Scaling Down to Zero

The Need to Reconsider Negative Emissions Technologies

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# Abstract

Global temperatures are rising quickly, as CO2 emissions continue to grow. We need to keep temperatures under 2°C, ideally 1.5°C, below pre-industrial levels; once that threshold is crossed, not only will there be grave consequences for society, but weather systems will react in unpredictable ways. Given the fact that there are no immediate plans to systematically cut C02 emissions, we have double the work cut out for us. Therefore, it’s tempting to ponder Negative Emissions Technologies (NETs), like Bioenergy with Carbon Capture and Storage (BECCS), as solutions that may ease the transition and/or even allow us to avoid ever reducing emissions to zero. This paper attempts to outline the main limits to and unknowns of scaling up BECCS to the levels being proposed in climate governance. The final section of the paper will provide an overview of a number of strategies that are being proposed by well-recognized environmental justice organizations and must be considered in order to create lasting systemic change. Despite the seemingly narrow focus of the paper, I believe the critiques that will be offered about this technology foster a healthy skepticism that can and should be applied to NETs or Net Zero solutions in general. For this review, a combination of sources was used, that draw from both academic studies and reports by international environmental justice organizations; this permits an analysis that is both based on scientific research and also rooted in social justice. This intersection will be key to promoting solutions that will work towards systemic change.

# Introduction

On October 8th, 2018 the International Panel on Climate Change (IPCC) published a report called the Special Report on Global Warming of 1.5° C (SR15). The main takeaway from this report was the declaration of a 1.5°C limit on global temperatures i.e. keeping them below a 1.5°C rise as compared to pre-industrial levels. This threshold was declared important, because once that it is crossed, not only will there be grave consequences for society, but weather systems will react in unpredictable ways. These reactions will lead to further difficult-to-predict feedback loops. Not surprisingly, this is a grand challenge, and according to the report would require “deep emissions reductions”. Yet even if we were to completely cut carbon dioxide emissions immediately, we would still need to account for historical accumulation. Given the fact that there are no immediate plans to systematically cut CO2 emissions, we have double the work cut out for us.

Considering the many obstacles that present themselves when thinking about drastically reducing emissions, it’s tempting to ponder technological solutions that may ease the transition and/or even allow us to avoid ever reducing emissions to zero. Many of these technologies already exist, such as Afforestation and Reforestation, Direct Air Capture, or Enhanced Weathering. These solutions assume that it’s possible to remove emitted CO2 while continuing to emit, thus creating a net of zero emissions (referred to as Net Zero). Or, in the case that they remove more than they emit, they are referred to as Negative Emissions Technologies (NETs). They are premised on the notion of offsetting emissions (while maybe simultaneously reducing emissions), rather than reducing emissions completely and absolutely. According to Friends of the Earth International (FOEI), “When the focus is only on the flows of carbon – carbon emitted, and carbon removed – the cumulative nature of carbon dioxide is hidden. CO2 remains in the atmosphere for hundreds to thousands of years, so any imbalance of additions over removals adds to atmospheric concentrations which will persist.” As we will see in this paper, they should not be considered a viable solution at the scales being proposed.

This paper attempts to outline the main limits to and unknowns of scaling up one specific NET referred to as Bioenergy with Carbon Capture and Storage (BECCS), while at the same time proposing alternative existing solutions. Although there exist studies that model the planetary boundaries of scaling up BECCS, I found that there was a lack of information on the more general critiques that might help an audience outside of the academic realm understand the nuances of such technologies. Despite the seemingly narrow focus of the paper, I believe the critiques that will be offered about this technology foster a healthy skepticism that can and should be applied to NETs or Net Zero solutions in general. For this review, a combination of sources is used that draw from both academic studies and from reports by international environmental justice organizations such as Friends of the Earth International. This methodology permits an analysis that is both based on scientific research and also rooted in social justice.

As we will see in more detail, there are many limits to and uncertainties of deploying BECCS, both on a small scale and large scale. I will be focusing my analysis on the proposed use of BECCS on a large scale, given that that is how it is most frequently being modeled. One of the main limits to these proposals is resources, such as land and water requirements. It’s important to consider these limits not only in terms of what’s commonly referred to as ‘planetary boundaries’ but also in terms of real human impact, as the land required for BECCS would greatly impact food production and most likely encourage land grabbing practices. We will also look at these impacts on ecosystems, such as the correlation of BECCS with biodiversity loss. Another critique will focus on the CO2 emissions that would result as a consequence of implementing BECCS at large scale, given that as of this writing, it’s not actually a negative emitter. These emissions come from a variety of places, including the use of industrial agricultural practices, the transport and storage of liquified CO2, and the production of these sites to begin with. Finally, we will end the critique by looking past material limits and towards ethical implications of BECCS. These will be centered around the current uses of liquified CO2.

The IPCC has shown that they are betting on this technology as an escape hatch in the second half of the century. But not all hope is lost. The final section of the paper will provide an overview of a number of transformative pathways that are being proposed by well-recognized environmental justice organizations and must be considered in order to create lasting systemic change. In fact, many of those strategies are already being used (traditional farming practices, for example). The main areas where real change can take place are agriculture and the energy sector. This paper echoes other concerned scientists’ calls to reconsider ‘business as usual’ practices through the use of purely technological fixes. Even the companies backing or proposing these initiatives recognize their limits. Therefore, they do not represent real solutions but rather a way for us to postpone making drastic changes.

# Treatment

## Context

### The Birth of Industrial Agriculture

Oftentimes, market solutions or geoengineering proposes to solve a problem without actually addressing the root cause and may in fact worsen the current situation. This is because these types of solutions are enmeshed in the same systems that created the problem. Solving the current converging crises, such as CO2 emissions or food scarcity, is not an issue of removing carbon from the atmosphere or producing more food. Rather, these issues are the biproducts of the root causes driving climate change, such as capitalism, imperialism, and colonialism. The main problem with techno solutions, then, is that they attempt to solve a problem by diminishing the symptom, not the cause. In response to rising fossil fuel emissions, they attempt to ‘master’ the planet’s climate through geoengineering, rather than dismantle the fossil fuel industry. This is also true in the food sector, which I will now elaborate on.

In order to supposedly solve a problem of efficiency and labor, industrial agriculture was born. But not only did this attempt to solve a problem that didn’t actually exist, it turned into a main driver of climate change: “agriculture's total contribution to global warming may be as high as 32.2%, making agriculture the single largest source of anthropogenic GHGemissions” (Gonzalez). I argue that industrial agriculture is just one of many strategies used to obtain nation-state domination and promote the global economy. Second, I will explain how some of the issues relating to the modern-day food, water and land systems are due to a historic pattern of land grabbing, which has consequently exacerbated migration, specifically the need to migrate due to climate-related or economic reasons. Finally, I will connect these historical experiences with current land-grabbing practices and draw similarities and differences between these and prior instances. Importantly, I will hint at alternative paths forward which will be expanded upon in the final section.

The Green Revolution marked a time of agricultural technology transfer in the 50’s and 60’s that increased food production. The exchange was not a transfer as much as it was a *system,* imposed on developing and developed countries. It transformed economies to rely on a new set of agricultural values. Instead of prioritizing biodiversity, which is crucial to most traditional farming methods, yield became the main driver of success. So, the Green Revolution may be considered positive if the definition of success was to increase food yield, but it came at the cost of myriad other agricultural factors that impact the growth and health of plants and animals as well as the people consuming them. One defining aspect of industrial agriculture that negatively impacts plant and human health is chemical use, especially synthetic fertilizers, pesticides, and herbicides. The excessive dependence on these inputs signals the loss of the ‘natural insurance policy’ that is granted when agroecological practices are used. This ‘natural insurance policy’ is achieved by growing many different species together, because the risk of one species becoming infected does not represent as great a danger, since it’s unlikely to be a risk to all the species being grown. On the other hand, if the only species being grown is affected, the entire food production is affected. For example, “Due to the genetic uniformity of the Irish potato crop, a single infestation was sufficient to produce widespread devastation” (Gonzalez). We can see just how reliant the food system has become on monocrop plantations by citing the same author: “75% of the world's food crop diversity was lost in the twentieth century as farmers abandoned local varieties in favor of genetically uniform high-yielding crops.” So, when analyzing one particular plantation’s crop yield, we may see an increase in production, but we simultaneously see the loss of an ecosystem which ultimately causes more negative consequences in the long run. Additionally, industrial agriculture created the precedence of ‘weeding out’ peasant farmers and their agricultural methods: “While the Green Revolution dramatically increased global food production, it also perpetuated food insecurity in the Global South by increasing poverty and inequality. The Green Revolution generally favored wealthy farmers because poor farmers lacked the resources to purchase the synthetic fertilizers, chemical pesticides, and irrigation equipment required to produce high yields” (Gonzalez).

As mentioned, chemical use within industrial agriculture does not only negatively affect plants and animals by reducing biodiversity, it also affects human health. This will not come as a surprise when taking into consideration the fact that the original reason for developing and implementing many of such chemicals was military domination. “In the United States, the chemical industry underwent a change of scale during the First World War...DuPont, Monsanto and Dow grew into powerful corporations. The income from confiscated German patents...promoted the conversion of the gas warfare industry to pesticides. The biplanes of the First World War, symbol of the alliance between military technologies and agriculture, were used to spread herbicides” (Bonneuil). War motivations fostered the development of agricultural chemicals and conversely, the development of those chemicals aided the war effort. Bonneuil continues, explaining that when the US got frustrated that their attempt to destroy the humid Vietnamese forests was failing, “the US Army finally sprayed defoliants developed from agricultural herbicides (Monsanto’s ‘Agent Orange’), the mutagenic effects of which on the human population still persist nearly half a century after the end of the war.” What is notable is that most of the US ammunitions in this war were not aimed at the inhabitants being invaded but at the forests that constituted their home. The military recognized this would create even more harm in the long term; thus, we can see that military strategies recognized the power of destroying ecosystems and traditional agricultural practices, and fertilizers and pesticides were created with this goal in mind.

Given the history of pesticides and fertilizers in industrial agriculture, and its narrow focus on yield as a sign of success, it’s no doubt that this type of food production uses more land while also producing less food in the long run. Although this may be one reason proponents of it justify land grabbing practices, which in turn increase migration, land grabbing’s history does not begin here. Gonzalez notes that despite debates about migration often being quite racialized, most of the academic discord conveniently avoids race and racism’s role in the climate crisis. This historical pattern of settler colonialism and racism are deeply intertwined with land grabbing practices that date back centuries. In fact, one could claim the ‘settlement’ of the United States as a massive land grab. Here, the term settler is misleading as it connotes reaching an agreement, which was not the case. According to Gonzalez, “the underlying goal of anti-Native racism was the physical eradication or forced assimilation of Indigenous peoples in order to seize their lands.” Once claimed, laws and regulations were created that ensured the rights of these lands to those who had stolen them, to prevent them ever being rightfully returned to their original inhabitants. In most cases, the seizing of these lands was tied to slave labor and thus a way to reap economic benefits. “Between 1600 and 1800, slaves in the Americas comprised less than one percent of the world’s population but produced the commodities that dominated world trade” (Gonzalez). The US further benefited from land grabs in Mexico and exploiting Mexican labor, which had a large effect on US prosperity in the twentieth century. These examples are evidence not just of racism but of forced labor, genocide and a pattern of general dehumanization and othering in the name of material and economic accumulation. Land grabs cannot exist without a deep-seated racism that ‘justifies’ and paves the way for the act of stealing. Taken together, these examples highlight the connection between labor, food production, land grabs and ultimately, economic gains.

At the same time, other current land grabbing practices are similarly justified by citing alternative urgent ‘needs’. In addition to food production, another common ‘need’ that has emerged is fighting global warming through geoengineered solutions. Even though the reasons are shifting, the dynamic is the same as it was centuries ago. Those in power claim to need land to solve a problem that is in fact a result of the actions that granted them that power. In the case of global warming, solutions such as Bioenergy with Carbon Capture and Storage (BECCS) are put forward as strategies to eliminate the excess of historic carbon emissions. Although this need is indeed valid, the solution does not attempt to address the root of the problem. Therefore, we can expect that implementing solutions such as this on a global scale will in fact do nothing to mitigate rising temperatures and may in fact exacerbate the problem. To quote Vandana Shiva, “the white man’s burden is to protect the environment, especially the Third World’s environment--and this, too, involves taking control of rights and resources...The salvation of the environment cannot be achieved through the old colonial order based on the white man’s burden. The two are ethically, economically, and epistemologically incongruent” (Adelman). Current land grabbing practices also increase acceptance of carbon trading markets as logical solutions within climate policy. These types of trading schemes make invisible the natural resources required to enable them. Suddenly, a company or country is carbon neutral because they’ve bought enough foreign land to offset emissions, whether through afforestation or other ‘solutions’. In this way, land is seen as neutral and expendable. The justification for using that land is that it’s barren or empty, a hardly valid conclusion from the point of view of the people living there.

Land is intrinsically tied to food production, ecosystem- and human well-being. As such, the historical destruction and stealing of land is tied to colonial powers seeking to exploit labor and seize power. Whether this land has been used for agricultural purposes or climate solutions, the justification is always in the name of some urgent problem such as food scarcity or climate change; these land grabs, however, have never made a dent in such problems.; those seizing the land do so for economic and power-motivated interests. Industrial agriculture’s implementation, born of military efforts, has been made possible by these land grabs. Agriculture continues to be affected by and affect global temperatures. Although food scarcity is a widely cited issue, “Not surprisingly, food insecurity is concentrated in developing countries that dedicate high quality agricultural lands to export production, do not produce enough food for domestic consumption, and rely on a small number of agricultural exports to earn the foreign exchange with which to import food”, and therefore, “Food insecurity is a function of poverty rather than food scarcity” (Gonzalez).

### How Does BECCS Work?

BECCS is a combination of two technologies; bioenergy, with carbon capture and storage. Bioenergy refers to energy produced through the burning of organic material (sometimes called biomass) like wood, sugarcane, and other crops (FOEI 2020). The second part of the process refers to re-capturing some of the carbon that is released when burning the biomass, liquefying it and then storing it underground, usually in saline aquifers or oil fields. Although it’s assumed to be a guaranteed solution for future mitigation, there are surprisingly few existing facilities worldwide, and none of them are negative emitters. Therefore, including them in future models is encouraging us to deploy them full-scale without having thoroughly tested them. Additionally, relying on bioenergy as a main source of energy is risky. Because the energy from bioenergy is not very efficient, it would require monocrop plantations to be heavily scaled up, most likely resulting in continued deforestation to make room for plantations.

### BECCS’ Role in Climate Governance

The SR1.5 in 2018 was actually not the first time BECCS appeared in international climate policy. In 2011 it was also included in the IPCC’s Special Report, but only in a limited fashion and its potential wasn’t quantified (Chatham House 2020). According to the same author, “The report identified the immaturity of the technology, uncertainty over the availability of sustainable biomass supply and secure and permanent carbon dioxide storage, and negative public perceptions of CCS as important barriers...” Despite this, three years later it made its debut into climate governance when it was included in the majority of scenarios of the IPCC Assessment Report 5 (AR5) put forward by Working Group III. Of the possible 116 pathways that had a greater than 66% chance of keeping global temperatures below the 2°C threshold, 101 of them relied on NET, namely Afforestation and Reforestation (AR) and BECCS. Fast forward to 2018, and, although the SR5 recognized the limits to BECCS more so than past reports, it was still heavily incorporate into emissions pathways and scenarios (Chatham House 2020). From this brief timeline we can see the reality of BECCS begin to emerge; despite the fact that historically and currently BECCS is still highly theoretical and carries many feasibility questions, it is recognized as a valid and necessary solution by the IPCC and other climate governance bodies (including the Paris Agreement).

## Feasibility of BECCS

### Land Use

The first limiting factor of BECCS is its sheer land requirement. I begin here because it is one of the main critiques of implementing this technology at scale. If you look through the research intending to find some consensus of how much land BECCS would require when implemented at a certain scale, you will be hard-pressed to find a singular answer. This is true when considering any material requirements of BECCS, even when comparing them at the same scale. That is because BECCS is not actually a singular process with a defined equation, but rather a group of processes that describe storing the carbon released from bioenergy underground. So, any quantification of this technology really depends on what kind of biomass is being used to burn. For the purposes of simplification, land requirement is discussed here irrespective of the type of biomass used. In addition to this variable, which we are setting aside for this research, another variable to take into account when calculating land requirement is how much CO2 BECCS is attempting to remove. I chose two scenarios to demonstrate a general range of how much land might be required. In the first scenario, 1 gigaton of CO2 is assumed to be removed through BECCS; in the second scenario it is 12 gigatons.

Starting at the lower end, let’s look at an estimate of how much land would be required. One study that looked at removing 1 gigaton of CO2 (which is only equal to a fiftieth of global annual emissions) “concluded that between 218 and 990 million hectares of land would be needed to grow the biomass...” (Geoengineering Monitor 2018). To put these numbers in perspective, that’s a range roughly falling between the size of Mexico and the size of the United States. Even when considering the lower end of that range, the land requirement is significant. However, 1 gigaton is not even representative of the scale that most models consider. Of the 116 models referenced earlier, the median commitment of CO2 removal through BECCS was 12 gigatons. In order to accomplish this, one study estimated that it could take up to 1.2 billion hectares or, put another way, 80% of the amount currently used for global cropland (Field and Mach 2017). As many others have asked, where would this land come from? Deploying BECCS at this scale would inevitably lead to land grabs and deforestation in order to plant monoculture plantations (FOEI 2020). Both of these facts would have direct consequences on small farmers and create further competition for arable land at a time when millions of people are already going hungry.

### Carbon Lifecycle and Water Use

Apart from considering the sheer quantity of land that would be required to deploy BECCS at scale, there are other land-related considerations to keep in mind. Obviously, growing any sort of plant requires water, so using land at that scale would most certainly bring in to question sufficient water supply and the risk that that water would be taken from local communities. Additionally, quantifying resource use for BECCS must also include the fact that crops are grown under a setting of industrial agriculture and monoculture plantations, which are much more resource intensive than other types of farming. When considering the whole picture of water use, we should consider “the water used for crop growth, water pollution resulting from fertilizer application at the farm level, and the intensity of water use in the BECCS power plant” (Fajardy et al. 2019). This distinction is important because industrial agriculture is one of the main industries contributing to CO2 emissions and uses the majority of fossil fuels (Big Bad Fix 2017).

In addition to looking at water use in this context, we also must take into account the entire carbon cycle. According to optimistic models of BECCS, the cycle of carbon is something like this: carbon is captured naturally through crops; when those crops are burned for bioenergy CO2 is emitted; most of that CO2 is captured and liquified; that liquified CO2 is then stored underground. However, there are crucial emissions that are missing from that scenario. Take for example the planting of those monoculture crops that will be used as biomass. Just looking at that part of the cycle we see that “converting the necessary land to bioenergy would itself generate significant direct CO2 emissions due to land cover change, loss of forests and grasslands, soil disturbance, and increased use of agricultural chemicals, thus reducing its climate benefit. Indirect emissions from producing and using bioenergy would reduce those benefits still further” (CIEL 2019). When considering building the infrastructure required to transport, store and convert biomass there are further emissions still. Overall, “A large body of peer-reviewed literature indicates that many bioenergy processes result in even more CO2 emissions than burning the fossil fuels they are meant to replace – it is certainly not carbon neutral” (Geoengineering Monitor 2018).

## Current State of BECCS and EOR

With so many limitations and unknowns, it begs the question: what is the current state of BECCS projects? Perhaps unsurprisingly, as of 2019 only one of the five BECCS plants operating worldwide was running at commercial scale: the Illinois Industrial CCS facility at Decatur (Chatham House 2020, CIEL 2019). Funded by the Department of Energy, it claims to provide a carbon negative footprint, capturing about one gigaton of CO2 every year since 2017. This is equivalent to around 11-13% of the CO2 it emits (FOEI 2020). “Since the plant itself is largely powered by gas, however, it is still a net emitter overall. Furthermore, the ethanol is largely destined for use in road transport, thus ultimately producing carbon dioxide and rendering the lifecycle emissions of the bioenergy potentially net positive despite the significant CCS component.” Although there are few BECCS plants working, there are slightly more plants that only focus on carbon capture and storage; at the end of 2019, worldwide there were 19 commercial CCS plants operating (FOEI 2020). This is because CCS technology has been around longer than BECCS. So, to understand the reasons that BECCS plants may be gaining support we can look towards historic use of CO2 captured at CCS plants. According to Geoengineering Monitor, the *original purpose of CCS* was as a technique for enhanced oil recovery (EOR). EOR refers to the process of “injecting highly-pressurized CO2 and water into a depleted well [so that] oil companies can force remaining oil to the surface and extract it for sale and use” (CIEL 2019). Within the same report, many examples are given that illustrate the fossil fuel industry’s involvement in, support of, and profit from CCS plants. There is a direct connection between what oil companies gain from encouraging and funding CCS technologies and what they will most likely gain from BECCS. In fact, in 2018 a report was done by the Carbon Sequestration Leadership Forum analyzing BECCS “acknowledging that EOR provided the primary economic market for CO2 from BECCS facilities and highlighting that three of the only five operational BECCS projects world-wide were designed for EOR” (CIEL 2019). According to the same report, it is unlikely that the companies backing BECCS technologies are attempting to do so at scale, because that would result in the phasing out of oil and gas. What is more probable is that they are using this strategy as a way to continue fossil fuel extraction for as long as possible.

## Alternative Solutions

As previously noted, the number one step forward should be to drastically reduce fossil fuel emissions until they are at absolute zero, or as close to zero as possible. Although this will not address how to deal with historic emissions, it is nonetheless a necessary step. In terms of strategies that address historic emissions, it is important to look to current and traditional strategies that foster nature as it is, rather than focus on *nature-based* technologies. Specifically, we should be promoting the preservation and regeneration of natural carbon sinks, like forests, rather than transferring emissions underground, a process which brings with it many risks and consequences. However, there is a caveat: we should not assume that using natural carbon sinks means we can prolong the reduction of fossil fuel emissions. That assumption exaggerates the capacity of natural sinks. “The amount of carbon stored ‘biologically’ is part of a dynamic balance between the atmosphere, the oceans, and land-based ecosystems. Releasing geologically locked carbon disturbs this delicate balance. Ultimately, if this dynamic is further interrupted, the biological ecosystem may cease to act as a sink, and instead become a source of carbon emissions” (FOEI). In order to restore forests and ecosystems, we must grant management and ownership of those lands to the communities that live on them. Indigenous leadership is crucial to this; “80% of the world’s land-based biodiversity [is] located on indigenous peoples’ territories” yet in many cases they are not legally entitled to this land (Macleod 2020).

Furthermore, alternative solutions will need to occur in a variety of sectors, namely food systems and energy. In some ways, solutions from one sector may aid solutions in another. For example, FOEI names “a just and climate-friendly food system based on the principles of agroecology” as one solution. The definition of agroecology is “a way of producing food, a way of life, a science, and a movement for change. It draws on social, economic, political and biological/ecological dimensions and integrates these with ancestral and customary knowledge and practices of peasants, indigenous peoples and other small-scale food providers. It is based on principles that may be similar across the diversity of peoples’ territories, but are practised in many different ways, with each sector contributing based upon its local reality and culture, while always respecting nature and common, shared values” (FOEI 2018). From this definition, several points are immediately clear. First, agroecology is not universal. As mentioned, there is no one set of instructions to be followed because it is dependent on local contexts. This sets it apart from monocrop plantations. Second, a respect for nature is integral to agroecology. Again, this puts it on the other side of the spectrum from industrial agriculture, whose ultimate benefit is profit, not ecosystem wellbeing. Next, although agroecological practices draw on ‘ancestral and customary knowledge’, it’s not to say there doesn’t exist innovation. To the contrary, agroecology uses many innovations, which are ‘improving resilience, raising incomes and reducing risks, including by creating new market opportunities and encouraging diversification, or by reducing natural resource depletion and degradation’ (COAG 2018). Focusing on agroecology means moving away from industrial agriculture and its harmful practices. This is extremely important given that “the industrial food system uses more than 80% of the land, fuel and resources, and is the largest emitter of greenhouse gases on the planet” (Big Bad Fix 2017). This would reduce the need for heavy machinery like tilling tractors, thus reducing energy needs. At the same time, reductions in fertilizers and other agrochemicals will help to lower current emissions. Agroecological practices are already largely used by the peasant food web, which is made up of peasants, pastoralists, urban gardeners and fisher people. Amazingly, this group of people uses less than 25% of the land, water and resources and yet is able to feed 70% of the population (Big Bad Fix 2017). By using agroecological practices, we could avoid emissions of up to eight gigatons of CO2 by the year 2050 (CLARA).

The global North’s fostering of technological advances in every facet of life imaginable has led us to the current climate crisis we face today. The energy efficiency paradox is an example of this; the more efficient our energy systems become, the more energy we end up using. Therefore, technological solutions implemented under the same systems that fostered the use of fossil fuels will most likely be implemented for financial gains rather than as real solutions. Although these solutions may make sense on a small scale, this decision should be made by those whose land and other resources would be used. Furthermore, if deployed, the whole decision-making process should be decentralized. Regardless, we must look towards systemic solutions that shift historic power dynamics and place more emphasis on traditional, proven solutions.

## Data Visualization

### Data Sources

The majority of visualizations in my project obtain their data from the statistics cited throughout this paper. The only charts that use data that haven’t been mentioned are those that show historic CO2 emissions and future pathways. These two datasets were derived from the database “Our World in Data.” Although their data regarding historic emissions began in the 1700s, I decided to begin the visualization around 1860 which is when emissions began to rise above 1 gigaton. For the future scenarios, although both a high and low trajectory for each pathway was included, I made the choice to only consider the lower end, due to time constraints regarding coding. Additionally, I decided to leave out the ‘Pledges and Targets’ pathway because I felt it was similar to the trajectory of current policies.

### Design Decisions

Although one doesn’t need to understand historical emissions in order to learn about how BECCS works, I decided it was important to include in my visualizations for a few reasons. First, the user might not have heard the unit gigatons, which is a central unit when talking about CO2 removal using BECCS or any NET, so I used the historic emissions partly to introduce this unit (i.e. in 1882, we were emitting 1 gigaton). But I also included historic emissions because I was able to more concretely convey to what scale BECCS is being proposed. If the user first understands accumulation of emissions, and then sees that even to scale BECCS up to 12 gigatons, (which is not much compared to the accumulation) would require absurd amounts of land, I can hopefully convey that it’s unrealistic to assume depending on BECCS as one of the main NETs in the second half of the century. Really, it’s unrealistic to assume that of any techno fix which doesn’t address the root of the problem.

Another design decision I made was implementing a ‘choose your own ending’ function. The reason for this is that for most people, I assume that it’s sufficient to learn about a couple critiques of BECCS, like land use and its’ limited testing, to get the general idea that it’s probably not a great technology to rely on. However, these few critiques represent a small portion of the total issues regarding BECCS. For that reason, I wanted to do justice to the issue by providing a few additional critiques that are also prominently mentioned in research articles expressing concern about BECCS. If the user feels that it’s not necessary to continue exploring critiques they can jump to the conclusion. This function is important because I didn’t want to lose the user’s attention span before they get to the conclusion, since that is the part that mentions alternative pathways and a more positive outlook for the future. I felt that it was important to end on a positive note in order to not give the impression that ‘we’re doomed’ which is sometimes a common sentiment regarding climate change.

A final design choice that I made was converting the corresponding temperatures associated with the future pathways from Celsius to Fahrenheit. Although Celsius is the unit used in academic research, given that most of my audience is viewing from the United States, Fahrenheit made more sense. I tried to be explicit when using temperatures to always include the unit, since for the last two pathways their names are ‘1.5°C’ and ‘2°C’ respectively and didn’t want to confuse the user by my switching from Fahrenheit to Celsius. Going forward I would like to implement a toggle between the two so that if someone prefers to see all temperatures in Celsius, they can.

# Conclusion

Although one could argue for using BECCS on a small scale rather than a global scale, many of the key issues remain. For example, less land may be required on a small scale but there is still the very probable risk that local communities will be affected by this land use, water use, and possible pollution. Therefore, the question we should be asking is not to what scale should BECCS be implemented, but what other solutions can we foster that are not technically innovate in nature but that restore existing biodiversity and autonomy to local communities. It’s not to reject any and all technological solutions, but rather only those that are produced under the systems responsible for the current crisis, and which have in fact profited of it. I have briefly mentioned only one of the possible alternative solutions, namely agroecology, but there are numerous others that are also currently used around the world and which are promoted as ecologically sound by many climate-activist groups. In order to solve a crisis created by the intersection of many systems, it will require the transformation of those systems rather than any singular technology.

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