# Carbon Storage Utilising Timber Products

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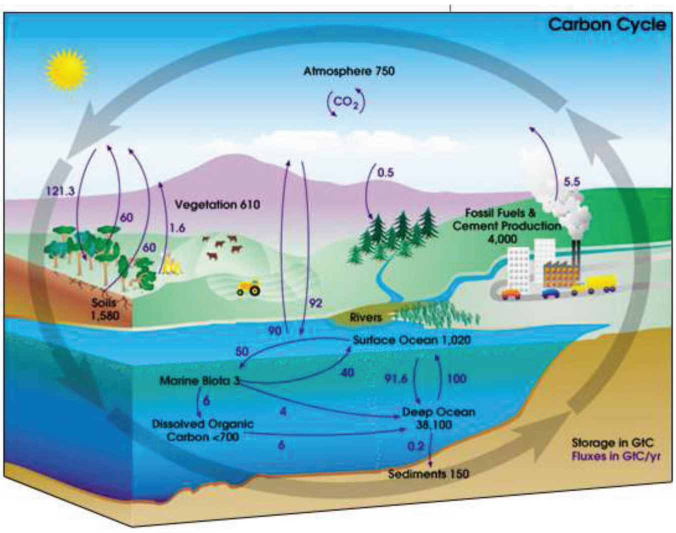



**Figure 1:** The global carbon cycle (source NASA)

## Introduction - Global warming

Current consumption in human society shows a strong addiction to non renewable materials and fossil fuels while deforestation of tropical rainforests still continues at a high rate, which not only results in resource depletion but also means extra releases of greenhouse gases further enhancing the global warming problem. There are various strategies for climate change mitigation either by reducing their sources (e.g. higher energy efficiency, better insulation, using renewable energy, etc) or by increasing their sinks (carbon sequestration), in which forests and forest products play a major role. This essay deals with the role of forests and timber products as a carbon sink to mitigate climate change.

## Carbon Sequestration at Global Level

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). A good overview of the global carbon cycle and sequestration of carbon in forests is depicted in Fig. 1 (source NASA Earth Science Enterprise) revealing that the human role on CO2 emissions is three-fold:

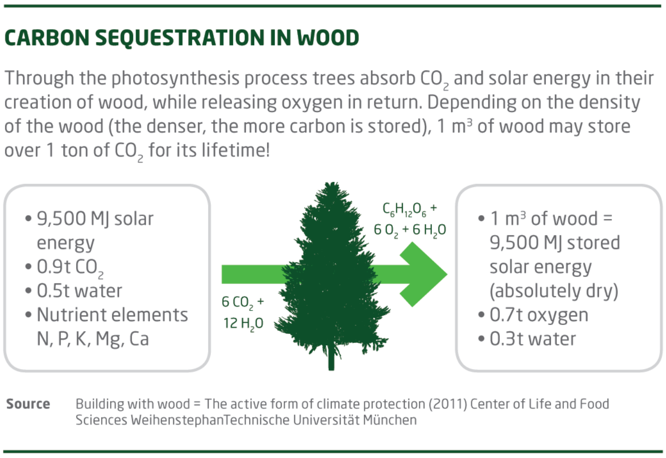
- 5.5 Gt carbon emissions per year caused by burning of fossil fuels
- 1.6 Gt carbon emissions per year caused by deforestation in tropical and sub-tropical areas
- 0.5 Gt carbon sequestration per year by re-growth of forests on the Northern Hemisphere.

It can be concluded that the global carbon cycle can significantly be improved in the short term by i) less burning of fossil fuels, ii) stopping deforestation, iii) forest conservation by better management and wood production in plantations, iv) afforestation (planting of trees on soils that have not supported forests in the recent past) and v) increasing application of wood in durable (construction) products

## Carbon Sequestration in Wood

Besides forming a natural ecological habitat, forests are an important carbon sink by filtering CO2 out of the air and absorbing this in the biomass of the tree as biogenic carbon (see figure 2).

The sustainable use of wood in durable products reduces the rise in CO2 levels in the atmosphere, thus acting as a brake on the greenhouse effect.



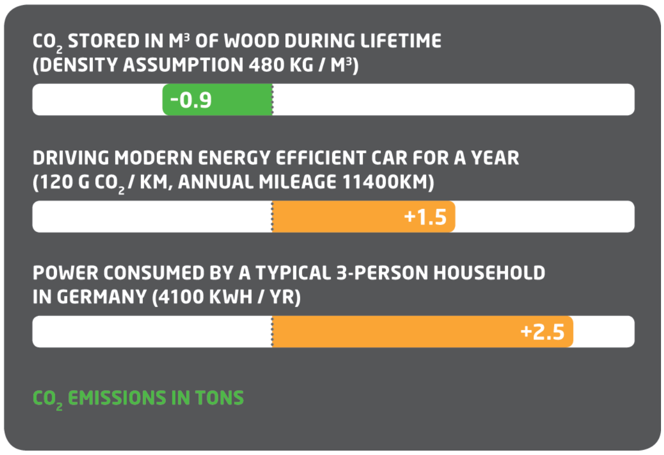




**Figure 2:** Explanation of the carbon sequestration process in wood

Although there are many misconceptions about this issue, for the sake of climate protection, actually the best thing to do is to preserve the forest through responsible management, while harvesting as much wood as sustainable from plantations in temperate and boreal climates for production of durable products such as furniture or construction products, which will act as additional carbon stores while providing the forest the opportunity to regenerate and produce new biomass (acting as additional carbon store).

## Use of Wood - the Solution for Global Warming?

However, it is far too simple to claim 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 and the way of sourcing. One should realise that, if there is no change in the area of forests and no change in the volume of wood in the built environment there is no change in sequestered carbon on a global level and hence no effect on carbon emissions. This means that only when the global area of forests is increasing, and when the total volume of wood in the built environment is increasing, there will be extra carbon sequestration.

### Carbon sequestration in forests

While in the tropical regions deforestation is still continuing, in temperate regions such as in Europe and North America the net forest area, including the corresponding carbon stock, has been increasing steadily for several decades due to afforestation (see figure 3).

Although afforestation in temperate regions is a positive development, for the world as a whole, carbon stocks in forest biomass still decreased by an estimated 0.5 Gt due to deforestation in (sub)tropical regions worldwide between 2005 and 2010.

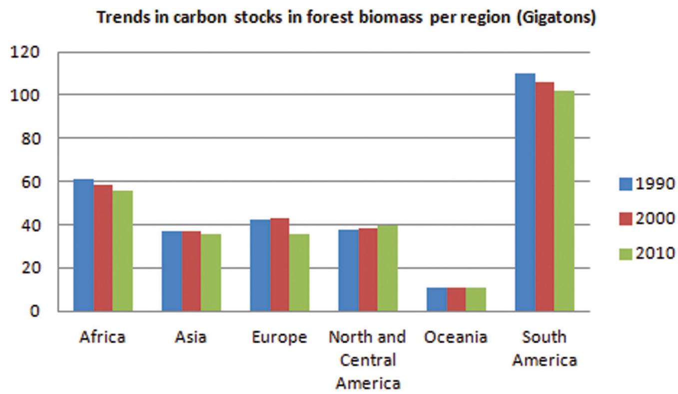
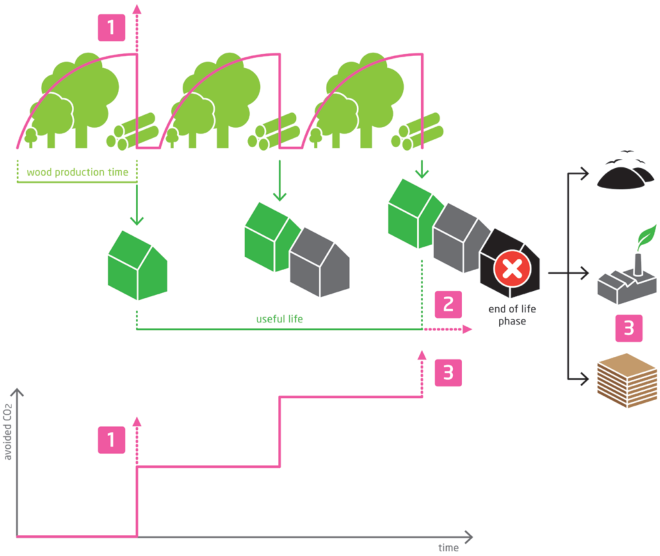



**Figure 3:** Trends in carbon storage in forests from 1990 - 2010 (Source: FAO Global Forest Resources Assessment 2010)




**Strategies for increasing carbon storage**
(for details see text below):

1. utilising wood species with higher annual yield
2. increasing durability of the wood product
3. recycling

**Figure 4:** Avoided CO2 emissions in case of new sustainably managed plantations being established for manufacturing durable products (adapted after Technical University Munich, 2012)

Demand of good quality certified (e.g. FSC, PEFC) tropical hardwoods suitable for outdoor use is higher than supply, resulting in illegal logging which, in turn, leads to the deforestation of tropical rainforests. Note that there are many other causes for deforestation besides illegal timber sourcing, such as the conversion of forest land to agriculture land, and forest fires.

**Carbon sequestration in durable products**

The volume of wood in the built environment is slowly rising on a global scale (because of increasing population), which is positive in terms of extra 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.
However, due to better performance, especially in outdoor use (durability, hardness, stability), tropical hardwood is often preferred over softwood from temperate regions, which as argued above, may lead to additional deforestation (and therefore carbon emissions) in tropical regions and thus may even have a negative impact on global warming.

## Carbon Sequestration at Product Level

Now that we understand the carbon cycle at the global level, including the role that wood can play in carbon sequestration, let's focus at the product level on what the consequences are for carbon sequestration during production, consumption and disposal of wood products. Given the increasing attention worldwide with respect to global warming potential (GWP), the GWP of products is often assessed separately in a so-called 'carbon footprint'. In such an assessment all the greenhouse gas emissions during the life cycle of a product are measured and expressed as kg CO2 equivalent (in short CO2e).
It is important to understand that there is currently no general consensus in Life Cycle Assessment (LCA) and carbon footprint methodology (the most important ones being PAS 2050, ILCD and WRI/WBCSD GHG protocol) or how exactly to allocate credits for temporary storage of biogenic carbon (use phase) as well as fossil fuel substitution (end of life phase) in wood products. Most notably there is not a consensus about the time horizon to choose for such calculations. However, using common sense makes the issue of carbon sequestration over the life cycle (from growth and production, to use, to end of life of a timber product) comprehendible. See also figure 4.

**Production phase**

If a tree from a well managed forest is harvested (thus replaced by a new tree), depending on the wood species (density) approximately 1 ton of CO2 is locked per m3 of timber product manufactured (wood species with a density of 550 kg/m3 absorb 1 ton of CO2, the higher the density the more CO2 is stored). Note that transport and manufacturing these timber products on the other hand yields new emissions, however these are usually many times lower than the CO2 absorbed during growth.

**Use phase**

During its use in applications the CO2 is locked in the wood products for the life time of the product, acting as a temporary carbon sink until the wood breaks down into its original components, including CO2. Needless to say, the longer the wood remains in the application, the longer the CO2 is removed from the atmosphere, mitigating the global warming effect. An indirect CO2 saving effect of using wood is related to the good insulation properties wood has when used in the envelope of a building (e.g window frame, cladding, roof), providing energy saving benefits and consequently CO2 reductions.

**End of Life phase**

When the wood product does reach the End of Life phase there are various scenarios possible. From an ecological and economic point of view if the quality of the discarded wood product permits (containing no toxic substances) , the best option is to recycle it to a secondary wood product such as MDF or particle board, thus further lengthening the carbon sink effect of the wood. Alternatively, the wood product can be burnt at end-of life in a biomass energy plant (preferred over a municipal waste incinerator due to the higher efficiency because of the focus on biomass), to generate green electricity, which can replace electricity from other sources, including fossil fuels. As a result the use of fossil fuels and the emissions of fossil $CO_2$ is consequently avoided, which results in a reduction of potential global warming effects and can therefore be regarded as a carbon credit (see figure 3). It should be noted that all too often wood is just being discarded in landfills, where during rot the same amount of $CO_2$ is released in the atmosphere as was absorbed during growth. Additionally, there is the negative side-effect that upon dumping in landfills, other more harmful greenhouse gases may be released, most notably methane.

**Strategies to increase the carbon storage effect in wood**

In each phase of the life cycle a strategy can be identified to further increase the carbon storage effect in wood products (see also figure 3).

First, during production there are large differences between wood species with respect to the amount of biomass which is accumulated in the trees during their growth in a certain period of time (rotation cycle), also known as the Mean Annual Increment (MAI). Even when compensating for density (usually slower growing species have larger density thus larger carbon storage per cubic meter of wood), there are large differences between wood species which makes it interesting to opt for faster growing wood species to increase the carbon sink effect that can be reached in the global durable products pool. Besides the increased carbon sink effect, from a materials depletion point of view (another global environmental problem), it is obviously better to look to wood species with a higher ability to regenerate (and to renewable materials in general as opposed to non renewable abiotic resources).

Second, in the use phase there are carbon storage advantages to be reached if the wood has a higher durability, thus lasts longer in the application. As argued above, tropical hardwood often has higher durability than many wood species from temperate regions, but is often not sourced responsibly, yielding extra $CO_2$ emissions during production (deforestation).

Finally, during the End of Life phase wood products may be recycled into new wood products in which the carbon sink effect will be lengthened for the lifespan of the new application in which it is used (even when taking into account the $CO_2$ emissions released during the recycling process). Techniques of increasing wood life through the addition of toxic compounds can complicate or eliminate this potential.

## Conclusion

Looking at the potentialities and downsides of wood on both the product and global level, the big challenge for wood products to really make a global difference in carbon sequestration lies in enabling wood species from temperate regions (more stable forestry policies resulting in increasing afforestation & certified forest area) to substitute for popular but endangered tropical hardwoods.

A promising route enabling temperate wood species in high performance applications is large scale non toxic modification of fast growing sustainable species from certified sources. These kinds of wood technologies can compensate for the typical poor performance characteristics of most softwoods, especially in (outdoor) use, such as a

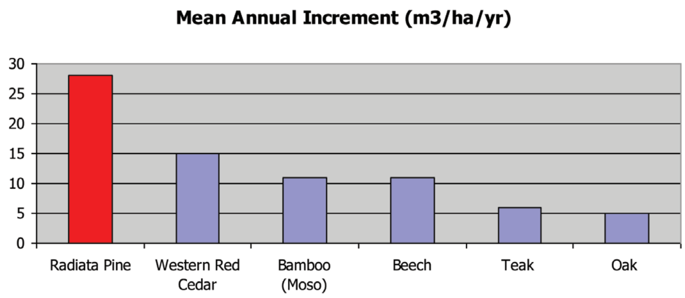



**Figure 5:** Cubic meters of wood produced per hectare per year (M3/ha/yr)

low durability and dimensional stability. As such they adopt the carbon storage increase strategies as mentioned above and thus might provide the solution for a well performing, sustainable alternative to meet and even increase the market demand for high performance timber products, including their huge potential for carbon sequestration. Given these improved properties, modified wood may even be used in applications typically reserved for carbon intensive manmade materials such as plastics, metals and concrete. For more information about the potential of wood modification for carbon sequestration and saving see 'Carbon Sequestration in Wood'.

## Wood modification as a means of improving net carbon sink

Wood modification is a means of improving the performance of wood without the typical negative impacts of traditional preservation techniques based on impregnation with toxic preservatives such as CCA or ACQ. Wood modification works at a molecular level to change the structure of the wood itself and thus improve many of its performance characteristics, most importantly the durability and dimensional stability. There are a variety of modification techniques being used in the market currently, of which acetylation is widely acknowledged as the method of achieving the greatest performance improvements.

Acetylation is the name of a chemical wood modification process which was already developed almost a century ago.
In this process, the free -OH (hydroxyl) groups within the cell wall are replaced by acetyl groups, a compound which occurs naturally in unmodified timber. These non-toxic acetyl groups are hydrophobic, and prevent water bonding onto the cell wall and so prevent the water causing swelling of the wood or providing a food source for the fungus and attacking insects that bring about decay, resulting in the highest durability class possible (class 1 in EN 350). The bi-product of this process is acetic acid, otherwise known as vinegar in its dilute form, which can be reused in a wide range of industries including the food industry.

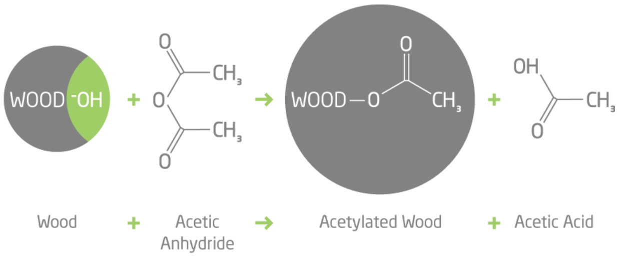



**Figure 6:** the chemical reaction occurring during acetylation


**Figure 7:** A large scale application of Accoya® wood – Sneek bridge, the Netherlands

Acetylated wood has recently been developed to commercial scale under the brand names Accoya® (acetylated timber) and Tricoya (acetylated fibres for products such as MDF).

The features above make acetylated wood a very promising alternative for tropical hardwood in outdoor applications such as external joinery, decking and canal lining, but due to the good processability (machining, glueing) also for structural glulam applications such as bridges, normally preserved for traditional carbon intensive materials such as steel and concrete, as tropical hardwood is not suitable for glue lamination.

Figure 7 shows one such structural application for Accoya® wood. The traffic bridge in Sneek, the Netherlands, is the first ever heavy traffic road bridge constructed with a wooden bearing structure.

The following calculations are based on carbon footprint studies executed by Verco and reviewed LCA study of the Delft University of Technology, and use the PAS 2050 methodology for identifying the CO2 sequestered in acetylated wood during the expected life span (80 years) of this application, showing the huge carbon sink potential of this kind of wood modification technology. Note that this calculation still excludes potential End of Life benefits (e.g. substitution of fossil fuels upon incineration) and the fact that the carbon footprint for Accoya will likely improve even more as more local wood species are introduced and factory efficiency increases.

## CO2 sequestered in the Sneek bridge

| | | | |
|---|---|---|---|
| **1** | Density of wood (kg/m3 based upon radiate pine at 12% moisture content) | | 450 |
| **2** | Assumed carbon content of wood | | 50% |
| **3** | CO2 sequestered excluding PSA 2050 weighting (kgCO2/m3) | [1] x [2] x 44 / 12 | 825 |
| **4** | Expected lifespan of the bridge (years) | | 80 |
| **5** | CO2 sequestered including PSA 2050 weighting (kgCO2/m3) | [3] x ( [4] / 100 ) | 660 |
| **6** | CO2 emitted during production (Acetylated Radiata Pine) | | -391 |
| **7** | Total: CO2 sequestered during production and use (kgCO2/m3) | [5] - [6] | 291 |