How much carbon does a tree store?

According to data from available literature and on the internet, the general consensus is that the average tree absorbs 1 ton of CO2 during a lifetime of roughly 100 years. But what is an average tree, how big is it and is it a hardwood or a softwood? Are you now wondering how much CO2 the trees in your neighbourhood absorb?

Goal: Pupils calculate how much carbon is retained in a tree's trunk in a garden, the school grounds, a forest or woodland. They will measure the height of the tree and its diameter and use a table to find out how much wood the trunk contains. From the weight of the tree they then calculate the amount of sequestered carbon.

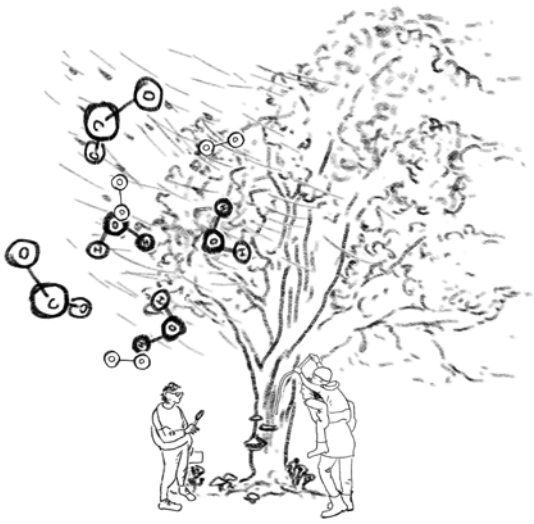
How long: 60–90 minutes

Who: Grades 8 / 9 and high school

Where: School surroundings (or closest location with trees on hand)

When: All year round

You need: Tools for measuring the tree (tape measure, calliper, two-metre pole and Christen hypsometer, clinometer or any other altimeter), electronic device to download tree weight calculator app or forestry weight charts, paper, pad and pencil for each group, calculator, periodic table (for advanced calculations)



1. ESTIMATE

Pupils will choose a mature tree or use a pre-selected one. Before getting to work, individuals or groups discuss and record:

a) estimates of:

- the height of the tree
- its diameter (at an approximate height of 1.3 m)
- the volume of wood in the tree
- the weight of the tree
- how much carbon the tree is storing

b) the possible methods to detect and measure these quantities

2. TREE MEASUREMENT

Find out the height and diameter of the tree and determine its species. You can measure the height in several ways, for example, with the help of a Christen hypsometer. Measure the diameter at a height of 1.3 m.

3. WOOD VOLUME

With help of volume tables or wood calculators find out the tree's volume of wood.

4. TREE WEIGHT

Use an online wood calculator to find out (using the volume and species of the tree) the weight of the tree without branches and bark. This means that the true weight of wood will in fact be about 5–20% more (depending on the tree species, crown shape, age...).

TIP: You can also use calculation for fresh logs, but then count with up to 50% of the weight of the wood being water.

5. QUANTITY OF CARBON

Wood is made up mainly of cellulose and lignin. The chemical formula for cellulose is $C_6H_{10}O_5$. Lignin is a more complex mixture of organic substances (carbohydrates) but its composition is very similar to cellulose (and wood is 20–30% lignin). According to the atomic weight (high school students can calculate it by themselves using the periodic table of elements) carbon makes up some 44% of wood.
Relative atomic weight of elements: carbon: 12, hydrogen: 1, oxygen: 16.
Multiply the weight of wood from the calculator (in dry state – almost without water) by
44% and you will get the amount of carbon (C).

6. WEIGHT OF SEQUESTERED CO_2

If you wanted to know the weight of the sequestered CO_2, proceed as follows: in CO_2, carbon makes up only 27% of the weight (C: 12, 2x O: 2x 16 = 32, so 12 + 32 = 44; 12/44 = 0.27 = 27%), therefore we divide the weight of carbon from the previous point by 0.27 and get the weight of the absorbed carbon dioxide CO_2. Attention! That weight is 63% greater than the total weight of the tree – but you need to realise that the tree returns a greater part of the CO_2 molecule into the atmosphere in the form of oxygen, O_2.

When you cut down a mature tree, you now know how much CO_2 is released when you burn it. It is just the weight of CO_2 the tree has spent decades absorbing into its body.

If you cut it down and let it rot, it will release the same amount of carbon gradually, for decades, but if you build a house from it, it will continue to retain the carbon it contains, possibly for a hundred years or more... But if you let it grow, it will absorb more and more carbon with some trees working for 500 years.

7. SCIENTIFIC CONCLUSIONS

Conclude this scientific research with the students by evaluation. What were the students‘ results? What numbers and data did they find? How accurate were the estimates at the beginning of the lesson? You can further discuss these questions:

If you cut down a mature tree, would you now know how much CO_2 it will release when you burn it? (It is precisely the weight of CO_2 that the tree has taken decades to accumulate.)

What happens when you let the tree rot? (The same amount of carbon will be released gradually, again for decades.)

What happens if you use the tree as a building material? (It will continue to hold the carbon until the wood is burned or left to rot.)

What happens if we let it continue to grow? (It will continue to store carbon and not just the carbon it has already accumulated during its lifetime but more carbon from the atmosphere for many more decades.)

WHAT CAN BE EVALUATED (EVIDENCE OF LEARNING):

The students wrote down their estimates alone or in groups (e.g. how much CO_2 the selected tree captured). They measured the dimensions of a tree and calculated the required steps between tree weight and amount of carbon.
They calculated the amount of stored carbon in the tree, the potential CO_2 and evaluated the effect of wood processing on the CO_2 release rates.

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Worksheet for grades 8/9:

How much carbon does a tree store?

1. Species of the tree: .....

2. Estimate and measure:

Tree height:
Estimate: ..... m Actual height: ..... m

Diameter (at 1.3 m):
Estimate: ..... cm Actual diameter: ..... cm

3. Estimate and calculate:

Estimate the volume and weight and enter the type of tree, its height and width into the table:

Wood volume:
Estimate: ..... m^3 From tables: ..... m^3

Calculate the approximate weight of the wood:

Tree types	Density of dry matter	Examples of tree species
light	400 – 500 kg / m^3	spruce, fir, pine, poplar
slightly heavy	500 – 600 kg / m^3	willow, larch, mahogany
medium heavy	600 – 700 kg / m^3	birch, ash, oak, beech
heavy	700 – 1000 kg / m^3	acacia, hornbeam

Wood weight:
Estimate: ..... kg Calculation: ..... kg

Amount of carbon (C) – 44% of the total tree weight: ..... kg

Weight (CO_2): The mass of CO_2 is 27% carbon by atomic weight. Divide the weight of the carbon by 0.27: ..... kg

Our tree ..... with a height of ..... msequesters ..... kg of CO_2.

Worksheet for high schools:

How much carbon does a tree store?

1. Species of the tree: .....

2. Estimate and measure:

Tree height:
Estimate: ..... m Actual height: ..... m

Diameter (at 1.3 m):
Estimate: ..... cm Actual diameter: ..... cm

3. Estimate and calculate:

Estimate the volume and weight and enter the type of tree, its height and width into the table:

Wood volume:
Estimate: ..... m^3 From tables: ..... m^3

Calculate the weight of dry wood from the volume using wood-volume tables (calculate dry wood / lumber) or fresh logs (reduce by 50% to get dry weight).

Wood volume:
Estimate: ..... kg Calculation: ..... kg

Dry wood weight:
Estimate: ..... kg Calculation: ..... kg

The total weight of the wood contains cellulose and lignin with a chemical formula of C6H10O5. Use the periodic table to calculate what percentage of wood is made up of carbon: ..... %

What is the weight of carbon in your tree? ..... kg

How much CO2 was needed for the tree to sequester that amount of carbon, what weight of CO2 did the tree absorb?
..... kg

Is this number higher or lower than the weight of the tree and why?

Our tree ..... with a height of ..... msequesters ..... kg of CO2.