

*5 Ministry of Agriculture, Forestry and Fishery. *Basic Statistics on Sawmills* (Sawn timber shipment/Raw materials consumed at Sawmills from 2000–2003)

*6 Ministry of Agriculture, Forestry and Fishery. *Statistics on Plywood*. (Ordinary-type plywood production/Supply of raw materials for producing veneers from 2000–2003)

*7 Data obtained based on data provided by one producer.

*8 Data obtained based on data provided by one producer.

*9 Data obtained based on data provided by four producers.