Life Cycle Assessment
and
Carbon Sequestration

Bamboo products
of
MOSO International

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Executive summary

This report gives an LCA analysis on the product portfolio of bamboo products of Moso International.

The LCA is made for cradle-to-gate, plus the end-of life stages of the bamboo products. For end-of-life it is assumed that 90% of the bamboo products are incinerated in an electrical power plant, and 10% will end-up in landfill, which is considered to be a realistic scenario for the Netherlands (NEN 8006) and Western Europe.

Additional to the standard LCA (ISO 14040 and 14044), the sequestration (capture and storage) of CO2 has been taken into account. The report provides a comprehensive explanation how such a calculation on carbon sequestration must be made within the general logic of the LCA methodology (and the general logic in science), since there is a lot of confusion regarding this issue.

The overall result of the calculations is that all bamboo products of Moso International are "CO2 neutral" i.e. these products have a negative Carbon Footprint.

1. Goal

The reasons for carrying out this LCA study is twofold

a) for the management of MOSO International[1]: to establish the strengths and the weaknesses of the MOSO bamboo products and the production process in terms of CO2 and toxic emissions, in order to further improve the sustainability of these products
b) for external parties: to communicate the relative position of MOSO Bamboo products in terms of "zero CO2 emissions" throughout the life time

The analyses in this report are fully in line with the ISO specifications (ISO 14040 and 14044) and the LCA manual for LCA [1]. Details on the calculations have been published in peer reviewed papers [2] and books [3,4,5]. Therefore, an extra critical review of this report (as normally required in LCA studies which are intended to be disclosed to the public) has been regarded as superfluous.

There is a distinction of two levels of Carbon Sequestration in natural renewable products (like wood, bamboo and agricultural products):

1. the level of the life cycle of a product (from cradle-to-grave), which is the domain of LCA analyses
2. the level of the global CO2 cycles and global storage of CO2, which is not the domain of a standard LCA, and which has to be analysed separately.

Discussions on Carbon Sequestration are often blurred, since the aforementioned distinction in system levels are often not made clear. This leads to a secondary goal of this report:

- to clarify the LCA calculation as such, and the way "biogenic CO2" is dealt within the life cycle
- to clarify how Carbon Sequestration on a global scale can be defined and calculated for bamboo products, and can be incorporated in the standard LCA calculations (Chapter 3 and Annex I)

The analyses on biogenic CO2 in LCA and carbon sequestration on a global scale are according to a recent book on this subject [6].

[1] For more information on MOSO International and its bamboo products, see www.moso-bamboo.com

2. Scope

The scope of this LCA study is the full range of MOSO bamboo products:

- Flooring & Floor covering (Solid strip – MOSO PureBamboo, Solid wide board – MOSO Bamboo Elite, 2-Ply flooring – MOSO Bamboo Supreme, Tapis, On-edge / Industrial floor – MOSO Bamboo Industriale) and Thermally modified decking – MOSO Bamboo X-treme
- Panels & Panel covering materials (Solid panel, Thick veneer, Veneer, Solid joist)

Excluded from the scope are engineered products by MOSO such as TopBamboo (HDF carrier) and Unibamboo (latex backing).
Note: This LCA has been performed for the specific case of the MOSO production chain following best practice and can therefore **not** be perceived as being typical for the production chain of other industrial bamboo material manufacturers.

The system boundary of this LCA is "cradle-to-warehouse-gate" plus "end-of-life" as depicted in Fig. 1. The Use-Phase has been kept out of the analyses, because the emissions in this step are negligible (in comparison to the first and the last step)

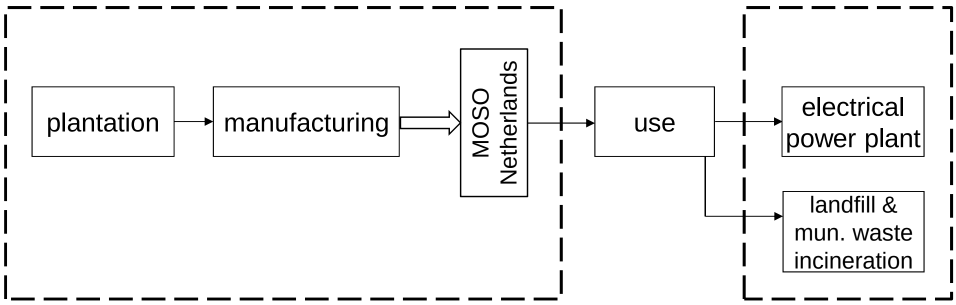

Figure 1. System boundary: cradle-to-gate plus end-of-life.

The LCIA (Life Cycle Impact Analysis) is not done at the level of so called "midpoints", since a set of midpoints is not meaningful for the average reader (even specialist often struggle with a meaningful interpretation of midpoints). In this report, so called "single indicators" are used. The advantage of a single indicator is that the environmental burden of the product life cycle is expressed in one number.
Two single indicators are used:

- the "CO2 equivalent" ("carbon footprint") , which can easily be understood and explained, but is lacking other polluting emissions (like SOx, NOx, carcinogens, fine dust, etc.)
- the "eco-costs" system which incorporates 3000 polluting substances (as well as materials depletion), see Annex II

An important advantage of bamboo is its yield of land due to the high growing speed. This additional sustainability issue, excluded in LCA, is related to land-use and the "Ecological Footprint". This aspect is dealt with in Annex III.
Some social aspects of the manufacturing of bamboo products are dealt with in Annex III.

3. Scientific background of LCA and the CO2 cycle

Sequestration (= capture and storage) of CO_2 in wood is an important issue in sustainability. However, it is also a confusing subject, leading to many discussions.

First, we look at the issue at the level of a product.
There is consensus in science on the way "biogenic CO_2" (=CO_2 which is captured in wood during the growth of a tree) is to be handled in LCA. See Fig.2.
Biogenic CO_2 is first taken out of the air at the bamboo plantation, and then released back to the atmosphere at the End of Life. So biogenic CO2 is recycled, and its net effect on global warming is zero.
When the bamboo product, however, is burnt at end-of life in an electrical power plant, the total system of Fig. 2 generates electricity. This electricity can replace electricity from fossil fuels. In other words: the use of fossil fuels is avoided, so fossil CO2 emissions are avoided, which results in a reduction of global warming. In LCA calculations this leads to a system credit: the production of electricity from bamboo waste has a negative carbon footprint and negative eco-costs.
The conclusion is that the storage of biogenic CO2 (carbon sequestration) in bamboo is not counted in LCA, unless the bamboo (or any other bio-product like wood) is burned for electricity or heat.

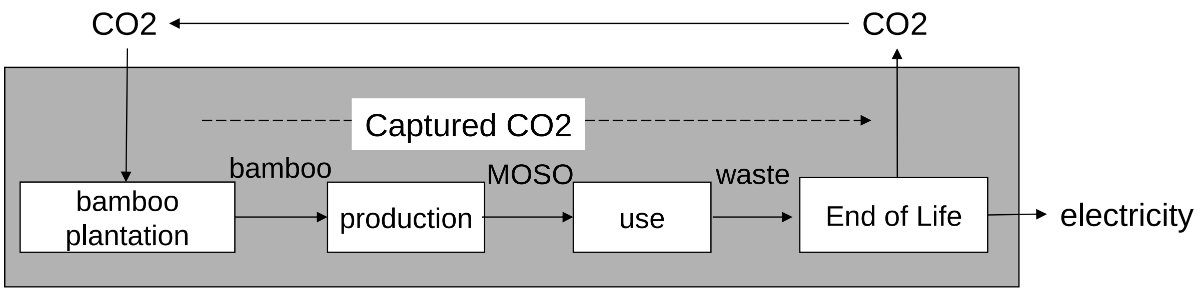

Figure 2. The CO2 cycle on product level.

The widespread confusion comes from the fact that the storage of CO2 as such, even temporary, is good for the environment, so "it has to be incorporated in some way in the total LCA calculation". However, the positive effect of storage cannot be analysed on the level of one single product.

The effects of carbon sequestration can be understood when we look at a global system level.
On a global scale, CO2 is stored in forests (and other vegetation), in the ocean, and in products (buildings, furniture, etc). One should realise that, when there is *no change* in the area of forests and *no change* in the total volume of wood in products (houses, furniture, etc.), there is *no change* in sequestered carbon. For a description of the global CO2 cycle, see Annex I.
The consequence is that there is only extra carbon storage on a global scale, when there is market growth of the application of bamboo. This market growth leads to more plantations and more volume of bamboo in the building industry. In chapter 6 it is explained that the positive major effect on global warming is mainly caused by the increase of bamboo plantations, rather than by the increase of bamboo products (e.g. bamboo in buildings).

4. Cradle-to-gate calculations on bamboo products

The production system of bamboo “from cradle-to-warehouse-gate” is depicted in Fig. 3.

The calculations have been made on the actual product chain of bamboo products of MOSO International based on consumption in the Netherlands:

- Type of bamboo: *Phyllostachys Pubescens* (density 700 kg/m3, length up to 15 m, diameter on the ground 10-12 cm, wall thickness 9mm), also called Moso.
- Plantation and first processing: the Anji region, the province of Zhejiang, China
- Final processing (Laminated bamboo board, compressed bamboo, veneer): Huangzhou, the province of Zhejiang
- The product is shipped via Shanghai and Rotterdam to the MOSO warehouse in The Netherlands (Zwaag)

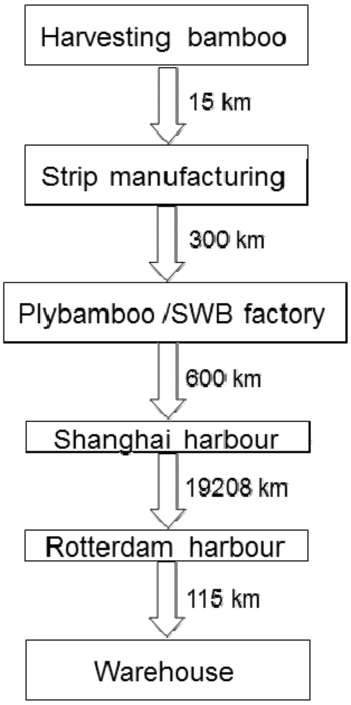

Figure 3: The production system of bamboo (cradle-to-warehouse-gate).

The required heat for the manufacturing process is generated locally by combustion of sawdust and bamboo waste.

Electricity is from the local grid.

Note: a cogeneration plant for electricity and heat is an opportunity for the future, to reduce the carbon footprint even further.

The calculations for the LCAs have been made with the computer program Simapro, applying LCI databases of Ecoinvent v2 (2008) and Idemat 2008 (a database of the Delft University of Technology, partly based on Ecoinvent Unit data). The assumption here is that the equipment for transport and

production in modern China does not differ much from the equipment used in Western Europe, however, the oil refineries for diesel are polluting twice as much.
The environmental damage of electrical power in China is considerably higher than that of power plants in Western Europe. However, the eco-costs of electricity are not based on end-of-pipe prevention measures, but on system integrated measures (i.e. the prevention costs of renewable energy sources like windmills and solar power systems). The assumption is that the costs of these systems do not differ considerably from the costs in Western Europe.
The eco-costs of construction materials (from cradle to gate) and transport can be found in the open access tables provided at www.ecocostsvalue.com or can be calculated with special databases in Simapro.

As an example, the analysis of laminated bamboo board is provided in Table 1 and Table 2 on the next two pages.
Laminated bamboo board, a hard aesthetical material which is often used in flooring or table tops, is manufactured in various varieties: 1, 3, or 5 layers, bleached or carbonized, side pressed or plain pressed. Table 1 and 2 provide data for 3 layer carbonized laminated bamboo board. A comprehensive description of the production processes and Tables for the other varieties can be found in [3,4,5].
The basic length of laminated bamboo board (and most of the other MOSO bamboo products) is 2.66 meters, based on which the complete Chinese industrial bamboo industry is standardised. Usually about 8 meters (3 x 2.66 m) of a harvested bamboo stem will be used for the development of bamboo products. The bottom two parts of 2.66 meters are mostly used as input for the manufacturing of industrial bamboo materials such as laminated bamboo boards, while the upper part may be used for smaller bamboo products such as blinds and chopsticks.
The bottom segments of the stem will first be processed into rough strips (approximately 2630 x 23 x 8 mm). This is done near the plantations. The strips are then transported to the manufacturing site of the laminated bamboo board, see Fig. 3. In the case which has been studied, the distance to the manufacturing site of laminated bamboo board was 300 km.

Note: The energy data for drying, line 8 in Table 3, have been changed in comparison to the data in [3,4, 5], since the required time for drying time appeared to be shorter (168 hours for a batch of 115.4 FUs, electrical power of fans and boiler: 6.64 kW).

The total scores (carbon footprint as well as eco-costs) for all MOSO bamboo products[2] are given in Table 3, Chapter 7.

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[2] Except from engineered products by MOSO such as Topbamboo (HDF carrier) and Unibamboo (latex backing).

Process step	amount	unit	Carbon fp kgCO2/unit	Carbon fp kgCO2/FU	Carbon fp kgCO2/kg	Carbon fp %
1. Cultivation and harvesting from plantation						
Gasoline consumption	0.224	litre / FU	3.895/ litre	0.873	0.0209	1.7%
2. Transport from plantation to strip manufacturing facility; eco-costs of a 5 tons truck (transport of 23.1 FUs)	30	km / truck	0.63/ km	0.818	0.0196	1.6%
3. Strip making	1.38	kWh/ FU	0.608/kWh	0.839	0.0201	1.7%
4. Transport from strip manufacturing facility to factory; eco-costs of a 10 tons truck (transport of 77.6 FUs).	600	km / truck	0.825/km	6.379	0.1530	12.7%
5. Rough planing	8.62	kWh/ FU	0.109/kWh	5.241	0.1257	10.5%
6. Strip selection						
7. Carbonization	4.73	kWh/FU	0.109/kWh	2.876	0.0690	5.7%
8. Drying carbonized strips	9.66	kWh/FU	0.109/kWh	5.873	0.1408	11.7%
9. Fine planing	5.8	kWh/FU	0.109/kWh	3.526	0.0846	7.0%
10. Strip selection						
11. Glue application (1-layer boards)	0.894	kg / FU	2.24 /kg	2.003	0.0480	4.0%
12. Pressing strips to 1-layer board	1.89	kWh/FU	0.608/kWh	1.149	0.0276	2.3%
13. Sanding 1-layer board	1.62	kWh/FU	0.608/kWh	0.985	0.0236	2.0%
14. Glue application (3-layer board)	0.983	kg / FU	2.24 /kg	2.202	0.0528	4.4%
15. Pressing three layers to one board	1.65	kWh/FU	0.608/kWh	1.003	0.0241	2.0%
16. Sawing	0.29	kWh/FU	0.608/kWh	0.176	0.0042	0.4%
17. Sanding 3-layer board	0.86	kWh/FU	0.608/kWh	0.523	0.0125	1.0%
18. Dust absorption (during all steps)	8.67	kWh/FU	0.608/kWh	5.271	0.1264	10.5%
19. Transport from factory to harbour	12.51	ton.km / FU	0.086/ton.km	1.076	0.0258	2.2%
20. Transport from harbour to harbour	800.9736	ton.km / FU	0.011/ton.km	8.811	0.2113	17.6%
21. Transport from harbour to warehouse	4.7955	ton.km / FU	0.086/ton.km	0.412	0.0099	0.8%
TOTAL carbon footprint				50.04	1.200	100.0%

Table 1: Input data and results in CO2 equivalent (carbon footprint) for the environmental impact assessment (cradle to gate) of carbonized 3-layer laminated bamboo board (consisting of two layers of 5 mm plain pressed at the outsides, and one layer of 10 mm side pressed in the core). The FU used as the base element for this assessment is one board of 2440 x 1220 x 20 mm (2.98 m2), with a weight of 41.7 kilograms (based on a density of 700 kg/m3).

Process step	amount	unit	ecocosts €/unit	ecocosts €/FU	ecocosts €/kg	ecocosts %
1. Cultivation and harvesting from plantation						
Gasoline consumption	0.224	litre / FU	1.04/ litre	0.233	0.0056	1.7%
2. Transport from plantation to strip manufacturing facility; eco-costs of a 5 tons truck (transport of 23.1 FUs)	30	km / truck	0.243/ km	0.316	0.0076	2.3%
3. Strip making	1.38	kWh/ FU	0.109/kWh	0.150	0.0036	1.1%
4. Transport from strip manufacturing facility to factory; eco-costs of a 10 tons truck (transport of 77.6 FUs).	600	km / truck	0.32/km	2.474	0.0593	18.0%
5. Rough planing	8.62	kWh/ FU	0.109/kWh	0.940	0.0225	6.8%
6. Strip selection						
7. Carbonization	4.73	kWh/FU	0.109/kWh	0.516	0.0124	3.7%
8. Drying carbonized strips	9.66	kWh/FU	0.109/kWh	1.053	0.0253	7.7%
9. Fine planing	5.8	kWh/FU	0.109/kWh	0.632	0.0152	4.6%
10. Strip selection						
11. Glue application (1-layer boards)	0.894	kg / FU	0.57/kg	0.510	0.0122	3.7%
12. Pressing strips to 1-layer board	1.89	kWh/FU	0.109/kWh	0.206	0.0049	1.5%
13. Sanding 1-layer board	1.62	kWh/FU	0.109/kWh	0.177	0.0042	1.3%
14. Glue application (3-layer board)	0.983	kg / FU	0.57/kg	0.560	0.0134	4.1%
15. Pressing three layers to one board	1.65	kWh/FU	0.109/kWh	0.180	0.0043	1.3%
16. Sawing	0.29	kWh/FU	0.109/kWh	0.032	0.0008	0.2%
17. Sanding 3-layer board	0.86	kWh/FU	0.109/kWh	0.094	0.0022	0.7%
18. Dust absorption (during all steps)	8.67	kWh/FU	0.109/kWh	0.945	0.0227	6.9%
19. Transport from factory to harbour	12.51	ton.km / FU	0.033/ton.km	0.413	0.0099	3.0%
20. Transport from harbour to harbour	800.9736	ton.km / FU	0.0052/ton.km	4.165	0.0999	30.3%
21. Transport from harbour to warehouse	4.7955	ton.km / FU	0.033/ton.km	0.158	0.0038	1.2%
TOTAL eco-costs (€)				13.75	0.330	100.0%

Table 2: Input data and results in eco-costs for the environmental impact assessment (cradle to gate) of carbonized 3-layer laminated bamboo board (consisting of two layers of 5 mm plain pressed at the outsides, and one layer of 10 mm side pressed in the core). The FU used as the base element for this assessment is one board of 2440 x 1220 x 20 mm (2.98 m2), with a weight of 41.7 kilograms (based on a density of 700 kg/m3).

5. End-of-life calculations on bamboo products

The end-of-life of bamboo is a combination of:

1. Combustion in an electrical power plant
2. Combustion in a municipal waste incineration plant
3. Landfill

In the Netherlands and other West European Countries, wood and bamboo is separated from other waste and ends up in an electrical power plant. Only a small proportion is combusted in a municipal waste incinerator. It is estimated that approximately 10% perishes in nature ("landfill"), as specified in the NEN 8006 on LCA.

The end-of-life credit for electricity production from bamboo waste is (data from the Idemat database):

- carbon footprint: 1.18 kgCO2 per kg of bamboo waste
- eco-costs: 0.21 € per kg of bamboo waste

In this report we assume that 90% of the bamboo products will be combusted for production of electricity and/or heat, leading to a credit of:

- carbon footprint: 1.18 x 0.9 = 1.062 kgCO2 per kg of bamboo product
- eco-costs: 0.21 x 0.9 = 0.189 euro eco-costs per kg of bamboo product

The overall scores for LCA ("cradle-to-warehouse-gate" + "end-of-life") of carbonized laminated bamboo board are

- carbon footprint: 1.2 – 1.062 = 0.138 kgCO2 per kg Laminated bamboo board (see Table 1)
- eco-costs: 0.33 – 0.189 = 0.141 € per kg Laminated bamboo board (see Table 2)

Although the above scores are according to the formal LCA (according to ISO 14040 and 14044, and according to the European LCA manual [1]), the effects of the carbon sequestration on a global level must be taken into account as well. This is dealt with in the next two chapters.

6. Calculation of carbon sequestration in forests and buildings

As has been explained in Chapter 3 and Annex I, the extra global carbon sequestration is proportional to the growth of the market for bamboo products.
According to van der Lugt and Lobovikov [8] annual growth of the market for industrial bamboo products in EU and China ranges between 17% to 25%. However, the establishment of new plantations often does not directly follow increase in market demand but is following the market growth with a delay. This phenomenon also becomes clear from the 7th Chinese National Forestry Inventory [9] where is shown that the area of bamboo resources in China in 2004-2008 has grown from 4,84 million ha to 5,38 million ha in 2008, thus a growth of 11,18% in 5 years which refers to an annual growth of 2,24%. Note that the growth of tree forest area in China lies at a similar level (11,74%) with a growth of 174,91 million ha to 195,45 million ha in the same period (2004-2008).
For this report it is assumed that the **annual growth in permanent plantations in China will increase to 5%** as a result of the domestic and international market growth. This can be considered a conservative approach as it may be expected that this number will turn out to be higher considering the high market growth.

It is assumed that the additional permanent plantations are established on grassland or other degraded land and do not come at the expense of natural tree forests[3]. This is a plausible assumption as a large portion of the MOSO bamboo resources comes from the industrialised provinces around Shanghai (Zhejiang, Anhui, Jiangxi) with few natural forests. Furthermore, this assumption fits well in the current policy for afforestation and natural forest protection of the Chinese Government controlled by the Chinese State Forestry. More information on this issue can be found at http://english.forestry.gov.cn/web/index.do, which shows the increasing forest area in China.

It is important to realize that one kg of a MOSO bamboo product relates to many kg of bamboo in the plantation (see Annex III, Fig. 10):

- 1 kg final MOSO bamboo product (A-quality bamboo material) consists of approx. 0.9 kg bamboo strip, 0.08 kg water (at 20 degrees Celsius and a relative humidity of 50%) and 0.02 kg glue;
- 0.9 kg bamboo strip is manufactured from 2.14 kg bamboo at the plantation above the ground (production efficiency 42%, see Fig. 10.)
- 2.14 kg bamboo contains 2.14 kg x 1.83 kg CO2 / kg bamboo = 3.92 kg CO_2 (see Annex I)
- 3.92 kg CO2 above the ground relates to 3.92/0.32 = 12.2 kg CO2 above + below the ground[4]

Concluding: 1 kg final MOSO bamboo product is related to 12.2 kg CO2 stored at the plantation

[3] The importance of this assumption is explained for tropical hardwood in Annex I.

[4] Besides in the trunks, branches and shrub, there is CO2 stored below ground in the soil and roots of a plantation. Zhou et al. [10] found that, for a medium intensity managed MOSO bamboo plantation in Lin'an, Zhejiang province, the distribution of biomass above ground versus below ground is 32.2% and 68.8% respectively.

Only 5% of this CO_2 is taken out of the air, needed for the growth of the new plantation area, following the assumed market growth. According to LCA, this 5% can be allocated to the total market of bamboo in the building industry. That means that 5% of the 12,2 kg CO_2 (i.e. 0,61 kg CO_2) can be allocated to 1 kg final MOSO bamboo product in the building industry.

If the scenario above is followed, an amount of **0,61 kg CO_2 per kg final MOSO bamboo product** can be allocated as ‘credit’ in the LCA calculation (in addition to the end-of-life credit in the case of combustion in electrical power plants, as explained in chapter 5).

Note: the carbon sequestration in buildings has been omitted. There are two arguments for that:

1. The carbon sequestration in the plantations (12.2 kg CO_2 per kg final product) is a factor 7.4 higher than the carbon sequestration in the end product (1.83 x 0.9 = 1.65 kg CO_2 per kg final product)
2. It is expected that the residence time of the bamboo products in buildings have a tendency to become shorter (the life time of flooring and other products has a tendency to become shorter in modern life). This reduces the relative extra carbon sequestration in buildings. Exact figures on this phenomenon are not known yet.

7. Results: Tables on combined cradle-to-grave calculations, including Carbon Sequestration

The calculations of Table 1 and Table 2 of Chapter 4 have been made for different layer types, later thicknesses and layer configurations by means of a computer program. Table 3 below shows the combined results of the calculations of the LCA (chapter 4 and 5) and the CO2 storage (chapter 6) for the product portfolio of Moso International. Note: SP = Side Pressed, PP = Plain Pressed, D = Density / Compressed

MOSO International Bamboo Products				Carbon Footprint (CO2eq) per kg final product						Eco-costs (€) per kg final product				
				PRODUCTION	End of Life	CO2	CO2	CO2	CO2	PRODUCTION	End of Life	eco-costs	eco-costs	eco-costs
				CO2 footprint	CO2 credit	life cycle	storage	total	Neutral	Eco-costs	Eco-costs	life cycle	CO2 storage	Total
	Thickness (mm)	Style	Color	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	Yes / No	Euro/kg	Euro/kg	Euro/kg	Euro/kg	Euro/kg
Flooring														
Solid strip -	15	SP	N	1.129	-1.062	0.0672	-0.6085	-0.5413	Yes	0.331	-0.189	0.142	-0.082	0.060
MOSO PureBamboo	15	PP	N	1.262	-1.062	0.2000	-0.6085	-0.4085	Yes	0.358	-0.189	0.169	-0.082	0.087
	15	SP	C	1.098	-1.062	0.0362	-0.6085	-0.5723	Yes	0.309	-0.189	0.120	-0.082	0.038
	15	PP	C	1.231	-1.062	0.1690	-0.6085	-0.4395	Yes	0.335	-0.189	0.146	-0.082	0.064
Solid wide board -	15	SP	N	1.284	-1.062	0.2220	-0.6085	-0.3865	Yes	0.363	-0.189	0.174	-0.082	0.092
MOSO Bamboo Elite	15	PP	N	1.262	-1.062	0.2000	-0.6085	-0.4085	Yes	0.358	-0.189	0.169	-0.082	0.087
	15	SP	C	1.253	-1.062	0.1910	-0.6085	-0.4175	Yes	0.341	-0.189	0.152	-0.082	0.070
	15	PP	C	1.231	-1.062	0.1690	-0.6085	-0.4395	Yes	0.336	-0.189	0.147	-0.082	0.065
	13	D	N	1.269	-1.062	0.2070	-0.6085	-0.4015	Yes	0.360	-0.189	0.171	-0.082	0.089
	13	D	C	1.238	-1.062	0.1760	-0.6085	-0.4325	Yes	0.337	-0.189	0.148	-0.082	0.066
2-Ply flooring -	10	SP	N	1.285	-1.062	0.2230	-0.6085	-0.3855	Yes	0.362	-0.189	0.173	-0.082	0.091
MOSO Bamboo Supreme	10	PP	N	1.269	-1.062	0.2070	-0.6085	-0.4015	Yes	0.358	-0.189	0.169	-0.082	0.087
	10	SP	C	1.254	-1.062	0.1920	-0.6085	-0.4165	Yes	0.340	-0.189	0.151	-0.082	0.069
	10	PP	C	1.238	-1.062	0.1760	-0.6085	-0.4325	Yes	0.335	-0.189	0.146	-0.082	0.064
MOSO Bamboo Tapis	5	PP	N	1.143	-1.062	0.0810	-0.6085	-0.5275	Yes	0.331	-0.189	0.142	-0.082	0.060
	5	PP	C	1.112	-1.062	0.0500	-0.6085	-0.5585	Yes	0.309	-0.189	0.120	-0.082	0.038
	7.5	SP	N	1.152	-1.062	0.0901	-0.6085	-0.5184	Yes	0.335	-0.189	0.146	-0.082	0.064
	7.5	SP	C	1.121	-1.062	0.0591	-0.6085	-0.5494	Yes	0.313	-0.189	0.124	-0.082	0.042

					Carbon Footprint (CO2eq) per kg final product						Eco-costs (€) per kg final product				
					PRODUCTION	End of Life	CO2	CO2	CO2	CO2	PRODUCTION	End of Life	eco-costs	eco-costs	eco-costs
					CO2 footprint	CO2 credit	life cycle	storage	total	Neutral	Eco-costs	Eco-costs	life cycle	CO2 storage	Total
	Thickness (mm)	type	Style	Color	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	Y / N	Euro/kg	Euro/kg	Euro/kg	Euro/kg	Euro/kg
Industrial Floor - MOSO Bamboo	10		SP	N	1.141	-1.062	0.0787	-0.6085	-0.5298	Yes	0.333	-0.189	0.144	-0.082	0.062
Industriale	10		SP	C	1.110	-1.062	0.0476	-0.6085	-0.5609	Yes	0.311	-0.189	0.122	-0.082	0.040
	15		SP	N	1.129	-1.062	0.0672	-0.6085	-0.5413	Yes	0.331	-0.189	0.142	-0.082	0.060
	15		SP	C	1.098	-1.062	0.0362	-0.6085	-0.5723	Yes	0.309	-0.189	0.120	-0.082	0.038
	10		D	N	1.200	-1.062	0.1380	-0.6085	-0.4705	Yes	0.346	-0.189	0.157	-0.082	0.075
	10		D	C	1.168	-1.062	0.1060	-0.6085	-0.5025	Yes	0.323	-0.189	0.134	-0.082	0.052
Panels															
MOSO Solid panel	16	3,5-9-3,5	SP	N	1.294	-1.062	0.2320	-0.6085	-0.3765	Yes	0.366	-0.189	0.177	-0.082	0.095
	16	3,5-9-3,5	PP	N	1.277	-1.062	0.2150	-0.6085	-0.3935	Yes	0.361	-0.189	0.172	-0.082	0.090
	16	3,5-9-3,5	SP	C	1.263	-1.062	0.2010	-0.6085	-0.4075	Yes	0.344	-0.189	0.155	-0.082	0.073
	16	3,5-9-3,5	PP	C	1.246	-1.062	0.1840	-0.6085	-0.4245	Yes	0.339	-0.189	0.15	-0.082	0.068
	19		SP	N	1.124	-1.062	0.0620	-0.6085	-0.5465	Yes	0.330	-0.189	0.141	-0.082	0.059
	19		SP	C	1.093	-1.062	0.0310	-0.6085	-0.5775	Yes	0.308	-0.189	0.119	-0.082	0.037
	20	4-12-4	SP	N	1.241	-1.062	0.1790	-0.6085	-0.4295	Yes	0.355	-0.189	0.166	-0.082	0.084
	20	4-12-4	PP	N	1.243	-1.062	0.1810	-0.6085	-0.4275	Yes	0.354	-0.189	0.165	-0.082	0.083
	20	4-12-4	SP	C	1.210	-1.062	0.1480	-0.6085	-0.4605	Yes	0.333	-0.189	0.144	-0.082	0.062
	20	4-12-4	PP	C	1.212	-1.062	0.1500	-0.6085	-0.4585	Yes	0.332	-0.189	0.143	-0.082	0.061
	20	4-12-4	D	N	1.168	-1.062	0.1060	-0.6085	-0.5025	Yes	0.338	-0.189	0.149	-0.082	0.067
	20	4-12-4	D	C	1.136	-1.062	0.0740	-0.6085	-0.5345	Yes	0.317	-0.189	0.128	-0.082	0.046
	20	5-10-5	PP	C	1.200	-1.062	0.1380	-0.6085	-0.4705	Yes	0.330	-0.189	0.141	-0.082	0.059
	20	5-10-5	PP	N	1.231	-1.062	0.1690	-0.6085	-0.4395	Yes	0.352	-0.189	0.163	-0.082	0.081
	20	5x4	PP	N	1.327	-1.062	0.2650	-0.6085	-0.3435	Yes	0.371	-0.189	0.182	-0.082	0.100
	20	5x4	PP	C	1.293	-1.062	0.2310	-0.6085	-0.3775	Yes	0.349	-0.189	0.16	-0.082	0.078
	25	4-17-4	SP	N	1.224	-1.062	0.1620	-0.6085	-0.4465	Yes	0.351	-0.189	0.162	-0.082	0.080
	25	4-17-4	PP	N	1.216	-1.062	0.1540	-0.6085	-0.4545	Yes	0.349	-0.189	0.16	-0.082	0.078
	25	4-17-4	SP	C	1.193	-1.062	0.1310	-0.6085	-0.4775	Yes	0.329	-0.189	0.14	-0.082	0.058

					Carbon Footprint (CO2eq) per kg final product						Eco-costs (€) per kg final product				
					PRODUCTION	End of Life	CO2	CO2	CO2	CO2	PRODUCTION	End of Life	eco-costs	eco-costs	eco-costs
					CO2 footprint	CO2 credit	life cycle	storage	total	Neutral	Eco-costs	Eco-costs	life cycle	CO2 storage	Total
	Thickness (mm)	type	Style	Color	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	CO2equ/kg	Y / N	Euro/kg	Euro/kg	Euro/kg	Euro/kg	Euro/kg
MOSO Solid panel	25	4-17-4	PP	C	1.185	-1.062	0.1230	-0.6085	-0.4855	Yes	0.327	-0.189	0.138	-0.082	0.056
	30	5-20-5	SP	N	1.200	-1.062	0.1380	-0.6085	-0.4705	Yes	0.346	-0.189	0.157	-0.082	0.075
	30	5-20-5	PP	N	1.190	-1.062	0.1280	-0.6085	-0.4805	Yes	0.344	-0.189	0.155	-0.082	0.073
	30	5-20-5	SP	C	1.169	-1.062	0.1070	-0.6085	-0.5015	Yes	0.324	-0.189	0.135	-0.082	0.053
	30	5-20-5	PP	C	1.159	-1.062	0.0970	-0.6085	-0.5115	Yes	0.321	-0.189	0.132	-0.082	0.050
	40	4-8-16-8-4	SP	N	1.220	-1.062	0.1580	-0.6085	-0.4505	Yes	0.351	-0.189	0.162	-0.082	0.080
	40	4-8-16-8-4	PP	N	1.215	-1.062	0.1530	-0.6085	-0.4555	Yes	0.350	-0.189	0.161	-0.082	0.079
	40	4-8-16-8-4	SP	C	1.189	-1.062	0.1270	-0.6085	-0.4815	Yes	0.329	-0.189	0.14	-0.082	0.058
	40	4-8-16-8-4	PP	C	1.184	-1.062	0.1220	-0.6085	-0.4865	Yes	0.327	-0.189	0.138	-0.082	0.056
	40	3-8-16-8-3	D	C	1.163	-1.062	0.1010	-0.6085	-0.5075	Yes	0.327	-0.189	0.138	-0.082	0.056
	40	3-8-16-8-3	D	N	1.193	-1.062	0.1310	-0.6085	-0.4775	Yes	0.340	-0.189	0.151	-0.082	0.069
	3		SP	N	1.192	-1.062	0.1300	-0.6085	-0.4785	Yes	0.342	-0.189	0.153	-0.082	0.071
	3		PP	N	1.181	-1.062	0.1190	-0.6085	-0.4895	Yes	0.338	-0.189	0.149	-0.082	0.067
	3		SP	C	1.161	-1.062	0.0990	-0.6085	-0.5095	Yes	0.320	-0.189	0.131	-0.082	0.049
	3		PP	C	1.150	-1.062	0.0880	-0.6085	-0.5205	Yes	0.315	-0.189	0.1261	-0.082	0.044
	5		SP	N	1.175	-1.062	0.1130	-0.6085	-0.4955	Yes	0.339	-0.189	0.15	-0.082	0.068
	5		PP	N	1.143	-1.062	0.0810	-0.6085	-0.5275	Yes	0.331	-0.189	0.142	-0.082	0.060
	5		SP	C	1.144	-1.062	0.0820	-0.6085	-0.5265	Yes	0.317	-0.189	0.128	-0.082	0.046
	5		PP	C	1.112	-1.062	0.0500	-0.6085	-0.5585	Yes	0.309	-0.189	0.12	-0.082	0.038
MOSO Veneer	0.6		SP	N	1.525	-1.062	0.4630	-0.6085	-0.1455	Yes	0.421	-0.189	0.232	-0.082	0.150
	0.6		PP	N	1.597	-1.062	0.5350	-0.6085	-0.0735	Yes	0.432	-0.189	0.243	-0.082	0.161
	0.6		SP	C	1.491	-1.062	0.4290	-0.6085	-0.1795	Yes	0.397	-0.189	0.208	-0.082	0.126
	0.6		PP	C	1.557	-1.062	0.4950	-0.6085	-0.1135	Yes	0.403	-0.189	0.214	-0.082	0.132
MOSO Solid joist	55		SP	N	1.159	-1.062	0.0970	-0.6085	-0.5115	Yes	0.338	-0.189	0.149	-0.082	0.067
	55		SP	C	1.127	-1.062	0.0650	-0.6085	-0.5435	Yes	0.316	-0.189	0.127	-0.082	0.045
Decking															
Bamboo X-treme	20		D	C	1.670	-1.062	0.6080	-0.6085	-0.0005	Yes	0.429	-0.189	0.24	-0.082	0.158

8. Conclusions

In this study, a Life Cycle Assessment was executed for the bamboo products of MOSO International, in which the effect of carbon sequestration was included. From the results can be concluded that MOSO bamboo products, based on use in Europe, are “CO2 neutral or better”. See the column “Total” in Fig. 4.

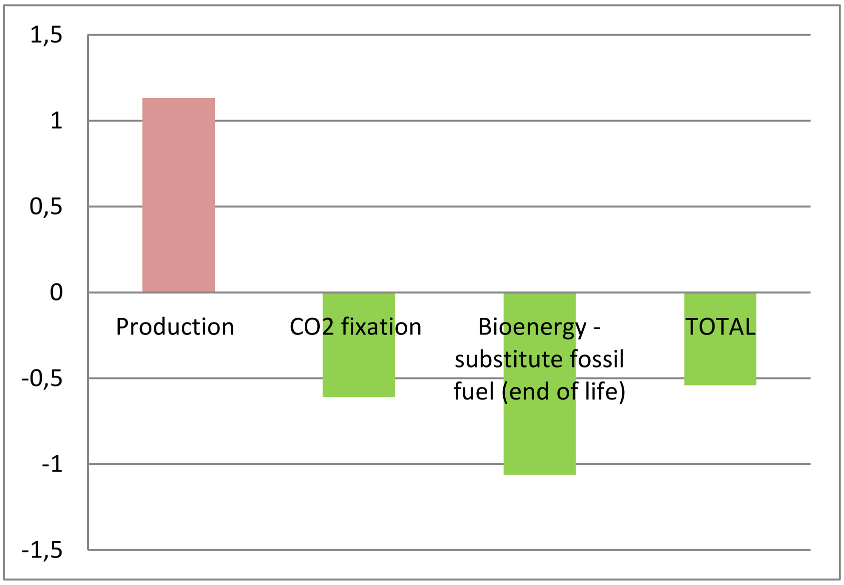

Figure 4. Carbon Footprint over Life Cycle (kgCO2eq / kg MOSO product), in this case for Solid strip side pressed natural – MOSO PureBamboo

The high annual yield of bamboo, in combination with its durable root structure which enables growth on difficult habitats such as eroded slopes, is another environmental advantage. In terms of land-use, bamboo seems to be one of the promising solutions in the required shift towards renewable materials.

Due to it’s good mechanical properties (hardness, dimensional stability) and aesthetical looks, the laminated and compressed MOSO bamboo products compete with A-quality hardwoods. In terms of annual yield as well as eco-costs and carbon footprint MOSO products score well compared to FSC hardwood [3], and therefore can be an eco-friendly, highly renewable alternative for (tropical) hardwood and thus mitigate the decrease of tropical forest area including it’s important ecoloigcal and biological functions.

Annex I Global Carbon Sequestration

Chemical background

The carbon sequestration stems from the photosynthesis in growing plants. The bio-chemical reaction of photosynthesis is:

$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$

Note: $C_6H_{12}O_6$ is sugar, transferred to cellulose ($C_6H_{10}O_5$) in further reactions

In this equation, carbon is stored in the plant, releasing part of the oxygen, and H_2O is split in H_2 (stored in the plant) and O_2 (released to the air).

When the plant is burned, it releases the CO_2 again, and heat is mainly produced by:

$2H_2 + O_2 \rightarrow 2H_2O$.

The global carbon cycle and the role of carbon sequestration in forests

A good overview of the global carbon cycle and sequestration of carbon in forests is depicted in Fig. 5 (source NASA Earth Science Enterprise). A short explanation of this Figure is given at the website of the NASA:

http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle4.html

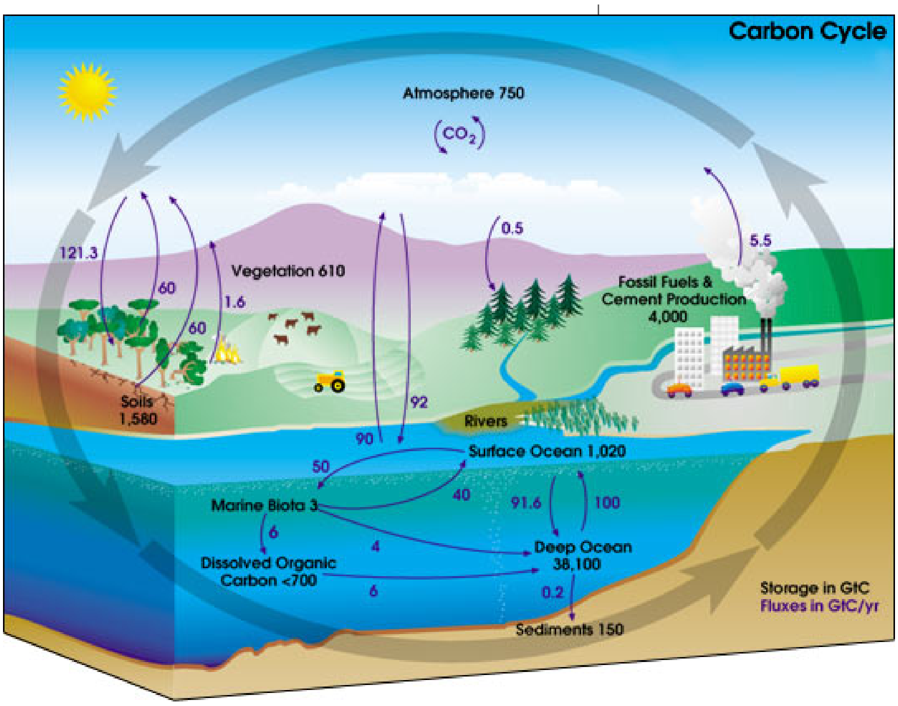

Figure 5. The global carbon cycle (Source NASA)

The issue is that the human role of the CO_2 emissions is three-fold:

a. 5.5 Gt carbon emissions per year caused by burning of fossil fuels
b. 1.6 Gt carbon emissions per year caused by deforestation in tropical and sub-tropical areas
c. 0.5 Gt carbon sequestration per year by re-growth of forests on the Northern Hemisphere.

So it can be concluded that the global carbon cycle can significantly be improved in the short term by:

a. less burning of fossil fuels
b. stopping deforestation
c. forest conservation by better management and wood plantations
d. afforestation (planting of trees on soils that have not supported forests in the recent past)

Carbon sequestration in wood from the perspective of designers, architects and engineers

Carbon sequestration is not an issue in LCA according to ISO 14040 and 14044, as was mentioned in chapter 3. However, the designer, architect and engineer might take the consequences of carbon sequestration into account.

It is far too simple to say that “application of wood in design and construction will lead to carbon sequestration, and therefore it will counteract global warming”. It depends on the type of wood.

There are two issues:

- carbon sequestration of wood in the forests
- carbon sequestration of wood in the houses, offices, etc. during the life time

One should realise that, if there is *no change* in the area of forests and *no change* in the volume of wood in houses, offices, etc., there is *no change* in sequestered carbon. Then, there is no effect on carbon emissions.

Only when the global area of forests is increasing, and when the total volume of wood in houses, offices, etc. is increasing, there will be extra carbon sequestration. This is the situation for European wood. See Fig. 6.

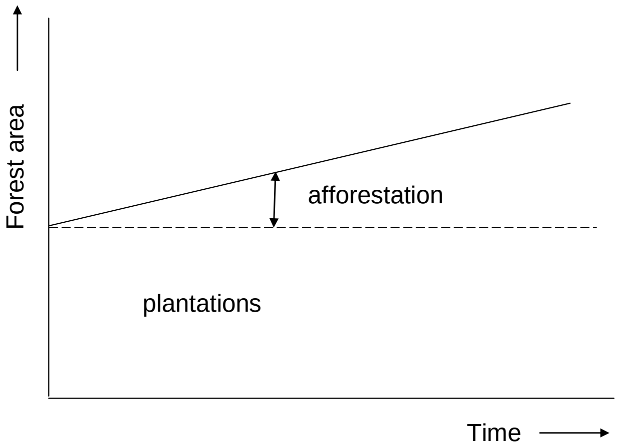

Figure 6. More demand of European wood leads to afforestation (extra forests) in Europe and more carbon sequestration

So, the issue is related with the *global growth* of production and demand of wood.

The situation is different for tropical hardwood. The demand for tropical hardwood is more than the supply from plantations (only 35% - 40% of FSC-wood is from plantations). This leads to deforestation, resulting in carbon emissions caused by less carbon sequestration. See Fig. 7.

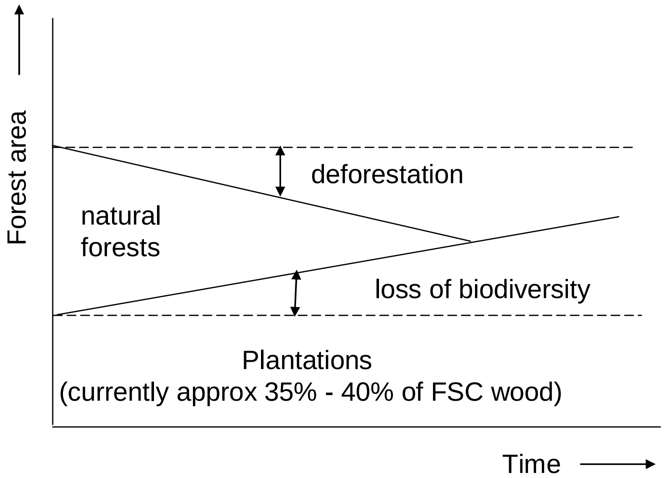

Figure 7. More demand of tropical hardwood leads to deforestation on the short term, and less carbon sequestration

The conclusion for the production side of wood is:

- extra demand of European wood leads to an increase in forest area, so more sequestered carbon
- (extra) demand of tropical hardwood leads to a decrease in forest area, so less sequestered carbon
- extra demand of bamboo, however, leads to an increase in forest area, since bamboo is not harvested from natural forests

The volume of wood in houses, offices, etc. is slowly rising on a global scale (because of increasing population), which is positive in terms of extra carbon sequestration. See Fig. 8. This volume, however, is generally low in comparison with the volume of standing trees in the forests (less than 25% of the wood ends up in housing).

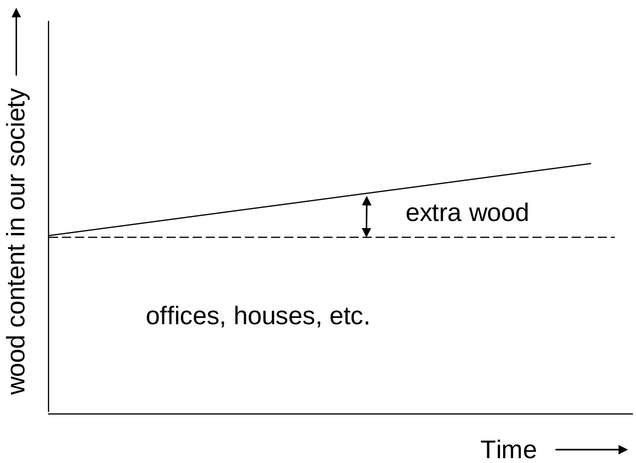

Figure 8. More applications of wood in the building industry leads to more carbon sequestration

The conclusion for designers, architects and engineers is that carbon sequestration is enhanced whenever more European wood and/or bamboo is applied. The application of tropical hardwood, however, is damaging carbon sequestration.

Note that carbon sequestration is not increasing per house which is built, but per extra house that is built above the number of houses that are required to replace discarded, old, houses (this is the reason that carbon sequestration cannot be modelled in LCA).

<u>The negative eco-costs of carbon sequestration in wood</u>
Although carbon sequestration should not be regarded as part of LCA, it might be related to eco-costs. These eco-costs are negative, since carbon sequestration is causing a carbon sink.
The negative eco-costs of (additional) carbon sequestration can be calculated as follows:
1 kg dry wood stores 0.45 kg C (ranging from 0.42 to 0.50)
0.45 kg C is equivalent to 1.65 kg CO_2
the marginal prevention costs of 1.65 kg CO_2 is 0.23 €
So the eco-costs of carbon sequestration in wood is 0.23 € per kg wood

These negative eco-costs apply to the *extra* wood which is “brought into the system” on a continuous, everlasting basis.

This Annex is a quotation of chapter 8.2 of [6]

Note: For bamboo the abovementioned data are slightly higher [7]:
1 kg dry bamboo stores 0.5 kg C
0.5 kg C is equivalent to 1.83 kg CO_2
1.83 kg CO_2 is equivalent to 0.247 € eco-costs

Annex II Eco-costs

General

Eco-costs are a measure to express the amount of environmental burden of a product on the basis of prevention of that burden. They are the costs which should be made to reduce the environmental pollution and materials depletion in our world to a level which is in line with the carrying capacity of our earth.
For example: for each 1000 kg CO_2 emission, one should invest € 135,- in offshore windmill parks (or other CO_2 reduction systems at that price or less). When this is done consequently, the total CO_2 emissions in the world will be reduced by 65% compared to the emissions in 2008. As a result global warming will stabilize. In short: “the eco-costs of 1000 kg CO_2 are € 135,-”.
Similar calculations can be made on the environmental burden of acidification, eutrophication, summer smog, fine dust, eco-toxicity, and the use of metals, fossil fuels and land (nature). As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (Life Cycle Costs). The eco-costs should be regarded as hidden obligations.
The eco-costs of a product are the sum of all eco-costs of emissions and use of materials and energy during the life cycle, “from cradle to cradle”.
The practical use of eco-costs is to compare the sustainability of several product types with the same functionality, applying LCA according to ISO 14040 and 14044. The advantage of eco-costs is that they are expressed in a standardized monetary value (€) which appears to be easily understood ‘by instinct’. Also the calculation is transparent and relatively easy, compared to damage based models which have the disadvantage of extremely complex calculations with subjective weighting of the various aspects contributing to the overall environmental burden.
The system of eco-costs is part of the bigger model of the EVR (Ecocosts Value Ratio, see Wikipedia).

Background

The eco-costs system was introduced in 1999 and published in 2000-2004 in the International Journal of LCA, and in the Journal of Cleaner Production. In 2007 the system was updated. The concept of eco-costs has been made operational with general databases, and is described at www.ecocostsvalue.com of the Delft University of Technology. The method of the eco-costs is based on the sum of the marginal prevention costs (end of pipe as well as system integrated) for toxic emissions, material depletion, energy consumption and transport, and conversion of land. For a visual display of the system see Fig. 9.

The classical way to calculate a “single indicator” in LCA is based on the damage of the emissions. Pollutants are grouped in “classes”, multiplied by a “characterisation” factor to account for their relative importance within a class, and totalised to the level of their “midpoint” effect (global warming, acidification, eutrophication, etc.). The classical problem is then to determine the relative importance of each midpoint effect. This is done by “normalisation“ (= comparison with the pollution in a country or a region) and "weighting" (= giving each midpoint a weight, to take the relative importance into account) by an expert panel.

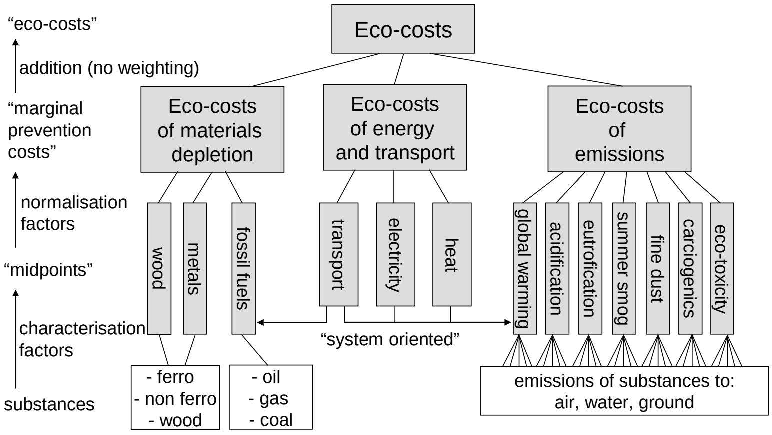

Figure 9. Structure of the eco-costs methodology

The calculation of the eco-costs is based on classification and characterisation tables as well (combining tables from IPCC, the Universities of Leiden and the University of Michigan), however has a different approach to the normalisation and weighting steps. Normalisation is done by calculating the marginal prevention costs for a region (i.e. the European Union), to reduce the pollution to the "no observable adverse effect level" (often the threshold level of a toxic substance). The weighting step is not required in the eco-costs system, since the total result is the sum of the eco-costs of all midpoints. The advantage of such a calculation is that the marginal prevention costs are related to the cost of the most expensive Best Available Technology which is required to meet the target, and the corresponding level of future Tradable Emission Rights.
Example: For reduction of CO_2 emissions to a sustainable level, the marginal prevention costs is the cost of replacement of coal fired power plants by windmill parks at the sea.
The eco-costs have been calculated for the situation in the European Union. It might be argued that the eco-costs are also an indication of the marginal prevention costs for other parts of the globe, under the condition of a level playing field for production companies.
A group of universities in Japan has developed a set of data for Japan as well ("abatement costs").

<u>Eco-costs 2007</u>

The method of the eco-costs has been updated in 2007. This method comprises tables of over 3000 emissions, and has been made operational by special database for Simapro, based on LCIs from Ecoinvent v2 and Idemat 2010 (over 5000 materials and processes), and a database for CES (Cambridge Engineering Selector). Excel look-up tables are provided at www.ecocostsvalue.com.
For emissions of toxic substances, the following set of multipliers is used in the eco-costs 2007 system:

- prevention of acidification 7.55 €/kg SO_x equivalent
- prevention of eutrophication 3.60 €/kg phosphate equivalent
- prevention of ecotoxicity 802 €/kg Zn equivalent

- prevention of carcinogens 33 €/kg PAH equivalent
- prevention of summer smog (respiratory diseases) 8.90 €/kg C_2H_4 equivalent
- prevention of fine dust 27.4 €/kg fine dust PM 2.5
- prevention of global warming (GWP 100) 0.135 €/kg CO_2 equivalent

Two groups of the abovementioned marginal prevention costs can be distinguished:

- eco-costs of human health = the sum of carcinogens, summer smog, fine dust
- eco-costs of ecosystems = the sum of acidification, eutrophication, ecotoxicity and global warming

The eco-costs of abiotic depletion is 0.7 €/kg for fossil fuels. The eco-costs of material depletion of tropical hardwood are based on the change of biodiversity before and after harvesting.
The characterization tables which are applied in the eco-costs 2007 system:

- IPCC 2007, 100 years, for greenhouse gasses
- CML-2, for acidification, eutrophication and summer smog (respiratory diseases)
- IMPACT 2002+, for aquatic eco-toxicity (inc. heavy metals), fine dust and carcinogens

Prevention costs versus damage costs

Prevention measures will decrease the costs of the damage, related to environmental pollution (e.g. damage costs related to human health problems in terms of QALYs). The savings which are a result of the prevention measures are of the same order of magnitude as the costs of prevention. So the total effect of prevention measures on our society is that it results in a better environment at virtually no extra costs, since costs of prevention and costs of savings will level out.

Discussion

There are many “single indicators” for LCA. Basically they fall in three categories:

- single issue
- damage based
- prevention based

The best known “single issue” indicator is the carbon footprint: the total emissions of kg CO_2, or kg CO_2 *equivalent* (taking methane and some other greenhouse gasses into account as well). The advantage of a single issue indicator is, that its calculation is simple and transparent, without any complex assumptions. It is easy as well to communicate to the public. The disadvantage is that is ignores the problems caused by other pollutants and it is not suitable for cradle to cradle calculations (because materials depletion is not taken into account).
The most common single indicators are damage based. This stems from the period of the 1990ties, when LCA was developed to make people aware of the damage of production and consumption. The advantage of damage based single indicators is, that they make people aware of the fact that they should consume less, and make companies aware that they should produce cleaner. The disadvantage is that these damage based systems are very complex, not transparent for others than who make the computer calculations, need many assumptions, and suffer from the subjective weighting procedure at the end. Communication of the result is not easy, since the result is expressed

in “points” (attempts to express the results in money were never very successful, because of methodological flaws).

Prevention based indicators, like the system of the eco-costs, are relatively new. The advantage, in comparison to the damage based systems, is that the calculations are relatively easy and transparent, and that the results can be explained in terms of money and in measures to be taken. The system is focused on the decision taking processes of architects, business people, designers and engineers. The disadvantage is that the system is not focused on the fact that people should consume less.

Four operational databases

In line with the policy of the Delft University of Technology to bring LCA calculations within reach of everybody, open access databases are made available.

To support the Fast Track LCA calculations of this Guide, excel tables are available on the internet. These excel tables contain the eco-costs data only (the total as well as the midpoints), since the underlying LCI data are protected with copyright (of Ecoinvent).

Experts on LCA who want to use the eco-costs as a single indicator, can download the full database for Simapro (the Eco-costs Method as well as the Idemat LCIs), free of charge, provided that they have licences for the Simapro software and for Ecoinvent LCIs.

Engineers, designers and architects can have databases, free of charge, for CES and ArchiCAD software, provided that they have a licence for the software.

So, the following databases are available:

- excel tables on the website www.ecocostsvalue.com, tab data (for designers, engineer, architects, business managers, and students, to be used for the Fast Track LCA calculations of this guide):
    - a table with data on emissions and materials depletion (more than 3000 substances)
    - a table on products and processes, based on Ecoinvent LCIs and Idemat LCIs[5] (more than 5000 lines)
- an import Simapro database for the method and an import database for Idemat LCIs (software for LCA specialists, only available for Ecoinvent licence holders)
- a database for Cambridge Engineering Selector, Level 2 (software for designers and engineers, available via www.grantadesign.com)
- a dataset for ArchiCAD (3D-BIM software for architects, available via www.kubusinfo.nl)

This Annex is a quotation of Wikipedia at http://en.wikipedia.org/wiki/Eco-costs

[5] The Idemat LCIs are based the Ecoinvent LCIs. The reasons to make this extra set of LCIs were:
- extra LCIs of alloys (frequently used by designers and engineers)
- a correction of the “market mix” data of metals (Ecoinvent data are outdated)
- extra LCIs of wood types (softwood types as well as hardwood types)
- a specific selection of LCIs for electricity, heat and transport
- extra LCIs of End of Life (combustion, waste incineration, recycling)
- the Danish food LCIs based on Ecoinvent (instead of ETH data)
- eliminate double counting (of CO_2 and fossil fuels) of electricity in eco-costs

Annex III Yield of land and social issues

Land-use

Yield of land is a specific aspect of sustainability, related with the fact that land is becoming scarce, especially when current materials (metals, fossil fuels) will be replaced by renewable materials like wood and non wood forest products like bamboo. This is the notion that the consumption of people is to be supported by the production of land: more consumption leads to less nature. See Fig. 10.

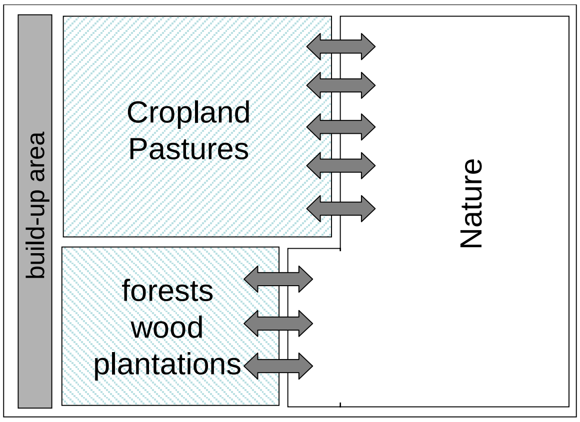

Figure 10. The yield of land must be as high as possible to achieve a minimum ecological footprint

A useful indicator for the scarcity of land is the Ecological Footprint, which is defined as "a measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates using prevailing technology and resource management practices" [11].

In 2003 the Ecological Footprint was 14.1 billion global hectares, whereas the global productive area is 11.2 billion hectares. This means that man is currently consuming more than 1.25 times the amount of resources the earth can produce according to this calculation method. So, renewable materials with a high yield of land are required.

Bamboo seems to be a good solution:

- it can grow in areas which are non-productive at this moment (e.g. eroded slopes)
- it is a fast growing material (it has a high yield)
- its root structure stays intact after harvesting, generating new shoots

The calculations below for both wood and bamboo are based on numbers for average plantation sites and processing facilities. Note that, depending on geographical and climatic circumstances (e.g. soil, precipitation, elevation, etc.), yields may be considerably higher or lower, so data is only meant to be indicative of the average yields of the specific species in question.

The annual yields have been calculated for the giant bamboo species Moso from China, and Guadua from Latin America. Guadua is bigger than Moso. It may reach heights up to 20-25 meters and diameters up to 22 cm. Like most bamboos, it reaches its final height in the first half year of its growth (with a growing speed up to 21 cm a day), and will come to maturity in the following 4-5 years. Guadua, like other tropical bamboo types, has a higher yield (approx. a factor 2) than Moso from the Chinese subtropical area of Zhejiang. However, the biodiversity of areas where Guadua grow is a factor 2,5 higher than the biodiversity of the Zhejiang area. Therefore, from the point of view of saving nature, it seems wiser to expand Moso plantations rather than Guadua plantations for future demand of bamboo products.

The maximum annual yield of bamboo and wood may differ depending on the kind of semi-finished materials produced. Calculations have been made on 3 scenarios (qualities), depicted in Fig. 11:

A. High value products (sawn timber, veneer, laminated bamboo board, compressed bamboo, taped mats)
B. Medium value products (MDF, chipboard)
C. For combustion as an energy source and for pulp (bamboo compared with eucalyptus)

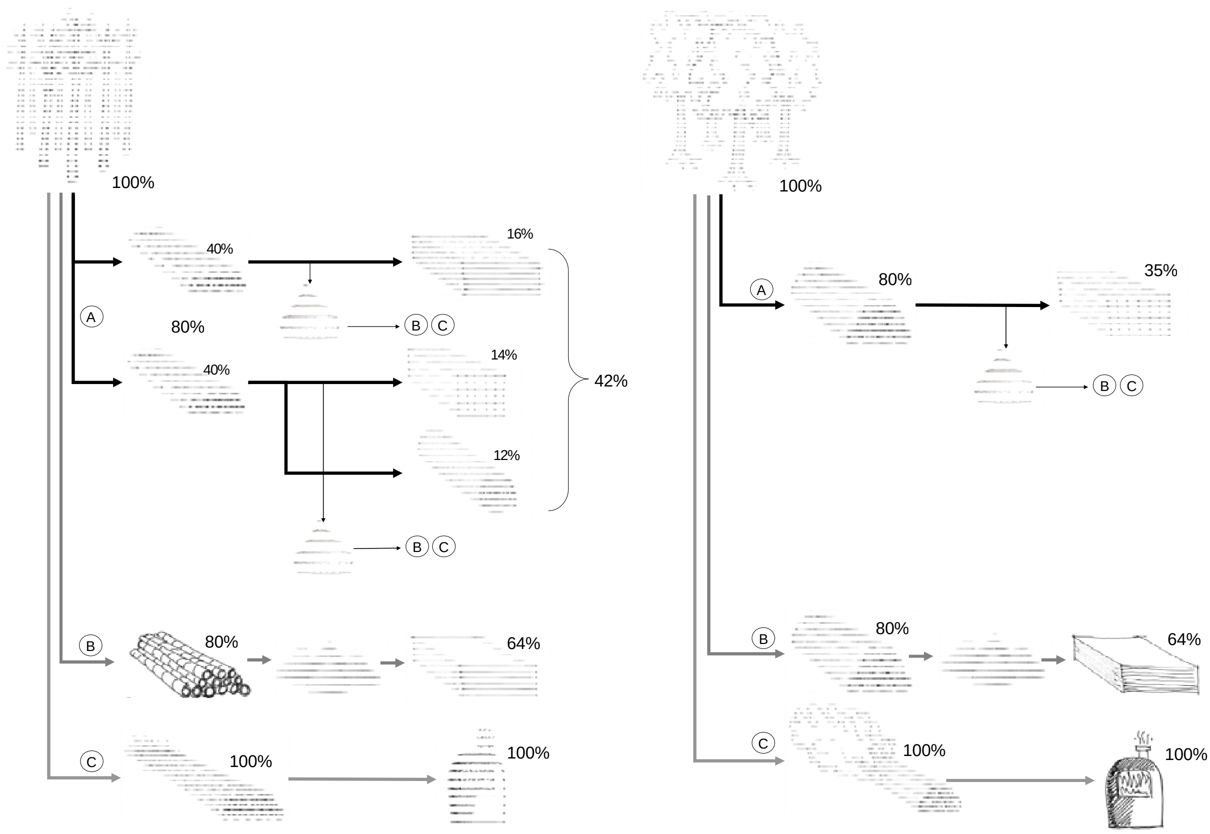

Figure 11: Efficiency during the conversion of bamboo (left) and wood (right) resources to semi-finished materials for 3 scenarios, A-quality, B-quality and C-quality; all percentages related to harvestable standing volume (100% [4]

The comparison of the A-quality scenario is made between bamboo, Teak, Oak and (modified) Radiata Pine, see Fig. 12.

Moso has a slightly higher annual yield in terms of A-quality materials compared to fast growing and early harvested Teak (so-called baby Teak), which is one of the fastest growing hardwood species that is used in high end interior decoration (e.g. flooring). Radiata Pine is known as one of the fastest growing softwood species available, however, unless modified (e.g. acetylation), is less suitable for high end applications.

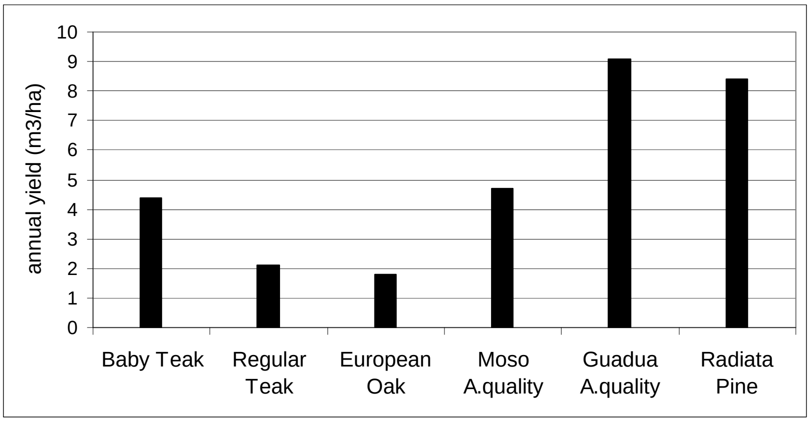

Figure 12: The annual yield in m3/ha A-quality semi-finished materials, sourced from plantations [2].

A general benefit of bamboo as a reforesting crop compared to wood, is the short establishment time of a bamboo plantation. While the establishment time of a plantation of tropical giant bamboo species such as Moso and Guadua to come to maturity will not take longer than 10 years, the establishment time of a wood plantation to maturity may range from 15 years (Eucalyptus), 30 years (baby Teak), 70 years (regular Teak) to 80 years (European Oak). This means that a bamboo plantation will be able to deliver the annual yield of a mature plantation faster than any wood species can.
Note that in case of sustainable harvesting, the root structure stays intact, so the bamboo stems grow from new shoots.

In terms of annual yield in terms of the end product, combined with the biodiversity of the area, it can be concluded that bamboo is one of the best performing renewable resource around, if used as “A-quality” semi-finished material in a durable application (e.g. for housing, and use outdoors).

<u>Social aspects</u>
An important sustainability issue of bamboo products, is the social aspect of the production system. An advantage of laminated bamboo board and compressed bamboo (e.g. decking) is that the value of the product is added locally. Therefore, these MOSO bamboo materials can make a good contribution in terms of local employment. A well managed bamboo industry may combine the P of People, the P of Planet, and the P of Profit, from the Triple P Model.

In this Annex, pieces of text are quoted of the publication on bamboo in JCP [2]

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