CO_2

In order to understand the basic science behind the climate crisis, let's start by considering wood.

I know, who in the world would begin a discussion of climate science by talking about wood? Perhaps only someone who really loved this particular material, like a furniture maker. (In case you didn't know, prior to becoming a professor, I spent two decades of my life making my living as an artisan, a furniture maker.)

So, where does wood come from? This might sound like an obvious question, but the answer may surprise you.

In other words, if you plant a tiny acorn and wait a hundred years or so, it will become an oak tree containing thousands of pounds of wood that can be made into things like furniture. Where did most of that mass come from? (Incidentally, I have a UCSB colleague, Lisa Berry, to thank for planting the idea of an acorn in my head in this context.)

Wood chiefly comes from four sources. Interestingly - although it is somewhat irrelevant to our discussion - these correspond to the four classical (Greek) elements: Earth, Water, Air, and Fire.

Earth. Without certain elements from the soil, like nitrogen, trees, indeed all, plants cannot thrive or even survive. This is why farmers add nitrogen to the soil, such as though petrochemical fertilizers (i.e. fertilizer made from fossil fuels) or organically through plants that add nitrogen to the soil, like legumes.

Water. Without water, trees and other plants cannot survive. This is why certain drought-tolerant plants, such as salvia (sages), can survive a drought while other plants like turf grass cannot. Hence, lawns are a bad idea in dry areas, like here on the Central Coast of California, as their roots only reach a few inches into the ground. In contrast, some sages have roots that go many feet down into the ground to access the ground water down there.

Air. As with animals, plants and trees cannot survive without air. Put a plant in a sealed bag and it will promptly die.

Fire (energy). Without solar energy, photosynthesis cannot occur. This is why certain growers use opaque plastic for weed control. It's a simple, but rather brilliant idea. If you lay black plastic on the ground and make holes for young plants, for example strawberries, then no other competing plants (i.e. weeds) can grow, as they will not have access to sunlight. Weeds may sprout under the plastic, but they will quickly die without the sun's lifegiving energy.

So, what do you think: Where does the wood that makes our furniture and houses principally come from? Earth (minerals from the soil)? Water? Wind (air)? Fire (photosynthesis by way of solar energy)?

The correct one is…drumroll please…Air. Believe it or not.

If you're like many people, most of your furniture and a good deal of your house is made of wood - and it all came from air, out of thin air.

To understand how this works, we need to consider CO_2 (carbon dioxide), the principal greenhouse gas.

Rising levels of atmospheric CO_2 are the primary cause of the climate crisis. Although a range of other gases, principally methane, are also involved, CO_2 is the primary greenhouse gas.

Although our atmosphere contains relatively small concentrations of CO_2, it has a profound impact on plants, animals, and the climate. Since Shakespeare's time, CO_2 in the atmosphere has risen from 280 parts per million (PPM) to a high of 420PPM today. That's an increase of almost 50%. If a 50% increase sounds like a lot, it should. Indeed, it should be more than a little alarming

Where did all that CO_2 come from? In order to tackle this question, we have to consider a little science. Don't worry, I'm a humanities person, not a scientist. I promise it is indeed just a little and not at all tough science. Honestly, it's really pretty fascinating.

Plants are capable of doing something altogether extraordinary with atmospheric CO_2 when combined with H_2O (water) and energized by solar radiation. Through the process of photosynthesis, molecules of CO_2 and molecules of H_2O are synthesized into a range of new molecules.

For example, six molecules of CO_2 plus six molecules of H_2O becomes one molecule of $C_6H_{12}O_6$, as well as six molecules of O_2 (the atmospheric oxygen that we animals breath). As you may recall from high school or college science class, $C_6H_{12}O_6$ is the glucose molecule, a simple sugar.

This is a crucial service for all animals, as six molecules of CO_2 are nicely converted into six molecules of O_2, which is the oxygen that we animals breathe. Again, as you very likely will remember from high school, this creates a planetary system wonderfully in balance, as it means that we animals exhale CO_2 and take in O_2, while plants take in molecules of CO_2 and return an equal number of O_2 molecules into the atmosphere.

But plants to do more, as they also make glucose, as well as range of similar molecules, such as fructose and sucrose. These sugars are essential foods for all animals. You probably are more familiar with them by the common name that they all share: “carbohydrates” or simply “carbs.”

The "carb" in the word "carbohydrates" comes from carbon, as carbohydrates are hydrates of carbon. As a hydrate is simply a substance that contains water, a carbohydrate contains water and carbon (and oxygen).

Carbon is thus an essential part of the food that we animals eat, whether we get it directly from plants or indirectly from the animals that we eat, like cows and chickens, that have eaten plants.

In addition to synthesizing sugars like glucose from CO_2 and H_2O through photosynthesis, plants can create other molecules, such as cellulose ($C_6H_{10}O_5$), hemicellulose, and lignin. Wood is chiefly composed of these three molecules, which, like gloucose, are also made of carbon, hydrogen, and oxygen.

This is also very handy for us. Some plants create edible carbohydrates (which are the basis of everything that we eat), while others create usable material that we can use, like wood.

When life on earth is referred to as "carbon based" (as it sometimes is in sci-fi, like the TV series *Altered Carbon*), it is an acknowledgment that carbon is an essential constituent of all plants and animals on earth. The human body is 65% Oxygen, 18.5% Carbon, 9.5% Hydrogen. However, if a human body is dried out, as in the case of a mummy, what is principally left is carbon.

Similarly, when we dry a tree’s wood to become usable lumber, about half of what is left is carbon, as well as nearly as much oxygen.

Hence, returning to our original question, all that carbon and oxygen (C and O) came out of thin air, or, more accurately, came out of the CO_2 in air that the tree (because it is a plant) pulled out. Water, of course, also plays a part, but the lion’s share of a piece of dried wood’s mass comes from CO_2. Furniture makers, incidentally, generally like to work wood that has just 6-8% moisture (water) content or so.

Although it sounds a little hard to believe on first hearing, a great deal of our world has been made out of thin air: carbon and oxygen (CO).

When we think of “natural” materials that we human beings use, this is generally the case. Up until recently, when we started synthesizing other materials, which are often made out of fossil fuels, this was almost always the case. For example, all of the following materials are made out of thin air, out of CO_2:

Clothing made directly of plant material, like cotton, linen, hemp, etc, and indirectly from plants metabolized into animal (and insect) products, such as leather, wool, silk, etc. Even buttons were made of shells and bone. Clothes were often dyed with plant material, like indigo, which was once used to color blue jeans, though now a synthetic version is generally employed.

Food, either directly from plants, or from animals like cows that turn grass and soybeans into milk and meat. This is worth underscoring, as nearly everything that you have ever eaten came, either directly or indirectly, from CO_2. And drank as well, with the notable exception of water (which is just more hydrogen and oxygen), as nearly all other drinks we consume are made of plant or animal products. Even alcohol like whiskey and vodka is distilled from plant material, such as grains and potatoes.

Our homes and their furnishings, as many houses and pieces of furniture are principally made of wood. Even upholstered furniture was generally made out of animal products, such as woolen fabrics stuffed with horse hair for cushioning.

A range of supporting products also come from CO_2. For example, furniture was traditionally finished with things like oil, lacquer, or shellac. We're not talking petroleum oil here, but rather oil derive from plants, like linseed oil. Similarly, traditional Chinese and Japanese lacquer comes from the sap of a tree, which is collected not unlike maple syrup. And shellac is made from the shells of an insect, the lac bug, dissolved in alcohol distilled from plants.

Finally, up until a couple centuries ago, the human world was principally illuminated and powered (cooking, heating, manufacturing, etc) by the combustion of wood and other plant and animal products, including things like whale oil for lamps.

Hence, it is not only that we human beings are made of carbon and oxygen (CO), our world is powered and filled with things made out of CO_2.

Incidentally, all of these things are sustainable in so far as they are all part of the carbon cycle. Not only did all these things come from plants, they can return to plants, as everything noted above can be composted. Even cotton jeans dyed with natural indigo can be composted.

I mention all this, just to get you thinking about it. As we shall see when we move to discuss fossil fuels, a range of products are now created out of petroleum oil, rather than plant material. Incidentally, even though they too contain large amounts of carbon, these materials are generally outside of the carbon cycle – and hence not sustainable.

In any event, when a plant dies and decays, the carbon that it contains (whether in the form of glucose, cellulose, lignin, etc) generally recombines with oxygen to again become atmospheric CO_2.

Every Spring, plants "spring" up with new plant growth and pull CO_2 from the atmosphere. Each Fall sees the "fall" of decaying plant material to the ground where it releases CO_2 back into the atmosphere. Hence, global CO_2 levels go up slightly during Winter and down in the Summer.

If you think about it for a moment, everything else being equal, this annual rise in CO_2 shouldn't really happen, as if should be offset by the Southern Hemisphere.

In other words, when it is Fall and Winter in the Northern Hemisphere, the fallen plant matter (like decaying leaves) should be returning CO_2 to the atmosphere. However, as it is simultaneously Spring and Summer in the Southern Hemisphere, the CO_2 should be being re-absorbed by the springing forth of plants. Hence, the two should cancel each other out.

However, because 68% of the earth's land mass is in the Northern Hemisphere, CO_2 levels go up during Winter in the global North. It's a little more complicated than that, as ocean plants also comes into play here, but the Northern Hemisphere still wins out.

Under certain circumstances, plant matter does not decay in the above manner, which is via aerobic decomposition (i. e. in the presence of oxygen, which allows the carbon to again form CO_2). Although relatively rare today, at least when the whole earth is taken into account, these conditions were quite common a few hundred million years ago, when the earth was far more swampy and in general pretty watery - largely because it was warmer and hence there was little ice on the planet.

So, let's take up the question of how plant and animal material, along with the carbon of which they are made, can fossilize into the fuels that have - quite ironically - both made modern life possible and are now threatening it.

Incidentally, some climate change deniers (Alex Epstein is an example), like to focus on this point, underscoring that fossil fuels have me made modern life possible. While this is true, it does not mean that we need to continue burning fossil fuels - and in the process release vast amounts of CO_2 into the atmosphere. There are new alternatives that sidestep combustion, such as renewable sources of energy like wind and solar

In any event, when plant matter falls under water, aerobic decomposition largely stops, as the decaying process loses access to atmospheric oxygen and becomes mostly anaerobic. Under these circumstances, carbon in the form of CO_2 is not released back into the atmosphere, but is instead sequestered underwater and ultimately, under the right conditions, underground.

After a few hundred million years of heat and pressure, plant and animal matter is fossilized into what we commonly call "fossil fuels," as molecules like glucose ($C_6 H_{12} O_6$) are transformed into entirely new molecules that also contain carbon and hydrogen, as well as sometimes oxygen and certain other atoms.

Here are some important examples:

CH_4 (methane, which is the "natural gas" we cook & heat with). Note that, as there are four hydrogen atoms, which is the lightest element in the universe, methane is lighter than air and can hence quickly rise to the upper atmosphere.

$C_6 H_{18}$ (gasoline, a refined form of petroleum oil).

$C_{240} H_{90} O_4$ NS (anthracite, the most energy rich form of coal).

Note also that this fossilized carbon exists in the three regular forms of matter: gas (methane), liquid (petroleum oil), and solid (coal).

Note that oil and coal can pick up nitrogen (N) and sulfur (S) during the fossilization process. When combined with oxygen during combustion, these produce oxides of nitrogen and sulfur dioxide, which are worrisome types of point-source pollution. Generally speaking, this is what causes smog. Oxides of nitrogen can indirectly also act of greenhouse gases.

When methane, petroleum oil, or coal is burned, the carbon (C) that had been buried under ground for hundreds of millions of years - and hence safely sequestered - combines with oxygen to become CO_2, the most common greenhouse gas.

Methane is a dangerous greenhouse gas even without being burned. Over a 100-year period in the atmosphere, it is up to 34 times more potent as a greenhouse gas than CO2. The chief sources of methane release are hydraulic fracturing (fracking) for gas & oil, the beef industry, coal mining, and landfills.

Methane is responsible for more than 1/6th of global greenhouse gas emissions (perhaps more, depending on how you calculate its life in the atmosphere). Roughly a third comes from fracking, a third from the beef industry, and a third from everything else.

Returning to CO2, for the past million years atmospheric CO2 has held pretty steady at 280 parts per million (PPM). However, in the past 400 years it has soared to a high of 420PPM. The principle reason is obvious: human beings have been digging up fossil fuels and burning them at an alarming - and increasing - rate. In 1988, atmospheric CO2 was 350PPM.

In other words, it took nearly 400 years for CO2 to rise by 70 PPM by 1988. Since then, in the last 30 years it has risen 65PPM. This is why some people refer to the period from around 1945 until today as the "great acceleration."

85% of the CO2 in the atmosphere has been put there since 1945.

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Allow me to repeat that: “Although Americans are only 4% of the global population (330 million people), 29% of global atmospheric CO2 was put there by us. Conversely, the poorest 3 billion people on the planet have only contributed about 5% of atmospheric CO2.”

Scientists agree that the solution is clear: we need to keep 80% of unextracted fossil fuels in the ground. As 350.org notes, "It’s not 'we should do this,' or 'we’d be wise to do this.' Instead it’s simpler: 'We have to do this.'”

To understand why, we need to consider the impact that CO2 and other greenhouse gasses (like methane) have on our planet and its climate, which is the subject of the next section in this chapter.