Verco

Accoya® wood 2012 cradle-to-gate carbon footprint update

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1. Introduction

1.1 Background

Climate change presents a serious challenge for responsible business leaders in the 21st Century. Rising atmospheric concentrations of greenhouse gases (including carbon dioxide) threaten to have severe impacts on food production, ecosystems and human health over the next 100 years. Industrialised and rapidly growing countries are the main sources of greenhouse gases. The greatest impacts will be felt by people in developing countries and, particularly those in low lying coastal regions and marginal agricultural areas. However, developed countries are far from immune.

There is a clear need to develop more sustainable solutions to every day demands. Accsys Technologies "Accsys" believes that Accoya® wood offers an alternative to conventional construction materials which is less environmentally damaging than current de facto materials, while offering comparable or improved durability and other performance benefits. This report develops a measure of carbon emissions for the product which enables environmental comparisons against other materials.

In 2009 Verco undertook a full cradle to gate carbon footprint for Accoya®. As Accsys used this information to change several production parameters in a continuing attempt to improve environmental and overall performance, an update of the carbon footprint was requested to better understand the current environmental impact of the production of Accoya®, including the differences between various available wood sourcing scenarios.

This is a public version of the original report, and hence excludes some sensitive data relating to the Accoya® wood production process. The original is available on request after signing an NDA.

1.2 Why carry out a carbon footprint assessment?

National governments, individual states and regional groupings such as the European Union, are taking a variety of steps to reduce greenhouse gas emissions, including:

- Emissions trading schemes
- Voluntary reduction and reporting programmes
- Carbon or energy taxes and regulations
- Standards on energy efficiency and emissions

Increasingly companies will need to understand and manage their greenhouse gas risks in order to maintain their license to operate, to ensure long term success in a competitive business environment, and to comply with national or regional policies aimed at reducing greenhouse gas emissions. (Source: World Business Council for Sustainable Development, and World Resource Institute (WBCSD and WRI)).

A Greenhouse Gas (GHG) assessment is the first step in a longer term carbon management process; if a company knows the size and breakdown of its carbon footprint it can then start to set reduction targets and manage its emissions effectively. A product carbon footprint is the total set of GHG emissions caused directly and indirectly by the product. Measuring the carbon footprint of a product across its full lifecycle is a good way for a company to collect the information it needs to:

- Reduce GHG emissions
- Identify cost saving opportunities
- Incorporate emissions impact into decision making on suppliers, materials, product design, manufacturing processes etc.
- Demonstrate environmental and corporate responsibility
- Meet customer demands for information on product carbon footprints

1.3 Product details

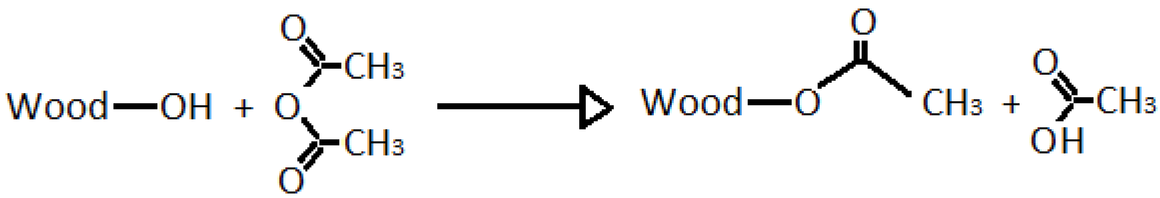
The technology behind Accoya® is based on the acetylation of wood. This is a non-toxic wood modification process that has been studied globally for over 80 years that Accsys Technologies has been able to bring to commercial scale production.

The physical properties of any material are determined by its chemical structure. Wood contains an abundance of chemical groups and those which are important in the acetylation process are the OH (oxygen and hydrogen covalently bonded) group at the end of the longer chain molecules within the wood:

Wood — OH

These 'OH' groups, also known as 'hydroxyl' groups readily absorb and release water according to changes in the climatic conditions to which the wood is exposed to. This is the main reason why wood swells and shrinks in the damp and the dry. It is also believed that the digestion of wood by enzymes initiates at these sites – which is one of the reasons why wood is prone to decay.

The acetylation process reaction takes place at the hydroxyl group and changes this group into a stable acetyl group. Acetyl groups are naturally present in all woods but the acetylation process increases the acetyl content to a much higher level. The process involves reacting acetic anhydride with the hydroxyl group. Acetylation changes the hydroxyl groups into acetyl groups and gives a co-product of acetic acid (also known as vinegar in its dilute form):



Wood	Acetic anhydride	Acetylated wood	Acetic acid

When the reaction has taken place, the ability of the acetylated wood to absorb water is greatly reduced (hydroxyl groups present with much lower frequency throughout the wood). The wood becomes more dimensionally stable and because it is no longer easily digestible, therefore becomes extremely durable (durability class 1 according to EN350-1). As such, acetylated wood can serve as a viable alternative for the most durable tropical hardwood species and in several applications even for typically used manmade materials such as steel, concrete and plastics. Accsys, the producer of

Accoya® wood, derives all of its timber from sustainably managed plantations, for example following certification under Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC) mandates, and generally uses abundantly available species such as Radiata pine for the acetylation process.

2. Assessment methodology

The assessment that has been carried out by Verco is a cradle-to-gate product assessment. This means that the carbon footprint is analysed from the source (forest) to the factory exit gates, thus including the acetylation process. It is not a cradle-to-grave, or full life cycle assessment. If it were, the carbon stored within the wood could be taken into account as an additional benefit (carbon credit, see also chapter 6). This cradle-to-gate perspective of the supply chain enables incremental addition of GHG assessments at different stages of the supply until the product or service is made available to the consumer (where the assessment will include the emissions and removals arising from the entire life cycle).

Verco's carbon footprints cover all 6 Kyoto gasses and encompass Scopes 1, 2 and 3 emissions sources in line with the *Greenhouse Gas Reporting Protocol* from the World Business Council for Sustainable Development (WBCSD) and World Resource Institute (WRI). All emissions factors used are the most up-to-date available from the referenced sources such as the Department for Environment, Food and Rural Affairs (Defra), WBCSD/WRI, Intergovernmental Panel on Climate Change (IPCC), Energy Information Administration (EIA), and the Swiss Centre for Life Cycle Inventories (SCLCI) also known as Ecoinvent. The global warming potential (GWP) of each of the greenhouse gases of the Kyoto Protocol is expressed in terms of CO_2 equivalent (CO_2e). For those gases with a high GWP a relatively small emission can have a disproportionally large impact.

Kyoto Gas	Example sources	GWP
Carbon Dioxide CO_2	Combustion of fuels	1
Methane CH_4	Anaerobic decay	21
Nitrous Oxide N_2O	Chemical industry	310
Hydrofluorocarbons HFC	Air conditioning/refrigeration	140 – 11,700
Perfluorocarbons PFC	Air conditioning/refrigeration	6,500 – 9,200
Sulphur Hexafluoride SF_6	Metal production	23,900

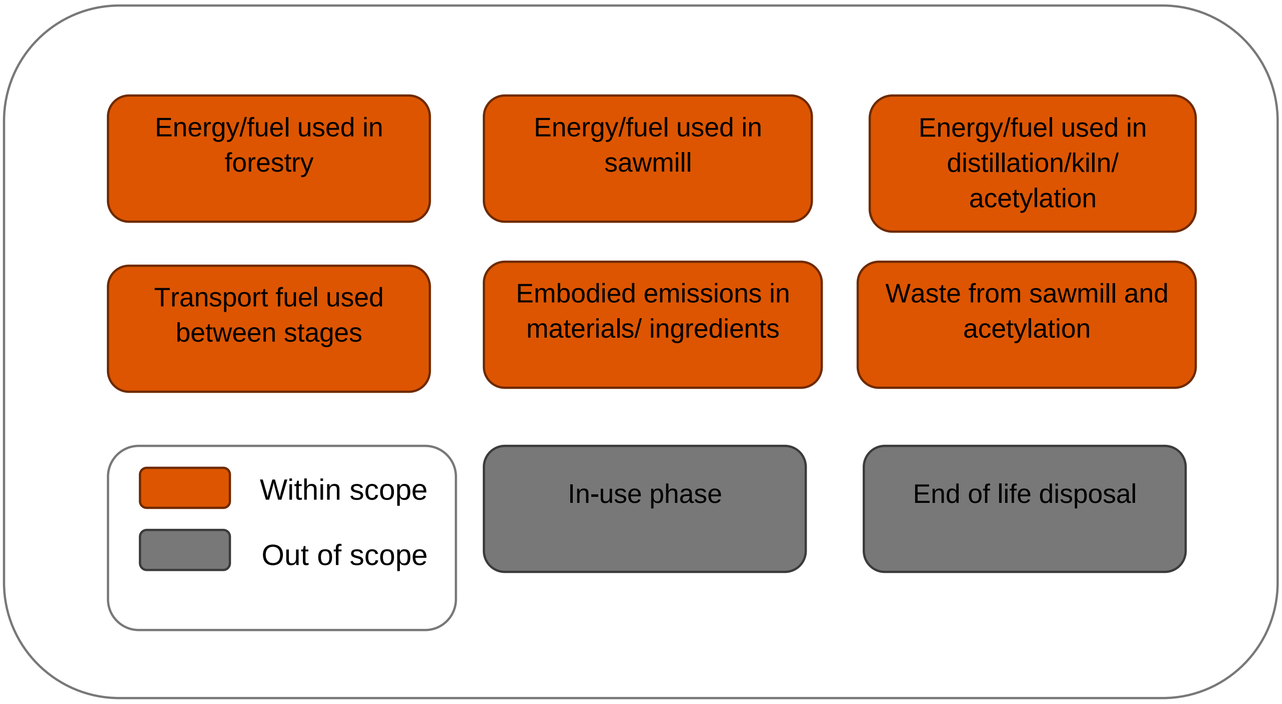
Accoya® wood does not have any associated HFC, PFC and SF_6 emissions. Only the first three gases – CO_2, CH_4, and N_2O are emitted in varying quantities throughout the processes. A summary of the procedure followed to complete this assessment is as follows:

1) Completion of the process map from forest to factory exit gate
2) Review and comprehension of processes (transportation, chemical and static) to ensure correct inclusion of relevant carbon emissions sources
3) Review of available data and clarifying of any gaps/raising of any queries
4) Review of available emissions factors and possible derivation/estimation of unavailable ones
5) Application of emissions factors to emissions sources ($kgCO_2e$/unit)

A detailed description of the emissions calculations and associated assumptions are presented in the appendices of this document.

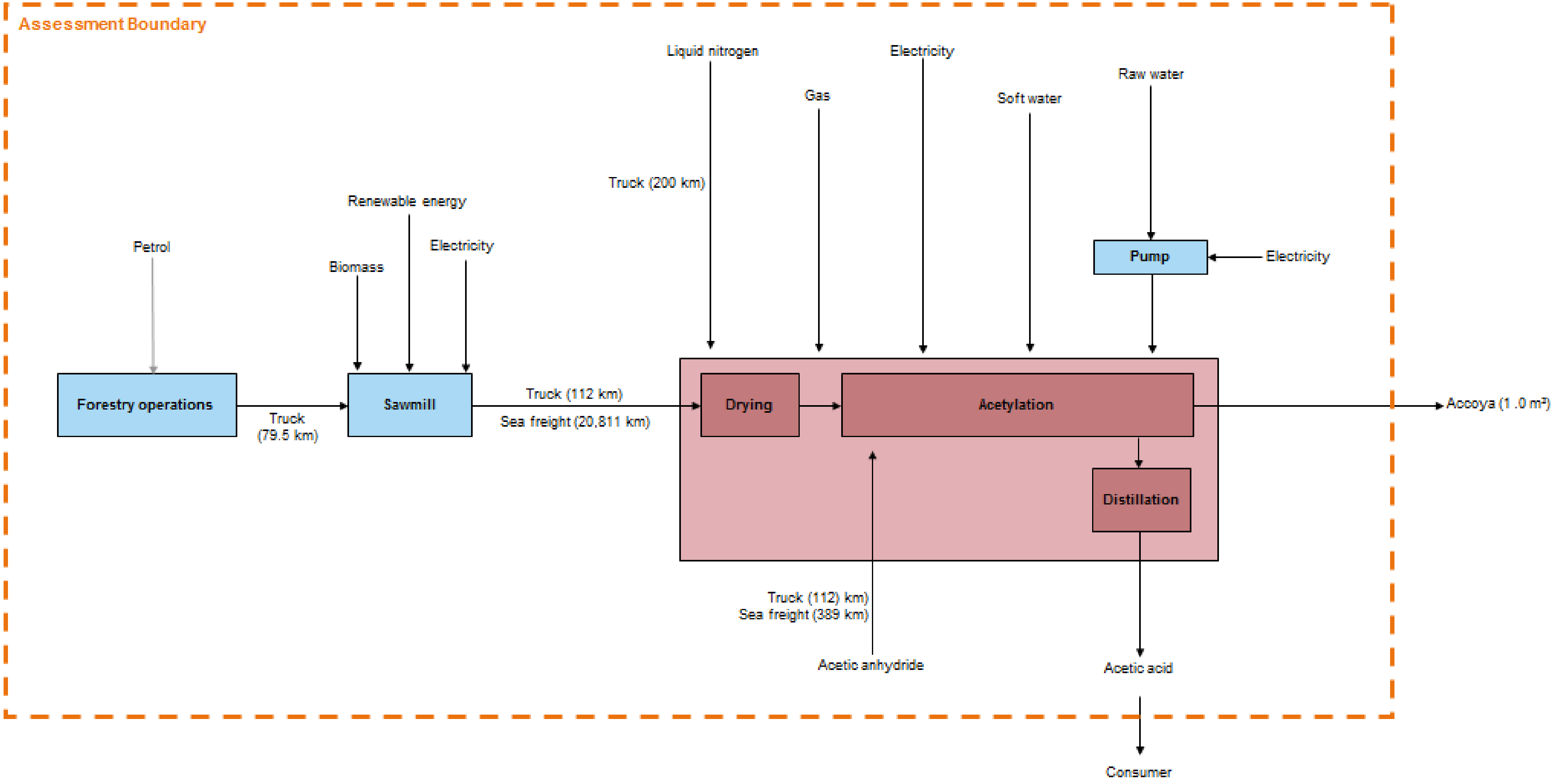
3. Assessment boundary

The scope of the cradle-to-gate assessment of Accoya® wood is illustrated below:



The assessment determines the associated greenhouse gas emissions to produce one cubic metre ($1m^3$) of Accoya® wood using the acetylation process.

Diagram of the whole process from cradle to gate for the Radiata Pine scenario.



4. Results

This section discusses the results of all aspects of the cradle to gate carbon footprint of the Accoya® wood product.

There are three key components which have the greatest bearing upon Accoya® wood's embodied greenhouse gas emissions. The acetic acid co-product has the single greatest effect upon emissions in that it is sold as a useful co-product and hence its emissions are subtracted from that applicable to Accoya® wood. This is discussed in further detail in section 4.1. Acetic anhydride is the largest input from a CO_2 perspective, followed by utilities consumption and transport in the case of intercontinental sourcing.

The majority of the product's emissions are generated either within the acetylation facility, or embodied within the raw materials consumed on-site. This is advantageous, as it means that Accsys is in control of the majority of their greenhouse gas sources. As will be explained in section 4.2, Accsys has taken advantage of this possibility - using the results from the 2009 carbon footprint undertaken by Verco as a guide to alter production parameters, and make distinct choices with respect to the procurement of input materials.

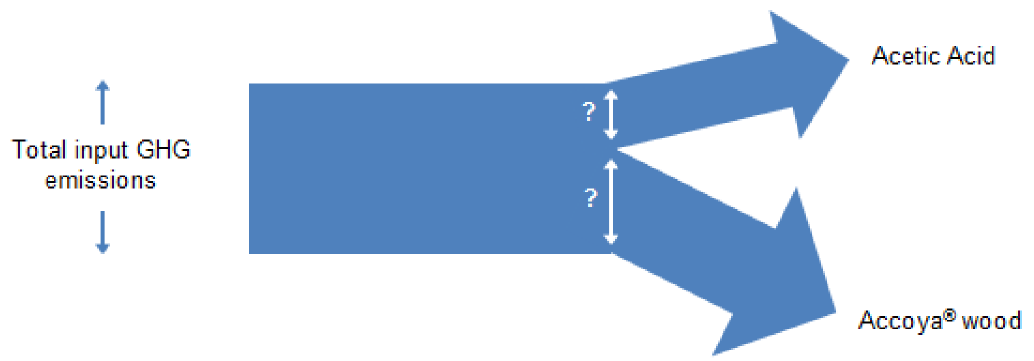
The following sections highlight the most important assumptions that were made during the calculation process before presenting the results for various Accoya® production scenarios.

4.1 Acetic acid

Acetic acid is produced as a co-product to the acetylation process. Accsys sells this chemical to a wide range of industries including producers of PET bottles, ester producers, and is even approved for use in halal and kosher foods. This creates a slightly complex situation in terms of allocating greenhouse gas emissions.

The acetic acid should be considered as a product of the acetylation process, in the same way that Accoya® is. Hence, the emissions which are generated through the acetylation process (from electricity, natural gas, liquid nitrogen consumption etc.) should be split between Accoya® wood and the acetic acid. That is, not all of the greenhouse gas emissions of the acetylation process are attributed to Accoya® wood. This is depicted in the figure below.

Schematic for allocating greenhouse gas emissions between the acetylation process co-products



There are a number of methods for determining how to 'split' the greenhouse gas emissions between these co-products. In the UK, PAS 2050: 2011 *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*, suggests two preferred approaches for achieving this split. In order of preference, the first approach looks to separate a process into discrete sections for each co-product. For the Accsys acetylation process, this is not possible since the Accoya® and acetic acid emerge from the same single batch process.

The second approach is to expand the product system to assume additional functions related to the co-product, and that the process is displacing alternative supply streams of the co-product in the open market. Hence, it can be considered that the average GHG emissions arising from the alternative process represent the GHG emissions of the co-product. Referring to the acetic acid example is a good illustration of this: Acetic acid is a commonly produced chemical which is refined on an industrial basis. It was assumed that any acetic acid which was produced by Accsys acetylation process will displace some of the supply via the refinery process. Therefore, Accsys acetic acid can be assumed to have equal greenhouse gas emissions as the refinery acetic acid it replaces. This is also in line with ISO 14044, see section 4.3.4.2. (system expansion).

This is the methodology which has been applied to this emissions assessment. The greenhouse gas emissions of the acetic acid have been subtracted from the emissions of the Accoya® wood product. This enables the dedicated emissions for Accoya® wood to be identified.

4.2 Acetic anhydride production process

Acetic anhydride is a key ingredient for the production of Accoya® wood. It is a chemical that can be produced in several ways. The method of production of acetic anhydride used has an impact on the embodied carbon of the acetic anhydride.

The methods of producing acetic anhydride are:

1) Methyl acetate carbonylation (involves the reaction of methyl acetate and carbon monoxide with a catalyst)
2) The ketene route (cracking acetic acid to form a ketene, followed by the reaction of the ketene with further acetic acid)

The embodied emissions of methyl acetate carbonylation to make acetic anhydride have been calculated in a similar way to the 2009 carbon footprint by Verco. In March 2002, academics at Imperial College London undertook a life cycle assessment of acetylated wood used for cladding, issued for The Ministry of Housing, Spatial Planning and the Environment (VROM) in The Netherlands (referenced as 'Hillier & Murphy, 2002' in the appendices). This report listed economic and environmental inputs and outputs for the production of acetic anhydride via methyl acetate carbonylation. This data was agreed as seeming more modern and appropriate than the reported emissions factors within the SCLCI database. The full calculations for this data set can be found in Appendix 2. Emissions factors for the UK are employed due to the acetic anhydride being sourced from BP in Hull.

The following table allows a comparison to be made between the routes of acetic anhydride production. It can be seen that according to Verco calculations the carbonylation route generates by far the least GHG emissions. Thus, procuring acetic anhydride, which has been produced by methyl acetate carbonylation, enables Accoya® wood to claim significantly lower embodied emissions compared to when using other production methods.

Acetic anhydride production route	$kgCO_2/kg$	$kgCH_4/kg$	kgN_2O/kg	**kg CO_2e/kg acetic anhydride**	Notes
Acetaldehyde	2.2727	0.009665	0.000027256	**2.48**	Ecoinvent list: #6608
Ketene	3.3915	0.014091	0.000049793	**3.70**	Ecoinvent list: #6609
Production mix	3.1342	0.013073	0.00004461	**3.42**	Ecoinvent list: #361
Verco calculation (carbonylation)	-	-	-	**0.78**	Hillier and Murphy (2002)

All acetic anhydride used in the Accoya® manufacturing process is purchased from BP specifically, originating from the carbonylation production method. This makes the embodied emissions from the acetic anhydride as low as possible. The choice to only purchase acetic anhydride produced through methyl acetate carbonylation by setting up a strategic arrangement with BP was a specific choice by Accsys to lower the environmental impact as a result of the 2009 carbon footprint results.

4.3 Acetic Anhydride and wood type

Verco were advised by Accsys that different woods use different amounts of acetic anhydride during the acetylation process.

This was taken into consideration when making the calculations which were based on actual certified production run figures (DNV, November 2011) for Radiata Pine in the acetylation plant in Arnhem. For the other wood species it is assumed, based on Accsys experience to date, that a directly proportional relationship exists between the wood density and quantity of acetic anhydride required.

In turn it was assumed that this meant that a directly proportional relationship also existed between the input quantity of acetic anhydride and the output of acetic acid.

4.4 Results of Scenarios

Four scenarios reflecting different wood types and source locations that are currently used to produce Accoya® wood, have been footprinted. These are as follows:

- Scots Pine sourced from Scandinavia
- Radiata Pine sourced from New Zealand
- European Alder sourced from Germany and Latvia (EU)
- Red Alder sourced from the United States (US)

The results are as follows:

Wood sourcing scenario	Cradle-to-gate carbon footprint
Scots Pine sourced from Scandinavia	**140** $kgCO_2e/m^3$ Accoya®
Radiata Pine sourced from New Zealand	**342** $kgCO_2e/m^3$ Accoya®
Alder sourced from Germany and Latvia (EU)	**204** $kgCO_2e/m^3$ Accoya®
Alder sourced from the United States (US)	**293** $kgCO_2e/m^3$ Accoya®

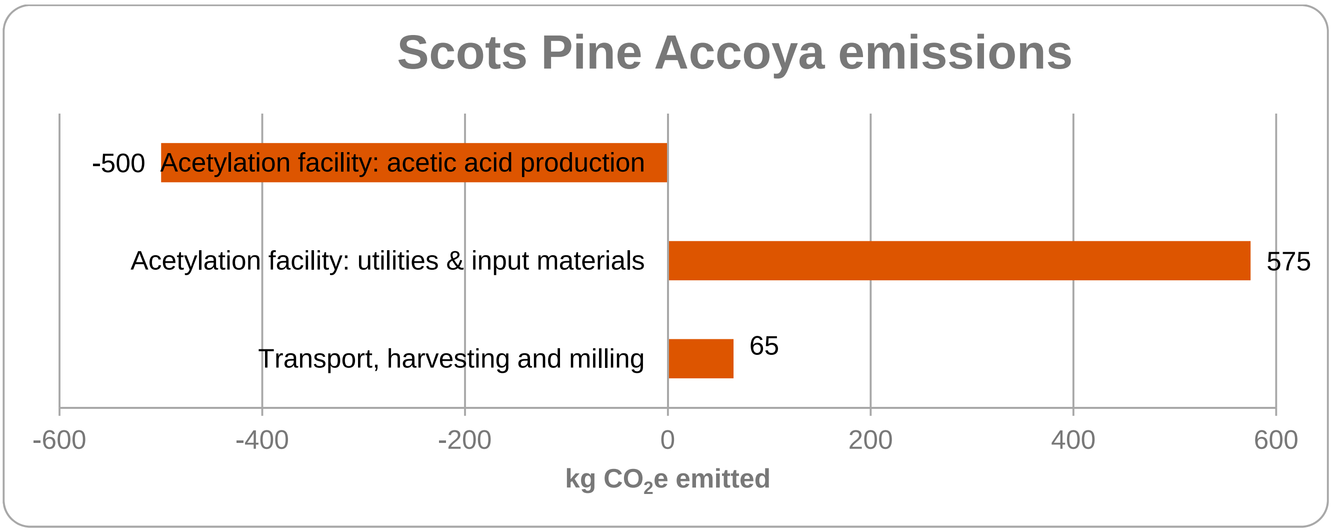
The following sections break down the calculation for the various Accoya® scenarios.

Scots pine sourced from Scandinavia

The total cradle-to-gate emissions for **Scots Pine Accoya®** are **140kgCO_2e/m^3**. A break-down of the emissions is as follows:

Emissions source - scots pine derived emissions	Tonnes CO_2e per m^3 of Accoya	kg CO_2e per m^3 of Accoya	Percentage of total (%)
Transport, harvesting and milling	0.06	65	46%
Acetylation facility: Utilities & input materials	0.52	575	411%
Subtotal: emissions	**0.6**	**640**	**457%**
Acetylation facility: Acetic acid production	-0.5	-500	-357%
Subtotal: avoided emissions	**-0.5**	**-500**	**-357%**
Total	**0.1**	**140**	**100%**

This is presented in the following graph:



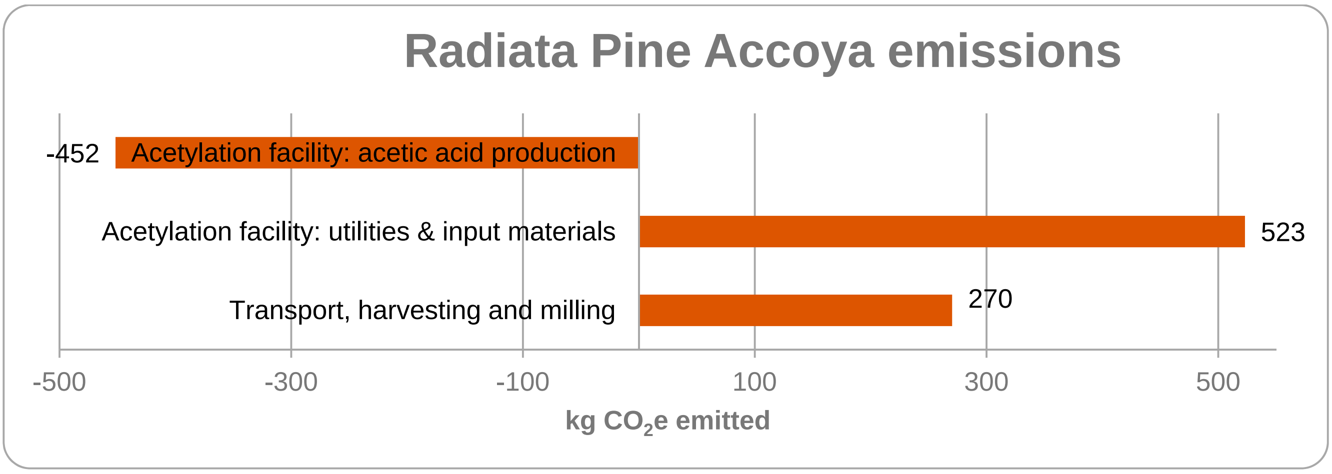
The avoided emissions from the co-product acetic acid partially offset the emissions from the Accoya® footprint. Without this offset the footprint would have been 640kgCO_2e/m^3.

Radiata Pine sourced from New Zealand

The total cradle-to-gate emissions for **Radiata Pine Accoya®** are **342kgCO_2e/m^3**. A break-down of the emissions is as follows:

Emissions source - radiata pine derived emissions	Tonnes CO_2e per m^3 of Accoya	kg CO_2e per m^3 of Accoya	Percentage of total (%)
Transport, harvesting and milling	0.3	270	79%
Acetylation facility: Utilities & input materials	0.53	523	153%
Subtotal: emissions	**0.8**	**793**	**232%**
Acetylation facility: Acetic acid production	-0.5	-452	-132%
Subtotal: avoided emissions	**-0.5**	**-452**	**-132%**
Total	**0.3**	**342**	**100%**

This is presented in the following graph:



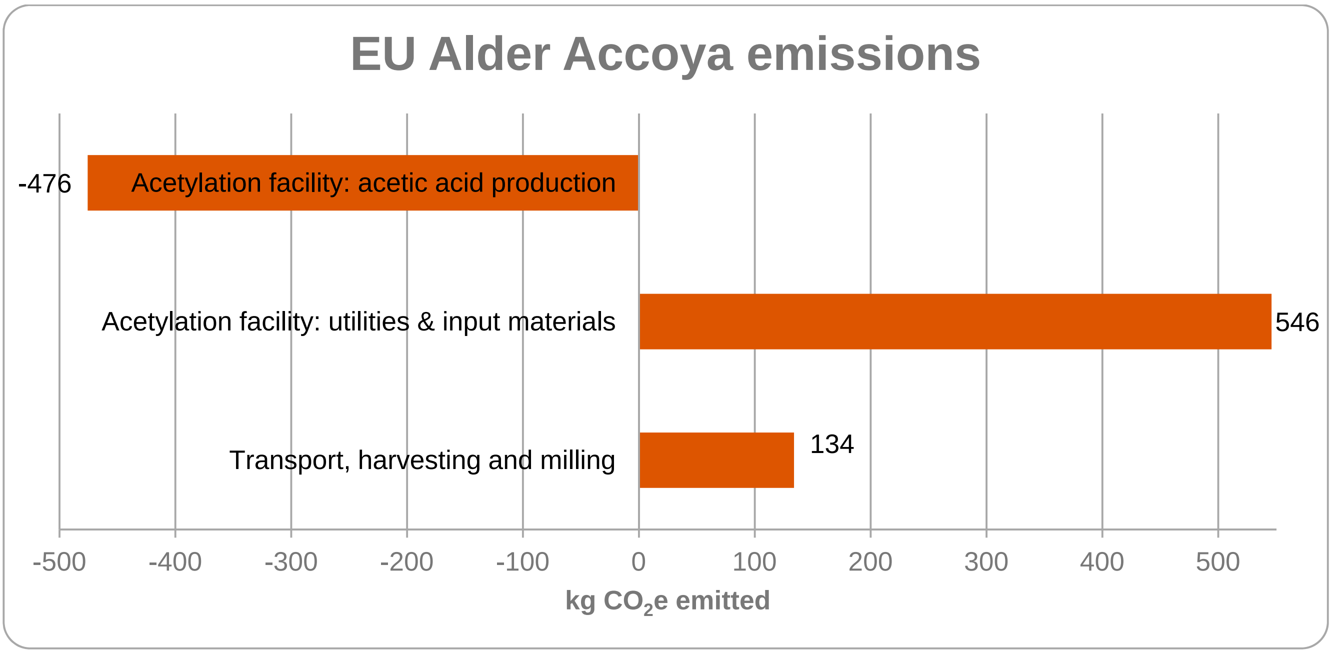
The avoided emissions from the co-product acetic acid partially offset the emissions from the Accoya® footprint. Without this offset the footprint would have been 793kgCO_2e/m^3.

Alder sourced from Germany and Latvia

The total cradle-to-gate emissions for **EU Alder Accoya®** are **204kgCO_2e/m^3**. A break-down of the emissions is as follows:

Emissions source alder (EU) derived emissions	Tonnes CO_2e per m^3 of Accoya	kg CO_2e per m^3 of Accoya	Percentage of total (%)
Transport, harvesting and milling	0.1	134	66%
Acetylation facility: Utilities & input materials	0.55	546	267%
Subtotal: emissions	**0.7**	**680**	**333%**
Acetylation facility: Acetic acid production	-0.5	-476	-233%
Subtotal: avoided emissions	**-0.5**	**-476**	**-233%**
Total	**0.2**	**204**	**100%**

This is presented in the following graph:



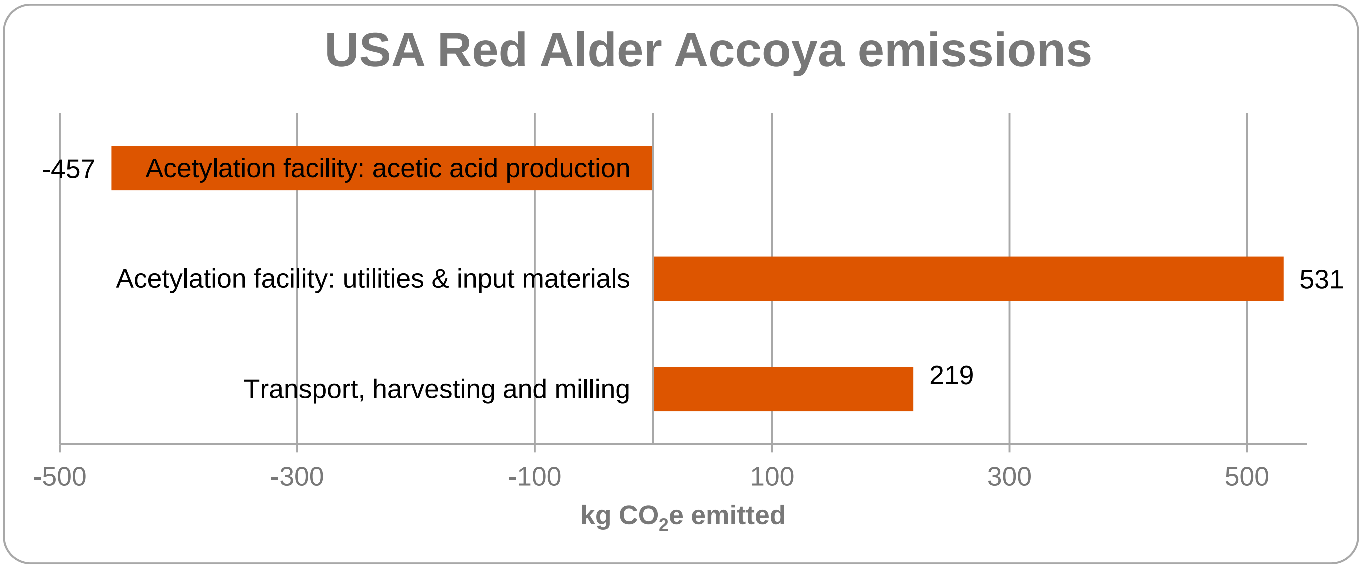
The avoided emissions from the co-product acetic acid partially offset the emissions from the footprint. Without this offset the footprint would have been 680kgCO_2e/m^3.

Red Alder sourced from United States

The total cradle-to-gate emissions for **USA Red Alder Accoya®** are **293kgCO_2e/m^3**. A break-down of the emissions is as follows:

Emissions source - red alder (USA) derived emissions	Tonnes CO_2e per m^3 of Accoya	kg CO_2e per m^3 of Accoya	Percentage of total (%)
Transport, harvesting and milling	0.2	219	75%
Acetylation facility: Utilities & input materials	0.54	531	181%
Subtotal: emissions	**0.7**	**750**	**256%**
Acetic acid output	-0.5	-457	-156%
Subtotal: avoided emissions	**-0.5**	**-457**	**-156%**
Total	**0.3**	**293**	**100%**

This is presented in the following graph:



The avoided emissions from the co-product acetic acid partially offset the emissions from the footprint. Without this offset the footprint would have been 750kgCO_2e/m^3.

Transport, harvesting and milling

The emissions from Accoya® vary with respect to wood type and the sourcing of the wood. The emissions from transport, harvesting and milling are broken down in the following table:

Emissions source	Scots Pine ($kgCO_2e/m^3$)	Radiata Pine (Average) ($kgCO_2e/m^3$)	Alder (USA) ($kgCO_2e/m^3$)	Alder (Average) (EU) ($kgCO_2e/m^3$)
Forestry - petrol consumption	12.9	16.3	15.1	15.1
Transport - Forest to sawmill	2.9	11.1	22.5	5.3
Sawmill operations - electricity	8.3	51	34	67
Sawmill operations - biomass	8.3	35.7	28.4	12.0
Sawmill operations - waste	0	0	0	0
Transport - sawmill to plant	32	157	119	34
Total	**65**	**270**	**219**	**134**

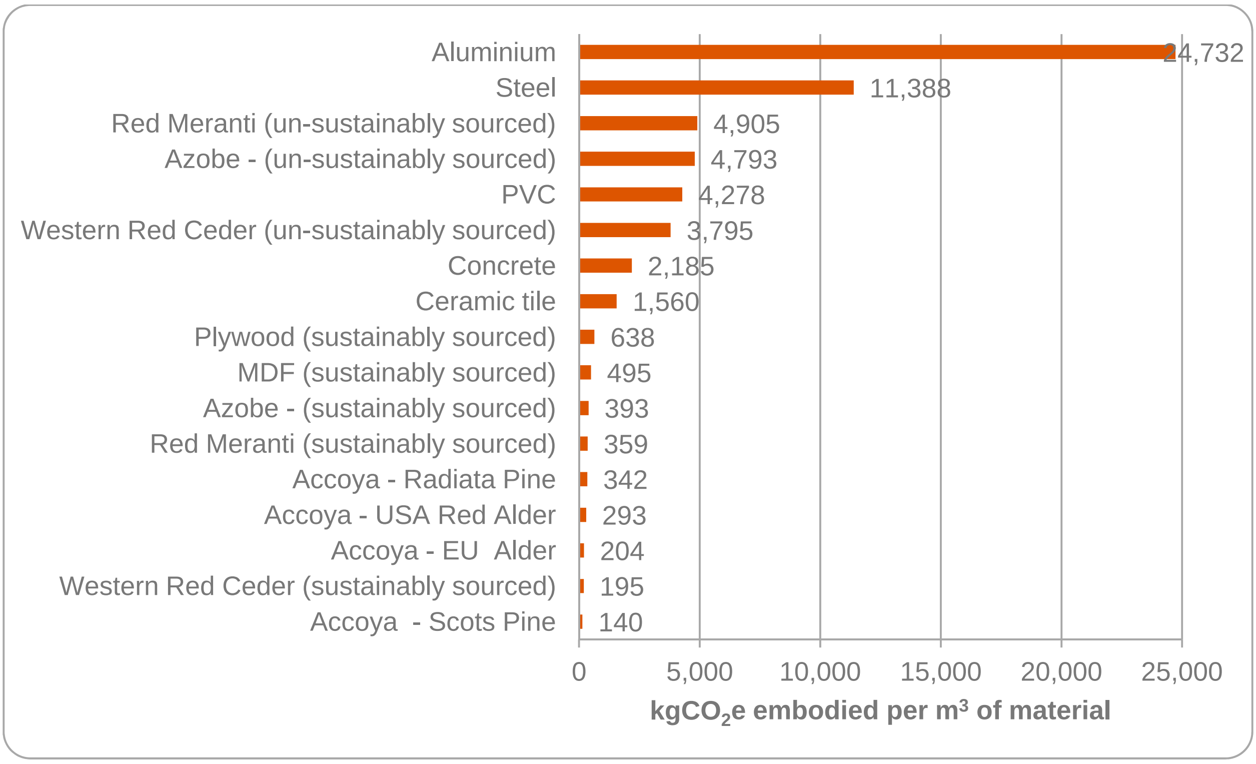
The data for sawn timber production and milling comes directly from the Accsys suppliers. “Average” indicates that there was more than one supplier/source of wood. For Radiata Pine two representative suppliers from New Zealand were selected. For EU Alder there were two countries of source – Germany and Latvia. The numbers presented in the table are averages of the sets of values for those two wood types.

It can be seen that by far, the greatest contributory factor to the variation of the numbers is the transport from sawmill to acetylation plant, particularly for Radiata Pine and USA Red Alder. This is because of the sea freight and distance required to transport the wood to the acetylation plant in Arnhem, the Netherlands. The relative impact of this transport requirement versus the embodied GHG emissions of alternative typically used materials can be seen in chapter 5.

In general the sawmills that Accsys works with have efficient operational procedures: No waste is reported from the sawmill operations in any of the four scenarios. This is because all waste wood is either burnt in the wood drying kiln or sold to be used for a purpose such as particle board production, paper pulp etc. The kilns at all sawmill plants were fired with biomass. One sawmill co-fired biomass and natural gas, and one used geothermal fluid. The emissions from the waste and kiln operations were therefore very minimal.

5. Comparable materials

Accoya® wood competes in the market against other building materials. It is of interest to compare how greenhouse gas emissions differ between Accoya® wood and alternative, commonly used materials. A number of greenhouse gas inventories have been examined to identify the cradle-to-gate emissions from other materials and the comparative results are summarised below.



In the table below the assumptions made for the alternative materials in the graph are summarized.

Material	Assumption
Aluminium	Assumed (UK) ratio of 25.6% extrusions, 55.7% Rolled & 8.7% castings. World-wide average recycled content of 33%. Inventory of Carbon and Energy, University of Bath, 2011..
Steel	EU 3-average recycled content of 59%. Estimated from UK's consumption mixture of types of steel (excluding stainless). All data excludes the final cutting of the steel products to the specified dimensions or further fabrication activities. Estimated from World Steel Association (Worldsteel) LCA data. Inventory of Carbon and Energy, University of Bath, 2011.
PVC	28.1 MJ/kg Feedstock Energy (Included). Based on market average consumption of types of PVC in the European construction industry. Inventory of Carbon and Energy, University of Bath, 2011.
Ceramic tile	Ceramic Tiles and Cladding Panels. Density from Inventory of Carbon and Energy, University of Bath, 2011.
Plywood	Worst case scenario - outdoor use plywood (more similar to Accoya®). Inventory of Carbon and Energy, University of

	Bath, 2011.
Concrete	This is standard cement with no cementitious additions (i.e. fly ash or blast furnace slag). Composition 94% clinker, 5% gypsum, 1% minor additional constituents (mac's). This data has been estimated from the British Cement Association's factsheets. Inventory of Carbon and Energy, University of Bath, 2011.
MDF	Ecoinvent, 2010 database, list number 2,479

The graph shows that Accoya® wood offers low emissions compared to a range of typical building materials, on a cradle-to-gate basis. The embodied emissions of Accoya® in several scenarios are comparable or even perform better than sustainably sourced woods, and offer significant improvements against unsustainably sourced woods, plastics and metals.

A cradle-to-gate analysis does not cover the in-use and disposal phase of the product. For the materials illustrated above, in-use emissions are likely to be centred around:

- Material properties such as density or strength, which dictate the volume of material required
- Durability of the material which influences lifespan
- Maintenance procedures and maintenance frequency
- Carbon sequestration properties of renewable materials
- Disposal and recycling routes available

Adding these components to the analysis may present different outcomes in terms of each material's environmental performance and could provide additional benefits to Accoya® wood, compared to certain materials, due to its high strength to weight ratio, durability, low maintenance requirements, use of renewable materials and multiple end-of-life options. The potential for developing this analysis, to consider cradle-to-grave factors for Accoya® wood, is discussed further in chapter 6 of this report.

6. Further considerations

Further work could be carried out to develop the emissions factor for Accoya® wood in specific applications and to reflect the specific variables in countries where the process could be licensed. This would support the environmental credentials of Accoya® wood for the “in-use” phase.

As explained earlier, adding the in-use phase would draw a completely different picture from the comparable materials, which is based on the emissions per cubic meter of material. Therefore, for a more complete emissions assessment the cradle-to-gate results would need to be translated in actual applications relevant for Accoya® wood, where materials with a very high durability are required, such as in window frames, decking, cladding or structural outdoor applications (e.g. bridge components). In such a so-called cradle to grave assessment of the embodied emissions for Accoya® wood, the following aspects should be taken into account:

6.1 Amount of material (kg) per functional unit per application

A steel or concrete beam in a bridge might require a lower volume of material compared to the amount of wood needed to perform the same task (functional unit), because of the different material properties of steel or concrete, as opposed to wood (strength, density, etc). It would be interesting to compare the embodied emissions of a steel bridge and concrete bridge to those of a wooden bridge.

6.2 Lifespan

Because of the high durability of Accoya® wood, it is expected to have a longer lifespan than most alternative materials in several applications. Accsys guarantees the quality of Accoya® wood both in applications above and below ground (*above ground*: guaranteed for 50 years in Use Classes 1, 2 and 3 according to EN 335 – 1 and *below ground*: guaranteed for 25 years in Use Class 4 according to EN 335 – 1). In a cradle to grave assessment lifespan is taken into account.

6.3 Maintenance cycle

When wood is used in a product it is often coated to protect it from weathering, rot etc or for aesthetic reasons. If wood is coated, this can increase the embodied emissions of the product. Although for functional requirements it is not necessary to coat Accoya® given its high durability, it may occur for aesthetic preferences. Nevertheless, the high dimensional stability of Accoya® means that as a stable substrate it does not have to be coated as much or as often as other wood products. This implies that in comparison to other wood species Accoya® wood has less associated in-use greenhouse gas emissions.

6.4 End of life scenario

A cradle-to-grave assessment such as the one carried out in the 2010 Life Cycle Assessment (LCA) by Delft University of Technology explores the end of life phase of the product. This has been addressed for three products that are in the LCA – window frames, decking and the bearing structure of a bridge.

Typically a product is disposed to a landfill, incinerated or sent for recycling. If the product contains harmful materials then a treatment phase may need to be considered before the disposal stage. This is not the case for Accoya® wood, as the material is fully biodegradable and does not contain any toxic substances. The associated greenhouse gas emissions for the different end of life disposal methods can be variable in size.

The best end of life scenario is that which generates little or no emissions. An example of this is if the product is 100% recycled. The product is either recycled in its complete form, or, it is processed into another form. Emissions associated with recycling are attributed to the party undertaking the process and not to the original owner of the product.

The original product can also be used by a third party as a fuel source, such as for an incinerator which generates electricity and/or heat. This scenario is the same as for the recycling – emissions arising from this are not allocated to the original owner of the product, but to the third party, however, may be allocated in LCA to the Accoya® process as a credit (substitution for fossil fuels).

When the product is disposed of in landfill or incinerated with no energy recovery there is no environmental benefit. The emissions are allocated to the original product.

6.5 Carbon sequestration

Trees absorb CO_2 during their lifetime. This is locked away as carbon in the tree itself. This carbon is only released into the atmosphere if the wood decays or is burnt at the end of its useful life. PAS 2050:2011 allows for the carbon sequestered in the wood to be included as a negative CO_2 value with respect to the embodied emissions i.e. it lowers the overall embodied emission value. This can be calculated using the formula in PAS 2050 annex E, page 33. The benefits of carbon sequestration can only be realised if the emissions associated with the product are calculated on a full cradle-to-grave lifecycle analysis.

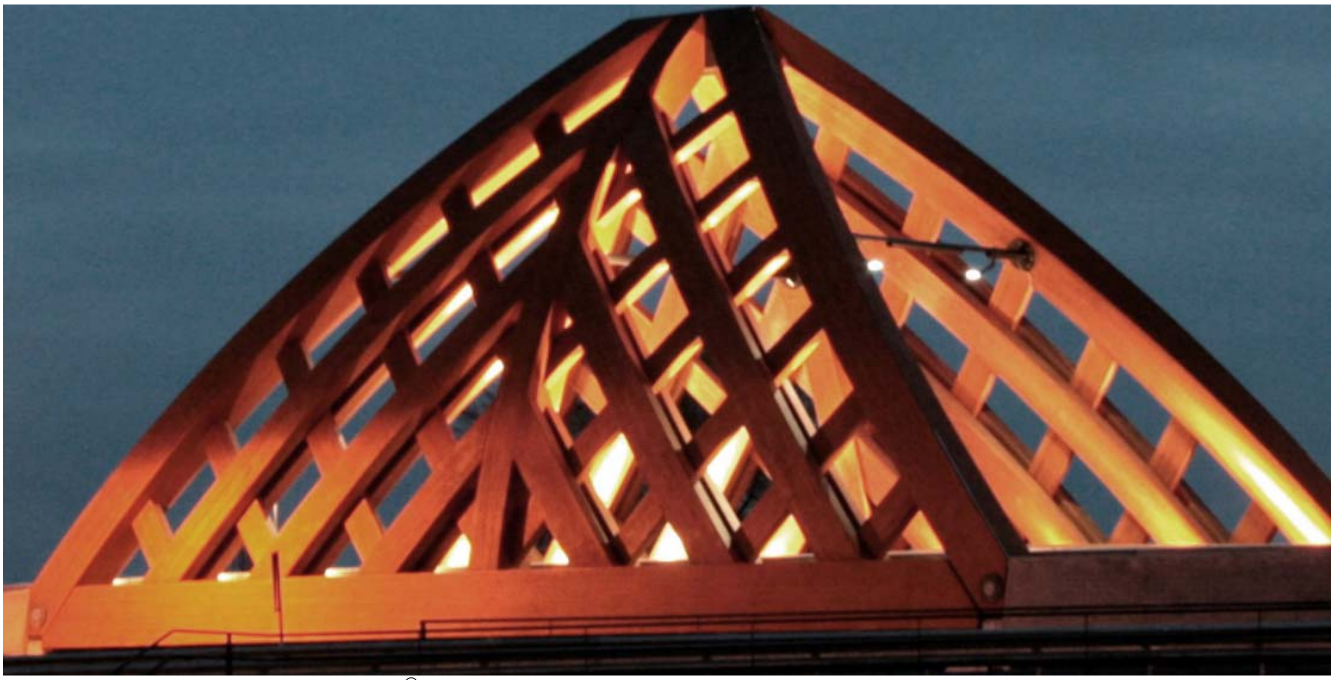
The carbon footprint in this report is cradle to gate so the carbon sequestered in the Accoya® wood is not taken into account. However, the following calculations show the quantity of carbon sequestered for Accoya® wood from Scots Pine, Radiata Pine and Alder.

Wood species	Weight of wood in 1m^3 of finished Accoya® (kg)	Quantity of carbon in wood (kg)	Quantity of equivalent sequestered carbon dioxide (kg)
Scots Pine	486	243	**891**
Radiata Pine	439	220	**806**
European Alder	463	231	**849**
American Red Alder	444	222	**814**

See appendix 2 for full calculations.

To make this more tangible, below is a real life case in which Accoya® has been applied (Sneek bridge), for which the carbon sequestration potential has been calculated including PAS weighting.

Sneek Bridge is the first ever heavy traffic road bridge with a wooden load bearing structure, with an anticipated lifespan of 80 years. It certainly illustrates the potential for Accoya® wood to replace traditional more carbon intensive construction materials, such as steel and concrete.



Carbon sequestered in Accoya® applied to Sneek bridge according to PAS 2050 weighting:

1)	CO_2 sequestered in Accoya® Radiata Pine (see table above) ($kgCO_2/m^3$)	806
2)	Expected lifespan of the bridge (years)	80
3)	CO_2 sequestered including PSA 2050 weighting ($kgCO_2/m^3$) (1) x ((2) / 100)	645

The CO_2 sequestered per m^3 of wood in Sneek bridge according to PAS 2050 weighting is therefore 645$kgCO_2/m^3$. Although this calculation provides a promising indication, only under the following conditions is Accoya® wood expected to be a net sequester of carbon dioxide:

- Cradle-to-grave emissions assessment is carried out
- Accoya® wood requires no extensive maintenance and treatment during in-use phase
- Accoya® wood is recycled at end-of-life phase (energy or panel production)

While the Sneek bridge is a dramatic example, large volumes of smaller products, such as doors, windows, decking and cladding can have a similar or greater net environmental impact.

Appendix 1: Generating carbon value from Accoya® wood

As governments and policy makers pursue a transition from a high carbon to a low carbon economy, products and services with a lower climate impact should be and in some cases already are rewarded for the public good they provide. Policy mechanisms to slow the onset of climate change can be broken down into three categories:

- Command and control: tougher government regulation on the type of technology and materials used;
- Carbon taxes: a fixed levy on every tonne of CO_2 emitted; and
- Cap and trade: a cap on national and/or regional emissions with the market setting the price according to the marginal CO_2 abatement costs

These policies are not mutually exclusive. In the UK for instance, all three mechanisms are used:

- Promotion of tougher regulations from power plants, to that of capturing methane from landfill gas sites;
- Climate change levy, charges businesses a fixed amount per kWh of power used;
- European Union Emissions Trading Scheme (EUETS) focuses on large sources of CO_2 emissions and applies a cap to over 40% of the UK's emissions.

For Accsys, policy measures will generate risks and opportunities. The focus here is on the opportunities presented by the development of cap-and-trade schemes around the world. Consequently implicit and explicit value which could be generated through the:

- Processing and production of Accoya® wood;
- The displacement of other more carbon intensive materials typically used instead;
- The amount of carbon stored or the sequestration value of the product.

Projects which sequester CO_2 and which reduce the CO_2 emissions below an established baseline can add value. Accsys can generate value through the processing and production of Accoya® wood and the carbon stored within the product. Those aspects of the production chain are broken down by process chain ownership below. Ownership of emission reductions or sequestered carbon needs to be defined at a company level and also at a country level. Under the Kyoto Protocol sovereign entities' emissions reductions which occur in one country effectively belong to that country and require the consent of that country. Consent is then required if emissions are to be sold overseas and to third parties.

Primary harvesting and milling

A number of opportunities exist here to monetise the carbon benefits within this activity. Verco assumes that this activity takes place within a country that has ratified the Kyoto Protocol (either an Annex 1 developed country or a non-Annex 1 developing country).

Afforestation, reforestation and forest management activities often provide a net CO_2 benefit, provided that in the absence of carbon finance they would probably not have occurred. These activities typically apply where a forest is not harvested regularly and/or when forest management activities improve the productivity of the forest beyond what would have occurred naturally under a business as usual scheme. Some examples of this are multi-cropping, such as growing and managing shade trees on coffee plantations. Forestry has up until now mostly operated outside of the carbon markets for a variety of reasons:

- The difficulty in establishing baselines and land ownership;
- The accuracy of monitoring the carbon stored and its non-permanent nature.

This is changing and post 2012 there is likely to be an even greater focus on avoided deforestation and forestry management reflecting the importance of forests in absorbing and reducing global emissions; however this has still not been established. Accsys can look at the forestry and land-use practices and the potential carbon benefits of improving these. It is unclear whether Accsys or its clients will have direct control over forests where timber is sourced from. It may be possible for Accsys to secure the rights to carbon sequestration through assisting the forest owners in undertaking changes in practices to improve the carbon stock.

Harvesting and milling is assumed to take place in the country close to the timber source. Harvesting and milling activities can present a number of emission reduction opportunities that stretch beyond a business as usual scenario.

Examples include:

- Switch to a less carbon intensive fuel, e.g. biomass and geothermal fluid, than fossil fuel (e.g. oil, gas, coal) for powering the kiln to dry wood;
- Generating clean electricity from waste products of the cutting process in the saw mill;
- Using waste products to avoid the generation of methane from the anaerobic decomposition of organic material.

Examples of all the above have been developed as emissions reduction projects in both the developing and developed world. For Accsys to generate carbon revenue from any of these projects it would need to show that they represented a departure from business as usual in the locations where the harvesting and milling took place. This would be easier to do if an existing facility was going to be used and needed to be retrofitted rather than building a new unit.

Energy options

Opportunities to generate saleable emissions reductions may arise from the use of less heat and from switching to fuels with lower carbon intensities. If this process is undertaken within the EU and the fuel input required for heating has a rating higher than 200MW (thermal) then the installation will fall under the EU ETS.

End use

Accoya® wood may be used as an alternative material to steel and other more energy intensive materials in construction and large infrastructure projects. Theoretically there is a net carbon benefit in using Accoya® wood. For example, the emissions from 1m^3 of wood are less than 1m^3 of steel, though a smaller volume of steel might be required to perform the same task. However it is not currently possible to generate carbon value, in international markets, from the substitution of steel with Accoya® wood.

Appendix 2: Calculations

QUANTITY OF WOOD USED TO MAKE 1M^3 OF ACCOYA®

During the acetylation process the wood swells. The implication of this is that to get 1m^3 of final product out, less than 1m^3 of wood needs to be input into the acetylation process. Accsys state that 0.935 m^3 of wood is required to make 1m^3 of Accoya wood product. This information has been used to calculate the weights of wood required from the upstream processes from sawmill to factory gate.

Scots Pine - density at 12% moisture content:	*520*	kg/m^3
Quantity of Scots Pine required:	*0.935*	m^3
Weight of Scots Pine:	**486**	**kg**
Radiata Pine - density at 12% moisture content:	*470*	kg/m^3
Quantity of Radiata Pine required:	*0.935*	m^3
Weight of Radiata Pine:	**439**	**kg**
European Red Alder - density at 12% moisture content:	*495*	kg/m^3
Quantity of European Red Alder:	*0.935*	m^3
Weight of European Red Alder:	**463**	**kg**
American Red Alder - density at 12% moisture content:	*475*	kg/m^3
Quantity of American Red Alder:	*0.935*	m^3
Weight of American Red Alder:	**444**	**kg**

QUANTITY OF CARBON SEQUESTERED IN 1M^3 OF ACCOYA®

Scots Pine Accoya®		
Weight of Scots Pine:	486	kg
Carbon content of wood:	243	kg
Moles of carbon:	20,258	moles
Mass of CO_2:	891,367	g
Quantity of CO_2:	891	kg
Radiata Pine Accoya®		
Weight of Radiata Pine:	439	kg
Carbon content of wood:	220	kg
Moles of carbon:	18,310	moles
Mass of CO_2:	805,658	g
Quantity of CO_2:	806	kg
European Red Alder Accoya®		
Weight of European Red Alder	463	kg
Carbon content of wood:	231	kg
Moles of carbon:	19,284	moles
Mass of CO_2:	848,513	g
Quantity of CO_2:	849	kg

American Red Alder Accoya®		
Weight of American Red Alder	444	kg
Carbon content of wood:	222	kg
Moles of carbon:	18,505	moles
Mass of CO_2:	814,229	g
Quantity of CO_2:	814	kg

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