

# Carbon and its storage in forest and wood products

National curriculum links – Yr 10 Understanding

Science – Properties of elements (ACSS186)  
Global systems – carbon cycle (ACSSU189)  
Energy conservation (ACSSU190)

Maths – Evaluating statistics (ACMSP253)  
Measurement of volume (ACMMG242)  
Algebraic formulas (ACMNA234)

## What is carbon?

Carbon is represented by the symbol 'C' and is the 6th element in the periodic table of elements, with an atomic number of 6 and an atomic mass of 12.001. It is a non-metal and the fourth most abundant element in our solar system, only surpassed by hydrogen, helium and oxygen. Carbon is the major component of the non-living things coal, charcoal, and diamonds, as well as living things including trees. The melting point of carbon is very high at 3550 degrees Celsius and its boiling point is 4827 degrees Celsius. Carbon can be in gas or solid states.

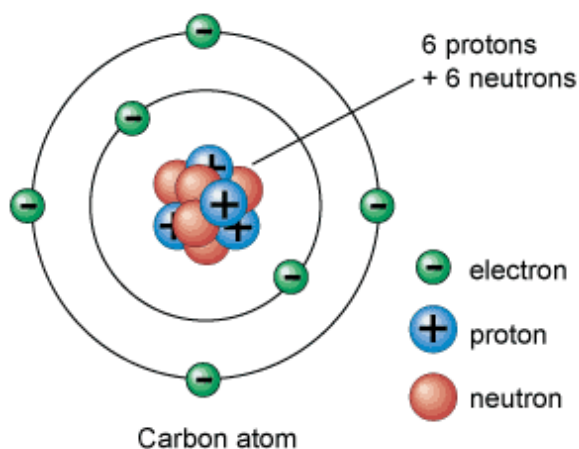


Diagram: The carbon atom

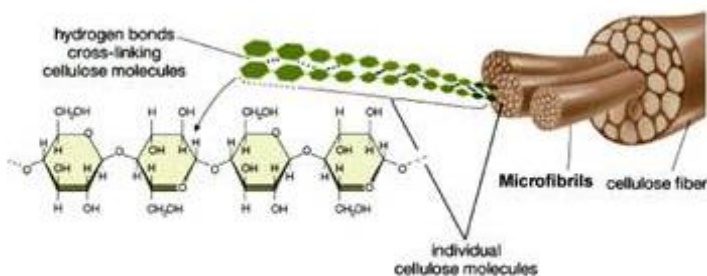


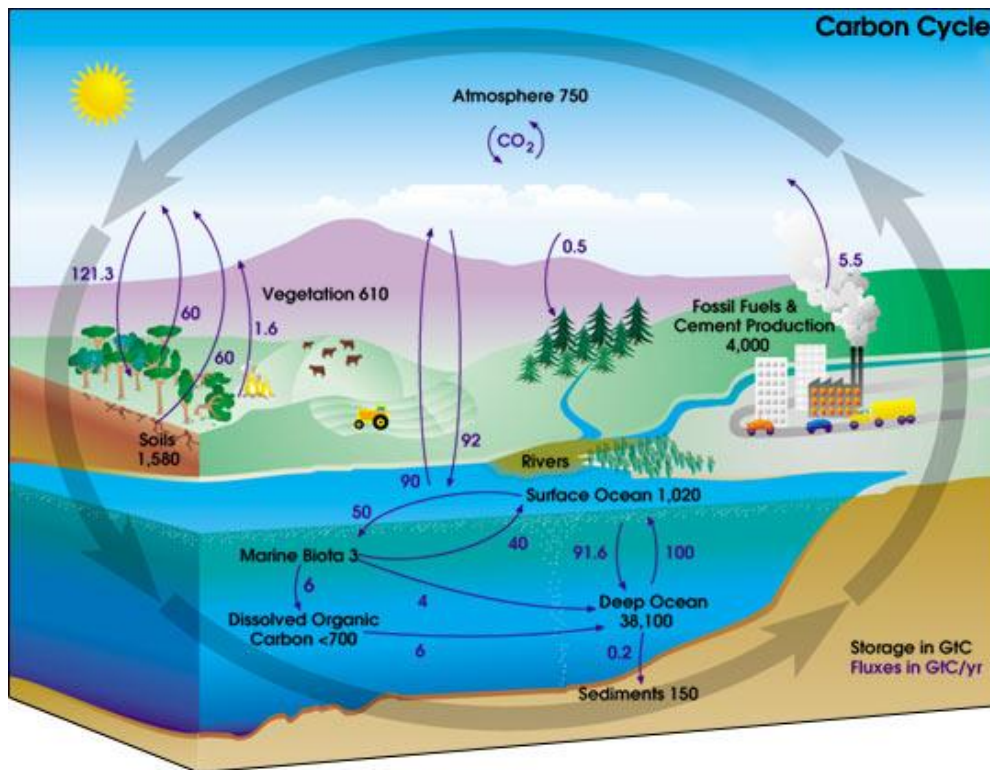
Diagram: Carbon in structural cellulose

## **How is carbon cycled in ecosystems?**

Carbon is cycled through ecosystems in several different forms. It has a tendency to be attracted to oxygen and form gaseous compounds such as carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) which are considered air pollutants and contributors to climate change. Carbon dioxide (gas) can be removed from the atmosphere by trees through photosynthesis. This process involves plant cells converting the carbon from carbon dioxide to a solid form in sugars (the carbohydrates glucose and starch) that can be stored in leaves, stems, trunks, branches and roots, and contribute to tree growth.

Starch is also stored in reproductive tissue including flowers, fruit, nuts, pods or cones, while glucose is used in respiration to help keep the tree alive. Oxygen is released back into the air as a by-product of plant respiration which animals are dependent on for their survival. Cellulose is another sugar manufactured by the plant and is particularly important in plant cell walls to help maintain structure and keep plants upright, and is the main energy source in woody biomass used in renewable energy production.

The carbon cycle demonstrates the various phases of carbon through living things, the soil, water and atmosphere. If the carbon cycle was in equilibrium, the rate at which carbon is removed from stores would equal the amount being taken out of the atmosphere. The current concern about the carbon cycle is that it is considered to be out of equilibrium in response to intervention by man. The burning of fossil fuels high in carbon has disturbed the natural balance of the cycle and enhanced the rate at which carbon is returned to the gas phase. This increase in carbon gas in the atmosphere, particularly as carbon dioxide and methane, has been found to contribute to global warming and is referred to as the 'Greenhouse effect'. This is the process where greenhouse gases trap infrared radiation in the atmosphere and cause the earth to warm.



**Diagram:** The Carbon Cycle (The black numbers indicate how much carbon is stored in various reservoirs across the earth in billions of tonnes ("GtC" stands for GigaTons of Carbon). The blue numbers indicate how much carbon moves between reservoirs each year. (Source: New World Encyclopaedia)

### **Why are forests and wood products important in helping tackle climate change?**

Australian forests and wood products store or sequester approximately 57 million tonnes of carbon dioxide which offsets around 10% of all greenhouse gases emitted in Australia (DAFF, 2008). Carbon constitutes approximately 50% the dry weight of trees (Robinson & Kile, 2007) and when wood from these trees are used in construction gives carbon storage life for around 100 years in homes, around 30 years in furniture, 30 years in railroad ties, 6 years in pallets and also paper (Skog and Nicholson, 2000). Carbon stored in wood is only released back to the atmosphere when the wood is burnt or decays. This compares to construction steel which contains only 0.2 - 1.5% of carbon and is a net emitter of carbon in the production process.

## Calculating the amount of carbon stored in trees and sawn timber

The amount of carbon stored in trees depends on tree species, growth conditions in the environment, age of tree and density of surrounding trees. For the purpose of this exercise, formulae will be used to obtain an average estimate over the life span of a sample tree, and excludes stores in soil carbon. This is based on generalisations that 35% the green weight of a tree is water and after drying (at 70°C) 50% the dry weight of a tree is carbon (Source: Ximenes et al., 2008). Further, since 20% of tree biomass can be below ground level in roots, a multiplication factor of 120% has been used. To determine the equivalent amount of carbon dioxide, the carbon figure is multiplied by a factor of 3.67.

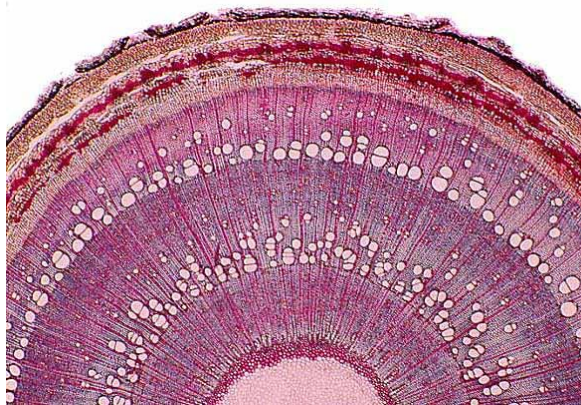
$$\text{CO}_2 \text{ sequestered per tree (kg)} = \text{Tree mass (kg of fresh biomass)} \times 65\% \text{ (dry weight)} \times 50\% \text{ (carbon \%)} \times 3.67 \times 120\% = X$$

$$\text{CO}_2 \text{ sequestered per tree per year (kg)} = X / \text{age of the tree (yrs)}$$

**Example** For a 12 year old spotted gum tree weighing 600kg green, then the amount of CO<sub>2</sub> sequestered by the entire tree = 600 x 65% x 50% x 3.67 x 120% = 859 kg CO<sub>2</sub> or 72 kg CO<sub>2</sub>/yr

Harvesting of trees from both native and plantation forests has been estimated to remove approximately 8 million tonnes carbon per year, while prescribed burning, wildfires and wood for energy remove another 4.4 million tonnes, leaving a net sink of around 12 million tonnes carbon per year in Australia (Robinson and Kile, 2007). Therefore forests sequester more carbon than they emit, thereby helping to offset the country's total greenhouse gas emissions.

An increase in tree height and canopy cover is an indication of tree growth. The age of a tree can be determined by growth rings in a number of species, where each year there is a concentration in conductive tissue known as xylem. Tree growth occurs outwards from the centre of the tree, so the rings on the outside nearest the bark are the youngest.



**Diagram:** A woody stem showing annual growth rings (3 year old Ash tree)

The weight of a tree can also be estimated using parameters of volume and wood density. Firstly standing tree volume needs to be calculated; this can be done using formulas for either cone shaped or cylindrical shaped trees (Source: Snowdon et al., 2002).



Conical



Cylindrical

Tree weight (kg) = Volume of the tree (m<sup>3</sup>) x density of wood (kg/m<sup>3</sup>)

Where Volume (m<sup>3</sup>) = (Tree height(m) x d<sup>2</sup>(m<sup>2</sup>) x 0.7854)/3 (for conical shaped trees e.g. pines)

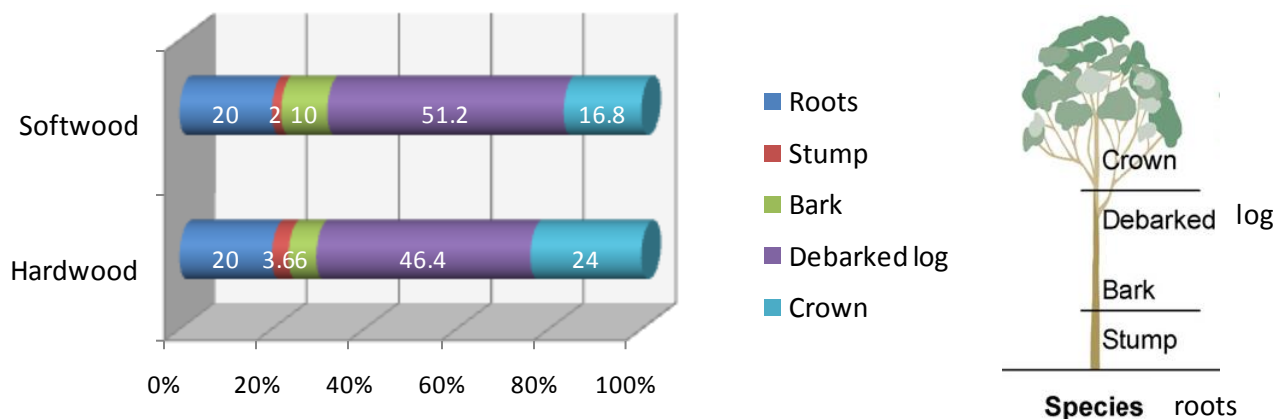
Or = Tree height (m) x d<sup>2</sup> x 0.7854 (for cylindrical shaped trees e.g. eucalypts)

And diameter 'd' is taken at breast height of the tree (1.3m above ground level)

Using average oven dry densities for hardwood eucalypts of 700 kg/m<sup>3</sup> and softwood pine of 400 kg/m<sup>3</sup>

**Example** For a 10 year old eucalypt tree of height 12 metres with a basal trunk diameter of 25cm, the volume would be = 12 x 0.25<sup>2</sup> x 0.7854 = 0.589 m<sup>3</sup>. Then the tree weight can be estimated at =0.589 x 700= 412.3 kg. The amount of carbon dioxide sequestered in this tree = 412(kg) x 65% x 50% x 3.67 x 120% = 590 (kg) CO<sub>2</sub>. The average sequestration rate then is = 590kg CO<sub>2</sub> / 10years = 59kg CO<sub>2</sub>/year.

Carbon stores in tree biomass are distributed in different proportions throughout the tree in the stump, trunk (bark and debarked log), crown and roots as shown below, and differ for softwood and hardwood species.



**Diagram:** Proportions of biomass distributed across the various parts of a tree (%)

(Adapted from Ximenes et al., 2008)

The amount of carbon in sawn timber logs for use in construction can be calculated using average rates of recovery after processing, estimated at around 35% for hardwoods such as eucalypts and 50% for softwoods such as pine. The standard moisture content for air dried timber (and wood products) is 12%, which accounts for the multiplication factor of 88% after moisture removal. The remaining mill waste from processing also has various uses including source of biomass in renewable energy production and saw dust.

**CO<sub>2</sub> sequestered in construction timber (kg) = air dry weight of saw log (kg) x 88% (oven dry weight) x 50% (carbon %) x 3.67 x recovery rate (%)**

**Note: use a 35% recovery rate for hardwoods and 50% for softwoods during processing of saw logs**

*Example* For a 150 kg hardwood saw log seasoned in a timber yard then processed into construction beams, the amount of carbon sequestered in the timber and stored for the life of the building is calculated as = 150kg x 88% x 50% x 3.67 x 35% = 84.8 kg CO<sub>2</sub>



## Student questions

- Indicate and label where carbon is placed on the following representation of the periodic table. Is carbon a metal, non-metal, halogen or noble gas?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1																		
2																		
3																		
4																		
5																		
6																		
-																		

- What is the name and symbol of the major greenhouse gas removed by trees from the atmosphere in the process of photosynthesis?

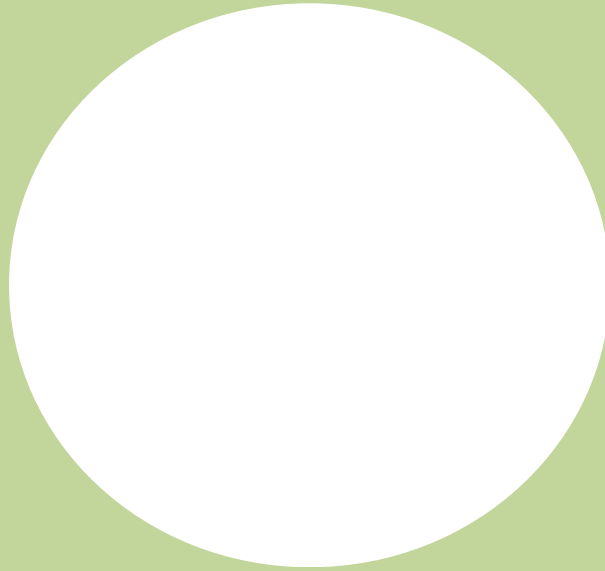
- How does this gas contribute to global warming in the atmosphere?

- What proportion of biomass (%) of a hardwood tree would you expect to find in the trunk after the bark has been removed for log production?

## Class activities

- Construct some carbon based molecules using an organic chemistry molecular kit e.g. glucose ( $C_6H_{12}O_6$ ). Cellulose consists of long chains of glucose ( $C_6H_{10}O_5$ )<sub>n</sub>. Draw and label the glucose structure.

- Test a cross section of a tree branch for the presence and location of starch. In preparation, collect and soak pieces of branch overnight to make them softer and easier to cut into cross sections. Use iodine solution (iodine in potassium iodide) that will turn from brown to dark blue in the presence of starch and examine under a binocular microscope. Draw and label what you see in the field of view below. (Note: This is a practical experiment and requires a risk assessment to be completed in preparation).



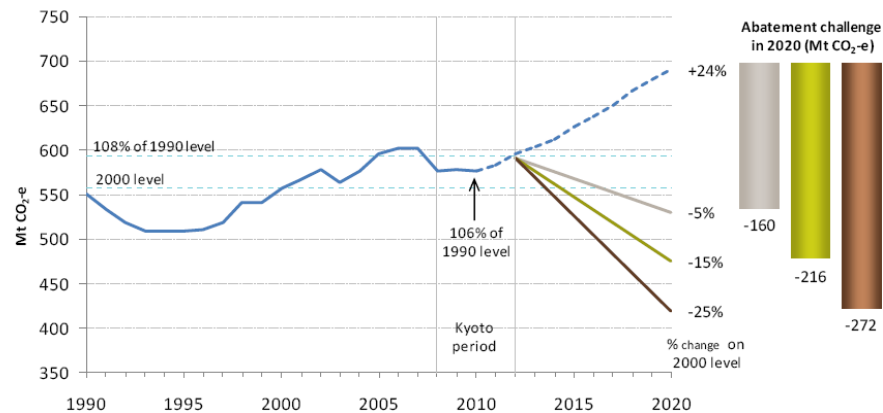
### Problems to solve

- Calculate the amount of carbon dioxide sequestered during the growth of a spotted gum eucalypt plantation forest on an annual basis (i.e. per year) using the equations provided above. Based on the forest being 12 years of age, 200 hectares in size at a thinned density of 650 trees / hectare, and each tree having an above ground green mass of 600 kg.

- How much carbon dioxide would be sequestered in a sawn hardwood timber beam processed from a log of diameter 40 centimetres and length of 6 metres using a recovery rate of 35%. Use equations provided above and show all working out.

## Analysing the situation

Figure 1 Australia's emissions trends, 1990 to 2020



Note: Trajectories to the 2020 target range are illustrative, they begin in 2011-12 at 108 per cent of 1990 levels (consistent with Australia's Kyoto Protocol first commitment period target) and assume a straight line reduction to the target.

Australia's annual greenhouse gas emissions were estimated at 597 million tonnes CO<sup>2</sup>-e in 2007 (CSIRO, 2009), dropping slightly to 582 million tonnes CO<sup>2</sup>-e in 2010, although projected to increase to 690 mill tonnes in 2020 if urgent measures are not taken to reduce emissions from the energy sector, in particular export of coal and liquefied natural gas (DECCEE, 2010).

- Research and discuss measures that could be taken to reduce greenhouse gas emissions, otherwise referred to as 'abatement measures' as illustrated on the above graph.

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