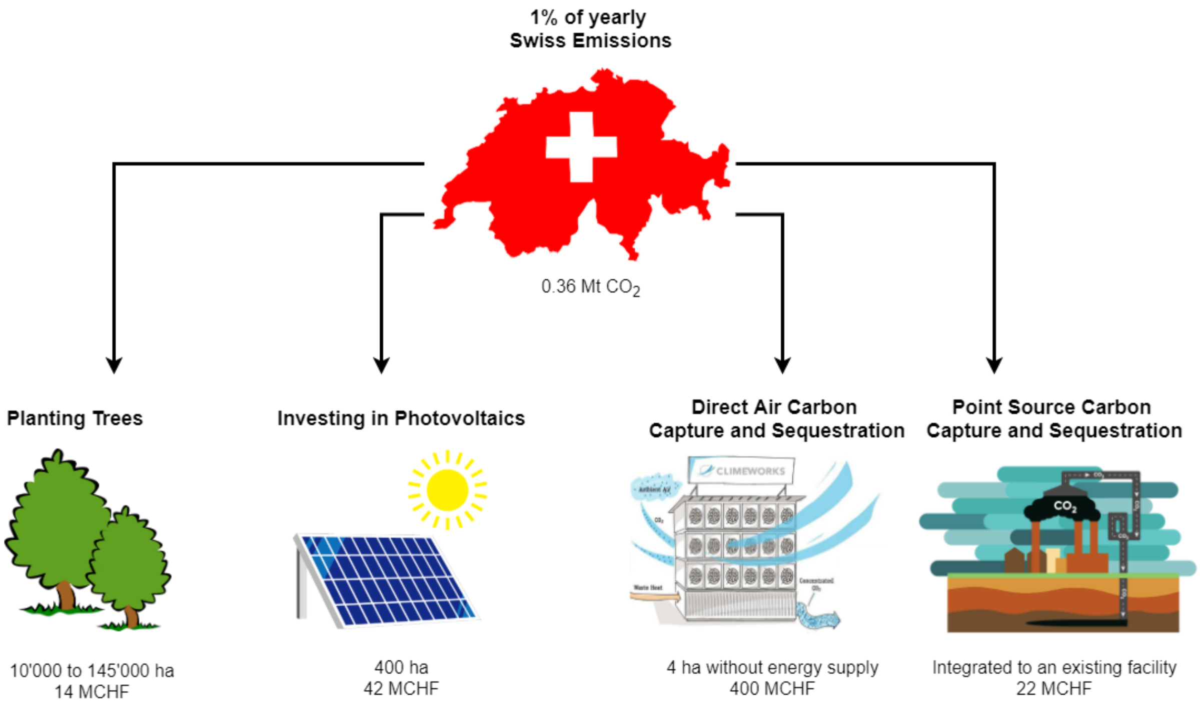
Why planting trees won't be enough to tackle climate change



Authors: David Unnervik, Benjamin Herbreteau, Nicolas Tétreault

Switzerland, like many other countries, is commited to reaching the net-zero in carbon emissions by 2050. To do so, the conventional toolset for avoiding carbon emissions has been deployed, which includes measures such as energy efficiency optimization, renewable energy promotion and waste minimization. Nonetheless, an incompressible part of the carbon footprint will always remain, thus warranting the need for yet additional strategies. As such, the infamous carbon off-setting policy was born, gaining much momentum following the 2015 Paris agreements. Reforestation schemes were officially encouraged as a response to the threat of climate change, leading to the wide-scale development of forest restoration programs. Other off-setting measures involving project funding in energy efficiency and renewable energy sectors have also gained in popularity, with the same goal of compensating emissions. Alternatively, an increasing number of companies such as Nespresso [1] resort to carbon in-setting, a measure aiming to offset the emissions in a way that is beneficial to the company's value chain. While these measures are laudable, the actual carbon compensation performance is often inaccurate or overlooked for being difficult to evaluate. For example, the precise impact of trees on the issue of global warming still remains unclear [2] and should thus be studied in more detail before heavily resorting to planting trees. Nevertheless, this article aims at quantifying common carbon off-setting measures in order to provide a more critical understanding of the actual performance of these strategies. To give context to the numbers provided, modern CO_2 capture and sequestration technologies are included in the discussion.

> "To compensate 1% of the yearly Swiss emissions, 10'000 to 145'000 hectares of forest would be required."

The challenge surrounding reforestation

Data from the United Nations Food and Agriculture Organization (FAO) was used to estimate the cost of carbon sequestration, as well as the required surface area to compensate 1% of the 2018 Swiss CO_2 emissions, amounting to 0.36 million tons [3]. According to the FAO,

Sofies SA
Quai du Seujet 28
1211 Geneva, CH
www.sofiesgroup.com

one hectare of forest has the potential to store 2.5 to 36.5 tons of CO_2 per year, based on the species, geographical location and type of management [4]. To compensate 1% of the yearly Swiss emissions, 10'000 to 145'000 hectares of forest would thus be required, or in other words, between one-third of the canton of Geneva and half of the canton of Vaud. (e.g. 0.2 to 3.6% of Switzerland). For reforestation schemes which target tropical forests, typical restoration costs range from 1'400 to 3'400 CHF per hectare [5, 6]. If the restored tropical forest stores CO_2 for 50 years, overall carbon sequestration costs reach around 1 CHF/ton CO_2 at best.

Carbon off-setting with electricity

Alternatively, some companies opt for financing renewable power generation projects such as the installation of photovoltaic (PV) panels for electricity generation. Although such technologies are known to require considerable investments, they have the advantage of causing no direct CO_2 emissions during their 20 to 30 years lifetime. Nonetheless, indirect emissions, such as those associated with the manufacturing, maintenance and end-of-life stages of the PV cell, are non-negligible. The "embodied carbon", the emissions caused by these steps, are however compensated in 2 to 6 years [7], and some suppliers are even starting to participate in carbon off-setting schemes to further compensate these emissions. Energy-wise, the PV cell avoids on average 475g CO_2 per kWh produced [8]. Taking the Swiss context where a PV cell produces 185 kWh m^{-2} yr^{-1} [9] at a cost of 1'100 CHF per kWp (for large installations) and at an average of 1000 peak hours per year [10], the cost of CO_2 avoided comes down to 116 CHF/t CO_2, taking into account 5 years for compensating the embodied carbon. As such, about 400 hectares of PV would be required to compensate 1% of the yearly Swiss emissions, equivalent in size to one-fourth of the city of Geneva.

Carbon Capture and Sequestration

When it comes to modern carbon capture and sequestration, the costs vary widely. For direct air carbon capture and sequestration (DACCS), the Swiss company Climeworks currently offers an atmospheric CO_2 mineralization service at roughly 1000 CHF/t [11]. In comparison, point source carbon capture and sequestration (PSCCS) offers costs over an order of magnitude lower. The Petra Nova facility in Texas for instance, a retrofitted coal power plant equipped with carbon capture, claims it captures and stores 1.6 Mt CO_2 per year at a cost nearing 60 CHF/ton [12]. While these costs are comparatively much lower, such capture facilities must be integrated into existing industrial sites (e.g. coal power plants), thus warranting renovations and prolonging the lifetime of often inefficient or obsolete facilities. Conversely, despite its large cost, DAC offers many advantages in terms of flexibility and simplicity. Because the technology is still emerging, the associated costs are also expected to considerably fall in the coming years.

Biochar as a multi-benefit approach

Pyrolysis is a type of Bio-Energy with Carbon Capture and Sequestration (BECCS), a set of technologies that is defined as Negative Emission Technologies (NET) by the IPCC [13]. In some sense, pyrolysis can be seen as an improved version of reforestation, as it extends the sequestration time of the carbon assimilated by converting it to a recalcitrant form known as biochar. Its production comes with a wide range of benefits for the local farmers who can incorporate it into the soil to improve the retention of water and nutrients, a practice fully in line with the 4p1000 initiative [14]. In so doing, the farmers increase the overall sustainability of crop production and the resilience of local communities. Sofies has been active in the field of pyrolysis for several years and has already demonstrated its benefits in Vietnam [15]. Based on the production of biochar from different biomass wastes (coffee, rice and nuts), we estimate the carbon sequestration cost to range from 40 to 80 CHF/ton CO_2. Biochar is thus an opportunity to combine long-term carbon storage and regenerative agriculture at a low cost. Quantitatively, considering the process to yield 30% biochar containing 50% carbon, roughly 650'000 tons of biomass would be required to store 1% of the yearly Swiss emissions as biochar [16]. While these numbers appear high, it must be understood that using waste as the primary resource for biochar production nullifies the need for additional crops and thus bypasses competition with food production, while allowing waste valorisation. In the Swiss context, 35% of the non-used sustainable biomass waste (wood and agricultural by-products) could in this way be valorised [17].

"Biochar is an opportunity to combine long-term carbon storage and regenerative agriculture at a low cost."

Sofies SA
Quai du Seujet 28
1211 Geneva, CH
www.sofiesgroup.com

sofies
leading sustainability

How should we proceed

Despite efforts to avoid the release of CO_2 into the atmosphere, additional measures to compensate or capture remaining emissions are necessary if the net-zero target is to be reached. Carbon off-setting measures such as reforestation schemes are useful in the short term, but measures involving carbon capture, sequestration and utilization must ultimately also be part of the energy strategy to minimize land-use and guarantee long-term carbon storage. Furthermore, on-going discussions which revolve around the 2050 net-zero goal imply halting the accumulation of CO_2 in the atmosphere, but the long run goal must be to eventually reduce the amount of CO_2 that has already accumulated, thus effectively reversing the adverse climate effects that are already being felt. For this to be achieved, two types of CO_2 mitigation technologies must be implemented:

1. CO_2 storage for extended periods of time, thus effectively removing CO_2 from the anthropogenic carbon cycle, and
2. CO_2 conversion into value-added products, thus creating a market around CO_2 and promoting its capture and use in a circular economy.

Currently, the costs for DACCS and PSCCS can seem prohibitive in a purely market-driven economy, but the CO_2 is effectively stored for centuries to millenniums. The cost associated with these technologies is also expected to decrease in the coming years as we continue to implement them on a global scale and in all industrial sectors. Conversely, carbon capture and utilization (CCU) is a CO_2 mitigation strategy anchored in the notion of circular economy, but currently suffering from the strong competitivity of fossil-based industries. Various incentives, favourable legislations but also the courage to disrupt the status quo are required to accelerate the deployment of such technologies during the early stages of transition from the fossil-based industries.

[1] Nespresso. [Online]. Available: https://www.nespresso.com/de/en/thepositivecup/carbon-footprint. [Accessed 16 04 2020].

[2] G. Popkin, "The forest question," *Nature,* vol. 565, 2019.

[3] IEA. [Online]. Available: https://www.iea.org/countries/switzerland. [Accessed 2020 04 15].

[4] FAO. [Online]. Available: http://www.fao.org/3/y0900e/y0900e06.htm. [Accessed 25 03 2020].

[5] B. Strassburg and A. Latawiec, "The Economics of Restoration: Costs, Benefits, Scale and Spatial Aspects," in *Convention on Biological Diversity*, 2014.

[6] FAO, "Forest landscape restoration for Asia-Pacific forests," 2016.

[7] E. Alsema, "Energy Payback Time and CO2 Emissions of PV Systems," *Practical Handbooks of Photovoltaics,* 2012.

[8] IEA. [Online]. Available: https://www.iea.org/reports/global-energy-CO2-status-report-2019/emissions. [Accessed 01 04 2020].

[9] OFEN, "Potentiel Solaire de la Commune de Genève," Geneva, 2019.

[10] Suisseenergie, "Coûts d'Exploitation des Installations Photovoltaiques," 2017.

[11] Climeworks. [Online]. Available: https://climeworks.shop/?utm_source=climeworks%20CO2%20removal&utm_medium=order%20now&utm_campaign=1. [Accessed 08 04 2020].

[12] PNPH, "W.A. Parish Post Combustion CO2 Capture and Sequestration Project," 2016.

[13] IPCC, "Climate Change 2014: Synthesis Report - Summary for Policy Makers," 2014.

[14] 4p1000. [Online]. Available: https://www.4p1000.org/. [Accessed 20 04 2020].

[15] Sofies. [Online]. Available: https://www.youtube.com/watch?v=3rWDJ4qwVhM&t=0s. [Accessed 15 03 2020].

[16] T. Thomsen, "The potential of pyrolysis technology in climate change mitigation," 2011.

[17] O. Thees, V. Burg, M. Erni, G. Bowman and R. Lemm, "Biomassenpotenziale der Schweiz für die energetische Nutzung," 2017.

Sofies SA
Quai du Seujet 28
1211 Geneva, CH
www.sofiesgroup.com