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Questionnaire

FOREST PRODUCT CONVERSION FACTORS

Please list the name of your country here

If these data are only representative of a particular segment of a country, please specify

Correspondents name and institute

Note: The data on conversion factors are to be filled in directly in the data tables (blue text) for the eight categories of factors. The black text is the explanatory text taken from the last UNECE/FAO Forest Products Conversion Factors publication (ECE/TIM/DP/49[1]).There are eight sections of this questionnaire.

[1] ECE/TIM/DP/49, *Forest Products Conversion Factors for the UNECE Region* can be downloaded at: http://www.unece.org/fileadmin/DAM/timber/publications/DP-49.pdf

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(Questionnaire tables are highlighted in yellow)

List of abbreviations

AB	Alberta
BC	British Columbia
bf	board foot or board feet
C	Celsius
cm	centimetre
FAO	Food and Agriculture Organization of the United Nations
GOST	Government standard of the Russian Federation
ft	foot or feet
ft^2	square foot
gj	gigajoule
gm	gram
kl	kilolitre
kg	kilogram
lbs	pounds
m	metre
m^2	square metre
m^3	cubic metre
m^3p	cubic metre product
m^3rw	cubic metre roundwood
m^3sw	cubic metre of solid wood
mbf	1,000 board feet
mcd	moisture content dry basis
mcw	moisture content wet basis
MDF	medium density fibreboard
mm	millimetre
mt	metric ton
n.a.	not applicable
NWLRAG	Northwest Log Rules Advisory Group
ob	over bark
odmt	oven dry metric ton
OSB	oriented strand-board
RW	roundwood
swe	solid wood equivalent
ub	under bark
UNECE	United Nations Economic Commission for Europe
USFS	United States Department of Agriculture, Forest Service

INTRODUCTION

The term “forest products conversion factors” is used to cover a broad spectrum of ratios utilized in the wood-based forest resource, manufacturing, and energy sectors. For the purpose of this publication, conversion factor is defined as using a known figure to determine or estimate an unknown figure via a ratio. Often these ratios are exact, for example converting cubic feet to cubic metres (there is exactly 35.315 cubic feet in a cubic metre). Annex table 1 is a listing of some of the exact conversion factors (equivalents) relevant to forest products.

Often ratios are not exact, but rather a good average; for example, a cubic metre (under bark volume) of freshly felled Norway spruce sawlogs may average 860 kg of which 80 kg is bark and 780 kg is wood (with both bark and wood containing a certain amount of moisture), but might vary as a result of wood density, moisture content, the presence or lack of bark, etc.

In other instances, conversion factors may have little meaning unless some of the parameters of the numerator and the denominator of the ratio are known. For example: a cubic metre of logs with an average small end diameter of 15 cm might make 0.41 m^3 of sawnwood, while a cubic metre of logs with an average small-end diameter of 60 cm might make 0.63 m^3 (50% more), given the same level of processing efficiency in a sawmill. That is not to say that a single factor to convert roundwood to sawnwood cannot be used; it can be done with an accurate factor and when looking at a large population in the aggregate. When looking at a lower level, however, factors that account for various parameters are better suited (e.g. a mill or a subregion that only processes small logs).

Related to forest product conversion factors, is the use of the “material balance” The sawnwood example above could lead to the incorrect assumption that only 41% of the wood fibre in the 15 cm sawlog and 63% of the 60 cm sawlog were utilized. In fact, almost 100% of the wood in each of these logs may have been utilized. The remaining non-sawnwood volume went to several wood residues having other and often distinct uses. For example: a cubic metre of 15 cm sawlogs could have a material balance of 41% sawnwood, 43% chips (raw material for paper, panels, wood energy, etc.), 9% sawdust (for making energy pellets, particleboard, MDF, etc.) and finally 7% shavings (particle board, MDF, animal bedding and wood energy, etc.). The components balance with 100%. Although not part of the material balance, as the log volume was represented as under bark, one might also apply a conversion factor to this scenario to estimate that 80 kg of bark (with moisture) are potentially available from each cubic metre of roundwood (measured under bark) for energy or other uses. Note that material balances are used at a manufacturing plant level, a sector level, or can be constructed to account for the cascading uses of wood raw material in a country, subregion, or region

Logs and their subsequent products have a predisposition towards inexact conversion factors, as a result of the wide range of shape and form, the variability of physical properties (density, moisture content and shrinkage), and other natural variables that affect conversion factors, such as species, size, defects or provenance. Wood fibre is also hygroscopic, thus its volume and weight change once dried in a kiln or exposed to the atmosphere. In addition, there are external biases that also have to be accounted for, such as differences in measurement procedures which often reflect a unit volume differently than another standard does. Finally, there are differences that occur as a result of product-manufacturing efficiency levels and utilization practices.

Conversion factors general use

Conversion factors have long been utilized by the forest sector as a tool for analysing forests and forest products manufacturing facilities. Virtually every aspect of forecasting and analysis in the forest sector is somehow touched by conversion factors. Silvicultural growth models, biomass calculations, carbon sequestered in the forest, timber sale appraisals, to name just a few, are all dependent on conversion factors.

A practical example of this would be a timber sale appraisal that a sawmill is conducting to determine a bid price. The stand volume may be reported in cubic metres over bark but the purchaser may need to convert these volumes into inside bark volumes, weight or board feet[2] to match their units of measure. To

[2] A board foot is ostensibly the equivalent volume of a board that is 1 inch thick x 1 foot wide x 1 foot long (0.00236 m^3).

determine the value of the timber, the purchaser will need to know the cost of getting the timber from the stump to the mill site, thus weight to volume ratios are likely to be an important parameter for determining weight-based transport costs. Primary product recovery will need to be estimated using conversion factors from roundwood to the primary product, e.g., 2 m^3 roundwood will produce 1 m^3 sawnwood. A material balance will be used to determine the quantity and thus value of the residual products made, and finally, ratios may be used to estimate the quantity of unmeasured products from the timber sale such as bark and logging residue (top-wood, limbs, foliage) which may be profitable to utilize for energy or other purposes.

Conversion factors covering the input of raw material to output of forest products are a good indication of efficiency levels and thus are often used to benchmark a manufacturing facility's effectiveness at converting raw materials into finished or semi-finished products.

At a higher level, policy analysts and policymakers may utilize conversion factors to determine the sequestered carbon in the forests of their country.

Finally, outlook studies on long-term wood availability depend on conversion factors to predict needed raw materials to match the forecasted demand of wood and paper products.

1. ROUNDWOOD

The conversion factors requested in this questionnaire relate to two areas: 1. physical properties; and 2. national method of measuring roundwood as it relates to the "true volume". Note that true volume of roundwood for the purposes of this questionnaire and for UNECE/FAO/ITTO statistics on roundwood volume always means under bark volume and assumes the use of a logical cubic formula (one that approximates the volume of the log form) and unbiased rounding logic. Conversion factors for roundwood are often used to convert from one unit of measure to another, e.g., from weight to volume. Additionally, conversion factors within the same units are also quite common, e.g. a cubic metre of roundwood measured by the national standard in one country may be different if measured by the national standard of another country.

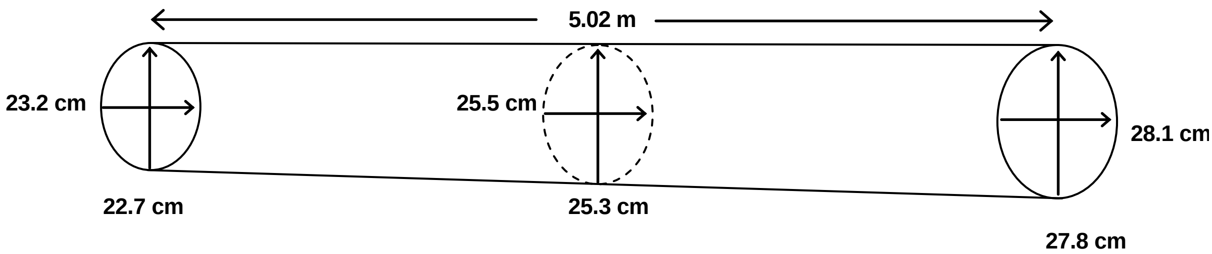
1.1 Volumetric measurement

1.1.1 Cubic volume

Assessing the volume of roundwood is typically referred to as log scaling. In general, log scales attempt to either predict the displaced volume of the log (cubic log scale), or as is the case in the United States and some regions of Canada, in units of predicted output of sawnwood (board foot log rule).

One of the questions asked in the questionnaire is: "what is the ratio of volume as determined by your national standard to a m^3 of true volume?" As mentioned above, "true volume" is defined as the volume as determined using a logical cubic formula (one that approximates the volume of the log form) and unbiased rounding logic. There are a number of different cubic formulas, e.g. Smalian, Huber, Newton, centroid, or two-end conic, most with potential strengths and weaknesses which are dependent on log dimensions and form. All of the aforementioned cubic formulas will give similar results most of the time when measurement conventions are applied uniformly and on logs with typical parameters (figure 1.1). Thus, it is not within the scope of this report to specify a standardized roundwood volume formula. Figure 1.1 is an example of volume calculation using unbiased rounding logic and two different formulas (Smalian and Huber).

Figure 1.1 True log volume calculation



Smalian formula: $(((23.2+22.7)/2)^2+((28.1+27.8)/2)^2) \times 5.02 \times 0.00003927 = 2.58\ m^3$

Huber formula: $((25.5+25.3)/2)^2 \times 5.02 \times 0.00007854 = 2.54\ m^3$

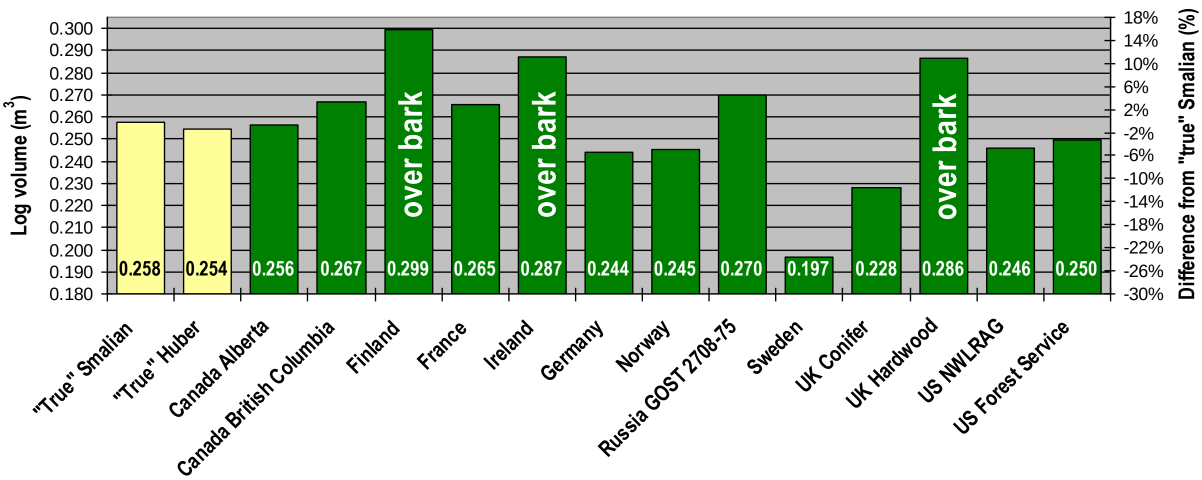
Source: UNECE/FAO, 2009.

Of much greater concern, in terms of harmonizing conversion factors based on national volumes to "true cubic," is the common practice of truncating (rounding down) diameters and lengths. For example: a log with an actual length of 10.3 metres is recorded as being 10.0 m in length (with 30 cm of unmeasured "trim allowance"); and a log end with a diameter of 27.9 cm is recorded as having a diameter of 27.0 cm. The purpose of truncation should not be construed as a purposeful way of understating volume; it is generally done to make the mathematical calculation easier and to allow the manufacture of products at least as long as the recorded log length.

There are other areas that also create discrepancies between log scales, such as the reduction of volumes for defects vs. not accounting for defect with a volume reduction, but rather using a value reducing mechanism such as log grade. Additionally, some national and subregional log scaling standards treat the log as a cylinder with a diameter of the small-end of the log; assume the log form is a cylinder with the diameter that exists in the middle of the log length; or use assumed taper rates to establish diameters other than the small-end. Additionally, some national standards calculate the over bark volume. All of these differences can lead to variation in roundwood volume (figure 1.2). The figure shows saw/veneer log volumes calculated using thirteen different log scaling standards. Please note that this figure only represents one log and is included as an example of some of the differences that can occur. Logs with different dimensions and characteristics may produce quite different relative results, owing to the degree and points of rounding, as well as the relative size of truncated units, e.g. truncating a diameter of 13.9 cm to 13 will have a more significant impact to the volume on a percentage basis (-12.5%) then would truncating a diameter of 77.9 cm to 77 (-2.3%). While not included in the figure, the log shown in figure 1.1 would have a board foot volume of:

- 30 bf if measured in coastal Alaska, Oregon and Washington, US (Scribner long log rule).
- 40 bf if measured in the western US, except as noted above (Scribner short log rule).
- 25 bf if measured in the southeast of the US (Doyle log rule).
- 50 bf if measured in the northeast of the US (International ¼ inch log rule).
- 45 bf if measured in the province of Ontario, Canada (Ontario log rule).
- 48 bf if measured in the provinces of New Brunswick or Nova Scotia Canada (New Brunswick log rule).
- 54 bf if measured in the province of Newfoundland, Canada (Newfoundland log rule)

Figure 1.2 Log volume comparison between national log scales for log in figure 1.1



Note: Calculated using the log dimensions in figure 1.1 and applying the procedures from the national roundwood measurement standards from the countries or organizations listed. NWLRAG = Northwest Log Rules Advisory Group, GOST 2708-75 is the standard for domestically consumed roundwood in the Russian Federation, UK Conifer = top diameter method, UK Hardwood = mid diameter method.

Source: See references under subsection on roundwood measurement standards (section 9.).

For the purpose of this report, conversion factors using roundwood input are assumed to be based on true volume, which is what was requested in the questionnaire.

1.1.2 Board foot log rules

In the United States and in Canada there are still regions that use board foot log rules. Most of these rules date from the 19th century and attempt to predict sawnwood as measured in board feet which could be milled from a log. Log rules are either based on diagrams or formulas, with assumptions made as to saw kerf, and slab loss. Except for the International ¼" rule, log segments were considered to be a cylinder having no taper. A US study used a population of 175 logs to model the conversion factors of various board foot rules used in North America and found that the board foot per cubic metre[3], for just the Scribner rules (of which there are three subregional variants), ranged, on average, from as little as 108 (9.26 m^3/1,000 board feet (mbf)) for logs with a small-end diameter of 4.5 to 7.49 inches to as much as 246 (4.06 m^3/mbf) for logs with a small-end diameter over 15.5 inches (Fonseca, 2005).

1.2 Weight and physical properties

The weight of roundwood generally correlates well with the volume. In many areas of the world, roundwood is bought and sold via weight. Usually weight is used in conjunction with sample volume measurement in order to establish the relationship. The presence of drive-on weight scales along many transportation routes, national ports of entry, and at many industries that consume roundwood, make this data readily available and inexpensive to ascertain relative to taking measurements on all logs. There are a number of factors which determine the weight of a given amount of roundwood volume.

1.2.1 Wood density

Wood is structured with cell walls and void spaces. Wood cell walls all have about the same basic density, regardless of species, approximately 1,560 kg per m^3, (Van Vuuran, et al. 1978). What varies is the amount of wood material to cell cavity area.

Wood density is typically measured as a ratio of the weight of oven dry fibre per m^3 (basic density), or in the unitless measure of specific gravity, which is an index of the relationship of said material to the same volume of water (water weighs 1,000 kg/m^3). For example, a cubic metre of wood (volume measured when green), without any water weighs 400 kg; it has a basic density of 400 kg/m^3 and a specific gravity of 0.40. In the UNECE region basic density (green volume and oven dry weight) will vary from approximately 290 kg/m^3 to 540 kg/m^3 for coniferous wood, while non-coniferous will vary from about 320 kg/m^3 to 800 kg/m^3 (USDA Forest Service, Forest Products Laboratory, 1999) and (Austrian Energy Agency, 2009).

When using published averages for calculating the basic density or specific gravity of a species, be careful to note whether the volume was established in the green state (prior to shrinkage) or in the dry state (after shrinkage), as wood volume in the UNECE region will shrink approximately 10% for coniferous species and about 15% for hardwood species when taken from green to a fully dry state. The exact amount of shrinkage will vary from one species to another and even from one sample of the same species to another. Basic density based on green volume and oven dry weight (0% moisture) is the standard for this questionnaire, Which has the advantage of being applicable to standing tree volume and roundwood without having to know or estimate volumetric shrinkage.

1.2.2 Moisture content

Freshly cut wood (also referred to as "green") contains large amounts of water, both in the cell cavities (free water) and within the cell walls themselves (bound water). Normally the moisture content is measured in terms of the weight of the moisture relative to the weight of the dry wood fibre. For example, if wood weighs 812 kg/m^3 in the green state, and 400 kg m^3 in the oven dry state (devoid of moisture), it is said to have 103% moisture content "dry basis" (mcd). In this example the wood had 400 kg of wood and 412 kg of moisture. Therefore, dividing the weight of the moisture by the weight of the dry wood gives the moisture content. Note that freshly cut wood can vary from 30% mcd to more than 200%.

Moisture content can also be reflected via the ratio of moisture weight to the total weight of the wood fibre plus moisture content, which is referred to as moisture content "wet basis" (mcw). This is typically used for measuring the moisture content of wood particles, wood for energy, and pulp and paper, which will be

[3] The roundwood measurement standard of the province of British Columbia, Canada (B.C. Firmwood) was chosen as the index because it has unbiased rounding logic and uniform application of formulas and measurements.

elaborated upon further in sections 2 and 6. This method is not normally used for solid wood, as the numerator is made up partly by the denominator.

It is also important to note that the moisture content of the wood and bark of many species has distinct seasonal variation while others may have little if any differences.

Finally, the heartwood of many species, particularly coniferous trees, often have less moisture than the sapwood. Thus, older (generally larger) trees often have a lower weight to volume ratio than that of younger trees (generally smaller) by virtue of the age related increase in the ratio of heartwood to sapwood. Related to this, many species have a higher ratio of bark when young and small vs. old and large, thereby magnifying this trend.

1.2.3 Bark and other unmeasured volume

Bark, like wood, typically contains large amounts of water when fresh. In general, the bark of most species has weight to volume characteristics similar to the wood of the same species. The bark of conifers and non-coniferous species can typically range from as little as 4% of the total over bark volume (and weight) to as much as 30%. Roundwood weight is normally reported with bark present; however, roundwood volume for UNECE/FAO/ITTO purposes and many national roundwood measurement standards is reported for wood only, meaning that bark increases the weight to volume ratio of roundwood. Bark is an important source of forest-based energy, as well as having other uses such as decorative ground cover and soil treatment (mulch). Knowing the ratio of bark to roundwood volume is useful in terms of understanding weight ratios, but also for potential energy and other products that can be produced from bark. It is important to note, however, that bark volume typically decreases during handling from forest to mill, so the potential volume as reflected in over bark to under bark volumes are seldom available and highly variable depending on log handling practices and season (bark loss from handling is generally higher during the spring of the year).

Defects in roundwood, such as unsound fibre (decay), fractures, splits, crooked portions, etc., have weight, but often no volume, when the scaling method calls for a deduction, thus increasing the ratio of weight to volume for roundwood.

1.3 Roundwood (please update or enter new data in yellow column)

Products	unit in/ unit out	Czech Republic	Finland	France	Germany	Ireland	Netherlands	Norway	Slovakia	Spain	Sweden	Switzerland	United Kingdom	United States	Your country	Median	Average
Saw/veneer logs																	
Conifer																	
Green weight with bark/volume wood only	kg/m³	940	930	970	810	--	780	820	940	881	950	900	1 018	1 000		935	912
Wood basic density (dry weight/green m³)	kg/m³	434	410	420	405	360	440	400	--	436	415	440	--	455		420	420
Volume ratio wood/bark plus wood	ub/ob	0.90	0.89	0.87	0.89	0.89	0.81	0.9	0.901	0.87	0.9	--	0.89	0.88		0.89	0.88
Non-conifer																	
Green weight with bark/volume wood only	kg/m³	1 150	1 050	1 130	1 130	--	910	900	1 180	902	1 050	1 100	1 143	1 086		1 093	1 061
Wood basic density (dry weight/green m³)	kg/m³	680	510	560	565	--	420	500	--	554	550	625	--	527		552	549
Volume ratio wood/bark plus wood	ub/ob	0.87	0.88	0.88	0.91	--	0.83	0.85	0.893	0.88	0.88	--	0.88	0.88		0.88	0.88
Conifer and non-conifer																	
Green weight with bark/volume wood only	kg/m³	1 045	935	1 018	865	--	820	820	1 060	886	950	--	1 019	1 029		950	950
Wood basic density (dry weight/green m³)	kg/m³	557	415	462	432	--	435	400		461	415	--		465		435	449
Volume ratio wood/bark plus wood	ub/ob	0.89	0.88	0.87	0.89	--	0.82	0.90	0.90	0.87	0.90	--	0.89	0.88		0.89	0.88
National m³/"true" m³	m³/m³	--	--	--	--	--	--	0.975	--	1.00	--	--	--	0.94		0.975	0.972
Pulp/fuelwood logs																	
Conifer																	
Green weight with bark/volume wood only	kg/m³	940	850	1015	810	--	780	820	940	882	920	900	1 018	855		891	894
Wood basic density (dry weight/green m³)	kg/m³	434	400	407	405	360	440	400	--	436	400	444	--	444		407	415
Volume ratio wood/bark plus wood	ub/ob	0.9	0.87	0.83	0.89	0.89	0.81	0.9	0.901	0.84	0.9	--	0.89	0.89		0.89	0.88
Non-conifer																	
Green weight with bark/volume wood only	kg/m³	1 150	950	1 090	1 130	--	910	900	1 180	1 155	970	1 100	1 143	893		1 095	1 048
Wood basic density (dry weight/green m³)	kg/m³	680	490	550	565	--	420	500	--	620	500	625	--	471		525	542
Volume ratio wood/bark plus wood	ub/ob	0.87	0.86	0.85	0.91	--	0.83	0.85	0.89	0.85	0.88	--	0.88	0.89		0.87	0.87
Conifer and non-conifer																	
Green weight with bark/volume wood only	kg/m³	1 045	885	1 038	865	--	820	820	1 060	978	930	--	1 019	864		930	939
Wood basic density (dry weight/green m³)	kg/m³	557	430	450	432	--	435	400	--	461	420	--	--	451		435	448
Volume ratio wood/bark plus wood	ub/ob	0.89	0.87	0.84	0.89	--	0.82	0.9	0.897	0.85	0.9	--	0.89	0.89		0.89	0.88
National m³/"true" m³	m³/m³	--	--	--	--	--	--	0.99	--	1.0	--	--	--	0.94		0.990	0.977

2. WOOD PARTICLES

Wood particles (chips, sawdust, flakes and shavings), can be measured by volume or by weight (both in the dry state and "as delivered"). All of these products start out as solid wood from logs of varying density, are broken down into somewhat irregular shaped particles, and often contain varied amounts of moisture and void space between the particles.

Conversion factors for wood particles are determined by wood density, moisture content and compaction. In general, large enterprises that produce and use wood particles obtained from many sources, utilize oven dry weight as the unit of choice for measuring wood particles. Enterprises that work with wood particles obtained from fewer and more homogeneous sources might favour the use of volume or weight as delivered. Ultimately, the yield of most manufacturing processes using wood particles as a raw material is driven by the quantity of fibre excluding moisture and void.

2.1 Volumetric measurement

Procedures for establishing the volume of particles is straightforward. Volumes contained in truck-loads, ship-hulls and bins can be easily calculated. Even huge irregularly shaped stockpiles at manufacturing facilities can be measured with surveying equipment to establish volume.

Solid wood equivalent is more complicated, however, as a result of the variation in void space. Wood particles in containers or piles will settle over time and the heavier the particles (due to density or moisture content) and the greater the depth (thus increasing weight), the more compaction will occur.

In *Conversion Factors for the Pacific Northwest Forest Industry* (Hartman et al, 1981), the following are listed as typical ratios of m^3 loose to m^3 solid for wood particles:

- pulp chips (compacted) 2.50
- pulp chips (un-compacted) 2.86
- sawdust 2.50
- planer shavings 4.00

2.2 Weight

The weight of wood particles is generally reflected "as delivered" or as an oven dry weight (all moisture removed). The "as delivered" weight can have substantial variability as a result of the moisture content. For example: chips from a sawmill may have 50% mcw (50% of the weight is water and 50% is dry fibre), while a veneer plant, using identical logs for raw material as the sawmill, may produce chips where only 6% (mcw) of the weight is moisture. In this example, the sawmill chips were green, while the veneer chips would have been produced from dried veneer.

The normal procedure for establishing oven dry weight of wood particles is via a sampling system. For example:

- if the net weight of a truck load of chips is 32,200 kg;
- a sample of "as delivered" chips is taken, which weighs 922 gm;
- the sample is placed in a vented oven at approximately 103° C for 24 hours, until the weight stabilizes at 497 gm (devoid of moisture);
- the oven dried weight of the sample is divided by the "as delivered" weight and this ratio is multiplied by the "as delivered" net weight of the truck load of chips;
- (497 ÷ 922) x 32,200 = 17,356 kg or 17.356 oven dried metric tons (ODMT)

2.3 Wood particles (please update or enter new data in yellow column)

	unit in/ unit out	Czech Republic	Finland	France	Germany	Ireland	Netherlands	Norway	Slovakia	Spain	Sweden	Switzerland	United States	Your country	Median	Average
Conifer																
swe[4] to oven dry metric ton	m^3/odmt	2.41	2.40	2.25	2.47	2.78	--	2.50	2.44	2.45	2.30	2.25	2.31		2.41	2.41
Avg. delivered metric ton/odmt	mt/odmt	2.00	2.00	1.85	--	2.11	--	1.80	1.98	--	2.00	--	2.15		2.00	1.99
m^3 loose to solid m^3	m^3/m^3	2.88	2.55	2.5	--	2.7	2.86	3.30	3.38	--	2.70	2.80	3.04		2.83	2.87
Non-conifer																
swe to oven dry metric ton	m^3/odmt	--	2.02	2.04	1.77	--	--	2.10	1.54	2.40	--	1.60	2.00		2.01	1.93
Avg. delivered metric ton/odmt	mt/odmt	--	1.80	1.50	--	--		1.80	1.57	--	--	--	1.79		1.79	1.69
m^3 loose to solid m^3	m^3/m^3	--	2.67	2.50	--	--	3.23	2.86	2.57	--	--	2.80	--		2.74	2.77
Conifers and non-conifers																
swe to oven dry metric ton	m^3/odmt	--	2.35	2.19	2.31	--	--	2.46	1.92	2.20	--	--	2.27		2.27	2.24
Avg. delivered metric ton/odmt	mt/odmt	--	2.0	1.75	1.67	--	--	1.8	1.71	--	--	--	2.10		1.78	1.84
m^3 loose to solid m^3	m^3/m^3	--	2.65	3.00	2.44	--	3.23	2.94	2.88	--	--	2.80	--		2.88	2.85

Source: UNECE/FAO Forest Products Conversion Factor Questionnaire, 2009.

[4] Solid wood equivalent (swe) assumes green volume of wood, prior to any shrinkage. This number will correspond with the wood fibre contained in the product and the roundwood equivalent volume needed to produce the product when there are no losses or wood residues. For example, a cubic metre of green sawnwood will have a cubic metre solid wood equivalent, but it will take more volume of roundwood to produce that cubic metre of sawnwood because of the loss of residual products, such as chips and sawdust. Thus a cubic meter of sawnwood will have a swe of one cubic meter, however, the roundwood input required may be two cubic metres. A cubic meter of particleboard may contain 1.5 cubic meters of solid wood equivalent and use the equivalent of 1.5 cubic meters of roundwood to produce it since there are no losses.

3. SAWNWOOD

Sawnwood covers a large spectrum: from semi-processed cants[5], boules and flitches[6], which are often still green; to fully edged, dried, trimmed, and planed sawnwood. The state of manufacture, such as boules/flitches vs. dried and planed sawnwood, will have a large impact on the conversion factor, e.g. a cubic metre of roundwood might produce 0.8 cubic metres of green boules and flitches but only half that amount (0.4 m^3) of fully dried, edged, grade-trimmed and surfaced (planed) sawnwood. As a result, countries are asked to provide conversion factors for sub-categories of sawnwood products in order to understand why national conversion factors vary so much.

For example, according to the results of the 2008 questionnaire on conversion factors, Germany reported that the conversion factor for coniferous sawnwood is 1.67 m^3 of roundwood per m^3 of sawnwood vs. 2.04 for the United States. On face value, this might lead one to believe that the sawmills in the US are much less efficient than sawmills in Germany (this number indicates that United States mills require 22% more roundwood volume to make the same quantity of sawnwood). Upon further analysis of the sub-categories of sawnwood, however, it is seen that roundwood to sawnwood conversion factors for the sub-product categories such as rough green and surfaced dry are similar between the two countries.

Several countries report that sawnwood production in their countries is measured in the rough green state in order to avoid "double counting" volume, which may be dried, grade trimmed or planed at a separate, off-site facility. This contrasts with the Nordic region and North America, where sawnwood volume is more often tallied and reported in a final state of manufacture. This, for example, can lead to a situation whereby the ratio of roundwood needed (RW factor) to make sawnwood is reported as 1.57 (64% recovery) in the rough green state; or 1.75 (57% recovery) if reported in the rough dry state, or 2.27 (44%) if reported in a fully planed and finished state (figure 3.1).

Figure 3.1 Example of roundwood to sawnwood factors by state of manufacture

	Sawmill			Dry kiln or yard			Planing mill and/or grading chain				To customer	
	Roundwood	Loss m^3		Rough green in		Loss m^3	Rough dry in		Loss m^3		Sawnwood shipped	
	m^3	saw kerf	slabs/trim/ edge/cull	m^3	RW factor	shrinkage	m^3	RW factor	planing	trim/cull/ re-edge	m^3	RW factor
Softwood (construction)	1.00	0.07	0.29	0.64	1.57	0.03	0.62	1.63	0.08	0.06	0.48	2.08
Hardwoods (appearance)	1.00	0.14	0.22	0.64	1.57	0.07	0.57	1.75	0.10	0.03	0.44	2.27
		sawdust	chips			H_2o vapour			shavings	chips		

Aside from the issue of state of manufacture, there are many other drivers of efficiency that will affect the conversion factor from roundwood to sawnwood. The issue of volumetric measurement will be discussed in section 3.1, but log quality and size have a substantial impact on conversion efficiency, as do differences in how roundwood volume is measured (see section 1.1). In addition, the efficiency of the milling process and the type of products made will affect recovery ratios.

3.1 Volumetric measurement

3.1.1 Cubic volume

In most of the UNECE region, outside North America, sawnwood is measured in cubic metric volume. It is generally assumed that volumes are determined based on actual dimensions allowing for a small variation, e.g. ± 2 millimetres (mm). The formula is:

width in millimetres x thickness in millimetres x length in metres ÷ 1,000,000 = m^3 sawnwood

[5] A cant is a semi-processed log with at least one (generally 2 or 4) flat faces (either sawn or chipped) on it.

[6] A flitch is sawnwood, which has not yet had the edgings removed, thus the wide face is tapered lengthwise and includes the rounded profile of the log on its edges. A boule is a log manufactured into flitches and stacked together into a unit resembling the original log.

It is known that sawnwood is sold in the retail market based on volumes determined by nominal sizes in some areas of Europe. For example: dried and planed lumber that is 45 mm x 95 mm, which might have started out at 50 mm x 100 mm prior to planning, will have its volume reported based on the latter dimensions. Where the ratio of actual to nominal volume is known, e.g. in North America for sawn softwood, production statistics and conversion factors are adjusted to reflect actual volume, however, where they are not known, no adjustments are made.

3.1.2 Board foot volume

In North America sawnwood is usually measured in terms of “board feet”, with a board foot defined as a board one inch (2.54 cm) thick and one foot square (30.48 cm x 30.48 cm), equivalent to 0.00236 m^3. Therefore one cubic metre of sawnwood ostensibly equals 424 board feet (bf). This measure arose when sawnwood was commonly sold in a rough, green form. Today, sawn softwood is typically dried and surfaced before sale. To accommodate this, a set of standards allows wood of smaller dimensions to be sold on a nominal basis ignoring the shrinkage and material removed during surfacing. For example dried and planed sawnwood may have the volume calculated based on the nominal dimensions of 2 inches in thickness x 4 inches in width x 96 inches in length (0.0126 m^3), while its actual dimensions may be 1.5 inches in thickness x 3.5 inches in width x 92.625 inches in length (0.008 m^3).

The formula for determining board feet is:

Nominal width in inches x nominal thickness in inches x nominal length in feet ÷ 12 = board feet.

Thus a board that is nominally 2 inches x 4 inches x 8 feet would have 5.333 bf.

When measuring the volume of sawn softwood, the width, thickness and, to a smaller degree, length have nominal measurement allowances. In other words, what nominally is represented as having 1 m^3 is often as little as 0.66 m^3. Since this is known, it is adjusted for in the conversion factors and the UNECE/FAO Timber Database. Sawn softwood was reported to have an average actualization factor of 0.72, which is 589 bf per m^3.

3.2 Weight

The relationship between weight and volume of sawnwood varies as a result of the basic density, moisture content and shrinkage (see sections 1.2.1 - 1.2.3). The relationship is useful, however, for estimating shipping weight from known volumes, or volumes from known shipping weights. It is also common to estimate this ratio by using the following formula (Briggs, 1994):

(basic density ÷ (1-shrinkage)) x (1 + moisture content)

For example, to estimate the kilograms per m^3 of Scots pine sawnwood coming from a region where it has an average basic density of 400 kg/m^3 (volume measured prior to shrinkage), volumetric shrinkage will be about 7.5%, assuming that the sawnwood will be dried to 15% mcd:

(400 ÷ (1-0.075)) x (1 + 0.15) = 497.3 kg/m^3

3.3 Material balance

Many countries also submitted the material balance for the manufacture of sawnwood. The sawnwood component only accounts for roughly half of the roundwood volume that is input to the sawmilling process, thus it is also important to understand the residual products that later become the raw material for other wood products. These include chips and slabs, sawdust and shavings. Figures 3.2 and 3.3 shows the material balance for the countries that reported it in 2008.

3.4 Sawnwood (please update or enter new data in yellow column)

	unit in/ unit out	Austria	Canada	Czech Republic	Finland	France	Germany	Ireland	Lithuania	Netherlands	Norway	Slovakia	Spain	Sweden	United Kingdom	United States	Your country	Median	Average
Conifer	m^{3}rw/m^{3}p	1.64	2.22	1.67	2.00	1.61	1.67	1.89	2.00	1.67	2.00	1.72	1.69	2.04	2.00	2.04		1.89	1.86
Sawnwood green/rough	m^{3}rw/m^{3}p	–	–		–	1.65	1.66	1.89	–	1.67	1.75	1.54	1.69	–	–	1.62		1.67	1.68
Sawnwood green planed	m^{3}rw/m^{3}p	–	–		–	–	–	–	–	–	–	–	–	–	–	2.00		2.00	2.00
Sawnwood dry/rough	m^{3}rw/m^{3}p	–	–		2.00	1.88	–	1.99	–	–	2.00	1.72	1.90	2.04	2.00	1.69		1.99	1.91
Sawnwood dry planed	m^{3}rw/m^{3}p	–	–		–	2.35	1.97	2.13	–	–	2.50	–	–	–	–	2.08		2.13	2.21
Flitches and boules (rough/green)	m^{3}rw/m^{3}p	–	–		–	1.18	–	–	–	–	–	1.33	–	–	–	–		1.26	1.26
Flitches and boules (rough/dry)	m^{3}rw/m^{3}p	–	–		–	–	–	–	–	–	–	1.49	–	–	–	–		1.49	1.49
Material balance																			
Sawnwood	%	61%	45%	60%	50%	62%	60%	53%	50%	60%	50%	58%	59%	49%	50%	49%		53%	54%
Chips/slabs	%	–	38%	30%	34%	24%	25%	35%	–	–	34%	19%	22%	32%	–	27%		30%	29%
Sawdust	%	–	8%	10%	11%	14%	13%	11%	–	–	10%	11%	12%	12%	–	10%		11%	11%
Shavings	%	–	5%	–	–	–	1%	–	–	–	–	–	–	2%	–	10%		0%	2%
Shrinkage loss	%	–	4%	–	5%	–	1%	1%	–	–	6%	12%	7%	5%	–	4%		5%	5%
Average sawnwood shipping weight	kg/m^3	–	–	–	–	–	–	415	–	–	440	600	–	–	549	581		549	517
Non-conifer	m^{3}rw/m^{3}p	–	1.96	1.56	1.85	2.13	1.54	1.89	2.10	1.67	2.00	1.52	1.89	1.90	2.50	1.85		1.89	1.88
Sawnwood green/rough	m^{3}rw/m^{3}p	–	–	–	–	2.20	1.53	1.89	–	1.82	2.00	1.54	1.90	–	–	1.79		1.86	1.83
Sawnwood green planed	m^{3}rw/m^{3}p	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–			
Sawnwood dry/rough	m^{3}rw/m^{3}p	–	–	–	1.85	2.59	–	–	–	–	2.20	1.72	2.10	1.90	2.50	1.92		2.01	2.10
Sawnwood dry planed	m^{3}rw/m^{3}p	–	–	–	–	3.23	–	–	–	–	–	–	–	–	–	2.38		2.81	2.81
Flitches and boules (rough/green)	m^{3}rw/m^{3}p	–	–	–	–	–	–	–	–	–	1.40	1.33	–	–	–	–		1.37	1.37
Flitches and boules (rough/dry)	m^{3}rw/m^{3}p	–	–	–	–	–	–	–	–	–	1.70	1.49	–	–	–	–		1.60	1.60
Material balance																			
Sawnwood	%	–	51%	64%	54%	47%	65%	53%	48%	60%	50%	66%	53%	53%	40%	54%		53%	55%
Chips/slabs	%	–	33%	–	–	39%	12%	35%	–	–	34%	17%	27%	–	–	30%		32%	28%
Sawdust	%	–	12%	–	–	14%	13%	11%	–	–	8%	9%	14%	–	–	13%		13%	12%
Shavings	%	–	0%	–	–	–	8%	–	–	–	–	–	–	–	–	1%		0%	1%
Shrinkage loss	%	–	4%	–	–	–	2%	1%	–	–	8%	8%	6%	–	–	2%		3%	4%
Average sawnwood shipping weight	kg/m^3	–	–	–	–	–	–	–	–	–	550	790	–	–	699	–		699	680
Conifers and non-conifers		1.64	2.17	–	2.00	1.75	1.64	1.89	–	–	2.00	1.67	1.72	2.00	–	–		1.75	1.83
Sawnwood green/rough	m^{3}rw/m^{3}p	–	–	–	–	1.85	1.64	1.89	–	–	1.75	1.48	1.75	–	–	–		1.75	1.73
Sawnwood green planed	m^{3}rw/m^{3}p	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–			
Sawnwood dry/rough	m^{3}rw/m^{3}p	–	–	–	2.00	2.09	–	–	–	–	2.00	1.66	1.94	2.00	–	–		2.00	1.95
Sawnwood dry planed	m^{3}rw/m^{3}p	–	–	–	–	2.61	–	–	–	–	2.50	–	–	–	–	–		2.56	2.56
Material balance																			
Sawnwood	%	61%	46%	–	50%	57%	61%	53%	–	–	50%	60%	58%	50%	–	–		55%	54%
Chips/slabs	%	–	37%	–	34%	29%	23%	35%	–	–	34%	18%	24%	–	–	–		32%	29%
Sawdust	%	–	8%	–	11%	14%	13%	11%	–	–	10%	11%	12%	–	–	–		11%	11%
Shavings	%	–	5%	–	–	–	2%	–	–	–	–	–	–	–	–	–		0%	1%
Shrinkage loss	%	–	4%	–	5%	–	1%	1%	–	–	6%	11%	6%	–	–	–		5%	4%
Ratio of captured bark	odmt/ m^{3}rw	–	0.075	–	–	–	0.037	–	–	–	0.03	0.1	–	0.035	–	–		0.037	0.055

4. VENEER AND PLYWOOD

Veneer is produced either by means of a lathe (the log is chucked and rotated against a stationary knife), or sliced, whereby a log is halved or quartered into flitches (sometimes referred to as cants) with a saw; with the flitch then pressed against and moved across a knife. Rotary peeled veneer is often used for producing thicker veneers for structural applications, and sliced veneer is used for producing thinner veneers having decorative uses; however, there are exceptions to this generalization.

Plywood is a composite product manufactured from veneer. It is produced by laminating sheets of veneer together into a panel.

The determiners of veneer and plywood recovery ratios are similar to sawnwood, in that log size and characteristics, product specifications, and milling efficiency have a strong influence.

4.1 Volumetric and surface measurement

Veneer and plywood are normally measured via two systems: surface measure, which strictly measures the surface area and does not account for volume (because thickness is not accounted for); and volumetric. Volumetric measure has two distinct variations: straight cubic volume (e.g. thickness x width x length) and surface measure on a thickness basis.

In Europe, veneer and plywood can be measured in square metres 1 mm basis; and in North America, veneer and plywood are often measured in square feet 3/8 inch basis. In other words a sheet of plywood that measures 1.22 m x 2.44 m x 12 mm has 35.72 m^2, 1 mm basis, which is easily converted to m^3 by dividing by 1,000 (.03572 m^3). In North America, this sheet would be measured in imperial measure and would be 4 feet x 8 feet x 0.472 inches which has 40.37 ft^2 3/8 inch basis (4 x 8 x [0.472 ÷ 0.375] = 40.37).

Typically, shrinkage has a significant effect on veneer and plywood because of the low moisture content (<6%) that is often initially required.

4.2 Weight

Data on conversion factors for weight to volume was limited. Like sawnwood, a theoretical approach can be used to calculating the weight of veneer (see section 3.2). This approach will work for plywood as well; however, an allowance may be made for the weight of the glue line between the veneer plies. A glue weight of 122 gm per m^2 of glue-line surface area should be approximate (United States Department of Agriculture, Forest Service, 1956).

4.3 Material balance

The material balance for the production of plywood and veneer is interesting in that to varying degrees, other solid wood products are also made during the production of veneer, i.e., sawnwood in the production of sliced veneer and peeler cores[7] in the production of rotary peeled veneer. When producing flitches for slicing, sawnwood is often a co-product made from sections of the log that are not suitable for veneer, but are, however, suitable for sawnwood.

Peeler cores, which are a co-product from the manufacture of rotary peeled veneer, are often sold as round wood product e.g. posts for fencing, landscaping, etc.; or they may be chipped. In addition, some peeler cores are large enough to make into sawnwood.

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[7] When a log is rotary peeled, it is often held and pivoted by lathe-chucks. In this situation, the minimum diameter limit of the log at which veneer can no longer be peeled is usually controlled by the diameter of the chucks. Thus a lathe chuck which is 8 cm in diameter will result in a peeler core, which is slightly larger in diameter (e.g. 8.5 cm) in order to prevent the veneer knife from coming into contact with the lathe-chucks.

4.4 Plywood (please update or enter new data in yellow column)

	unit in/ unit out	Canada	Finland	France	Germany	Ireland	Netherlands	Norway	Slovakia	Spain	Sweden	United Kingdom	United States	Your country	Median	Average
Conifer	m^3rw/m^3p	1.92	2.31	2									1.84		1.96	2.02
Rotary peeled veneer, green/rough	m^3rw/m^3p	--	--	2.00	--	--	--	--	2.00	2.35	--	--	1.51		2.00	1.97
Rotary peeled veneer, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	2.25	--	1.90	--	1.6		1.90	1.92
Rotary peeled plywood, dry/rough	m^3rw/m^3p	--	2.27	--	--	--	--	--	--	1.85	2.50	--	1.87		2.07	2.12
Rotary peeled plywood, dry/sanded	m^3rw/m^3p	--	2.31	--	--	--	--	--	--	--	--	--	1.92		2.12	2.12
Sliced veneer, green/rough	m^3rw/m^3p	--	--	--	--	--	--	--	1.60	5.20	--	--	1.51		1.60	2.77
Sliced veneer, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	1.70	--	--	--	1.6		1.65	1.65
Sliced plywood, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	1.87		1.87	1.87
Sliced plywood, dry/sanded	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	1.92		1.92	1.92
Material balance																
Veneer	%	52%	43%	--	--	--	--	--	--	--	--	--	53%		52%	49%
Other products (chips, peeler cores, etc.)	%	37%	47%	--	--	--	--	--	--	--	--	--	42%		42%	42%
Sanding dust	%	6%	3%	--	--	--	--	--	--	--	--	--	2%		3%	4%
Shrinkage/losses	%	5%	7%	--	--	--	--	--	--	--	--	--	3%		5%	5%
Average panel shipping weight	kg/m^3	--	535	--	--	650	--	--	500	--	--	649	--		592	584
Average panel thickness	mm	--	--	--	--	18	--	--	15	--	--	--	--		16.5	16.5
Non-conifer	m^3rw/m^3p	1.89	2.68	2.5	--	--	--	--	--	--	--	--	2.09		2.30	2.29
Rotary peeled veneer, green/rough	m^3rw/m^3p	--	--	--	--	--	--	--	1.95	3.20	--	--	2.00		2.00	2.38
Rotary peeled veneer, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	2.15	--	--	--	2.00		2.15	2.55
Rotary peeled plywood, dry/rough	m^3rw/m^3p	--	2.63	--	--	--	--	--	2.25	--	--	--	2.05		2.25	2.31
Rotary peeled plywood, dry/sanded	m^3rw/m^3p	--	2.68	--	--	--	--	--	--	2.40	--	--	2.14		2.40	2.41
Sliced veneer, green/rough	m^3rw/m^3p	--	--	--	--	--	--	--	1.60	3.00	--	--	1.51		1.60	2.04
Sliced veneer, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	1.70	--	--	--	1.60		1.70	2.43
Sliced plywood, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	1.87		1.87	1.87
Sliced plywood, dry/sanded	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	1.92		1.92	1.92
Material balance																
Veneer	%	53%	37%	--	--	--	--	--	--	--	--	--	48%		48%	46%
Other products (chips, peeler cores, etc.)	%	35%	54%	--	--	--	--	--	--	--	--	--	47%		47%	45%
Sanding dust	%	7%	2%	--	--	--	--	--	--	--	--	--	2%		2%	4%
Shrinkage/losses	%	5%	9%	--	--	--	--	--	--	--	--	--	3%		5%	6%
Average panel shipping weight	kg/m^3	--	680	--	--	650	--	--	600	--	--	--	--		650	643
Average panel thickness	mm	--	--	--	--	18	--	--	25	--	--	--	--		21.5	21.5
Tropical	m^3rw/m^3p	--	--	1.80	--	--	--	--	--	--	--	--	--		1.80	1.80
Rotary peeled veneer, green/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Rotary peeled veneer, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Rotary peeled plywood, dry/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Rotary peeled plywood, dry/sanded	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Material balance																
Veneer	%	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Other products (chips, peeler cores, etc.)	%	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Sanding dust	%	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Shrinkage/losses	%	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Average panel shipping weight	kg/m^3	--	--	--	--	650	--	--	--	--	--	--	--		650	650
Average panel thickness	mm	--	--	--	--	18	--	--	--	--	--	--	--		18	18
Conifers, nonconifer, tropical	m^3rw/m^3p	--	--	2.08	--	--	1.55	--	1.96	--	--	--	1.89		1.93	1.87
Rotary peeled veneer, green/rough	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--			
Rotary peeled veneer, dry/rough	m^3rw/m^3p	--	--	1.80	1.80	--	--	--	--	--	--	--	--		1.80	1.80
Rotary peeled plywood, dry/rough	m^3rw/m^3p	--	--	2.30	2.30	--	--	--	--	--	--	--	--		2.30	2.30
Rotary peeled plywood, dry/sanded	m^3rw/m^3p	--	--	--	--	--	--	--	--	--	--	--	--			
Material balance																
Veneer	%	--	--	--	--	--	--	--	--	--	--	--	52%		52%	52%
Other products (chips, peeler cores, etc.)	%	--	--	--	--	--	--	--	--	--	--	--	43%		43%	43%
Sanding dust	%	--	--	--	--	--	--	--	--	--	--	--	2%		2%	2%
Shrinkage/losses	%	--	--	--	--	--	--	--	--	--	--	--	3%		3%	3%
Average panel shipping weight	kg/m^3	--	--	--	--	650	--	--	--	--	--	--	--		650	650
Average panel thickness	mm	--	--	--	--	18	--	--	--	--	--	--	--		18	18

5. PANELS MADE OF WOOD PARTICLES

Unlike panels made of veneer, panels made of wood particles (e.g. particle board, OSB, fibreboard) can have significantly different properties depending on the source wood from which they were produced. Wood particles can be pressed into panels that are denser or less dense than the parent wood, so cubic metre of product will seldom equal a cubic metre of solid wood equivalent (swe). In addition there are non-wood components introduced that add to the bulk and weight, such as binders and fillers. In some countries a significant percentage of bark volume can be part of the raw material for non-structural panels.

It is important to note that most producers of panels made of wood particles use oven dry weight of raw material, rather than the volume of solid wood input, to track the raw material to product conversion efficiency. Less volume of raw materials from dense species is needed to make a given quantity of panels made of wood particles vs. what would be required from low-density species. For example, when using Norway spruce with a basic density of 380 kg/m^3 as a raw material for MDF which will be pressed to a basic density of 760 kg/m^3, it will require 2 m^3 of solid wood equivalent raw material per m^3 of MDF panel. However, if Siberian larch with a basic density of 460 kg/m^3 is used, only 1.65 m^3 would be needed (discounting the small effects of binders and fillers).

5.1 Volumetric and surface measurement

As in plywood and veneer, panels made of wood particles are typically measured via cubic volume, surface measure, and surface measure on a thickness basis. In Europe, as with veneer and plywood, surface measure on a thickness basis is 1 mm. In North America panels made from wood particles and measured on a thickness basis have different thickness basis standards dependent on the product. These are as follows:

- OSB and waferboard 3/8 inch (0.375 inch)
- Particleboard and MDF 3/4 inch (0.75 inch)
- Hardboard 1/8 inch (0.125 inch)
- Insulation board 1/2 inch (0.5 inch)

5.2 Weight

The weight of panels made from wood particles will vary dependent on the density of the parent wood, the density at which the wood fibre is pressed into the panel, the moisture content, which is typically about 6-8%, and finally the weight of binders and fillers.

5.3 Panels made from wood particles (please update or enter new data in yellow column)

	unit in/ unit out	Canada	Czech Republic	Finland	France	Germany	Ireland	Lithuania	Netherlands	Norway	Slovakia	Spain	Sweden	United Kingdom	United States	Your country	Median	Average
Particle board (without OSB)	m³sw/m³p	1.48		1.59	1.60	1.30	1.93	1.57	1.30	1.50	1.20	1.40	1.50	1.62	1.60		1.50	1.51
Average thickness	mm	15.9	23	--	--	--	18	--	--	18	19	16	--	--	--		18.0	18.3
Product basic density	kg/m³	--	668	675	650	--	625		--	665	650	650	--	649	720		650	661
Material balance																		
Binders and fillers	%	--	--	9%	6%	--	8%	--	--	9%	9%	--	--	--	9%		9%	8%
Bark	%	--	--	5%	5%	--	5%	--	--	--	--	--	--	--	1%		3%	3%
Moisture	%	--	--	7%	7%	--	8%	--	--	7%	8%	--	--	--	7%		7%	7%
Wood	%	--	--	79%	82%	--	79%	--	--	83%	--	--	--	--	84%		83%	82%
Share of recycled fibre in panels	%	--	--	--	--	--	45%	--	--	--	--	--	--	--	--		--	--
OSB and waferboard	m³sw/m³p	1.61			2.00	1.30	1.93		1.30						1.65		1.63	1.63
Average thickness	mm	11.1	19	--	--	--	18	--	--	--	--	--	--	--	--		18.0	16.0
Product basic density	kg/m³	--	565	--	850	--	630	--	--	--	--	--	--	--	407		598	613
Material balance																		
Binders and fillers	%	--	--	--	--	--	4%	--	--	--	--	--	--	--	3%		4%	4%
Bark	%	--	--	--	0%	--	0%	--	--	--	--	--	--	--	1%		0%	0%
Moisture	%	--	--	--	--	--	6%	--	--	--	--	--	--	--	7%		7%	7%
Wood	%	--	--	--	--	--	90%	--	--	--	--	--	--	--	90%		90%	90%
Fibreboard, hard	m³sw/m³p	1.79	--	--	2.20	2.40	1.93		--	--	--	1.75	--	2.37	1.75		1.93	2.03
Average thickness	mm	3.2	--	3.0	--	--	3.0	--	--	--	--	3.0	--	--	--		3.00	3.10
Product basic density	kg/m³	--	--	950	1 000	900	940	--	--	--	--	830	--	950	880		940	921
Material balance																		
Binders and fillers	%	--	--	--	--	--	9%	--	--	--	--	--	--	--	--		9%	9%
Bark	%	--	--	--	7%	--	0%	--	--	--	--	--	--	--	--		0%	0%
Moisture	%	--	--	--	--	--	6%	--	--	--	--	--	--	--	--		6%	6%
Wood	%	--	--	--	--	--	85%	--	--	--	--	--	--	--	--		85%	85%
Fibreboard, medium (MDF)	m³sw/m³p	1.45	--	--	1.80	1.70	1.93	--	--	--	--	1.75	--	1.50	1.60		1.70	1.68
Average thickness	mm	15.9	24	--	--	--	15	--	--	--	--	16.5	--	--	--		16.2	17.9
Product basic density	kg/m³	--	765	--	780	650	740	--	--	--	--	730	--	600	704		730	713
Material balance																		
Binders and fillers	%	--	--	--	--	--	9%	--	--	--	--	--	--	--	--		9%	9%
Bark	%	--	--	--	7%	--	0%	--	--	--	--	--	--	--	--		0%	0%
Moisture	%	--	--	--	--	--	6%	--	--	--	--	--	--	--	--		6%	6%
Wood	%	--	--	--	--	--	85%	--	--	--	--	--	--	--	--		85%	85%
Insulation board	m³sw/m³p	--	--	--	0.60	1.10	--	--	--	--	1.10	--	--	0.63	0.71		0.71	0.83
Average thickness	mm	--	--	--	--	--	--	--	--	--	25	--	--	--	--		25	25
Product basic density	kg/m³	--	220	290	300	400	--	--	--	--	260	--	--	250	300		290	289
Material balance																		
Binders and fillers	%	--	--	--	--	--	--	--	--	--	2%	--	--	--	--		--	--
Bark	%	--	--	--	7%	--	--	--	--	--	--	--	--	--	--		--	--
Moisture	%	--	--	--	--	--	--	--	--	--	6%	--	--	--	--		--	--
Wood	%	--	--	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Fibreboard, all	m³sw/m³p	--	--	1.98	--	--	--	--	1.45	--	--	--	--	--	--		1.72	1.72

Source: UNECE/FAO Forest Products Conversion Factor Questionnaire, 2009.

6. WOOD PULP AND PAPER

Pulp is the raw material for paper and paperboard (cardboard). The manufacturing process involves separating the wood fibres by means of mechanical or chemical processes, or a combination of these.

Mechanical pulp is produced via a grinding action applied to wood, typically wood particles. As a result of the grinding process, the wood fibres tend to be short and thus lack strength compared to chemically produced pulp. However, the yield is high because little of the original components of the wood is lost. One oven dry metric ton of wood input will yield approximately 0.95 metric tons of oven dry pulp (i.e. 95% yield).

Chemical pulping involves using chemicals and heat to dissolve the lignin, leaving behind long wood fibres, which are strong, but at the price of lower yield, as much of the original wood is dissolved and suspended in the chemical treatment. There are several different chemical processes, with use dependent on species of wood and the desired characteristics of the paper. Bleached pulp results in white paper but at a lower yield in comparison to the non-bleached pulp. Chemical pulping generally results in yields in the 40-50% range (measured as oven dry input to oven dry output) (Briggs 1994).

Pulp is also produced using mechanical grinding in conjunction with chemical processes. There are a number of variations of this process and yield will generally be slightly less than that of strictly mechanical processes.

6.1 Weight

Pulp and paper measurement is usually handled via weight. Generally, an unspecified metric ton or an “air dried metric ton” is assumed to be 10% mcw. Note that pulp and paper moisture content is reflected on a “wet basis” (mcw), i.e. one air-dried metric ton of pulp is assumed to be 900 kg of oven dry fibre and 100 kg of contained water. Pulp and paper can also be measured on an oven dry basis. For the purposes of the conversion factor questionnaire, conversions to the metric ton were requested and respondents were informed that it was at an assumed 10% mcw.

6.2 Wood pulp and paper (please update or enter new data in yellow column)

	unit in/ unit out	Austria	Canada	Czech Republic	Finland	France	Germany	Netherlands	Norway	Slovakia	Spain	Sweden	UK	United States	Your country	Median	Average
Wood pulp		4.06	--	--	--	--	--	--	--	3.86	--	3.70	--	--		3.86	3.87
Mechanical	m³rw/mt	--	2.39	--	2.48	2.51	2.60	2.50	2.60	2.50	--	2.40	2.50	2.51		2.50	2.50
Basic density of wood input	kg/m³	--	--	--	--	420	--	--	390	--	--	--	--	466		420	425
Semi-chemical	m³rw/mt	--	--	--	2.49	2.98	2.70	2.50	--	3.00	--	2.30	2.75	--		2.70	2.67
Basic density of wood input	kg/m³	--	--	--	--	420	--	--	--	--	--	--	--	--		420	420
Chemical	m³rw/mt	--	5.22	--	--	--	--	4.90	--	--	--	--	--	3.35		4.90	4.49
Basic density of wood input	kg/m³	--	--	--	--	--	--	--	400	--	--	--	--	503		452	452
Sulfate bleached	m³rw/mt	--	--	--	4.15	4.26	--	--	5.10	4.50	2.98	4.80	4.50	--		4.50	4.55
Basic density of wood input	kg/m³	--	--	--		500	--	--	400	--	553	--	--	--		450	450
Sulfate unbleached	m³rw/mt	--	--	--	3.8	4.76	--	--	4.75	--	--	4.50		--		4.63	4.45
Basic density of wood input	kg/m³	--	--	--	--	420	--	--	400	--	--	--	--	--		410	410
Sulfite bleached	m³rw/mt	--	--	5.01	--	5.08	--	--	--	--	--	4.70	5.00	--		5.01	4.95
Basic density of wood input	kg/m³	--	--	445	--	410	--	--	--	--	--			--		428	428
Sulfite unbleached	m³rw/mt	--	--	--	--	4.88	--	--	--	--	--	4.40		--		4.64	4.64
Basic density of wood input	kg/m³	--	--	--	--	410	--	--	--	--	--			--		410	410
Dissolving grades	m³rw/mt	--	--	--	--	--	5.10	--	--	--	--	6.20		--		5.65	5.65
Basic density of wood input	kg/m³	--	--	--	--	--	--	--	--	--	--	--	--	--		--	--
Recovered paper (input to output)	mt/mt	--	--	--	1.30	1.25	1.25	--	--	1.3	1.15	--	--	--		1.28	1.28
Share of recycled fibre in total pulp	%	--	--	--	5.4	57	81	--	--	24	69	--	--	38		38	41
Paper and paperboard	m³rw/mt	--	--	--	--	--	--	--	--	3.60	--	--	--	--		3.60	3.60
Newsprint	m³rw/mt	--	2.50	--	3.20	--	3.20	2.80	2.70	--	--	--	2.80	--		2.80	2.87
Uncoated mechanical	m³rw/mt	--	--	--	3.50	--	3.50	3.50	2.60	--	--	--	3.50	--		3.50	3.32
Coated paper	m³rw/mt	--	--	--	4.40	--	4.40	3.50	2.50	--	--	--	--	--		3.95	3.70
Sanitary and household paper	m³rw/mt	--	--	--	4.90	--	4.90	3.25	--	--	--	--	--	--		4.90	4.35
Packaging materials	m³rw/mt	--	--	--	--	--	--	3.25	--	--	--	--	--	--		3.25	3.25
Case materials	m³rw/mt	--	--	--	4.20	--	4.20	3.25	--	--	--	--	--	--		4.20	3.88
Folding boxboards	m³rw/mt	--	--	--	4.00	--	4.00	3.25	--	--	--	--	--	--		4.00	3.75
Wrapping paper	m³rw/mt	--	--	--	4.10	--	4.10	3.25	--	--	--	--	--	--		4.10	3.82
Other paper mainly for packaging	m³rw/mt	--	--	--	4.00	--	4.00	3.25	--	--	--	--	--	--		4.00	3.75
Other paper and paperboard	m³rw/mt	--	--	--	3.70	--	3.70	3.25	--	--	--	--	2.50	--		3.48	3.29

Source: UNECE/FAO Forest Products Conversion Factor Questionnaire, 2009.

7. ROUND AND SPLIT WOOD PRODUCTS

For the purpose of this report, this category of forest products includes: barrel staves, utility poles, posts, pilings, house logs (manufactured round wood for constructing log buildings) and shakes and shingles. While shingles are a sawed product rather than a split product, they are generally manufactured along with shakes, which are split and thus are included in this grouping. Similar to this, barrel staves are both split and sawn, depending on the characteristics of the wood species used.

As these are relatively minor products in terms of volume, information on these products is limited. Where no country data were reported, as was the case for shakes and shingles, information from previously published sources is provided.

This category of products is not as technology driven as many of the other forest products, thus this aspect does not appear to be such a strong contributor of product recovery. Some of the significant controllers of product recovery by product are listed below.

The yield of barrel staves (used in the cooperage industry) is determined, to a great degree, by the process used to produce staves. Some species used for wine barrels (notably European oaks), need to be split in order to prevent the staves from being overly porous (caused by vessels that run parallel to the grain of the wood), while white oak of central and eastern North America does not have the same problems with porosity and thus can be sawn. The yield of sawn staves is significantly higher than for staves that are split. Staves generally have exacting standards in terms of quality, reducing yield according to the presence of knots or blemishes in the raw material used to produce them.

Utility poles, posts, pilings and house log yield is affected by the peeling process which is done to remove bumps and protrusions, as well as to round the profile. In addition, a portion of these products is peeled in order to remove taper, thereby creating a loss of roughly 10-40% dependent on the diameter and length of the product, with smaller diameter and longer products at the upper end of this range and larger, diameter, shorter products at the bottom of the range.

Shakes and shingles are generally used for roofing or siding. Shakes are split on one or both faces, while shingles are always sawn, thus losing a substantial volume to sawdust. Weatherization is an important factor, and quality standards tend to be exacting in terms of knots or other permeations which could allow water seepage, so a substantial percentage of the original log volume is often not usable and ends up as residue.

7.1 Volumetric and surface measurement

As staves, poles, posts, pilings and house logs tend to be manufactured to exacting specifications; it is fairly straightforward to convert from the piece, of a given standard, to volume.

This is not the case with shakes and shingles, which are typically measured on a basis of the surface measurement of coverage. In North America the unit is the “square”, which is the proper amount of shakes or shingles to cover 100 square feet (10.764 m^3). In Europe the unit is m^2 of coverage. Converting shakes and shingles from surface (coverage) measure to solid wood equivalent volume is not as straightforward, as there are many combinations, by product classification, of thickness, taper, widths, length and overlap. Additionally there is the irregularity of shake thickness as a result of the splitting process.

7.2 Weight

Like all other wood products, the weight to volume ratio will be driven by the basic density, moisture content and shrinkage of the wood. Using the methodology outlined in section 3.2 to calculate the theoretical weights of these products, it is important to consider that many of the round and split wood products will have treating done to them to prevent fungal decay or attacks by wood-boring insects and molluscs. Treated poles and pilings may have roughly 160 kg/m^3 of additional weight due to wood treatment added. If one were estimating the weight of the wood component as being 600 kg/m^3, a treated pole would be approximately 760 kg/m^3. Shakes and shingles are also often treated with decay and fire retardants, which adds to their weight.

7.3 Material balance

Barrel staves. In addition to chips, sawdust and shavings, sawnwood can be a residual product made during the manufacturing process of staves. Another interesting point is that some of the wood residue from producing staves still finds its way into the wine industry in the form of chips or sticks used to flavour wine in non oak barrels such as stainless steel.

Utility poles, posts, pilings and house logs. Because these products generally cannot have any decay, crooked portions or overly large knots, the removal of these defects from the logs used as raw materials will reduce the yield of these products and increase the yield of secondary products such as chips and energy wood.

Shakes and shingles. A cubic metre of western red cedar logs will yield approximately:

Log quality	Shingles	Shakes
Low grade logs	1.55 squares (14.4 m^2 of coverage)	NA
Medium grade logs	1.65 squares (15.3 m^2 of coverage)	NA
High grade logs	1.70 squares (15.8 m^2 of coverage)	1.9 squares (17.7 m^2 coverage)

Source: Herring and Massie, 1989

Hartman et al (1981) list the material balance for shingles as being roughly 40% shingles, 27% solid residue, and 33% sawdust. Briggs (1994) cites an unpublished study showing only 24% recovery of shingles and 53% for shakes (with the remaining balance of both (76% and 47% respectively) being classified as "residue". It is likely that the large difference in these material balances could be a result of the difference between the use of high grade logs vs. lower grade logs as a raw material, which will change periodically as a result of availability and competition for logs with other sectors, such as the sawmill sector.

7.4 Round and split wood products (please update or enter new data in yellow column)

	unit in/ unit out	Finland	France	Germany	Ireland	Norway	Slovakia	Spain	Your country	Median	Average
Barrel staves	m^{3}rw/m^{3}p	--	4.25	5.0	--	--	2.25	2.90		3.58	3.60
Utility poles	m^{3}rw/m^{3}p	1.30	1.12	1.20	1.10	1.15	1.67	--		1.18	1.26
Posts	m^{3}rw/m^{3}p	1.50	1.11	1.20	1.15	1.50	1.67	--		1.35	1.36
Pilings	m^{3}rw/m^{3}p	1.50	--	1.20	--	--	1.75	--		1.50	1.48
House logs	m^{3}rw/m^{3}p	1.70	--	--	--	1.65	--	--		1.68	1.68

Source: UNECE/FAO Forest Products Conversion Factor Questionnaire, 2009.

8. ENERGY WOOD PRODUCTS AND PROPERTIES

This category includes fuelwood, bark and chipped fuel, as well as manufactured products such as pellets and briquettes, charcoal, and wood-based ethanol. Sections 1 and 2 include information that is applicable to analysing conversion factors for wood, wood residue and bark for energy.

8.1 Volumetric measurement

These products can be measured in solid m^3 or in a loose m^3 (bulk m^3). In the case of fuelwood, a loose m^3 is often differentiated from "stacked m^3", with the difference being that loose m^3 would be randomly placed vs. the neatly fit together structure of stacked measure.

8.2 Weight

When moisture content is accounted for, the weight of energy products is likely the most reliable unit for understanding energy generating potential of a given quantity of wood. Moisture not only displaces the potential weight of combustible material, but also consumes some of the energy potential to vaporize the water when combusted.

8.3 Energy values

The energy content of wood can be reflected in many different measures and with assumptions made as to how much of the energy content can realistically be utilized, as no process of utilizing wood for energy is 100% efficient. For the purpose of the questionnaire, the joule was the basis, and the energy values were requested in "higher heating values," knowing that while these are unachievable, it is a consistent basis to which the user could apply their own assumptions regarding thermal efficiency.

8.4 Energy wood products and properties (please update or enter new data in yellow column)

	unit in/ unit out	Austria	Czech Republic	Finland	France	Germany	Ireland	Norway	Slovakia	Spain	Sweden	United Kingdom	United States	Your country	Median	Average
Fuelwood	m^3rw/odmt	2.4	--	2.45	1.90	2.30	1.82	2.50	1.72	1.60	2.22	--	--		2.22	2.10
Product basic density (solid volume, oven dry)	kg/m^3	417	--	460	526	432	550	450	780	625	450	--	--		460	521
Higher heating value	m^3 rw/gj	0.12	--	0.12	0.1	--	0.15	0.12	0.08	--	--	--	--		0.12	0.12
Pellets[8]	m^3rw/m^3p solid	--	--	2.86	2.86	--	2.20	--	2.23	--	--	--	--		2.55	2.54
Roundwood input to bulk m^3 pellets	m^3rw/m^3p bulk	1.44	--	1.51	1.79	1.44	--	--	--	--	--	--	1.44		1.44	1.52
Product basic density (solid volume, oven dry)	kg/m^3	--	--	1 080	1 200	1 120	920	--	1 070	1 010	--	--	--		1 075	1 067
Bulk density (loose volume, 5-10% mcw)	kg/m^3	652	--	650	750	650	--	--	670	--	--	--	689		661	677
Higher heating value (bulk volume)	m^3bulk/gj	.083	--	0.09	0.78	0.09	0.13	--	0.08	0.07	--	--	0.08		0.08	0.09
Pressed logs and briquettes	m^3rw/odmt	2.38	--	0.87	2.38	--	2.2	--	--	--	--	--	--		2.29	1.96
Product basic density (solid volume, oven dry)	kg/m^3	--	--	1 080	1 000	1 200	950	--	1 120	1 100	--	--	--		1 090	1 075
Bulk density (loose volume)	kg/m^3	761	--	--	--	--	--	--	--	--	--	--	--		761	761
Higher heating value	m^3bulk/gj	0.07	--	0.09	0.13	--	0.13	--	0.05	--	--	--	--		0.09	0.09
Bark and chipped fuel	m^3rw/odmt	2.38	--	2.5	--	--	--	--	1.83	--	2.85	--	--		2.44	2.39
Product basic density (solid volume, oven dry)	kg/m^3	393	350	400	--	--	--	--	--	--	350	--	--		372	373
Bulk density (loose volume at 50% mcw)	kg/m^3	236	--	--	--	--	--	--	--	--	--	--	--		236	236
Higher heating value	m^3 rw/gj	0.12	--	--	--	--	--	--	.08	--	--	--	--		0.10	0.10
Charcoal	m^3rw/odmt	--	--	6.1	7.0	5.0	--	--	5.7	--	--	6.0	--		6.00	5.96
Wood-based ethanol	m^3rw/kilolitre	--	--	--	--	8.62	--	--	--	--	--	--	6.80		7.71	7.71

[8] The ratios shown for wood pellets assumes only the wood fibre input into the manufacture of pellets and does not include any wood fibre that may have been burned by heat dryers for the removal of moisture from the wood fibre.

ANNEX

Annex table 1 List of equivalents

To convert from	To	Multiply by
Length		
millimetre	centimetre	0.1
millimetre	inch	0.0394
millimetre	foot	0.00328
millimetre	metre	0.001
centimetre	millimetre	10
centimetre	inch	0.394
centimetre	foot	0.0328
centimetre	metre	0.01
inch	millimetre	25.4
inch	centimetre	2.54
inch	foot	0.0833
inch	metre	0.0254
foot	millimetre	304.8
foot	centimetre	30.48
foot	inch	12
foot	metre	0.3048
metre	millimetre	1 000
metre	centimetre	100
metre	inch	39.37
metre	foot	3.281
Area		
square centimetre	square inch	0.155
square centimetre	square foot	0.001076
square centimetre	square metre	0.0001
square inch	square centimetre	6.452
square inch	square foot	0.0069444
square inch	square metre	0.0006452
square foot	square centimetre	929
square foot	square inch	144
square foot	square metre	0.0929
square metre	square centimetre	10 000
square metre	square inch	1 550
square metre	square foot	10.764
Density		
specific gravity	basic density	1 000
basic density	specific gravity	0.001
Stacked measure		
cubic foot	stere	0.02832
cubic foot	cord	0.0078125
cubic metre	stere	1
cubic metre	cord	0.2759
cord	cubic foot	128
cord	cubic metre	3.6245
cord	Stere	3.6245
stere	cubic foot	35.315
stere	cubic metre	1
stere	cord	0.2759

To convert from	To	Multiply by
Weight		
gram	pound	0.002205
gram	kilogram	0.001
pounds	gram	454
pounds	kilogram	0.454
pounds	ton	0.0005
pounds	metric ton	0.000454
kilogram	gram	1000
kilogram	pounds	2.205
kilogram	ton	0.0011023
kilogram	metric ton	0.001
ton	kilogram	907
ton	pound	2000
ton	metric ton	1.1023
metric ton	pounds	2205
metric ton	kilogram	1 000
metric ton	ton	0.907
Volume		
square foot (⅜ inch basis)	square metre (1 mm basis)	0.885
square foot (⅜ inch basis)	cubic foot	0.03125
square foot (⅜ inch basis)	cubic metre	0.000885
square foot (⅜ inch basis)	cunit	0.0003125
square metre (1 mm basis)	square foot (⅜ inch basis)	1.13008
square metre (1 mm basis)	cubic foot	0.35315
square metre (1 mm basis)	cubic metre	0.001
square metre (1 mm basis)	cunit	0.00035315
cubic foot	square foot ⅜"	32
cubic foot	square metre (1 mm basis)	28.32
cubic foot	cubic metre	0.02832
cubic foot	cunit	0.01
cubic metre	square foot (⅜ inch basis)	1130.08
cubic metre	square metre (1 mm basis)	1000
cubic metre	cubic foot	35.315
cubic metre	cunit	2.832
cunit	square foot (⅜ inch basis)	3 200
cunit	square metre (1 mm basis)	2 832
cunit	cubic foot	100
cunit	cubic metre	2.832
Heat		
British thermal unit	joule	1 055
joule	British thermal unit	0.0009479
Weight to volume ratios		
lbs per cubic foot	kg per cubic metre	16.019
kg per cubic metre	lbs per cubic foot	.06243