Bolin Centre
for Climate Research

Bolin Centre Climate Arena Policy Brief | November 2020

Making an educated decision about Carbon offsetting

The Bolin Centre Climate Arena aims to support cross-sector work aimed at "bending the curve" of climate change by:

- ✔ developing long lasting relations between academic, public, business and policy sectors,
- ✔ enhancing the impact and utilization of knowledge and research, and
- ✔ promoting climate education for the future.

At the time of writing this policy brief, Earth is getting warmer at an unprecedented 0.2°C every 10 years. Climate change can occur naturally, but the ongoing rapid climate change is anthropogenic, meaning that it is caused by humans. The function of this policy brief is multifaceted, it provides you as a policy-maker with the information needed to navigate decisions on policies concerning carbon offsetting. If you are a decision maker, it can aid you in your effort to reduce the carbon footprint of your organization or business. It can also help you as an individual in deciding on actions, such as compensating for a flight. However, before we are ready to make educated decisions about carbon offsetting, we need a basic understanding about climate and carbon. In doing so, it is useful to apply a geological perspective, because of the geological nature of the problem at hand.

Photo: Alasdair Skelton

The geological perspective

Ultimately, **anthropogenic** climate change is a geological problem. Its main cause is the burning of fossil fuels (i.e., coal, oil and natural gas) and cement production. Coal, oil, gas and limestone (which is used to make cement) are geological materials[1] which contain lots of carbon and take *millions of years* to form. The problem is that we burn them, which converts them into carbon dioxide, in a matter of *decades*.

Anthropogenic means originating from human activity and **anthropic** means of relevance to humans.

For example, since 1950, we have burned somewhere between 20 and 40% of all known fossil fuel reserves and by doing so we have put over 200 billion tons of carbon in the atmosphere, which is about a third of what it contained originally (IPCC 2013). The imbalance between the **geological timescale** on which fossil fuels are formed and the **anthropic** timescale on which we burn them causes atmospheric carbon dioxide concentrations to rise and cause climate change.

The **geological timescale** is a chronological system using time periods of millions of years.

Climate basics

On a geological timescale, Earth's climate is controlled by three factors; how much heat it receives from the Sun, how much heat is reflected back into space (the albedo effect) and how much heat is trapped by the atmosphere (the greenhouse effect). One can envisage these factors as a set of control dials (Figure 1). If we dial up heat from the Sun, Earth gets warmer. If we dial up the albedo effect, more heat is reflected back into space and

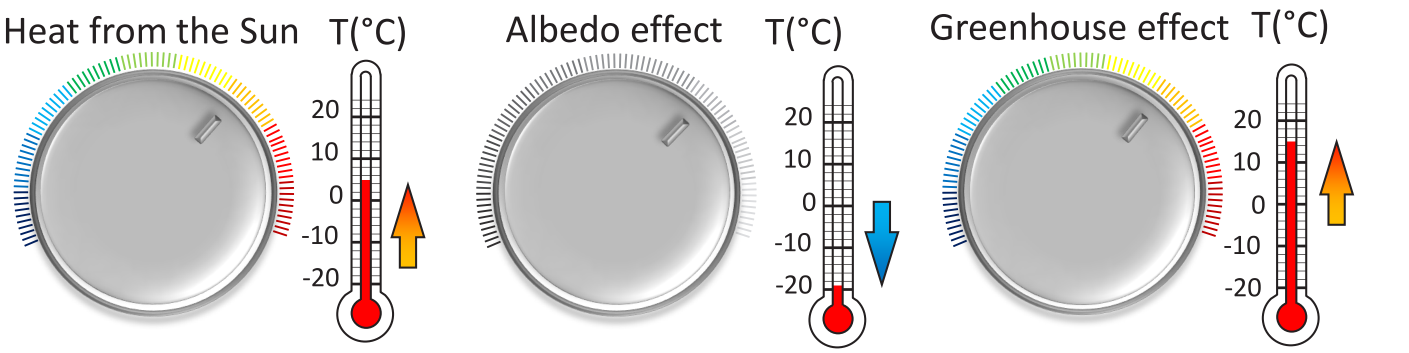

Figure 1. Controls of climate on a geological timescale.

[1] It is fairly easy to appreciate that coal is a "geological material". It is formed from the remains of plants and other organisms that lived millions of years ago. It is perhaps a little harder to appreciate that oil and natural gas are formed in the same way. One clue can be found in the etymology of the word *petroleum*. This word means "rock oil": *petra* (from Latin, borrowed from Greek) means "rock" and oleum (from Latin) means "oil".

Earth gets cooler. If we dial up the greenhouse effect, more heat is trapped by the atmosphere and Earth gets warmer.

Each of these factors varies naturally on a geological timescale. Their variance explains why it was warmer when dinosaurs lived on Earth, and why it was cooler during the last glaciation. These natural variations of Earth's temperature are dampened by its built-in "thermostat" (remember that a thermostat is a device which regulates temperature). This thermostat is the weathering of rocks. It might seem non-intuitive, but rocks dissolve in water, albeit very slowly (millions of years), and if carbon dioxide is added, rocks dissolve a little faster (hundreds of thousands of years). Moreover, the same chemical reaction whereby rocks dissolve also removes carbon dioxide from the atmosphere, and this reaction runs faster if it is hotter. So how is this a thermostat? This is illustrated in Figure 2. If Earth gets hotter, rocks dissolve faster and more carbon dioxide is removed from the atmosphere.

This weakens the greenhouse effect and cools the climate. As Earth gets cooler, rocks dissolve more slowly and less carbon dioxide is removed from the atmosphere. Then, carbon dioxide (which is released naturally from volcanoes) builds up in the atmosphere and strengthens the greenhouse effect and warms the climate, and so on. This thermostat operates on a timescale of a few hundred thousand years (Archer et al., 2009), making it very effective at dampening climate variations on geological timescales, but far too slow to cope with carbon emissions on anthropic timescales.

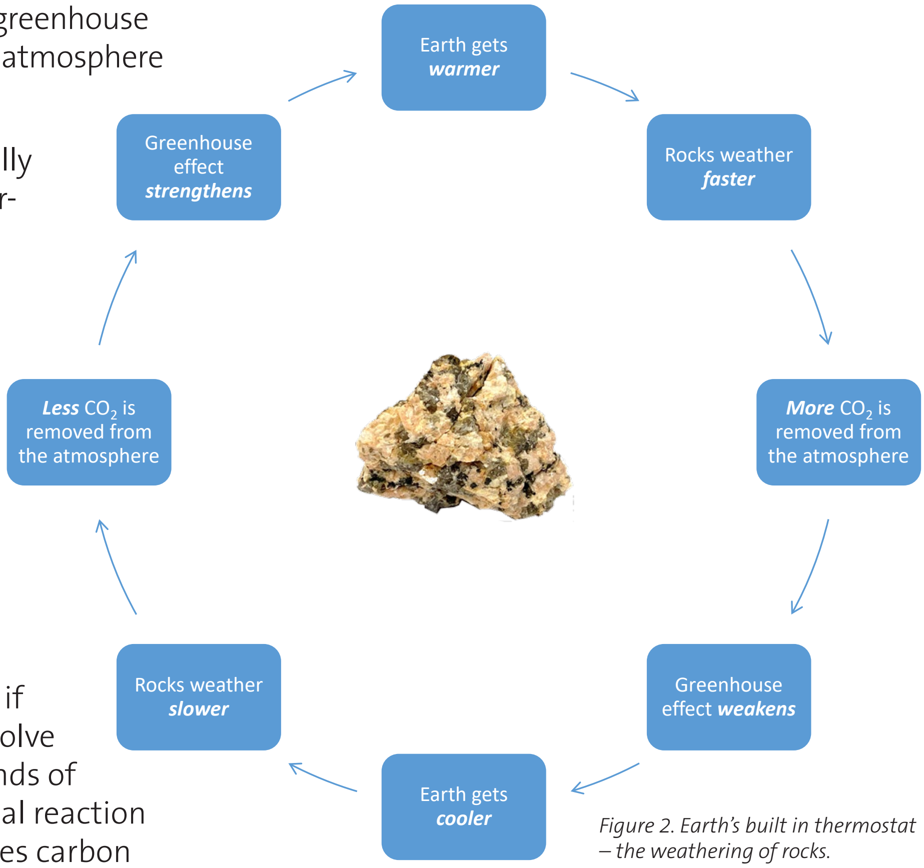

Figure 2. Earth's built in thermostat – the weathering of rocks.

1 **petagram** (Pg) is equal to one billion tons. That is the approximate weight of 5 million jumbo jets or 600 million cars.

Carbon basics

Figure 3 shows the carbon cycle *before* we started affecting the climate. The units are **petagrams** (Pg) of carbon per year (yr). The carbon cycle has two parts; the first part (shaded green in Figures 3 & 4) is a "fast cycle" whereby carbon circulates between the atmosphere, land, ocean, lakes and rivers. This cycle, which is governed by fast

processes such as photosynthesis (carbon dioxide + water + energy = carbohydrates + oxygen), operates on anthropic timescales.
The second part (which is shaded in grey in the figures below) is a “slow cycle” whereby carbon circulates between the atmosphere and rocks. This cycle, which is governed by slow processes such as the weathering of rocks, operates on geological timescales.

The manner in which we have perturbed the carbon cycle can be seen in Figure 4. According to the IPCC (2013), we release 8.9 petagrams of carbon annually from fossil fuels, cement production and land use change. This carbon is taken up by the atmosphere, oceans and land surfaces. The carbon that is added to the atmosphere takes the form of carbon dioxide (CO_2) and methane (CH_4), causing global warming, and the carbon that is added to the ocean causes acidification. In the caption of Figure 4, you can read about the calculations that goes into both figures.

Having covered a few basics about climate and carbon, we are now ready to tackle questions about carbon offsetting.

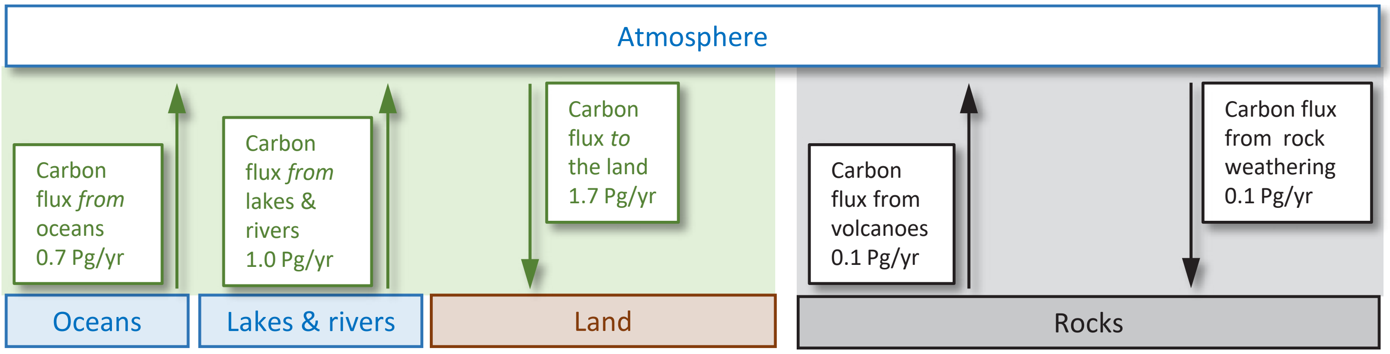

Figure 3. The pre-industrial carbon cycle (modified from the fifth assessment report of the IPCC, 2013).

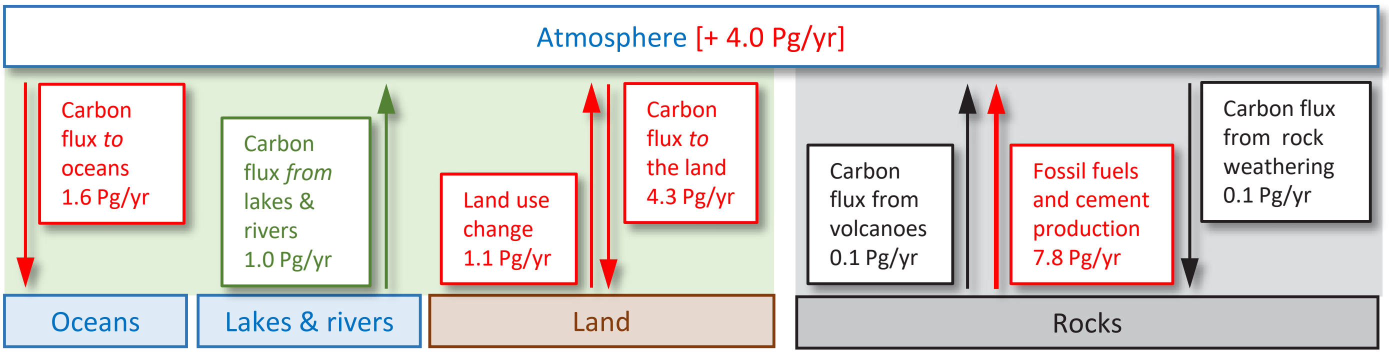

Figure 4. The carbon cycle from 2000–2009 (modified from the fifth assessment report of the IPCC, 2013). In this figure, red arrows denote carbon fluxes which have changed due to our actions. One way of getting a better understanding of the numbers in this figure is to add the carbon fluxes ***to the atmosphere*** *from lakes and rivers (1.0 Pg/yr), from volcanoes (0.1 Pg/yr), from land use change (1.1 Pg/yr) and from fossil fuels and cement production (7.8 Pg/yr). This gives a total of 10 Pg/yr for carbon* ***entering the atmosphere****. Now subtract the carbon fluxes* ***from the atmosphere*** *to the oceans (1.6 g/yr), to the land (4.3 Pg/yr) and due to rock weathering (0.1 Pg/yr). This gives a total of 6 Pg/yr for carbon* ***exiting the atmosphere****. The remainder of 4 Pg/yr* ***stays in the atmosphere****.*

The carbon offsetting dilemma

Carbon offsetting refers to an action or activity that is carried out as a means to compensate for human emissions of CO_2 or other greenhouse gases, by for example planting trees or investing in carbon sequestration (increasing storage of carbon). In his book entitled "An inconvenient truth", published in 2006, Al Gore writes "… when you purchase carbon offsets, you are funding a project that reduces greenhouse-gas emissions elsewhere by, for example, increasing energy efficiency, developing renewable energy, restoring forests, or sequestering carbon in soil." These definitions highlight some fundamental problems with carbon offsetting.

The fast and slow carbon cycles

The first problem concerns the fast and slow carbon cycles. Consider what happens if we offset emissions from fossil fuels or cement production by planting trees or sequestering carbon in soil (actions which are collectively referred to as "natural climate solutions"). For example, an individual contributes to a forest restoration project to compensate for a long haul flight, a company funds a reforestation project to compensate for "unavoidable" emissions from business travel, or a government funds projects aimed at sequestering carbon in soils to help meet its carbon neutrality pledge. The problem is that the carbon being compensated for (fossil fuels, cement production) belongs to the slow cycle and therefore affects the climate negatively for geological timescales, whereas the carbon used for offsetting belongs to the fast cycle and therefore affects the climate positively for anthropic timescales. These timescales vary widely, ranging from decades to millennia, depending on the types of trees and soils being used and the location chosen for carbon sequestration (Sierra et al., 2017; Carvalhais et al., 2014). Whereas carbon storage for centuries and millennia can buy us time to overcome our dependence on fossil fuels, many carbon offsetting projects can only guarantee a few decades of carbon storage. In these cases, the negative effect of the carbon being compensated for *far outlasts* the positive effect of the carbon used for offsetting. An additional aspect to the problem with the fast carbon cycle is its capacity to take up carbon. Griscom and co-authors (2017) estimate that natural climate solutions have a maximum global capacity of 6.5 petagrams of carbon per year "when constrained by food security, fiber security, and biodiversity conservation" of which less than half (3.1 petagrams of carbon per year) is "cost effective" and can therefore be considered of interest for carbon offsetting. This is only a third of the 8.9 petagrams of carbon we release to the atmosphere each year (IPCC 2013). This raises a second problem which concerns "negative emission". Put simply, we need to use the Earth's full capacity for natural climate solutions to repair the damage that we have already done to the atmosphere. This problem as well as the meaning of negative emissions will be explained below.

The need for negative emissions

If it was still 1950, and we had not yet added over 200 billion tons of carbon to the atmosphere, one could argue that we could maintain atmospheric carbon dioxide concentrations at a safe level by compensating for all of our emissions by various projects which returned carbon to its original (fast or slow cycle) source. This could then be done directly by offsetting emissions from fossil fuels or cement production by funding a project whereby carbon dioxide is sequestered in rocks, or indirectly by funding projects which aim to increase energy efficiency or develop renewable energy and thereby reduce our dependency on

Figure 5. Illustrations of climate investments: preservation of wetlands, renewable energy and carbon capture by mineralization in rocks. In the third image, white-coloured calcite crystals fill decimetre-long wavy-shaped veins in a greenish grey volcanic rock. Calcite ($CaCO_3$) is a mineral which contains carbon (C). Photo: Alasdair Skelton

fossil fuels. The second problem is that it is not 1950. It is seventy years later on, and we have already added over 200 billion tons of carbon to the atmosphere, and we continue to add an additional 8.9 billion tons every year. The fifth assessment report of the IPCC (2013) makes it very clear that not only emissions reductions but also "negative emissions" are needed to ensure that atmospheric carbon dioxide concentrations do not reach dangerous levels. So what are "negative emissions"? These can be classed as "carbon dioxide removal" and "natural climate solutions". Examples of natural climate solutions are forest restoration, wetland preservation and sequestering carbon in soils (Griscom et al., 2017). These solutions belong to the fast carbon cycle. Examples of carbon dioxide removal are afforestation and carbon capture and storage in rocks. The former belongs to the fast carbon cycle and the latter belongs to the slow carbon cycle. The key point is that the negative emissions use the *same* solutions as carbon offsetting.
As these solutions are already needed to ensure that carbon dioxide concentrations do not reach dangerous levels we cannot also use them for carbon offsetting.

What's the solution?

In conclusion, changing our mindset is crucial when it comes to how we think about carbon offsetting. Our planet's full capacity for providing natural climate solutions (such as forest restoration, wetland preservation and sequestering carbon in soils) is needed in its entirety to repair the damage we have already done to our atmosphere. This means that we cannot use the same solutions for carbon offsetting. Instead, as politicians, as organizations and as individuals we need to view actions that remove carbon from the atmosphere (without damaging ecosystems) as investments in our future climate, and not as a way to compensate for causing further damage to our atmosphere.

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This policy brief is an expert statement written by Alasdair Skelton, and peer-reviewed by Gustaf Hugelius, Richard Gyllencreutz and Nina Kirchner, all of whom are scientists at the Bolin Centre for Climate Research. It is not necessarily a collective standpoint shared by all members of the Bolin Centre for Climate Research.

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