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REPORT

CARBON REMOVALS AND EMISSION ASSOCIATED WITH PRODUCTION AND USE OF HARVESTED WOOD PRODUCTS:

A CASE STUDY ON PLYWOOD BASED FLOORING PRODUCT

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EXECUTIVE SUMMARY

Harvested Wood Products (HWP) includes all wood material such as sawn timber, composite wood and paper. While timber leaving harvesting sites is considered carbon emission, the HWP is a carbon store or pool and the use is preferable over other materials to combat climate change. Carbon is stored in the timber product for as long as it is still in used. At the end of the product life or upon decommissioning, the carbon will be released when it is incinerated or disposed in landfill. However, if it is reused or recycled, the carbon will still be stored and undergo the next product lifetime.

The accounting of carbon stored in HWP is provided for in the IPCC guidelines. This accounting and reporting of carbon is carried out at national level based of timber production, importation, export and life-time of the products in used. It may be not be easy for individual manufacturer and consumer to comprehend the contributions to carbon source or sink as a result of their respective roles in the timber supply chain. An assessment of the environmental impact of renewable and non renewable raw materials use and the resultant product is needed to enable consumers and policy makers to make informed choices.

A study was conducted at timber product level to demonstrate the associated carbon removal and emission. The objectives of this study were, (i) to establish the carbon mass balance related to plywood based flooring use for residential building with long life time, and (ii) to conduct the cradle-to-grave Life Cycle Impact Assessment on plywood based flooring.

The study was conducted for the whole supply chain of timber flooring: plywood manufacturing plant in Indonesia, and the production into flooring and use in Japan. Log harvested are made into plywood in Indonesia, shipped to Japan where timber flooring are made and installed in residential buildings. It was assumed that the timber flooring will have a half-life of 38 years, the average half-life of timber houses in Japan. Normally at the end of life, the remnant timber is recycled to particleboard and start the next product life.

As the plywood based flooring manufactured includes other timber based panel from other sources, only the carbon mass of the timber originated from the Indonesia was tracked. Based on the carbon mass balance conducted the carbon stored and emission for one square meter of plywood based flooring were 1.76 kg and 0.18 kg respectively. The carbon emission was as a result of burning wood wastes for process heat during the plywood production.

As with all anthropogenic activities, production of wooden products require the use of energy that entails some environmental impacts. However, timber being a renewable material which is easy to process into useful products and requires less energy. From the cradle-to-grave LCA conducted, the Global Warming Potential (GWP) per square meter of plywood based flooring was 19 kg CO_2 equivalent. The total environmental impact cost was estimated at 77.5 Yen per square meter of timber flooring.

Acronym and abbreviation

ITTO – International Tropical Timber Organization

HWP – Harvested Wood Products

LCA – Life Cycle Assessment

GHG – Greenhouse gases

ISO – International Organization for Standardization

IPCC – Intergovermental Panel on Climate Change

AFOLU – Agriculture, Forestry and Other Land Uses

INDC – Intended Nationally Determined Contributions

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I. INTRODUCTION

A. BACKGROUND

Timber harvesting in the natural forest, even if it is conducted sustainably, is still considered carbon emission. However, the carbon is stored in the timber product for as long as it is still in used; timber product acts as a carbon pool. At the end of the product life or upon decommissioning, the carbon will be released when it is incinerated or disposed in landfill. However, if it is reused or recycled, the carbon will still be stored and undergo the next product lifetime.

Harvested Wood Products (HWP) includes all wood material that leaves harvesting sites; these comprise mainly sawn timber, composite wood and paper. The contribution of HWP as a carbon store or pool is well recognized and the use is preferable over other materials to combat climate change. As with all anthropogenic activities, Greenhouse gases (GHG) are emitted in the production of wooden products through the use energy.

Timber for the assessment of carbon is termed Harvested Wood Products (HWP); the accounting procedures of carbon stored in HWP is provided for in the Intergovernmental Panel on Climate Change (IPCC) guidelines. Normally the accounting and reporting of carbon in HWP is carried out at national level based of timber production, importation, export and life-time of the products in used. It may not be easy for individual manufacturers and consumers to comprehend the contributions to carbon source or sink as a result of their respective roles in the timber supply chain.

As consumers all over the world make decision about whether to purchase and use wood and other non wood products everyday. In recent years, there has been increasing public interest in the environmental impacts associated with the manufacture, consumption, disposal, and re-use products that originate from the forest. An assessment of the environmental impact of renewable and non renewable raw materials use and the resultant product is needed to enable consumers and policy makers to make informed choices (Bergman et al, 2011). Details of literature review are provided in Appendix 1.

B. OBJECTIVES AND SCOPE

The objectives of this study were, (i) to establish the carbon mass balance related to plywood based flooring use for residential building with long life time, and (ii) to conduct the cradle-to-grave Life Cycle Impact Assessment on plywood based flooring.

The study was conducted for the whole supply chain of tropical plywood based flooring: plywood manufacturing plant in Indonesia and the production into flooring was conducted in Japan. Log harvested are made into plywood in Indonesia, shipped to Japan where it is processed to flooring product and installed in houses.

C. GENERAL APPROACH

Carbon mass balance

The carbon mass balance of material flow related to the plywood based flooring was evaluated. The final timber flooring product manufactured includes other timber based panel from other sources and these are excluded from the assessment; only the carbon mass of the timber originated from the Indonesia was tracked and accounted.

Conversions from wood flow to carbon mass balance starting with the harvested logs through to the installed flooring products and final disposal were tracked. Waste wood during the processing stages is treated as carbon store/pool if it is used to manufacture into timber products and as “carbon emission” when burn for process heat or decompose in landfill. When converting the weight of timber to the amount of carbon, carbon content constitute half the weight of timber.

Life cycle assessment

The LCA methodologies used in this study are consistent with the principles and guidance provided by the International Organization for Standardization (ISO) in standards ISO 14040 and 14044.

Life cycle inventories were conducted at two processing sites; plywood manufacturing plant in Indonesia and a timber flooring processing plant in Japan. Transportation of shipping between the two countries were also taken into account.

Product descriptions

The plywood based flooring comprises three layers, namely first layer is veneer, the second layer is Medium Density Fiberboard (MDF), and the third layer is plywood. These materials are glued together to form the flooring board. The total thickness of plywood based flooring is 12.0 mm.

In this study, The first layer is thin veneer imported from The Unites States of America (USA), and the wood species were maple, walnut, and black cherry. The average veneer thickness was 0.3 mm and the average density was 0.70 g cm^{-3}.

Medium Density Fiberboard (MDF) is used as second layer made from mixed recycle wood species bonded by urea formaldehyde resin. The MDF average density was 0.81 g cm^{-3} and the average thickness was 0.5 mm.

The plywood used as third layer is bonded by Melamine urea formaldehyde (MUF) resin, the construction is 5–ply using sengon (*Paraserianthes falcataria L. Nielsen*) veneer as face, back, cores and centre core layers. The plywood dimensions are 4 feet in width, 8 feet in length and 11.2 mm in thickness. The average of sengon density was 0.35 g cm^{-3}. The plywood was imported from Indonesia.

D. EVALUATION OF THE CARBON MASS BALANCE

It is common in tropical countries that timber processing are integrated to fully utilize the timber material. In the plant where this was conducted, plywood processing facility is integrated with a particleboard mill. All the wood wastes from the plywood processing are channeled to the chipper in the particleboard mill situated next to the plywood plant. Only the dust from the plywood sanding section are used to fuel the boiler for process heat. The mass balance was calculated based on a one meter square of the flooring produced and installed in Japan. The plywood flooring comprises of a base plywood panel, a 0.5 mm medium density fiberboard and 0.3 mm veneer. In this study, only the plywood base was assessed right to the raw logs.

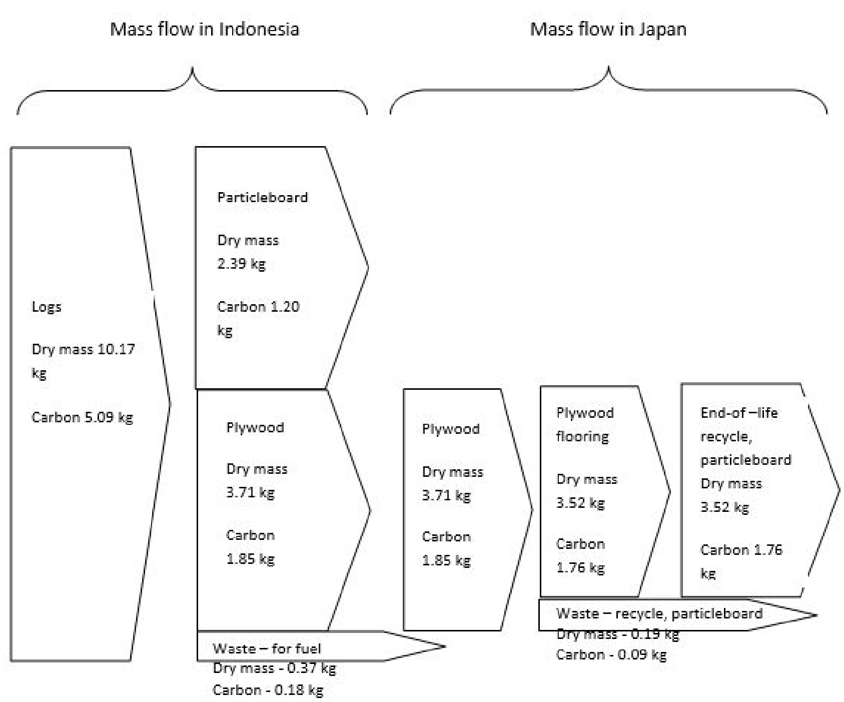

Figure 1. Mass and carbon balance of plywood used for making flooring.

For a square meter of plywood based flooring, the carbon content of wood in the plywood was 1.76 kg. When installed in residential houses in Japan, this carbon remains in the product over the life span of the house. The typical half life span of wooden residential houses in Japan is 38 years. This mean that under normal circumstances, the half the amount of carbon locked in the product will only be emitted after 38 years. However, if at the end-of-life the wood material was recycled to produce other products such as particleboard, then the carbon will be stored over the next product life. This is typically common in the Japanese wooden product uses.

The amount of carbon started from logs to produce the one square meter of plywood based flooring was 5.09 kg. During the plywood manufacturing 0.18 kg of carbon was emitted for process heat generation. The carbon content of co-products plywood and particleboards were 1.85 and 1.20 kg respectively. The reduction of carbon content during the manufacturing of flooring in Japan is normally not emitted but used for production of particleboard.

The carbon content in one square meter of plywood based flooring boards were determined from the factory inventory data and direct measurement (Figure 2). The total carbon content was 2.27 kg: plywood (1.76 kg), MDF (0.34 kg) and veneer (0.17 kg).

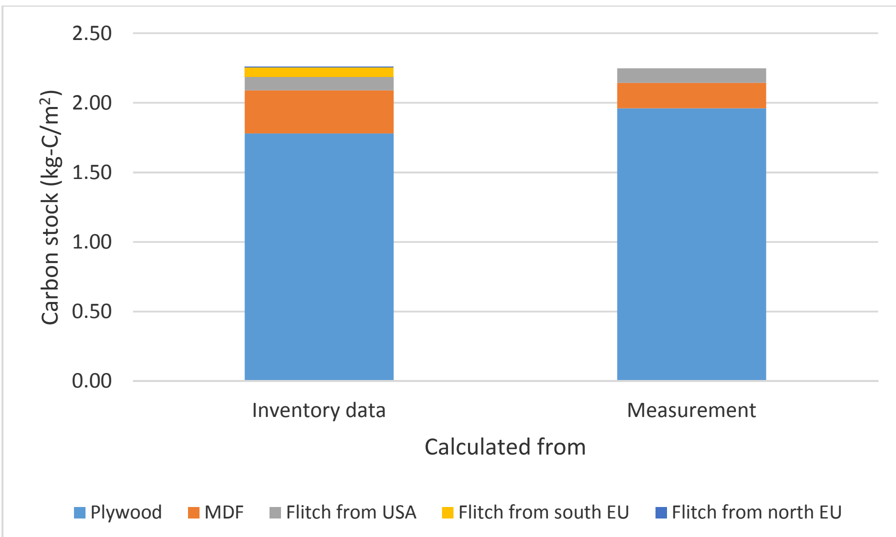

Figure 2. Carbon stored in one square meter of plywood based flooring calculated from inventory data and direct measurement.

E. LIFE CYCLE IMPACT ASSESSMENT

Life cycle inventories were conducted from cradle-to-grave of the plywood flooring product. For the plywood base, the logs were harvested in Jawa Island, processed to plywood in Jawa, shipped to Japan, reprocessed to plywood based flooring and installed in Japanese residential buildings, and at the end-of-life, the timber components are recycled for making particleboard. Appendix 1 details the cradle-to-gate production of plywood in Indonesia. The cradle-to-grave process flow for the timber flooring product is shown in Figure 3. The data collected were prepared and analyzed based on IDEA database (ver.1.1.0) in MiLCA (Ver.1.1.6.0).

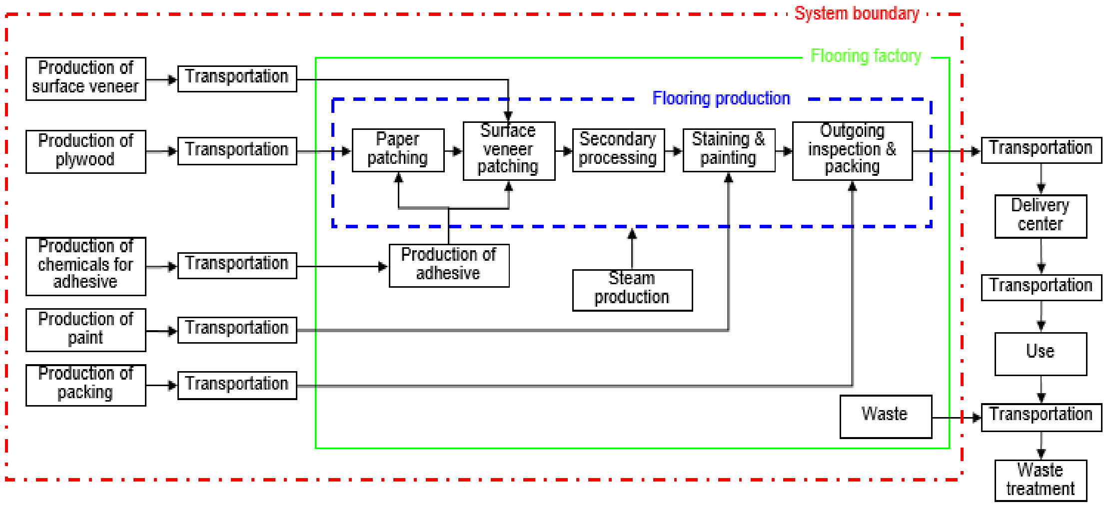

Figure 3. System boundary of the plywood based flooring installed in Japanese residential buildings.

The total GHG emission (or Global warming potential) for one square meter of plywood based flooring was 18.7 kg CO_2 equivalent (Figure 4). A big portion of the GHG emission was from the use of electricity and fossil fuels in the manufacturing processes and transportation. The other major contributions were log (raw material) extractions and resin used. The other environmental impact categories assessed were Resource depletion, Global warming potential, acidification potential, urban air pollution potential, Ecotoxicity Potential, Photochemical oxidant Potential, toxic chemicals and eutrophication potential. Generally, these environmental impacts were relatively low for renewable materials such as timber. These environmental values for the various impact categories were converted to Potential Damaged Cost provided by MiLCA. For one square meter of plywood based flooring, the value was 77.5 Yen (Figure 5 & 6). The main environmental Impact that make up the Potential Damage Cost was Global warming potential (Figure 5). This was actually contributed by the use of electrical energy at the various stages manufacturing (Figure 6).

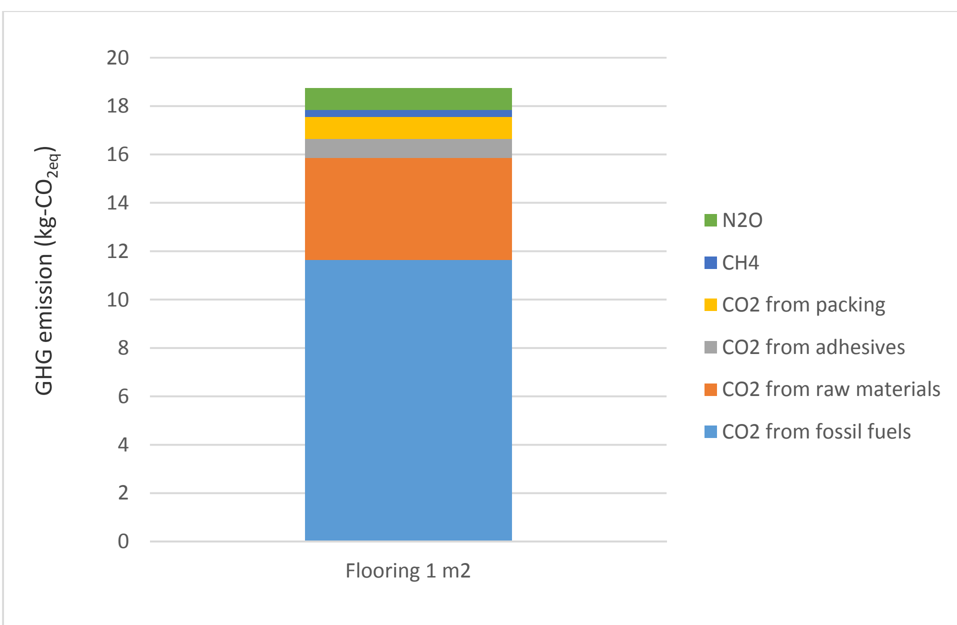

Figure 4. Greenhouse gases (GHG) emission or Global Warming Potential (GWP) for one square meter of plywood based flooring by input categary

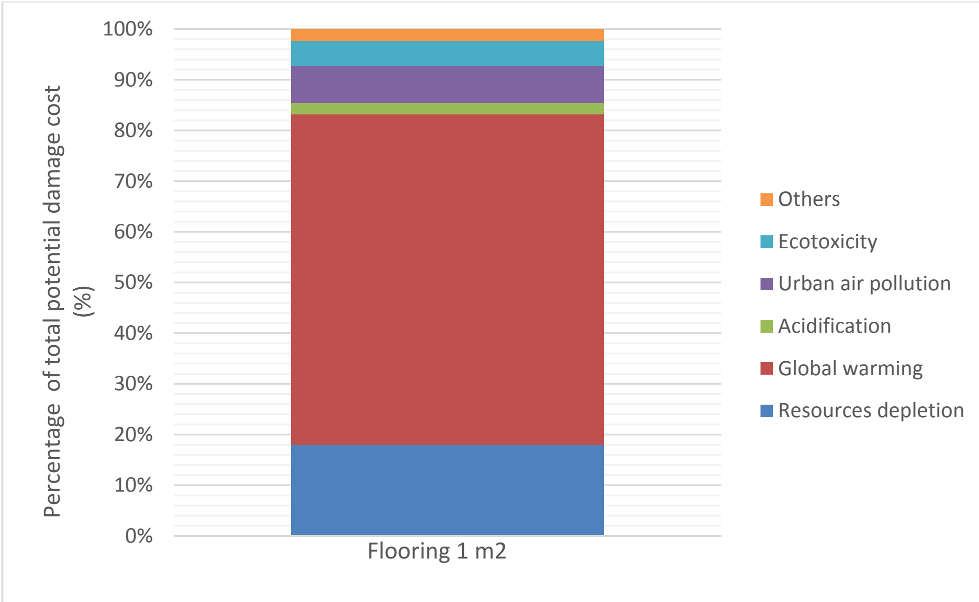

Figure 5. Proportion of contribution to total potential damage cost by environmental impact category for one m^2 of flooring. (Others: Photochemical oxidant Potential, Toxic chemicals and Eutrophication potential)

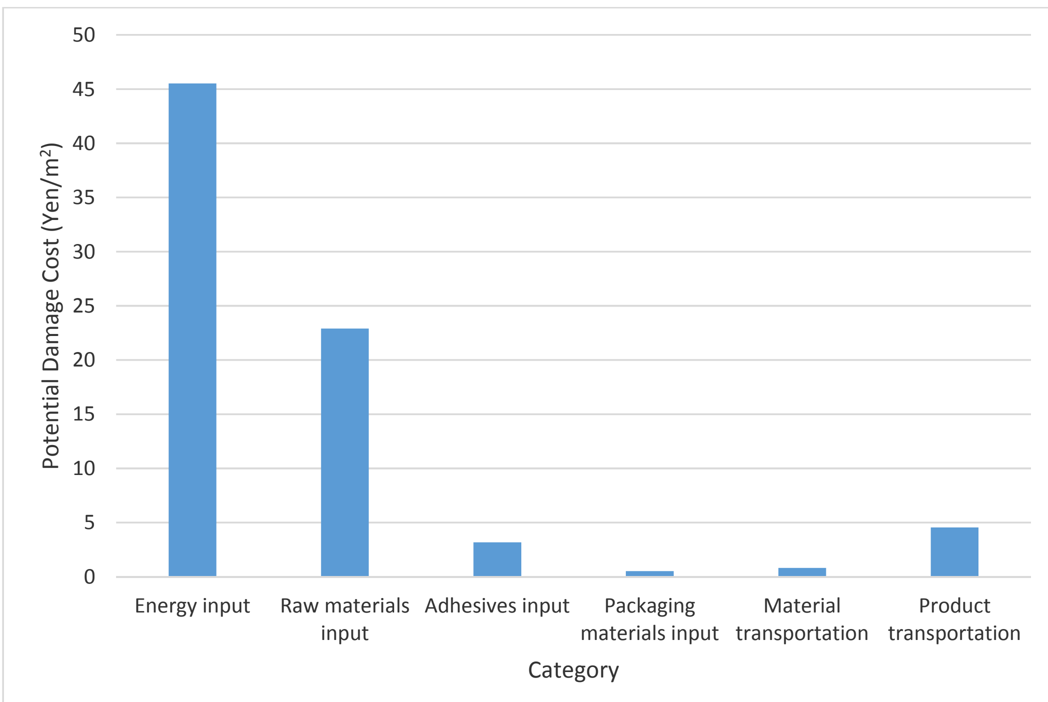

Figure 6. Potential damage cost of using one meter square of plywood based flooring by input category.

Several studies were conducted in Japan to investigate the life time distribution of Japanese houses since 30 years ago. The estimation based on the ledgers of buildings for fixed property taxes. The study reports on the life time of various kind of Japanese houses estimated by using a method similar to making life table of human being. Defining the representative value of life time as when the half of a cohort should be demolished, wooden residential houses have 38-year life (Figure 7), and wooden apartement houses have 32-year life. Another four type of houses, those of reinforced concrete and those of steel frame, were also investigated. And their life time do not differ much from those of the wooden ones. Two types of office buildings were also investigated for reference, and they had similar or a little shorter life time than the houses *(Komatsu et al., 1992)*. Further study was conducted to estimate statistically the life time of Japanese wooden houses used exclusively for residence. Data sources were the ledgers prepared for the fixed property taxes, from which the number of remaining houses and demolished one were took out in order of newly built year. Total of remaining house are over 7 million. Using terms of realibility theory, the probability density function of failure is supposed to follow a logarithmic normal distribution from graphic analysis, and by the realibility function presumed, the life expectancy of Japanese wooden houses are estimated at some 48 years (Kato and Komatsu, 1992).

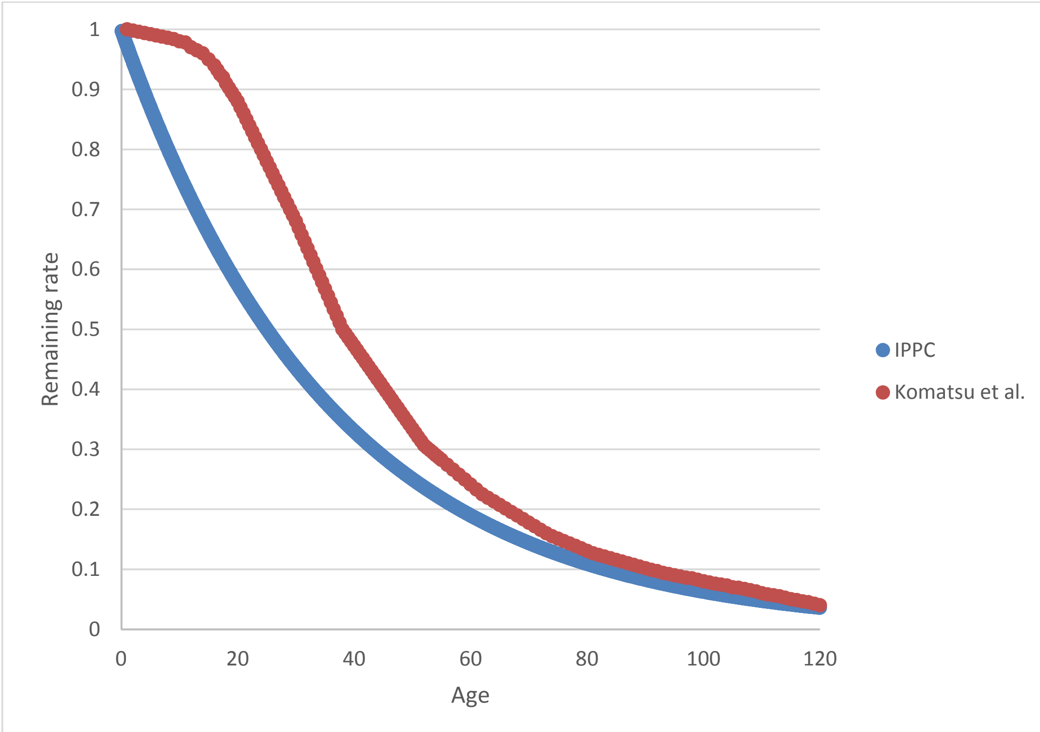

Figure 7. Life span of wooden products.

F. CONCLUSIONS

The carbon balance conducted on the plywood used for making the flooring and installed in Japanese house demonstrated that only 0.18 kg of carbon was emitted for every square meter of timber flooring which stored 3.52 kg of carbon over it life span. The half life span of the products was estimated at 38 years. At the end-of-life, the timber is actually recycled for making particleboard and start a new life span. In this respect, the carbon will still be stored and not emitted to the natural environment.

Life cycle assessment from cradle-to-grave was conducted on the plywood based flooring. The total global warming potential for one square meter of flooring was 18.7 kg CO_2 equivalent. The other environmental impacts were relatively low for timber based products. Based on MiLCA, the total environmental impact cost was 77.5 Yen per square meter of flooring.

G. RECOMMENDATION

Tropical timber are generally strong and durable, and if manufactured into high quality products for use in building, they can have long life span and store carbon for a longer period. Quantification of carbon removals and emissions from the production and use of major high quality tropical timber products, including the estimation of their life spans and retirement rates, will increase their competitiveness in markets. It may also enhance the efforts of producer countries in contributing to the mitigation of climate change, including through the development and improvement of INDCs, and increase opportunities for cooperation with the consumer countries in the framework of HWP.

Appendix 1

REVIEW DOCUMENT

Greenhouse gas emissions can be reduced through several pathways that directly impact the forest carbon stocks, such as improved planning of timber harvest (e.g. decreasing the incidental damage caused during tree felling, tree skidding and construction of roads and landing decks), reducing avoidable wood waste (e.g. tops of large trees that contain up to 50% or more of the tree carbon), converting low production forests to protected forest, and extending timber rotations. The urgent need for strategies to reduce global atmospheric concentrations of greenhouse gases has prompted action from national and international governments and industries, and a number of high-profile collaborative programs have been established including the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Commission on Climate Change, and the Global Climate Change Initiative. The capture and sequestration of carbon dioxide—the predominant greenhouse gas—is a central strategy in these initiatives, as it offers the opportunity to meet increasing demands for fossil fuel energy in the short- to medium-term, whilst reducing the associated greenhouse gas emissions in line with global targets (Alessandro et al 2010).

A growing concern about the environmental effects of the production and use of goods, as well as about how goods are disposed of at the end of their service life, has led to increasing interest in wood-based products made in a sustainable environmental manner. Long-term sustainable development is a key concern in many countries, giving rise to regulations regarding the impact of products during their life cycle, including the commitment to create effective reverse logistics strategies to manage post-use materials (Sathre et al., 2014; ITTO, 2012). Clear indication of the importance of the terrestrial biosphere as a part of the global carbon budget has been acknowledged, and inclusion of carbon sinks in greenhouse gas inventories was decided in Rio de Janeiro in 1992 by the UNFCCC (United Nations Framework Convention on Climate Change). The Kyoto Protocol of the UNFCCC was a first step towards limiting emissions of CO_2 and other GHGs. It was also agreed in Kyoto that sinks can be used to compensate emission reductions. The Conference of Parties (COP7), referred to as the Marrakesh Accords, invited IPCC to develop guidelines for GHG inventories in the LULUCF (Land use, and Land-use Change and Forestry) sector (Lehtonen, 2005).

Carbon footprint is a more recent term for global warming potential and refers to the total greenhouse gas emissions associated with a product or service. Emissions of different individual greenhouses gases are converted into global warming potential and expressed in the common unit of CO_2 –equivalents (Adu and Eshun, 2014).

Carbon emissions from land-use change are estimated to account for one-fifth of current global carbon emissions, and maintaining existing forests has been promoted as one of the least expensive climate change mitigation options. As a result, “Reduced Emissions from Deforestation and forest Degradation” (REDD) in developing countries has emerged as a likely component of the global climate protection regime, to be negotiated to replace the Kyoto Protocol, which comes to an end in 2012 (Kanninen *et al* 2007).

Adaptation and mitigation are the two major responses to tackle the effects of climate change. Designing mitigation policies and introducing low carbon technology are important ways to promote low carbon development. Low carbon development refers to the process of achieving a low carbon economy by way of developing sustainably and addressing climate change. Low carbon development and technological advancement can be achieved by implementing policies such as eliminating outdated production facilities and developing new technology and new energy. The implementation of such policies will bring about changes to the industrial structure and energy mix, thus impacting different sectors and the employment structures within them (IUE and CASS, 2010). One way to mitigate increase in atmospheric CO_2 concentration and climate change is carbon sequestration to forest vegetation through photosynthesis. Comparable regional scale estimates for the carbon balance of forests are therefore needed for scientific and political purposes (Muukkonen 2006).

For more than a century, we have been aware that changes in the composition of the atmosphere could affect its ability to trap the sun’s energy for our benefit. When it is assumed that the CO_2 content of the atmosphere is doubled and statistical thermal equilibrium is achieved, the more realistic of the modeling efforts predict a global surface warming of between 2^{o} C and 3.5^{o} C, with greater increases at high latitudes (Climate Research Board, 1979). More observations and theoritical work are needed to permit firm identification of the CO_2 warming and reliable prediction of larger climate effects farther in the future (Hansen et al., 1981).

Carbon dioxide (CO_2) is absorbed from the atmosphere during photosynthesis by the growing tree. This carbon is converted to wood, bark and other parts of the tree, which are about ½ carbon by weight. If the tree rots or burns, the solid carbon in the wood is released again to the atmosphere as carbon dioxide gas. However, as long a wood product is in service, it is keeping potential carbon dioxide gas out of the atmosphere. This ‘carbon storage’ of wood products reduces the carbon footprint of wood products (Bergman et al., 2011). Wood has a negative footprint because of the carbon dioxide fixed by the original living tree. The emissions associated with harvesting, transporting and processing of wood products are small compared to the total amount of carbon stored in the wood. This means that even when energy use for harvesting, transport and processing are taken into account, wood still has a negative footprint. Comparing the carbon footprints for wood and non-wood products shows that using wood products saves greenhouse gas emissions (ECCM, 2007).

According to US Department of Agriculture (1992), forest ecosystems are capable of storing large quantities of carbon in solid wood and other organic matter. Forests may add to the pool of carbon dioxide in the atmosphere through burning of forest lands, deforestation, or decomposition of wood products and byproducts. Forests may also reduce the amount of carbon dioxide in the atmosphere through increases in biomass and organic matter accumulation. Young, growing forests take up carbon at high rates, while carbon uptake in mature forests is balanced by carbon release from decaying vegetation.

The end use of timber harvested from forests is an important factor in evaluating the contributions of forestry to the global carbon cycle. If the end uses of forest products are in long-term durable goods such as furniture or timber bridges, the carbon is stored in those materials. If the end use is for paper products that are rapidly used and discarded to decay, then the carbon is released to the atmosphere. Carbon in waste from the manufacturing process and discarded wood products may be sequestered in landfills for long periods of time. When forest biomass is burned for energy it may be substituted for fossil fuels, which is an effective way to reduce the depletion of nonrenewable fossil carbon.

In forest and wildland ecosystems, forest floor and soil carbon (C) comprise a large C pool that is often of similar magnitude to or greater than aboveground C storage. These C pools often change slowly over time, but they are susceptible to rapid release to the atmosphere following natural or human-caused disturbances. Accurate estimates of these pools are needed both to quantify current ecosystem C storage and to understand the potential for future soil C sequestration or release due to disturbance, reforestation, or global change factors (Burton and Pregitzer, 2008).

Carbon footprint is a term used to describe the amount of greenhouse gas (GHG) emissions caused by a particular activity or entity, and thus a way for companies to assess their contribution to climate change. This includes activities of individuals, populations, governments, companies, organizations, processes, industry sectors, etc. In any case, all direct (on-site, internal) and indirect emissions (off-site, external, embodied, upstream, and downstream) need to be taken into account. More specific aspects such as which GHGs are included. and how double-counting is addressed can vary (Wiedmann and Minx, 2008). When applied to a nation, the Carbon Footprint relates to consumption of goods and services by households, governments, and other ‘final demand’ such as capital investment. It also relates to the GHG emissions embodied in trade: the Carbon Footprint of a nation is the sum of all emissions related to the nation’s consumption, including imports and excluding exports. As such, the consumption-based perspective of the Carbon Footprint complements the production-based approach taken by national greenhouse gas inventories, such as those considered by the Kyoto Protocol.

Consumption-based carbon footprinting could encourage and facilitate international cooperation between developing and developed countries; it could be used to make consumers aware of the GHG emissions from their life-style and raise awareness of indirect emissions in governments and businesses. Despite its name, the Carbon Footprint is not expressed in terms of area. The total amount of greenhouse gases is simply measured in mass units (kg, t, etc.) and no conversion to an area unit (ha, m^2, km^2, etc.) takes place. Any conversion into a land area would have to be based on a variety of assumptions that would increase the uncertainties and errors associated with a particular Carbon Footprint estimate.

When only CO_2 is included, the unit is kg CO_2; if other GHGs are included the unit is kg CO_2-e, expressing the mass of CO_2- equivalents. Those are calculated by multiplying the actual mass of a gas with the global warming potential factor for this particular gas, making the global warming effects of different GHGs comparable and additive. In the OPEN:EU project, the six greenhouse gases identified by the Kyoto Protocol are included in the analysis: CO_2, CH_4, N_2O, HFC, PFC, and SF_6. Understanding these emissions, and where they come from, is necessary in order to reduce them. In the past, companies wanting to measure their carbon footprints have focused on their own emissions, but now they are increasingly concerned with emissions across their entire supply chain. However, it should be kept clearly in mind that the carbon footprint is only one indicator of the environmental performance of a product. All the other environmental aspects can only be covered with full life cycle assessment. (Galli et al., 2012; Pihkola et al., 2010; Adu and Eshun, 2014).

The carbon footprint is a sub-set of the data covered by a more complete Life Cycle Assessment (LCA). LCA is an internationally standardized method (ISO 14040, ISO 14044) for the evaluation of the environmental impacts and resources consumed along the life cycle of products; from the extraction of raw materials, the manufacture of goods, their use by final consumers or for the provision of a service, to recycling, energy recovery, and disposal of remaining waste (EPLCA, 2009).

LCA analyzes the environmental aspects and potential impacts across the product life cycle from cradle to grave, including raw material acquisition, production, use, end-of-life treatment, recycling, and final disposal. LCA assesses the environmental impacts of product systems in accordance with the stated goal and scope. Life cycle assessment is a technique that has been developed to gain a better understanding of the potential environmental impacts of products. LCA can help in — identifying opportunities to improve the environmental performance of products at different life cycle stages — informing decision-makers in industry, government or non-government organizations (for example, for the purpose of strategic planning or product design) — selecting relevant indicators of environmental performance — marketing products (for example, making an environmental claim or applying for an eco label) (ISO 14040, 2006; Weidema et al., 2008).

The ISO standards for life cycle assessment do not actually describe a single method but allow organisations some flexibility. Application of life cycle assessment methodology in general and especially to food and farming systems is still the subject of on-going research and debate to achieve more harmonised and accurate practice across all practitioners even if the data quality requirements need to be adapted to the goal and scope of each study (Lundie et al., 2009). The LCA methodology allows not only the quantification of current environmental profiles but also the identification of improvement potentials in order to reduce future environmental impacts. LCA studies typically identify the most important contributors to the environmental impacts, which allows focused effort on reducing those impacts. Developing a life cycle assessment (LCA) by comparing human or ecosystem risks imposed across alternative cases such as using more fossil fuels in products, thereby producing more emissions, provides a blueprint for life cycle carbon accounting across all carbon pools, as well as insight into alternatives that can improve environmental performance (Lippke et al., 2011).

End-of-life management of wood-based products is found to be an important factor in energy and GHG balances. Recovery of the post-use material for use as bioenergy is beneficial, while disposal in landfills typically causes greater impacts. Forest activities to produce roundwood (the main raw material in woodbased products) may also be an environmental hot spot due to their contribution to impact categories such as acidifi cation, eutrophication, and formation of photochemical oxidants. The application of agrochemicals and use of forest machinery powered by fossil fuels are the main contributors in this area. Another hotspot involves activities related to processing of wood into wood-based panels (e.g., production of fi breboard) due to the use of petroleum-based resins such as urea- and phenol-formaldehyde (Sathre, 2014). Steps that needed to produce credible and transparent estimates of net changes in carbon stocks are a monitoring plan, including delineation of boundaries, stratification of project area, type and number of sample plots, duration of project, and frequency of monitoring, sampling procedures for carbon stocks, methods for estimating carbon stocks and techniques for analyzing the results, methods for estimating net change in carbon stocks, and a quality assurance/quality control plan (Pearson et al., 2007).

There are many ways and efforts underway to reduce carbon emissions and promote activities which help to store and remove carbon. Those who reduce emissions or sequester carbon, receive payments and those who have to decreaseemissions can buy carbon credits to offset their emissions. Carbon offsetting means to compensate emissions which cannot be avoided by paying someone else to save – sequester – GHGs (FAO, 2012). The prices which are received for one ton of CO^2 vary a lot and depend on the type of market and the type of carbon offset project. The use of carbon footprinting in both policy and labeling has assumed that the techniques of of carbon footprinting are capable of producing precise point estimates or at least estimates with small enough uncertainties to allow comparative assessment. However, it remains to be proven whether this level of precision is possible given large but poorly understood limitations in both methodology and data (Weber, 2010).

Adu and Eshun (2014) conducted a study that indicate that the environmental impact associated with khaya lumber production in Ghana is mainly caused by the use of fossil fuels. A change from using fuels in electricity generation, forest operations and timber transport, to renewable energy sources is an option that holds interesting prospects. Furthermore, to improve the environmental performance of khaya lumber production in Ghana, companies could reduce diesel use by trucks and resorting to improve transportation systems such as rail system and also improve material flow in the manufacturing process to reduce internal transportation. High frequency drying using solar energy is also an excellent environmental improvement for kiln drying of khaya lumber. Wood waste forms a critical issue and requires urgent attention.

Ni (2001) estimated the carbon storage of terrestrial ecosystems in China by using a common carbon density method for vegetation and soils relating to the vegetation types. Using median density estimates, carbon storage of 35.23 Gt (1 Gt = 1015 g) in biomass and 119.76 Gt in soils with total of 154.99 Gt were calculated based on the baseline distribution of 37 vegetation types. Total carbon storage of the median estimates at different spatial resolutions was 153.43, 158.08 and 158.54 Gt, respectively, for the fine (100), median (200) and coarse (300) latitude × longitude grids. There were differences of –1.56, +3.09 and +3.55 Gt carbon storage between baseline vegetation and those at different spatial resolutions. Change in mapping resolution would change area estimates and hence carbon storage estimates. The finer the spatial resolution in mapping vegetation, the closer the carbon storage to the baseline estimation. Carbon storage in vegetation and soils for baseline vegetation is quite similar to that of biomes predicted by BIOME3 for the present climate and CO_2 concentration of 340 ppmv. Climate change alone as well as climate change with elevated CO_2 concentration will produce an increase in carbon stored by vegetation and soils, especially a larger increase in the soils.

According to a study done by Lippke et al (2011), the estimation of the change in carbon storage and emissions with a change in a system is termed a 'consequential' LCA (CLCA) including indirect effects that may be associated with changes in output. CLCAs provide information about the consequences of changes in the level of production of a product and will include effects both inside (direct) and outside (indirect) the life cycle boundary of the product. Market forces generate the indirect effects; for example, the change in consumption of softwood lumber for construction would influence demand and production of non-wood substitutes for construction. Consequential LCAs may include, within their system boundary, a number of industrial sectors, including producers and users of wood plus producers and users of direct wood substitutes (e.g., fossil fuels and steel), or they may include all sectors that may have changes deriving from changes in production within the wood sector. They may focus on indirect impacts such as converting more land to sustainable forest management as prices rise thus, altering the land available for other uses whether for habitat, food production or altering cross country trade. CLCAs may be used to determine the effect of a decision or policy that would change production; for example, a softwood lumber CLCA that estimates the change in GHG flux with the atmosphere due to a decrease in production would include the change in GHG flux in forests if they were not harvested due to the lower level of production, and would include the change in GHG emissions from the higher production of non-wood products that replace wood products. In addition, a CLCA may include impacts in secondary products, which may have a change in production caused by the change in the production of wood products. Estimation of indirect impacts, can be simulated using economic models that show how demand and consumption of non-wood products change as production of softwood lumber changes or by sensitivity analysis that assume alternative levels of non-wood product change.

A review of current carbon policies indicates that many consider only the impacts on a limited set of carbon pools and frequently produce unintended consequences on other impacted carbon pools. Uncertainty is introduced into the estimation process by assuming that the results of specific ecosystem studies are representative of regional or national averages without being part of a statistical sample that represents a large geographical area (Lippke et al 2011; US Department of Agriculture 1992). It is very important that the accuracy of carbon density estimate should be discussed.

Accounting for carbon footprints is a question of quantifying and presenting emissions data for the whole life cycle of products in a consistent manner. In this sense, the existing ISO standards for LCA, product declarations, and greenhouse gas accounting (ISO 14040/44, ISO 14025, and ISO 14064) should be indispensable, and the carbon footprint calculation procedure needs separate guidelines to cover carbonspecific features. Internationally accepted consistent methods for calculating carbon footprints are under development. (Ni, 2001; Pihkola et al., 2010; Weidema et al., 2008).

Carbon footprint is a term used to describe the amount of greenhouse gas (GHG) emissions caused by a particular activity or entity, and thus a way for companies to assess their contribution to climate change. It includes the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Understanding these emissions, and where they come from, is necessary in order to reduce them. In the past, companies wanting to measure their carbon footprints have focused on their own emissions, but now they are increasingly concerned with emissions across their entire supply chain. The carbon footprint is an environmental indicator that measures the impact of human activities on global climate and expresses quantitatively the effects produced by so called greenhouse gases in terms of carbon dioxide equivalent (CO_2 - eq).

Biomass measurements and basal disc diameter increment assessments allowed carbon stock changes to be estimated from a single inventory measurement. According to study in New Zealand conducted by Beets et al. (2014) , above ground live biomass comprised the majority of the carbon stock based on inventory data acquired in 2012 and was dominated by two arboreal shrub species, manuka and kanuka. The diameter, height and decay class of dead stems in post-1989 natural forest and assumptions around the stem mortality rate allowed stock estimates for the deadwood and litter pools. Incorrect assumptions around decay rates are not likely to be of importance, because dead organic matter comprised a small proportion of the carbon stock (all pools excluding soil C). An age-based carbon yield table based on vegetation mean age was developed for use within New Zealand's Land Use Carbon Analysis System for reporting and accounting greenhouse gas emissions.

Lehtonnen (2005) estimated tree biomass of forests, representative BEFs (biomass expansion factors) with uncertainty estimate were developed for Finland. A method for quantifying carbon flux of branches to soil was also developed. Both biomass and branch litterfall estimates were tested against independent measurements. Biomass estimation method and litterfall estimates were applied with Finnish forest inventory data to estimate carbon stocks and their changes for Finnish forests for 1922-2004. According to the results, the NPP (net primary production) of Finnish forests has increased from 0.3 to 0.4 kg m-2 during studied period, while NBP (net biome production) was positive since 1970s. Results emphasize the importance of complete counting of changes of forest carbon pools i.e., trees, litter, soil and dead wood. Completeness will be important especially if forest management is used as a tool to mitigate climate change by enhancing carbon sinks of forests.

Increasing social and managerial interest in mitigating rising atmospheric CO concentrations and the resulting impacts on climate has focused attention on the ecosystem service of forest carbon storage, including storage in harvested wood products (HWP). HWP includes all wood material (including bark) that leaves harvest sites (Tanabe 2011). Greenhouse gas (GHG) impact of wood and paper products, in the following referred as harvested wood products (HWP), is two fold: 1) HWP form a renewable pool of woodbased carbon, whose changes act as carbon sink or source, 2) manufacture and whole lifecycle of HWP cause fossil carbon emissions.

These fossil emissions are often smaller than those of rival products from nonrenewable sources, and thus material and energy substitution by HWP can cause a relative decrease in GHG emissions. Forest management can affect the quantity of carbon stored in both ecosystems and forest products over time, and management activities in the US frequently include silvicultural treatments that produce HWP. Credible information on forest ecosystem and HWP carbon stocks and fluxes can inform forest managers and the public of the tradeoffs between carbon storage and other forest management objectives, and between short and longterm carbon consequences of alternative forest management strategies.

The United States Forest Service (USFS) and other agencies are interested in accurately accounting for carbon flux associated with harvested wood products (HWP) to meet greenhouse gas monitoring commitments and climate change adaptation and mitigation objectives. The study used the Intergovernmental Panel on Climate Change (IPCC) production accounting approach and the California Forest Project Protocol (CFPP) to estimate HWP carbon storage from 1906 to 2010 for the USFS Northern Region, which includes forests in northern Idaho, Montana, South Dakota, and eastern Washington. The result indicates The Northern Region HWP pool is now in a period of negative net annual stock change because the decay of products harvested between 1906 and 2010 exceeds additions of carbon to the HWP pool through harvest. However, total forest carbon includes both HWP and ecosystem carbon, which may have increased over the study period (Pingoud et al., 2003; Stockmann et al., 2012).

The concept *estimation and reporting* refers in this report to methods used in the national GHG inventories under the UNFCCC. The *Revised 1996 IPCC Guidelines for* 10 *National Greenhouse Gas Inventories* (IPCC 1997*a*, b and c) provide the present basis for Parties. The term *accounting* refers to the emission accounting rules associated with the Kyoto Protocol to the UNFCCC. Accounting rules are a result of negotiation process, and the accounted emissions under the Kyoto Protocol differ, in general, for instance, from full carbon accounting. or from national emissions reported under the UNFCCC. The GHG reporting according to the *1996 Guidelines* is divided into different sectors: Energy, Industrial Processes, Agriculture, Land-Use Change and Forestry and Waste. Considering HWP, it can be noted that at present practically all *fossil* CO_2 and other GHG emissions associated with their lifecycle (e.g. harvesting, transport and manufacture) are reported under the Energy sector. CO_2 emissions from wood fuels are reported as auxiliary data, but excluded from the CO_2 emission totals to avoid double counting. (This is due to the fact that emissions from wood fuels are already included when the net change of forest biomass stocks is reported.) Methane emissions from waste management are reported under the Waste sector (Pingoud et al 2003).

A study by Pingoud et al. (2003) developed a dynamic spreadsheet model of carbon balance in HWP which countries could use in their national emissions estimation and reporting under the UNFCCC. The model requires as basic input data the production and international trade rates of HWP, provided worldwide and since 1961 by the FAO database, which is easily accessible through the internet. The report presents a short description of the above model. In addition, a more robust method for estimation of national HWP stocks is presented, based on direct inventory of building stock. The GHG impacts of type 2) are also shortly illustrated by Finnish case studies, two of which consider material substitution in Finnish new construction.

According to Pingued et al. (2004), the production approach of HWP is also based on reporting of stock changes but, in contrast to the stock-change approach, the wood growing country would report the stock changes in HWP resulting from their forests, regardless of the location of the HWP stock (domestic or exported). Because it is based on stock change, this approach could be adopted within the existing reporting framework. However, for an exporting country, there are likely to be technical difficulties for national reporting systems in estimation of stock changes that occur in the importing country, especially when the country wants to use more sophisticated methods and data, such as statistics on use / fate of wood products.

Development of methods based on direct inventories of national wood product stocks, applied already in some countries, would also not be possible. In addition, the production approach would lead to inconsistencies in the GHG inventories, for instance, in case of geological sequestration of CO_2 (carbon capture and storage = CCS) from flue gases in energy production. CCS is being considered as a measure to reduce emissions from fossil fuel combustion, and it can also be applied to a fossil-fuel plant with biomass co-firing, or to a biomass-only plant. The permanent CCS from fossil fuels would be reported as an emission reduction in the country where the carbon is sequestered, whereas the permanent CCS from biomass fuels would be reported as a removal in the country where the wood was grown. For example, in case of co-firing of fossil fuels and biomass fuels, only the fossil portion of CCS would be credited to the country that applies CCS, not the biotic portion, which would be inconsistent. This inconsistency would be avoided best by using the stock-change approach for HWP. In this case biotic CCS would be reported as a positive stock change of the permanent CCS pool (i.e. a removal) in the country where the CCS occurs, not where the wood was grown, which is consistent with reporting of fossil CCS.

In order to estimate the contribution of cities to global climate change, many attempts have been made to quantify the carbon emissions associated with the accounting level in the community. Considerable progress has been made in technology development for implementation, monitoring and reporting of carbon benefits but barriers to technology transfer remain (Tanabe 2011). Carbon stock calculation provide a benchmark for selection of green materials and development of green labels, provide a basis for prediction of carbon emissions in infrastructure and building construction, help lower the construction's carbon footprint, and help meet the carbon footprint reduction target (Cheng, 2013). Better knowledge of carbon stocks and fluxes is needed to understand the current state of the carbon cycle and how it might evolve with changing land uses and climatic conditions (Hollinger, 2008). Understanding the information of carbon stock is crucial for the effects of climate change to be minimised.

ITTO has been conducted a study using Life Cycle Assessment to evaluate the environmental performance of meranti plywood made using tropical timber harvested from sustainably managed forest and urea-formaldehyde resin. The results are representative of the selected export orientated plywood companies in Indonesia and Malaysia. The company profiles differ due to specific practices such as capacity, recovery, co-products, co-generation and fuel used. The study reveals that the main sources of environmental impacts are raw material consumptions and electrical energy sources. To improve the environmental performance of meranti plywood, companies could: (i) improve the recovery of log input, (ii) conduct co-generation using biomass for thermal and electricity needs in the manufacturing process, (iii) use optimum amounts of resin for the targeted quality, (iv) improve material flow in the manufacturing process to reduce internal transportation. This may be adjusted for Environmental Product Declaration use based on the selected scheme or Product Category Rules (Gan and Massijaya, 2013).

Appendix 2

Production of plywood

Product definition

The plywood is used widely in the building construction sector as its strength, durability and cost make it a preferred building material. A small volume may be used for furniture manufacture. Plywood is made using veneers composed with wood grain perpendicularly to each other with mainly formaldehyde based resin. Plywood is normally made up of odd number of veneers, e.g. 3, 5, 7, 9, 15. The overall plywood thickness may range from 3 mm up to 28 mm and the sizes are usually 3' x 6' and 4' x 8'. Besides making the main product—plywood, a plywood plant may also sell dried veneer and other products like laminated veneer lumber (LVL) and block board using timber precovered from peeler cores. In this study, the plywood used is bonded by Melamine urea formaldehyde (MUF) resin, the construction is 5 –ply using meranti veneer as face and back layers, and sengon as core and centre core layers. The plywood dimensions are 4' in width, 8' in length and 11.5 mm in thickness.

Main product standards

Referenced standards used in the plywood plant sample are Japanese Agricultural Standard (JAS), British standard (BS), United States Standard (IHPA), German Standard (DIN), etc. Each country has different measurement, water content, veneer condition, products requirement, etc. Generally, Indonesian producers and exports the plywood according to standard determined by the buyer (importing country). According to field survey results, the plywood industry sample has been using JAS 233-2003 for plywood.

Description of the manufacturing companies

The plywood companies in Indonesia are privately owned manufacturing entities that purchase raw materials from forest concession owners, forest plantation and community forest. Nowadays, log supply from plantation forest in Indonesia is much higher compared to those of from natural forest. This phenomenon change drastically the wood species used as plywood raw material. In Indonesia, dominant fast growing species for plywood are sengon (*Paraserianthes moluccana*), acacia (*Acacia mangium* Willd), and jabon (*Antocephalus cadamba*). The company sample in Indonesia is classified as a big plywood company, estimated producing 36,000 m^3/year and 1,200 m^3/year of plywood for general use and concrete form plywood, respectively. The company is very efficient in wood utilization, the plywood plants use all the wood wastes generated for wood working, particleboard, wood pellet, and co-generation of electricity for its own consumption. Additional electricity requirement is obtained from the national electricity grid.

Raw materials and composition

The main wood species used for plywood based flooring are tropical timber obtained locally, namely meranti group for face and back layers, and sengon for core and centre core layers. Based on the veneer thickness usage, the wood proportion utilization for meranti and sengon wood species are 20% and 80%, respectively. The plywood company log supply come from West Java, Central Java, Central Kalimantan, and West Kalimantan.The log transportation are normally using truck, ship, and tug boats. The MUF resin are supplied by local adhesive companies. The construction of the plywood for flooring is 5 layers. Meranti veneer is used as face and back and the veneer thickness is 1.3 mm. In the core and centre core, sengon veneer is used at 3.3 mm thickness. The total thickness of the produced plywood is 12.5 mm.

INVENTORY AND ANALYSIS

Process of plywood production

Process of plywood production in general are the same among the plywood companies in Indonesia. However, they may vary in terms of specific condition based on their raw material condition, equipment/machines, thickness, kind of plywood and the target quality of the produced plywood. Figure 1 describes the plywood manufacturing process in the study sample industry.

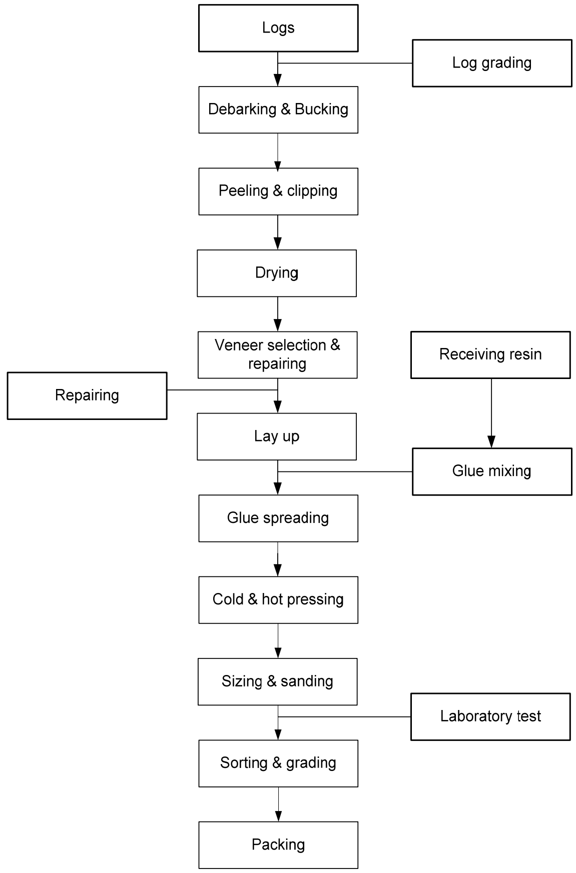

Figure 1. Plywood manufacturing process

Brief description of the process of plywood production are as follows;
Log pond and log yard: Segon logs as plywood raw materials are sorted in log yard, especially to determine the wood species and log quality. Figure 2 shows the condition of the sengon logs for plywood production raw materials.

Figure 2. Raw material logs for plywood production

The wood species used in the plywood companies sampled was sengon for face, core, centre core, and back veneers for flooring exported to Japan.

Debarking and Bucking: Debarking and bucking process were conducted by log supplier using manual tools created by the local people, so debarking process in the plywood industry is not necessary. The logs cut to 3, 4, 6 and 8 feet based on the order and the stardard used. Figure 3 shows the debarking process.

Figure 3. Debarking process

Log grading and cleaning: The cut logs/billets are then graded and transported to the log washer using conveyor. The logs were cleaned using water spray. The log grading and washing process can be seen in Figure 4.

Figure 4. Log grading and cleaning.

Peeling: Log centering before peeling process using laser projection as shown in Figure 5. The block is peeled using rotary lathe. Rotary veneer is the most popular technique in veneer production for ordinary plywood production. The veneer thicknesses for face/back and core/centre core was 1.3 mm and 3.3 mm, respectively. Figure 6 shows the peeling process of meranti log.

Figure 5. Log centering

Figure 6. Peeling process.

Reeling and unreeling veneer: the produced veneer was reeling using babon and sent to unreeling section using automatic transport machine. Figure 7 shows the reeling and unreeling veneer process.

Figure 7. Reeling and unreeling of veneer

Veneer Drying: Green veneer is dried in steam or electric heated ovens. The veneer is dried in hot pressed "continuous or batch dryers" to maximum 12 % moisture content for face and back; and maximum 10% for core and centre core. The continous dryer or roll dryer temperature is 180º C. Drying time range from 10 minutes to 25 minutes depend on veneer thickness, thicker veneer required longer drying time. Figure 8 shows continous veneer drying process.

Figure 8. Continuous veneer drying.

After dryer, each dried veneer should be separated to face, back and inner layer and proceed to next processing step.

Veneer selection and repairing; Dried veneer than selected based on their quality and repaired if necessery. Figure 9 shows veneer selection and repairing process.

Figure 9. Veneer selection and repairing

Table 4. Face, back, inner/core layer selecting standard

Criteria Item	Face		Back, Inner/core Layer
	Quality 1	Quality 2	
Total number of live knot, dead knots, bark pockets and resin pockets, whose largerst diameters are exceeding 5 mm.	Permitted up to a number of quintuple of the panel area expressed in square meters (if there are fractions below a decimal point add one (1) to integer part).	Permitted up to a number of sextuple of the panel area expressed in square meters (if there are fractions below a decimal point add one (1) to integer part).	Permitted up to a number of sextuple of the panel area expressed in square meters (if there are fractions below a decimal point add one (1) to integer part).
Live knots.	Permitted up to a longer diameter of 25 mm.	Permitted up to a longer diameter of 45 mm.	Permitted up to a longer diameter of 45 mm and widthwise diameter of not exceeding 30 mm.
Dead knots	Permitted up to a	Permitted up to a	Permitted up to a

	longer diameter of 15 mm.	longer diameter of 25 mm.	longer diameter of 40 mm and widthwise diameter of not exceeding 30 mm.
Loose knots and holes.	Permitted if loosened off sections or holes are not exceeding 3 mm in longer diameter.	Permitted if loosened off sections or holes are not exceeding 5 mm in longer diameter.	Permitted up to a longer diameter 0f 40 mm and widthwise diameter of not exceeding 10 mm.
Pin knots.	Permitting if not affecting appearance.	Permitting if not excessiveaffecting appearance.	Permitting if not excessive affecting appearance.
Bark pocket or resin pocket.	Permitted if the longer diameter is not exceeding 30 mm.	Permitted if not conspicuous.	Permitted if not conspicuous.
Sound burls or chicken track.	Permitted if slight.	Permitted if not conspicuous.	Permitted if not conspicuous.
Discoloration or stain.	Permitted if slight.	Permitted if not conspicuous.	Permitted if not conspicuous.
Decay	Not permitted.	Permitted if very slight.	Permitted if very slight.
Open splits or chips	Permitted up to a length of 20% of the panel length, up to a width of 1.5 mm and up to a number of two.	Permitted up to a length of 40% of the panel length, up to a width of 4.0 mm and up to a number of three, or up to a length of 20% of the panel length, up to a width of 2 mm and up to a number of six.	Permitted up to a length of 40% of the panel length, up to a width of 6.0 mm.
Cross break	Permitted if slight.	Permitted if slight.	Permitted if slight.
Worm holes.	As to those than linear worm holes are, permitted up to a longer diameter of 1.5 mm, and if they are not dark-rimmed and not located collectively. As to the linear worm holes, permitted up to a longer diameter of 10 mm, and if they are dark-rimmed, and located in the numbers less than quadruple of the panel area expressed in the square meters (if there are fractions below a decimal point, add one (1) to the integer part).	Permitted if not excessive.	Permitted if not excessive.
Rough grain	Permitted if slight.	Permitted if not excessive	Permitted if not excessive
Open joints	Permitted if joint parts are color matched and there is no opening with the joints.	Permitted if openings of joints are not so noticeable.	Permitted if openings of joints are not so noticeable.
Other defects	Permitted if slight.	Permitted if not conspicious.	Permitted if not conspicious.

Lay up: The veneer then lay up perpendicular fiber orientation with the adjacent veneer. Table 5 shows an example veneer composition of plywood for flooring production.

Tabel 5. Veneer composition of plywood

Veneer position	Number of plies	
	5 plies	7 plies
Face	1.30	1.50
Core	3.30	3.30
Center core	3.30	3.00
Core	-	3.30
Center core	-	3.00
Core	3.30	3.30
Back	1.30	1.50
Total veneer thickness	12.50	18.90
Total plywood thickness	11.50	17.50

Glue spreading: Glue spreading on core veneer or crossband veneer using glue spreader. The standard glue spread range from 150 g/m^2 to 300 g/m^2. Figure 10 shows glue spreading process.

Figure 10. Glue spreading process.

Table 6 shows an example of glue composition of melanime formaldehyde and urea formaldehyde adhesives of plywood for flooring.

Table 6. Glue composition of Melamine Formaldehyde and Urea Formaldehyde resin.

Resin	Melamine Formaldehyde	Urea Formeldehyde
Melamine formaldehyde	6.5 kg	-
Urea formaldehyde	-	6.5 kg
Flour	1.1 kg	0.7 kg
Melamine powder	0.3 kg	-
Hardener	0.5 kg	0.3 kg
Catcher	0.6 kg	0.6 kg
Total	9.0 kg	8.1 kg
Glue spread amount	150 – 300 g/m^2	150 – 300 g/m2
Viscosity	3-15	3-15
pH	6 $\pm$ 1	6 $\pm$ 1

Cold pressing: Cold pressing facilitate the adhesive develop better glue bonding through better glue transfer, wetting and penetration process. The pressure is 8 $\pm$ 1 kg/cm^2 for 30 minutes. Open assembly time 20 to 30 minutes, closed assembly time 240 minutes. Figure 11 shows the cold pressing process and Table 7 lists the cold press settings.

Figure 11. Cold pressing process.

Hot pressing: Heat and pressure are used to cure the resin, thereby bonding the veneers together to make plywood (pressing). The pressure is 8 + 1 kg/cm^2 . The standard average pressing time is 25 second per mm plywood thickness. The pressing tempeture is 115^{o}C for MUF bonded plywood. Figure 12 shows hot pressing process.

Figure 12. Hot pressing process.

Sizing/cutting: After hot pressing, the plywood panels are cut to the standard size 122 cm x 244 cm or based on the order size

Putty process: The defects were minimized by putty process. Figure 13 shows the plywood putty process.

Figure 13. Plywood putty process.

Sanding process: The outer layers of plywood (face and back) are sanded using sander machine. The standard sanding speed depend on the plywood thickness. For 11.50 mm plywood thickness, the standard sanding speed is 36 ± 2 m/min. Sand paper grits standard depend on the plywood thickness. For 11.5 mm plywood thickness, the sand paper grit standard for head no.1, 2, and 3 are 80/100, 120/150, and 180/240, respectively.

Table 14. Standard for finishing plywood for flooring

Item	Requirement for acceptance
Degree of adhesion	Should conform to the criteria of type I or II. An average value of wood failure ratio and shear strength shall not be less than the values provided in the using standard.
Moisture content	Should stand the moisture content test. An average moisture content of the meranti plywood not be more than 14%.
Formaldehyde emission	The average and the maximum amounts of the formaldehyde emission of the sample plywood shall be equal to or less than the values of 0.3 mg/l (average) and 0.4 mg/l (maximum) for F**** class of performance, and less than the values of 0.5 mg/l (average) and 0.7 mg/l (maximum) for F*** class of performance
Face quality	Quality of face and back should be fulfill the standard quality of face and back veneer.
Core overlap	Ermitted up to a number of two and up to length of 150 mm. Concerning those with surface quality grade 2, up to a number of 3 (three).
Finish of sides and end	There shall not be any scuffing.
Warping or twisting	Permitted up to a warping or twisting length of 50 mm (if the marked thickness is no less than 7.5 mm, up to 30 mm). Or when pressing by hand, the plane of plywood shall touch a horizontal plane. When putting 10 kg weight on (if the market thickness is not less than 7.5 mm, 15 kg), the plane of plywood shall touch a horizontal plane.
Bend of edges (straightness)	Permitted up to larges bending of 1 mm.
Dimensions	Dimensions of the meranti plywood should fulfill the standard use for grading. A difference between lengths of diagonals shall be not more than 2 mm.
Matters to be marked	The plywood should be marked collectively. The information should be including name of product, dimensions, bonding quality, quality of face, formaldehyde emission amount, name of manufacturer and species name of veneer.

Packing: The plywood is packed and marked based on the standard. Number of plywood per pack/crate for plywood thickness 11.50 mm, and 17.50 mm are 50, and 35 pieces, respectively. The following matters should be marked collectively: name of product, dimensions, bonding quality, quality of face, formaldehyde emission amount, and name of manufacturer. If a species name of veneer is marked, other those stipulated above, the species name shall be marked collectively in a group. Figure 15 shows plywood packing process for storage/shipment.

Figure 14. Packing of plywood for storage/shipment

Process of plywood based flooring
The plywood based flooring construction can be seen in Figure 15.

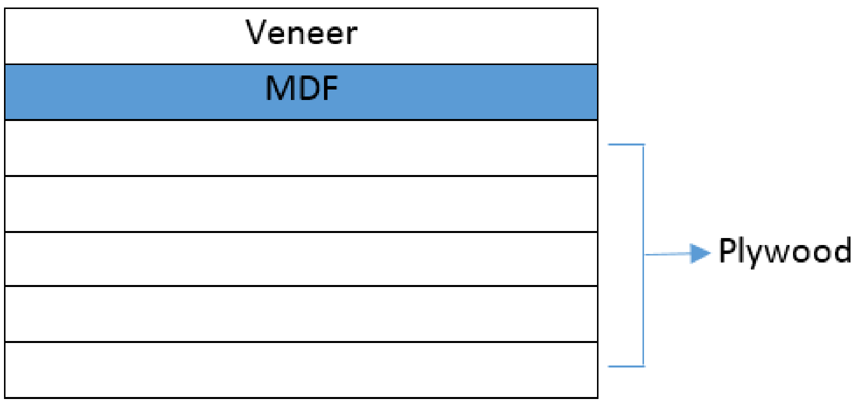

Figure 15. Construction of plywood based flooring

The plywood based flooring comprises three layers, namely first layer is veneer, the second layer is Medium Density Fiberboard (MDF), and the third layer is plywood. These materials are glued together to form the flooring board. The total thickness of plywood based flooring is 12.0 mm. The plywood core board is made by stacking the plies one on top of another in opposite directions, then glued together. By crossing the plies the finished plywood based flooring are much more dimensionally stable than solid wood, meaning they are much less likely to expand and contract in response to changes in temperature and humidity. This added dimensional stability means that plywood based flooring can be installed over concrete subfloors, over an in-floor radiant heating system and below grade. The more plies in the plywood, the more dimensionally stable the floor will be. The more plies, the greater the cost.

There are three different ways of cutting the veneer face that is glued on top of the core board. The cutting method, along with thickness, has an impact on price, namely :

- **Dry solid-sawn**: involves letting the wood dry out slowly with a low humidity level to keep moisture from inside the wood cells intact, reducing the risk of cupping. It is the most expensive type of plywood based flooring, but looks and acts more like a solid. Dry solid-sawn is the lowest yield for the highest cost, but has the best visual appeal, and strongest grain structure due to the sawing process. The grain pattern looks just solid hardwood.
- **Rotary-peel**: involves boiling the log for a certain amount of time at a certain temperature to prepare the wood. After the wood has been prepared, it is scraped from the log with a blade working from the outside in and then pressed flat. It typically has a plywood-like grain and can have issues with cupping and warping to try to revert to its original shape. Rotary Peeled provides the highest use of raw materials for the lowest cost, but has the lowest visual appeal and weakest grain structure. The grain pattern resembles plywood.

- **Sliced-peel**: involves boiling the log for a certain amount of time at a certain temperature to prepare the wood. After the wood has been prepared, it is sliced from the end and then pressed to create a veneer. Compared to rotary-peel, sliced-peel provides better yield with medium cost, better visual appeal, and better structural integrity.

The higher the quality of the plywood based flooring, the thicker the top veneer usually is. Veneer thicknesses range from 0.3 to 6 mm and can be made from any species of wood. The thicker the veneer the higher the price. If the veneer is less than 2mm thick, the floor cannot be sanded and refinished. The sample industry in Japan used sliced-peel method to produced face veneer for their products.

Once the layers are glued together, the edges are milled for tongue and groove construction or for a glueless click-lock system. It is important to understand the nature of the adhesive used to glue the layers together. Cheaper adhesives may emit unacceptable levels of formaldehyde. Plywood based flooring that are either E1 or E0 class or CARB-compliant are formaldehyde safe.

The schematic process and system boundary of plywood based flooring in this study can be seen in Figure 16.

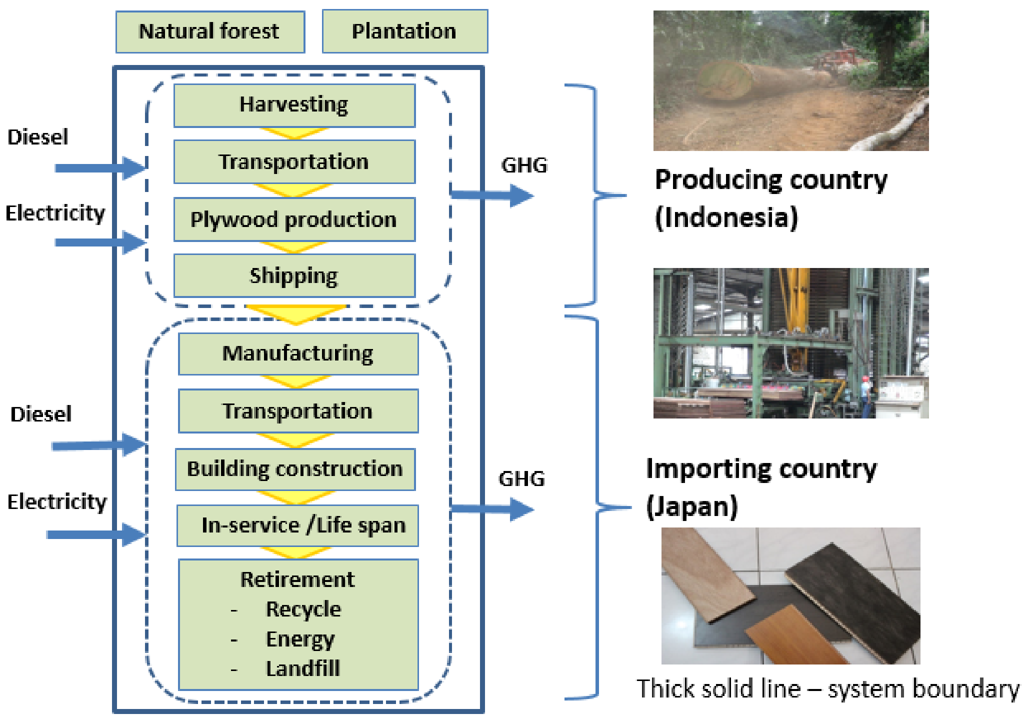

Figure 16. The process and system boundary of plywood based flooring

In this study, the first layer is thin veneer imported from The Unites States of America (USA), and the wood species were maple, walnut, and black cherry. The average veneer thickness was 0.3 mm and the average density was 0.70 g/cm^3.

Medium Density Fiberboard (MDF) is used as second layer made from mixed recycle wood species bonded by urea formaldehyde resin. The MDF average density was 0.81 g/cm^3 and the average thickness was 0.5 mm.

The plywood used as third layer is bonded by Melamine urea formaldehyde (MUF) resin, the construction is 5 –ply using sengon (*Paraserianthes falcataria L. Nielsen*) veneer as face, back, cores and centre core layers. The plywood dimensions are 4’ in width, 8’ in length and 11.2 mm in thickness. The average of sengon density was 0.35 g/cm^3. The plywood was imported from PT. Kutai Timber Indonesia, Probolinggo, Indonesia.

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