Cradle to Grave Carbon Footprint Assessment

for Accoya® Wood and its applications

Part 1: Window Frame

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1. Background

In 2010, the author executed a full peer reviewed LCA study for Accoya wood [Ref. 1] according to ISO 14040/44, which is available on the Accoya website (http://www.accoya.com/wp-content/uploads/2011/05/Life-cycle.pdf). After the study, Accsys Technologies ("Accsys"), made several modifications to the production process to further improve the efficiency and reduce the environmental impact of the acetylation process. After executing a new greenhouse gas or carbon footprint assessment for Accoya wood by the company Verco, UK in 2012 [Ref. 2], based on a cradle to gate scenario, Accsys requested the author to extend this assessment following relevant standards, to a cradle to grave scenario, i.e. including use-phase and end of life considerations.

Like for the LCA study, the reasons for carrying out this study are twofold:

1. for the management of Accsys Technologies: to establish the strengths and the weaknesses of their product and the production process in terms of greenhouse gas emissions.
2. for external parties: to communicate the environmental position of Accoya Wood in relation to the alternative materials for applications in the building industry.

This report presents the results of the cradle to grave carbon footprint assessment. It is not meant as a standalone report; for additional information is often referred to other reports and literature that are publicly available.

2. Scope & Resources

The scope of this carbon footprint study is the following product system with various kinds of materials:

- One window frame, size 1,65 x 1,3 m
- Materials: Accoya (Scots Pine, Radiata Pine, Red Alder, European Alder), Meranti (sustainably sourced), Meranti (unsustainably sourced), Aluminium, PVC / steel
- Functional unit: good condition over functional lifespan (Accoya 50 years, Meranti 35 years, Aluminium 50 years, PVC 35 years)
- Output of the calculations expressed in kgCO2eq / window frame

Assumptions are largely the same as the 2010 LCA study [1], with some modifications:

- Cradle to gate carbon footprint figures adopted from Verco [2].
- Accoya variations are based on Radiata Pine, USA Red Alder, European Alder and Scots Pine. The first three species are already commercially available on the market, the latter is being tested and is expected to become commercially available in the near future.
- Instead of a fixed lifespan for all material alternatives, the functional life of the window frame in the different materials has been assumed instead of a fixed lifespan for all alternatives (as was done in the LCA study). This was done to better compare the various material alternatives including End of Life considerations and the effect of carbon sequestration over a 100 year time frame, following ILCD section 7.4.3.7.3 and 14.5 [Ref. 3], PAS 2050 section 6.4.9.3 and 8.1 [Ref. 4] and the EN norm under development EN16449.

The system boundary is determined as follows:

- included in cradle to gate:
  wood (including stand establishment, forest management, harvesting, drying (to 12%), saw mill, transport from Forests - Rotterdam)
  energy and consumables used in acetylation plant in Arnhem
  embodied emissions in materials / ingredients for the acetylation process
  transport of wood and chemicals to Arnhem
  waste from sawmill and acetylation
  For details please refer to Verco [2]
- included in use phase:
  transport Arnhem - site
  maintenance
- included in End of Life (EoL):
  transport site - EoL destination
  EoL treatment (e.g. combustion, land fill, etc.)
- excluded (since it is assumed to be the same for all materials):
  assembling of components
  marketing and distribution activities of components
  construction activities on site

The LCI data, required for the calculations are from the Ecoinvent v2.2 database [Ref. 5] of the Swiss Centre for Life Cycle Inventories, and the Idemat 2012 database [Ref. 6] of the Delft University of Technology. The Idemat LCIs are based on Ecoinvent LCIs and some data of the Cambridge Engineering Selector [Ref. 7].

The system has two co-products:

- waste wood from saw mills, planing, profiling, etc
- acetic acid from acetylation of wood

Both types of co-products are dealt with by the so-called “system expansion” and “credits” for “substitution” in LCA. For acetic acid this means that the eco-burden resulting from the “avoided acetic acid production elsewhere” (as “market mix”) is subtracted from the total eco-burden of the Accoya Wood production chain. This is according to ISO 14044 [Ref. 8], section 4.3.4.2. step 1 point 2.
Wood waste of the saw mill (bark, chips and dust) is used for pulp, wood products and combustion. In this assessment, this flow is calculated as 100% combustion, transformed into energy output, applying the Lower Heating Value of the material. This is according to section 4.3.3.1. of ISO 14044. This energy output substitutes heat from oil (leading to a “eco-burden credit” for the avoided use of oil).
In the End of Life stage there are 3 forms of allocation where “system expansion” is applied:

- combustion of wood, applying the Lower Heating Value for the output of electricity from a municipal waste incinerator (with an overall efficiency of 25%)
- recycling of PVC, applying “system expansion” of the recycling step of PVC: the recycled PVC is substituting virgin PVC, leading to a “net credit of recycling” (= the eco-burden from the recycling activity minus the eco-burden of virgin PVC)
- for recycling of steel and aluminium, the “net credit of recycling” approach is used as well, however, only for the “virgin” part of the input of these materials, avoiding double counting of recycling (for the input, the “market mix” is taken, being the mix of recycled and virgin materials currently on the market).

For further explanation, see also www.ecocostsvalue.com FAQs question 2.4, 2.5, 2.6, and 2.7.
For comprehensive information on the subject of recycling and energy recovery, see General Guidance Document for Life Cycle Assessment (LCA) of the European Commission (ILCD) [3], Section 14, “consequentional modelling”.

The findings of this report apply to Western Europe. The transport scenarios which are used are specific to the manufacturing plant in Arnhem and a building site within a radius of 100 km. When the building site is at a further distance, extra transport must be added to the results as shown in this report.
It must be mentioned that this carbon footprint is characterized by the fact that most emissions are outside the production plant in Arnhem, so not in control of Accsys. This implies that the carbon footprint is heavily dependent on the data quality of third parties. It was decided to largely apply the data of the Ecoinvent v2.2 database from the Swiss Centre for Life Cycle Inventories and the Idemat

2012 database of the Delft University of Technology. The Idemat database has been built on Ecoinvent data of sub-processes, and is available as “open access” for organisations which have an Ecoinvent licence. Although the data quality of Ecoinvent v2.2 is not perfect, it is the best there is at this moment. For reasons of transparency, the LCIs which have been used are specified by its formal names, so the reader can check the data quality at the Swiss Centre for Life Cycle Inventories and the Idemat database.

3. Calculations

In this chapter per process step, the related greenhouse gas emissions are calculated for the various material alternatives.

Carbon footprint (cradle to gate) of input materials

For Accoya and Meranti the figures from the Verco report were adopted as these are based on the most recent production runs for Accoya. Note that the Idemat 2012 data on Accoya are 16% lower, and for Meranti 22% higher, which would result in more favourable results for Accoya. For PVC, Steel and Aluminium the Idemat 2012 figures were taken. These figures have a lower carbon footprint compared to the figures provided in the Verco report (derived from Bath University, 2011). The reason is that Bath University took the average CO2 data from journal papers, whereas Idemat 2012 has the LCIs of Ecoinvent V2.2 as basis which is commonly perceived as the best documented LCA database.

<u>Carbon footprint per kg material, cradle to gate</u>

- Accoya Radiata Pine: 342 kgCO2 eq / m3 (Verco), density 510 kg/m3 = **0.67 kgCO2eq / kg**
- Accoya Scots Pine: 140kgCO2 eq / m3 (Verco), density 564 kg/m3 = **0.25 kg CO2eq / kg**
- Accoya European Alder: 204 kgCO2 eq / m3 (Verco), density 537kg/m3 = **0.38 kgCO2eq / kg**
- Accoya Red Alder USA: 293 kgCO2 eq / m3 (Verco), density 515kg/m3 = **0.57 kgCO2eq / kg**
- Red Meranti (sustainably sourced): 359 kgCO2 eq / m3 (Verco), density 710 kg/m3 = **0.51 kg CO2 eq/kg**
- Red Meranti (unsustainably sourced): 4905 kgCO2 eq / m3 (Verco), density 710 kg/m3 = **6.91 kg CO2 eq/kg**
- Aluminium: “Idemat2012 Aluminium trade mix (45% prim 55% sec)”: **6.26 kg CO2eq/kg aluminium**
- PVC / Steel:
    - Idemat 2012 PVC: **2.01kg CO2eq/kg PVC**
    - Idemat 2012 Steel beams, pipes, sheet (from market mix): **1.89 kg CO2eq/kg steel**

<u>Kilograms material per window frame</u>

For the material use in the window frame the comparative study executed by Richter et al [Ref. 9] was used as point of departure, based on a 1650 x 1300 mm window frame. The exact amounts of material used in the window frame of the Richter et al study have been adopted from the LCA [1].
Applying the densities of the various wood species from the Verco report, the weight of the window frames in the various wood species was calculated.

- The total volume of wood / Accoya which is used in the window is 0.057 m3. This is based on a processing efficiency of (see p16 LCA): 1/0.935 (shortening) * 1/0.89 (profiling) = 16%. Thus originally 0.068 m3 of input timber was required (0.057 * 1/0.935 * 1/0.89 = 0.068m3)
- Accoya Radiata Pine: 0.068m3 * density 510 kg/m3 = **34.9 kg**
- Accoya Scots Pine: 0.068m3 * density 564 kg/m3 = **38.6 kg**

- Accoya European Alder: 0.068m3 * density 537kg/m3 = **36.8 kg**
- Accoya Red Alder USA: 0.068m3 * density 515kg/m3 = **35.3 kg**
- Red Meranti: 0.068m3 * density 710 kg/m3 = **48.6 kg**
- PVC / steel: The Richter et al. study provides the weight of the frame which comprises of **25.6 kg PVC** + **16.1 kg steel**.
- Aluminium: derived from the LCA study: **17.7 kg**

Carbon footprint per window frame (at factory gate)

- Accoya Radiata Pine: 34.9 kg * 0.67 kg CO2 eq/ kg = **23.4 kg CO2eq**
- Accoya Scots Pine: 38.6 kg * 0.25 kg CO2eq/kg = **9.6 kg CO2eq**
- Accoya European Alder: 36.8 kg * 0.38 kgCO2eq / kg = **14.0 kg CO2eq**
- Accoya Red Alder USA: 35.3 kg * 0.57 kgCO2eq / kg = **20.1 kg CO2eq**
- Red Meranti (sustainably sourced): 48.6 kg * 0.51 kg CO2 eq/kg = **24.6 kg CO2eq**
- Red Meranti (unsustainably sourced): 48.6 kg * 6.91 kg CO2 eq/kg = **336.0 kg CO2eq**
- Aluminium: 17.7 kg * **6.26 kg CO2eq/kg = 110.8 kg CO2eq**
- PVC / Steel:
    - PVC: 25.6 kg * 2.01 kg CO2 eq/kg = **51.5 kg CO2eq**
    - Steel: 16.1 kg * 1.89 CO2 eq/kg = **30.4 kg CO2eq**
    - Total PVC / steel: **81.9 kg CO2eq**

Transport to joinery factory

- Transport to planing mill: 100 km “Idemat2012 Truck+container, 28 tons net”: 0.070 kg CO2eq/tonkm
- For the wood scenarios 0.068 m3 input timber is required to produce the 0.057 m3 window frame profiles
- Accoya Radiata Pine: 3.49 ton.km (34.9 kg * 100 km) * 0.07 CO2eq/ton km = **0.24 kg CO2eq**
- Accoya Scots Pine: 3.86 ton.km * 0.07 CO2eq/ton km = **0.27 kg CO2eq**
- Accoya European Alder: 3.68 ton.km * 0.07 CO2eq/ton km = **0.26 kg CO2eq**
- Accoya Red Alder USA: 3.53 ton.km * 0.07 CO2eq/ton km = **0.25 kg CO2eq**
- Red Meranti: 4.86 ton.km * 0.07 CO2eq/ton km = **0.34 kg CO2eq**

Assuming no significant material losses during processing for PVC, aluminium and steel, the following transport emissions can be calculated:

- Aluminium: 1.77 tonkm * 0.07 CO2eq/ton km = **0.12 kg CO2eq**
- Steel / PVC: 4.17 tonkm * 0.07 CO2eq/ton km = **0.29 kg CO2eq**

Emissions during processing to window frame

Profiling

- Timber profiling: Electricity processing in mill “sawn timber, hardwood, planed, kiln dried, u=10%, at plant/m3/RER” 30.8 kWh/m3 * 3.6 = 110.9 MJ/m3, in case of a processing efficiency for planing of 12%. For profiling to window frames, material losses (and thus planing energy) are assumed to be proportional higher: 16%/12% * 110.9 = 147.9 MJ/m3 wood

- “Electricity, medium voltage, production UCTE, at grid” = 0.148 kg CO2eq/MJ
- Accoya (all variations) and Meranti: 147.9 MJ / m3 wood * 0.148 kg CO2eq/MJ = 21.9 kgCO2eq / m3 wood profiled * 0.057 m3 wood = **1.25 kgCO2eq**
- Aluminium, “Idemat 2012 Extruding alum” = 0.73 kgCO2eq/kg aluminium extruded * 17.7 kg = **12.9 kgCO2eq**
- PVC: “Idemat 2012 Extrusion PVC” = 0.392 kg CO2eq / kg PVC extruded: * 25.6 kg = **10.04 kgCO2eq** Note that steel profiling was already included in the carbon footprint of the input material above.

Coating per window frame

The amount of coating applied to the window frames has been derived from the Accoya LCA. As the LCA study was based on a 75 year time frame, for the wood frames in this study, the numbers from the LCA were adapted to match the lifespan of Accoya window frame (50 yrs) and Meranti window frame (35 yrs).

Coating systems:

- for various Accoya variations white acrylic 150-180 μm, plus 60 μm every 5 years[1]
- for Meranti white acrylic 150-180 μm, plus 60 μm every 6 years
- for Aluminium powder coating system, 80 μm (total surface approx. 2.2 m2)
- for PVC (with steel) powder coating system, 80 μm (total surface approx. 2.2 m2)

- Accoya (all variations): “Acrylic varnish, 87.5% in H2O, at plant/RER S” = 1.872 kg CO2eq / kg varnish. For Accoya this related to 0.65 kg (production) + 50/75 * 0.83 kg (maintenance) = 1.20 kg acrylic varnish * 1.872 kg CO2eq = **2.25 kgCO2 eq**
- Meranti: “Acrylic varnish, 87.5% in H2O, at plant/RER S” = 1.872 kg CO2eq / kg varnish. For Meranti 0.93 kg (production) + 35/75 * 0.79 kg (maintenance) = 1.30 kg acrylic varnish * 1.872 kg CO2eq = **2.43 kgCO2 eq**
- Aluminium: “Powder coating, aluminium sheet/RER S” = 3.781 kg CO2eq / m2 aluminium * 2.2 m2 = **8.31 kg CO2eq**
- PVC / steel: “Powder coating, steel/RER S” = 4.57 kg CO2eq / m2 PVC /steel * 2.2 m2 = **10.05 kg CO2eq**

Transport to building site

- Transport to building site: 100 km “Idemat2012 Truck+container, 28 tons net” 0.070 kg CO2eq/tonkm

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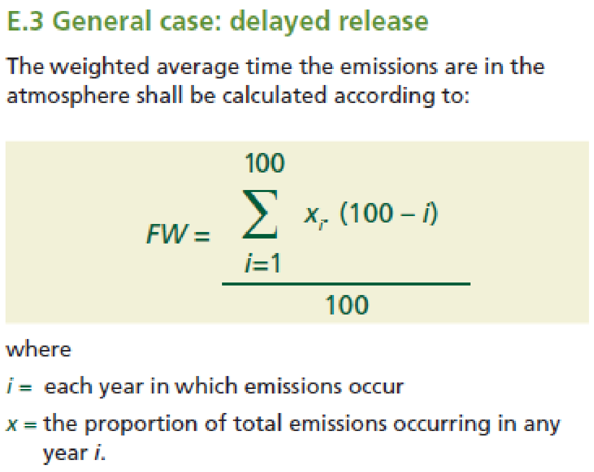
[1] Note that Accsys has a different maintenance advice for Accoya: 35 μm every 8 years. On request of the peer reviewers of the LCA study, however, the same painting system was applied to all wooden frames. Note that this difference in approach hardly affects the output of the total carbon footprint.

- For the wood variations the weight to be transported was calculated based on a volume of 0.057 m3 in the final window frame and the densities used in the Verco report.
- Accoya Radiata Pine: 2.93 ton.km * 0.07 CO2eq/ton km = **0.20 kg CO2eq**
- Accoya Scots Pine: 3.24 ton.km * 0.07 CO2eq/ton km = **0.23 kg CO2eq**
- Accoya European Alder: 3.08 ton.km * 0.07 CO2eq/ton km = **0.22 kg CO2eq**
- Accoya Red Alder USA: 2.96 ton.km * 0.07 CO2eq/ton km = **0.21 kg CO2eq**
- Red Meranti: 4.08 ton.km * 0.07 CO2eq/ton km = **0.29 kg CO2eq**
- Aluminium: 1.77 ton.km* 0.07 CO2eq/ton km = **0.12 kg CO2eq**
- PVC / steel: 4.17 ton.km* 0.07 CO2eq/ton km = **0.29 kg CO2eq**

Carbon sequestration per window frame during use phase

Via the photosynthesis process, trees absorb CO2 during growth which is locked in the wood until it rots or is burnt at the end of its useful life – this temporary “lock up” is known as carbon sequestration. According to PAS 2050 [4] and ILCD [3], the CO2 locked into the wood during the useful life in an application may be included in carbon footprint calculations as a negative CO2e value, which can be calculated for example using the formula in annex C in the PAS 2050 guidelines (freely downloadable from www.bsigroup.com), see also below.



E.3 General case: delayed release

The weighted average time the emissions are in the atmosphere shall be calculated according to:

$$FW = \frac{\sum_{i=1}^{100} x_i \cdot (100 - i)}{100}$$

where

i = each year in which emissions occur

x = the proportion of total emissions occurring in any year i.

Therefore for wood the following credits can be calculated, based on the carbon sequestration figures in appendix 2 of the Verco report (for Accoya).

- Accoya Radiata Pine: 806 kg CO2/m3 x 0.5 (formula in annex C of PAS 2050 based on 50 yrs lifespan) = -403 kg CO2eq / m3 Accoya * 0.057 m3 = **-22.97 kg CO2eq**
- Accoya Scots Pine: 891 kg CO2/m3 x 0.5 (formula in annex C of PAS 2050 based on 50 yrs lifespan) = -445.5 kg CO2eq / m3 Accoya * 0.057 m3 = **-25.39 kg CO2eq**
- Accoya EU Alder: 849 kg CO2/m3 x 0.5 (formula in annex C of PAS 2050 based on 50 yrs lifespan) = -424.5 kg CO2eq / m3 Accoya * 0.057 m3 = **-24.20 kg CO2eq**
- Accoya Red Alder USA: 814 kg CO2/m3 x 0.5 (formula in annex C of PAS 2050 based on 50 yrs lifespan) = -407 kg CO2eq / m3 Accoya * 0.057 m3 = **-23.20 kg CO2eq**

- Meranti: density 710 kg/m3 x 50% C content = 355 x 44/12 = 1301.7 kg CO2/m3 x 0.35 (formula in annex C of PAS 2050 based on 35 yrs life span) = -455.6 kg CO2eq / m3 Meranti* 0.057 m3 = **-25.97 kg CO2eq**

Transport to disassembling / sorting site and landfill / waste incinerator / recycling site
For the wood variations was assumed that all wood will be used for energy production in a biomass energy unit during End of Life (EoL), which is common practice in Western Europe. For PVC, aluminium and steel the industry average figures for End of Life have been assumed with respect to recycling, landfill, incineration. For both transport legs (building site to disassembling site, and disassembling to land fill / bioenergy plant) a distance of 100 km was assumed.

- Transport to building site: 200 km “Idemat2012 Truck+container, 28 tons net” 0.070 kg CO2eq/tonkm
- Accoya Radiata Pine: 5.86 ton.km * 0.07 CO2eq/ton km = **0.41 kg CO2eq**
- Accoya Scots Pine: 6.48 ton.km * 0.07 CO2eq/ton km = **0.45 kg CO2eq**
- Accoya European Alder: 6.17 ton.km * 0.07 CO2eq/ton km = **0.43 kg CO2eq**
- Accoya Red Alder USA: 5.91 ton.km * 0.07 CO2eq/ton km = **0.41 kg CO2eq**
- Red Meranti: 8.15 ton.km * 0.07 CO2eq/ton km = **0.57 kg CO2eq**
- Aluminium: 3.54 ton.km* 0.07 CO2eq/ton km = **0.25 kg CO2eq**
- PVC / steel: 8.34 ton.km* 0.07 CO2eq/ton km = **0.58 kg CO2eq**

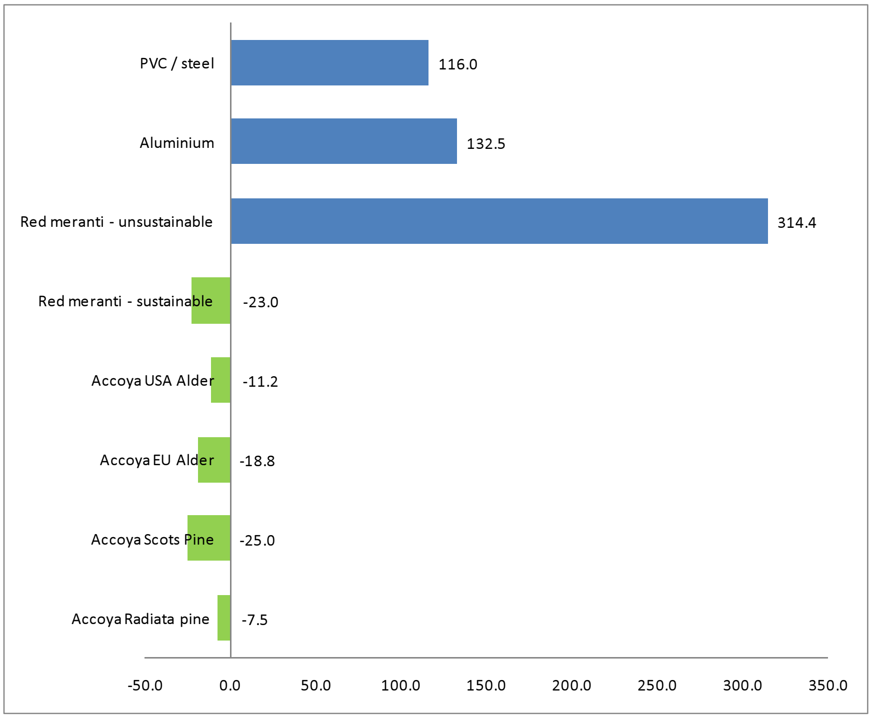
End of Life phase
As mentioned earlier, it is assumed that the wood will be incinerated at End of Life to produce electricity. Following ISO 14044, a credit can be allocated for the substitution of fossil fuels for both wood species in this scenario. For PVC (incineration), aluminium and steel the recycling credit has already been taken into account in the carbon footprint of the input material (see above) based on an industry average. Note that according to PAS 2050 [4] and ILCD [3] the 100 years time frame of 1% linear discounting per year is to be applied for wood. The electricity credits will be allocated after the service life of the material (delayed emissions), applying the same linear discounting system of 1% per year, to avoid double counting of credits (carbon sequestration).

- For wood the following assumptions were made: Heat of combustion 14.98 MJ/kg for Accoya (Accsys internal data), 17.7 MJ/kg for Meranti (MC 12%) [7]; efficiency biomass electricity plant 32% [10]; “Idemat 2012: Electricity, medium voltage, production UCTE, at grid” per production of 1 m3 wood, = 0.148 kg CO2eq/MJ
- Accoya Radiata Pine: Amount of electricity produced upon incineration (credit): 14.98 MJ/kg * 510 kg/m3 *.32 = -2444.7 MJ/m3 * 0.148 kg CO2eq / MJ = -361.8 kg CO2eq / m3 * 0.068m3 (as also the wood waste during profiling will be incinerated) = -24.6 * 0.5 (remaining 50 years after use phase) = **-12.30 kg CO2eq**

- Accoya Scots Pine: Amount of electricity produced upon incineration (credit): 14.98 MJ/kg * 564 kg/m3 *.32 = -2703.6 MJ/m3 * 0.148 kg CO2eq / MJ = -400.1 kg CO2eq / m3 * 0.068m3 (as also the wood waste during profiling will be incinerated) = -27.2 * 0.5 (remaining 50 years after use phase) = **-13.60 kg CO2eq**
- Accoya EU Alder: Amount of electricity produced upon incineration (credit): 14.98 MJ/kg * 537 kg/m3 *.32 = -2574.2 MJ/m3 * 0.148 kg CO2eq / MJ = -381.0 kg CO2eq / m3 * 0.068m3 (as also the wood waste during profiling will be incinerated) = -25.9 * 0.5 (remaining 50 years after use phase) = **-12.95 kg CO2eq**
- Accoya Red Alder USA: Amount of electricity produced upon incineration (credit): 14.98 MJ/kg * 515 kg/m3 *.32 = -2468.7 MJ/m3 * 0.148 kg CO2eq / MJ = -365.4 kg CO2eq / m3 * 0.068m3 (as also the wood waste during profiling will be incinerated) = -24.8 * 0.5 (remaining 50 years after use phase) = **-12.42 kg CO2eq**
- Meranti: Amount of electricity produced upon incineration (credit): 17.7 MJ/kg * 710 kg/m3 *.32 = -4021.4 MJ/m3 * 0.148 kg CO2eq / MJ = -595.2kg CO2eq / m3 * 0.068m3 (as also the wood waste during profiling will be incinerated) = -40.5 * 0.65 (remaining 65 years after use phase) = **-26.31 kg CO2eq**
- PVC: “Idemat2012 Polyvinylchloride (tpPVC) waste incineration with electricity”: 0.772 kg CO2/kg * 25.6 kg = 19.76 kg * 0.65 (delayed emissions in the remaining 65 years after use phase) = **12.84 kg CO2eq** (Note that the CO2 emissions from combustion in a municipal incinerator are more than the credits for electricity production).

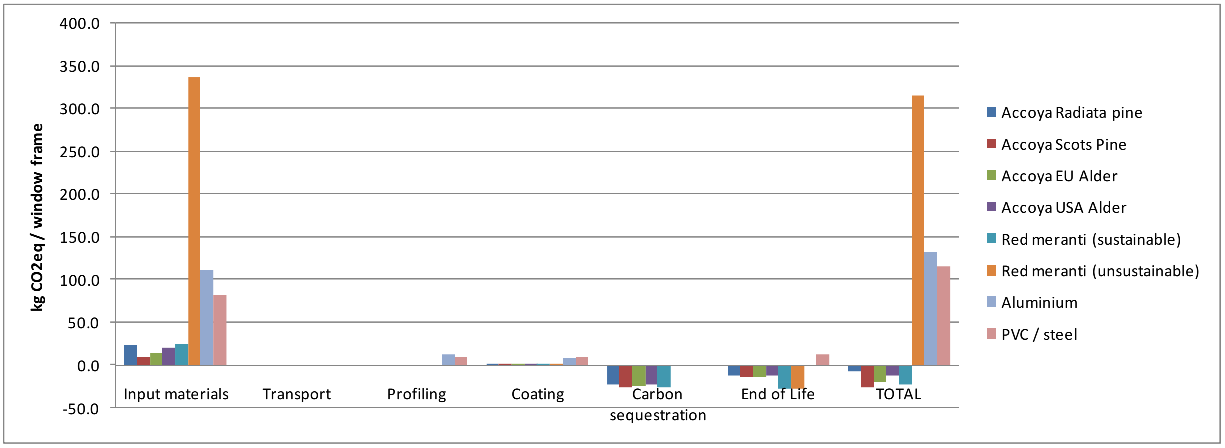
4. Results

Adding up all the calculations for the several life cycle steps in chapter 3, the total result can be defined. These are shown in the figures and table below, first on overall basis, then per process step over the life cycle of the window frame.



Greenhouse gas emissions (cradle to gate) in kg CO2 eq per window frame in various material alternatives

Material alternative	**Input materials**	**Transport**	**Profiling**	**Coating**	**Carbon sequestration**	**End of Life**	**TOTAL**
Accoya Radiata pine	23.43	0.86	1.25	2.25	-22.97	-12.30	**-7.49**
Accoya Scots Pine	9.59	0.95	1.25	2.25	-25.39	-13.60	**-24.96**
Accoya EU Alder	13.97	0.90	1.25	2.25	-24.20	-12.95	**-18.77**
Accoya USA Alder	20.07	0.87	1.25	2.25	-23.20	-12.42	**-11.18**
Red meranti (sustainable)	24.59	1.20	1.25	2.25	-25.97	-26.31	**-22.99**
Red meranti (unsustainable)	335.98	1.20	1.25	2.25		-26.31	**314.37**
Aluminium	110.80	0.50	12.90	8.31			**132.51**
PVC / steel	81.89	1.17	10.04	10.05		12.84	**115.98**



Greenhouse gas emissions per process step for a window frame in various material alternatives

From the graphs several conclusions can be made:

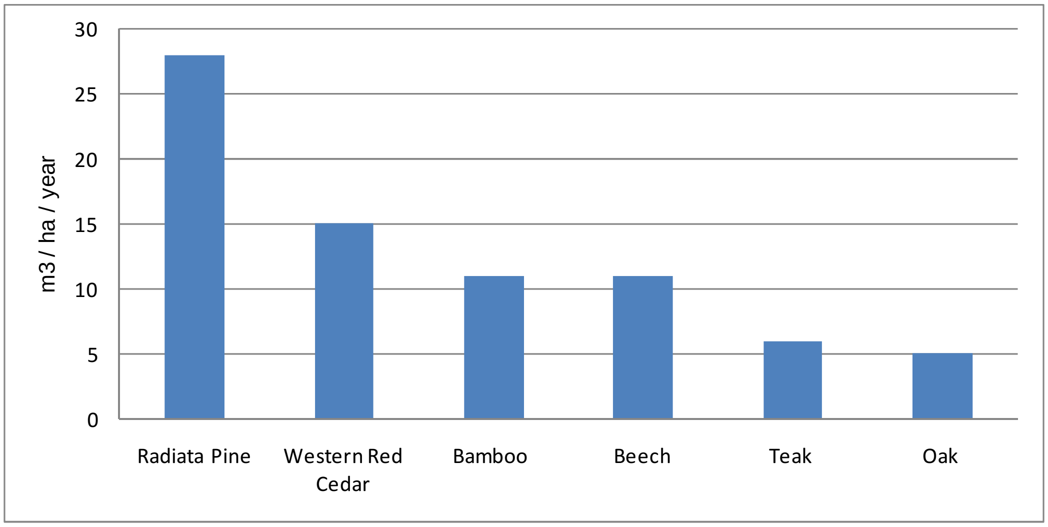
- Because of the limited emissions during production in case of sustainable sourcing, and credits that can be earned through carbon sequestration (especially in case of a long lifespan) and incineration for electricity in the End of Life phase, all wood products, including Accoya, are CO2 negative over the full life cycle. The best performing alternative is Accoya made from locally sourced species (in this case Scots Pine).
- The non renewable ‘man-made’ materials PVC, steel and aluminium perform considerably worse than sustainably sourced wood, especially because of the high embodied energy (emissions during production). Although through recycling Aluminium, PVC and steel earn some credits (for steel and aluminium integrated in the ‘input materials’ figures) this does not outweigh the high emissions during production.
- In case of unsustainably sourcing (deforestation) the picture totally shifts and wood is the worst performing alternative (see unsustainably sourced Meranti). This shows the importance of conservation of (tropical) forests as they act as important carbon sinks, and the need to search for (rapidly) renewable alternatives from sustainable managed forests and plantations.
- The eco-burden of transport and maintenance (coatings) appears to be negligible in the total context.

5. Discussion

It should be noted that several environmental issues cannot be caught by a carbon footprint or LCA. Although the scope of a LCA is a lot broader than the carbon footprint, and also includes several other eco-indicators besides greenhouse gas emissions (global warming effect), such as acidification, euthrophication, smog, dust, toxicity, depletion, land-use and waste, in both instruments the issue of social sustainability is not included. Especially land-use change is strongly related to the harvesting of tropical hardwood. For example, FSC certified tropical hardwood is partly sourced from plantations (40%), but the rest is still coming from natural forests (harvested with Reduced Impact Harvesting, RIL, techniques), having a negative impact on the biodiversity and carbon sequestration.

Yield of land is another specific aspect of sustainability, not included in a carbon footprint or LCA, which is related to the fact that land is becoming scarce, especially when current materials (metals, fossil fuels) will be replaced by renewable materials like wood and crops for biomass.

The high growing speed of species suitable to produce Accoya such as Radiata Pine is a “green” competitive advantage over regular wood species, and in particular slow growing tropical hardwood species. Therefore, the annual yield is another aspect of sustainability which should to be taken into account in addition to the LCA / carbon footprint performance results.



Annual yield for various wood species in cubic meters produced per hectare per year [Ref 11 – 14]

This does put the results of the carbon footprint in another perspective by looking at a global level. Whereas in temperate regions (Europe, North America) total forest surface area is growing, the area of tropical forests is still decreasing steadily because of deforestation, resulting in a net decrease in carbon storage in forests worldwide of 0.5 Gt between 2005 and 2010 [15]. Combined with the conversion of forests to agricultural land or for development of infrastructure, one of the main causes of deforestation in tropical regions is illegal logging of tropical hardwood, which is high in demand worldwide because of the superior performance over softwood in terms of durability, hardness and sometimes dimensional stability. Because of these characteristics tropical hardwood is often chosen as preferred material in outdoor applications. Although the amount of sustainable sourced and certified tropical hardwood on the market is increasing - also because of the European Timber Regulation becoming obligatory in March 2013, banning all illegally sourced wood - demand is still higher than supply.

This does show the potential of non toxic wood modification technologies such as acetylation as it enables an abundantly available resource (softwood) to substitute tropical hardwood, and even manmade materials such as plastics, metals and concrete which can help in further reducing greenhouse gas emissions through temporary carbon sequestration in products and especially substitution of carbon intensive materials.

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