Ranking Carbon Offsets: A Primer for Organizational Buyers

By Julian Duggan, Jessie Lu, and Kyle Navis[1]

In October 2018, the UN-convened Intergovernmental Panel on Climate Change delivered a high confidence estimate that the world has 12 years to achieve net CO_2 emission reductions in order to limit global warming to 1.5° C. The same report linked the difference between a 1.5° C and 2° C increase to disproportionately large impacts on sustainable development, poverty, and inequality, with especially outsized consequences for the low- and middle-income countries where the Center for Global Development's work aims to reduce poverty and improve lives.

Carbon offsets are touted as an easy way to lower emissions without disrupting existing systems and structures. However, offset schemes have also generated a large amount of controversy. In this primer, we review the carbon offsets available for retail purchase, survey research into their effectiveness, and identify the highest quality offset categories. This document is not intended as a comprehensive review of the carbon offsetting literature. Instead, we consider it a primer for interested parties trying to reduce their emissions by purchasing effective carbon offsets.

We rank carbon offset types by likelihood of effectively decreasing greenhouse gases (GHGs) and conclude that gas capture projects offer the highest confidence option for carbon reduction. This ranking considers three factors:

1) **additionality**, or how much carbon is prevented from entering the atmosphere;

2) **uncertainty** about additionality estimates; and

3) **offset supply** for organizational buyers.

This primer discusses each of these features in turn, provides a ranking of existing options, and ends with a case study to demonstrate the uncertainties associated with carbon offsetting, most notably around assessing additionality, and to underscore the need for continued rigorous research and monitoring.

ADDITIONALITY

The first and most fundamental criterion for any certified carbon offsetting project is that it is "additional." A project is additional if and only if there are fewer GHGs in the atmosphere than there would have been had no offsetting activity taken place. There are two ways for a project to be additional: it can prevent GHGs from ever entering the atmosphere (compared to a counterfactual projection without the project) or it can capture GHGs that have already entered the atmosphere.

[1] Thanks to Kelsey Ross, Alysha Gardner, and John Polcari for their input and feedback on this research.

Common offsetting projects like industrial gas capture or renewable energy generation qualify as the former while afforestation offsets belong to the latter.

Assessing additionality requires both scientific and economic analysis. From a scientific perspective, additional projects must have a clear biological or chemical mechanism by which they capture GHGs or prevent GHG release. For instance, preserving or planting a forest leads to carbon capture through photosynthesis. Likewise, installing a smokestack scrubber allows chemicals called absorbers to react with and neutralize GHGs before they can enter the atmosphere.

From an economic perspective, an additional project leads to human behavior that produces fewer emissions than would be produced in the project's absence (the counterfactual). Determining the counterfactual requires answering questions such as:

- Would an apartment block upgrade to more efficient lightbulbs regardless of whether it received offset funding?
- How many fields would farmers leave fallow without additional financial incentives?
- How much forest would be cut down if offset payments were not made to landowners?
- Would a solar farm have been a profitable investment even without offset payments?

UNCERTAINTY

Making the case for scientific additionality depends on our ability to measure carbon capture or estimate its diversion. While measurement of the precise amount of carbon captured by a project can require costly monitoring, engineers can often make reasonable, scientific estimates. Analyzing economic additionality tends to be more difficult—under some conditions, no conservative counterfactual emissions estimates can reasonably be made.

One-size-fits-all approaches to assessing economic additionality of purchasing carbon offsets are almost certain to fall short, but there are at least four common difficulties that analyses encounter. First, the businesses responsible for the emissions activities may have independent profit incentives to reduce their emissions, rendering purchased offsets of these emissions not additional. Similarly, a company may have a regulatory obligation to limit emissions.[2] In both cases, this is because the emitter is likely to offset the activity without funds from the offset buyer, though contextual factors can make assessments of this likelihood quite difficult.

Third, offsetting projects may create perverse incentives for emitters to increase their emissions in order to overestimate emissions savings. For example, in a report for the European Commission, Cames et al. (2016) relate, "On a site visit to landfill gas projects in China in 2005, engineers proudly explained how they had found a way to generate more methane by stacking waste higher in one section of the landfill rather than spreading it evenly across the landfill site." This technique inflated the counterfactual estimates of emissions and led to over-estimation of emissions reductions. Similarly, there is concern that widespread offsetting projects create incentives for governments to delay new emissions regulations because such regulations would end offset income for their industrial constituents.

Fourth, leakage effects can arise as emitters substitute one carbon-emitting activity for another in response to offsetting projects. For instance, payments to protect a tract of forestland might simply

---

[2] As an example, regulations mandating methane gas capture for waste facilities would negate the ability of waste treatment centers to apply for offset credits because gas capture would have taken place without the offset funding.

shift logging to another area because these payments do not necessarily change the underlying demand for timber. While Warman and Nelson's (2016) study of forest preservation policies in Australia found that substitution toward plantation-grown logs limited leakages to 1.8 percent, Meyfroidt, Rudel, and Lambin (2010) looked at the global wood trade and found that 22 percent to 74 percent of reforestation is displaced by deforestation elsewhere.

Because these sources of ambiguity may dramatically alter additionality estimates, we prefer projects with lower levels of uncertainty.

OFFSET SUPPLY

Even if a project type performs well by our first two criteria, there may be insufficient supply, making it impossible for buyers to purchase high quality offsets. Figure 1, taken from Cames et al. (2016, p. 13), shows estimates of offset supply categorized by their likelihood of additionality.

Figure 1. Offset Supply and Likelihood of Additionality

	CDM projects			Potential CER supply 2013 to 2020		
	Low	Medium	High	Low	Medium	High
	… likelihood of emission reductions being real, measurable, additional					
	No. of projects			Mt CO_2e		
HFC-23 abatement from HCFC-22 production						
Version <6		5			191	
Verson >5			14			184
Adipic acid		4			257	
Nitric acid			97			175
Wind power	2.362			1.397		
Hydro power	2.010			1.669		
Biomass power		342			162	
Landfill gas		284			163	
Coal mine methane		83			170	
Waste heat recovery	277			222		
Fossil fuel switch	96			232		
Cook stoves	38			2		
Efficient lighting						
AMS II.C, AMS II.J	43			4		
AM0046, AM0113			0			0
Total	**4.826**	**718**	**111**	**3.527**	**943**	**359**

Note: The left column lists common types of offset projects available through the Clean Development Mechanism (CDM). The CDM is defined in the Kyoto Protocol as projects which provide Certified Emissions Reduction (CER) units, which can then be traded on markets.

Though there is clearly a supply of high-quality carbon offset credits, they constitute the smallest fraction of all available supply. In part, this may be a marketing challenge—while industrial gas abatement (shown in the first five rows) fulfills our criteria, it lacks the visibility, "clean" image, and easy comprehension of—for example—a wind power project. In any case, high-quality credits are available but require additional effort to obtain.

RANKING OFFSETS

This review synthesizes the carbon offset project analyses conducted by the European Commission (EC), the Stockholm Environment Institute (SEI), the US Congressional Research Service (CRS), Google, and the World Bank. These analyses vary in terms of analytical rigor. Table 1 summarizes the three most critical reports from the EC, SEI, and CRS, while the documents from Google and the World Bank are institutional policies that are useful to inform the creation of internal offset policies. More information on specific carbon offset projects can be found in the EC, SEI, and CRS reports.

We present this table with two comments. First, carbon offsetting projects and assessment methods are continuously changing. The most impactful investments today may not be the most impactful investments in the future, and the most impactful investments in theory may not be the most impactful investments in practice. The table below can be used to guide carbon offsetting investment decisions and should be updated as more research on effective types of carbon offsets is made available.

Second, it is important to keep in mind that these rankings are only useful for evaluating the utility of a project for carbon offsetting. Low-impact carbon offsetting projects can still be important tools for achieving other sustainable policy goals. For example, a policy designed to protect forests is a public good which aligns directly with Sustainable Development Goals 13 and 15,[3] even though it is not the best way to offset emissions.

Table 1. Ranking of Types of Carbon Offset Projects

Type of Project	Subtypes Included	Pros/Additionality	Cons/Reasons for Uncertainty	Our ranking
Biological Sequestration	Tree planting; preventing deforestation; land use changes such as irrigation, conservation tillage, crop rotation; etc.	Many projects available at cheap prices Projects tend to be easy to implement	Difficult to assess whether carbon offsetting markets directly incentivize these practices, making additionality difficult to measure Difficult to measure carbon impact of these projects given the complexity of biological processes Issues with permanence—not sure if activities that generate offsets can continue indefinitely	Low impact
Renewable Energy Projects	Wind; solar power; hydropower; fossil fuel switch	Avoids emissions that are generated by fossil fuels	Some forms of renewable energy are already competitive with fossil fuels, meaning that there may be sufficient profit motive to implement them and offset funds are unnecessary No good system to ensure that renewable energy credits are equivalent to one ton of carbon removal from the atmosphere	Medium impact
Energy Efficiency	Increasing efficiency of appliances, machines, buildings, etc.	Multiple benefits (including cost-saving benefits)	Runs risk of double counting additionality Difficult to show whether improvements in efficiency are made because of the offset market or because of individual incentives	Medium to low impact
Reduction of Non-CO2 Emissions	Methane capture; reducing hydrocarbons;	Other GHGs trap more heat than carbon in the	High variety in types and quality of projects Non-carbon GHGs are limited—they only make	High impact

[3] SDG 13: Take urgent action to combat climate change and its impacts. SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

	nitric acid production; methane avoidance	atmosphere, so targeting one ton of other GHGs can be more effective against rising temperatures Relatively easy to quantify and measure	up about 20% of US GHG emissions	

CASE STUDY

To demonstrate the principles discussed above, we apply them in evaluating a landfill gas project.[4] The main point illustrated by this case study is that even one of the most defensible types of carbon offsets, landfill gas capture, relies heavily upon scientific assumptions and requires intense monitoring.

Estimating the Baseline Scenario

Waste decomposing in large, open air landfills releases CO_2 and methane into the atmosphere. Offset evaluators calculate the tons of CO_2 equivalent (CO_2e) emitted from waste in a year based on a few factors. These include the volume of each kind of waste deposited at the site in each of the previous years, the decay rate of each type of waste, and the climate at the site. Evaluators estimate the composition of the waste by randomly sampling it, ideally over a period of years. Site conditions also affect a few parameters used to calculate the final estimate. For instance, under the right soil conditions, evaluators will subtract out a fixed fraction from baseline emissions (10 percent) to account for a process known as “soil oxidation,” which naturally captures some of the methane. For clarity, we will call the figure reached after these adjustments the “raw baseline scenario.” This figure describes the GHGs that would escape into the atmosphere should no offsetting activity or regulation interfere.

If government regulations mandate that landfill operators capture their emissions, enforcement will be checked. If these regulations are not in fact enforced, then the raw baseline scenario remains as calculated. If, however, these regulations are enforced, then evaluators must determine what steps the landfill owners are likely to take to cut their emissions in the absence of offset funds. If regulations have been in place for some time, evaluators may use historical data from the site to revise the baseline scenario so that it accounts for regulatory requirements. However, in many cases, either no such data have been collected, or the regulations are new.

If the regulations allow the site to emit a fixed amount of GHGs, then the baseline scenario is altered to match these levels. However, regulations often fail to define an exact figure, or the likelihood of enforcement is unclear. In this case, evaluators make a back-of-the-envelope calculation. They assume that the average semi-enforced regulation requires landfills to flare the gasses they emit and flaring typically destroys about 50 percent of the CO_2e present in the emissions. Most offsetting projects capture about 90 percent of the CO_2e. Thus about 20 percent[5] of the gas that would have been emitted in the baseline scenario, in which flaring is mandated, is in fact emitted in the presence of the offsetting activity. Next, they estimate the levels of GHGs emitted from the site in the presence of the offsetting activity (which we describe next), multiply by 5, and use that as the baseline scenario.

---

[4] In this account, we sketch section 4.8 of the EC report and the CDM Methodology AMS-III.G, described here.
[5] Calculated as (100-90)/(100-50) = 0.2

In any case, evaluators arrive at a regulation-adjusted baseline scenario.

Estimating the Project Scenario

Next comes the calculation of the "project scenario," or the amount of CO_2e emitted in the presence of the offsetting activity. First, evaluators calculate an efficiency parameter based on the type of capture technology deployed. These technologies include oil, natural gas, and biomass fueled boilers that may or may not make use of condensers. Depending upon the technology, a default efficiency parameter is available, though evaluators are encouraged to use the efficiency parameters provided by the boiler manufacturers. They may also gather performance data themselves in order to estimate this parameter. This number, equal to some value between 0 and 1, describes the fraction of the emissions neutralized by the carbon capture technology. It is multiplied with the raw baseline scenario to produce a raw project scenario. This figure represents the amount of CO_2e emitted in the presence of the carbon capture technology, but it does not yet account for leakages or the carbon emitted by the capture process itself.

In order to account for leakages, evaluators determine how the capture technology (usually, the boiler) was used prior to its installation at the site. It may have been used to eliminate GHGs elsewhere, perhaps at another landfill site. In this case, they subtract the emissions it would have prevented at this site to produce a leakage-adjusted project scenario.[6]

Finally, evaluators produce a three-part estimate of project emissions to account for the GHGs emitted by the offsetting activity itself. First, they calculate the GHGs generated by the boiler, or other capture technology, in its day-to-day use. In the case that the technology is powered by electricity, they install a meter to calculate its electricity consumption. If it is powered by a public grid, they multiply this consumption by a default factor determined by the fuel mix of the relevant public power plant. A further factor is applied to account for the energy lost in transmission of power from the plant to the site. In the event that the capture technology is powered by an off-grid fuel source, a series of calculations are performed using measurements of that off-grid source's fuel consumption. These calculations rely on a number of assumptions about the efficiency of the fuel sources. A mix of on and off-grid calculations are performed in the event that the carbon capture technology uses both on and off-grid sources. Moreover, it may happen that the capture technology shares an off-grid source with other on-site electricity consumers. In this case, the off-grid source may produce a fixed amount of energy, regardless of whether that energy is ever consumed. If so, the off-grid consumption is ignored altogether, and only on-grid electricity consumption counts towards the day-to-day electricity consumption of the capture technology. In any event, evaluators arrive at a final figure for the GHGs emitted as a result of day-to-day electricity consumption.

The second step of the project scenario estimate accounts for flaring, which often forms a part of the capture process. The third and final part performs adjustments based on any upgrades to the capture technology implemented in the past year. Each of these adjustments deploys an algorithm of similar complexity to the one just described.

Finally, evaluators calculate a final project scenario net of day-to-day electricity consumption, flaring, and project upgrades.

[6] Currently, this is the only form of leakage considered by the methodology. As critiqued in the EC report, no attempt is made to adjust for more indirect, economic leakages.

Estimating the Final Emissions Reductions

To arrive at the final estimate of emissions savings resulting from the project, evaluators subtract the fully adjusted project scenario from the regulation-adjusted baseline scenario.

CONCLUSION AND NEXT STEPS

This primer has reviewed a few basic considerations and calculations that validate the carbon offset credits accessible to organizational buyers. We outline three factors used to determine the quality of an offset: additionality, uncertainty, and availability. We find that industrial gas capture projects offer the best combination of results.

The uncertainty about additionality raises important questions about the utility of carbon offsets as an ideal method for reducing an organization's carbon footprint. Instead, offsets might be best considered as a last resort when operations cannot otherwise be decarbonized. It is preferable to avoid unnecessary carbon emissions altogether. For example, investing in high quality videoconferencing technology in order to avoid the air travel required by in-person meetings is a surer method to lower carbon emissions. Likewise, we expect that government policies which mandate behavioral change are a more robust method for reducing emissions than government policies that permit carbon offsetting.

Finally, we would reiterate that this primer is not intended to be the final word on carbon offsets but rather a primer based on the best research available at the moment. This work would be enhanced by a comprehensive review of offset prices by type that could perform cost benchmarking.

REFERENCES

Bailis, R., Broekhoff, D., & Lee, C. M. (2016). *Supply and sustainability of carbon offsets and alternative fuels for international aviation* (Working Paper No. 2016–03). Retrieved from Stockholm Environment Institute website: http://assets.wwf.org.uk/downloads/sei_wp_2016_03_icao_aviation_offsets_biofuels.pdf

Cames, M., Harthan, R. O., Fussler, J., Lazarus, M., Lee, C. M., Erickson, P., & Spalding-Fecher, R. (2016). *How additional is the Clean Development Mechanism? Analysis of the application of current tools and proposed alternatives* [European Commission Report]. Retrieved from Institute for Applied Ecology website: https://ec.europa.eu/clima/sites/clima/files/ets/docs/clean_dev_mechanism_en.pdf

Google. (2011). *Google's Carbon Offsets: Collaboration and Due Diligence* [White Paper]. Retrieved from Google website: https://static.googleusercontent.com/media/www.google.com/en//green/pdfs/google-carbon-offsets.pdf

Meyfroidt, P., Rudel, T. K., & Lambin, E. F. (2010). Forest transitions, trade, and the global displacement of land use. *Proceedings of the National Academy of Sciences*, *107*(49), 20917–20922. https://doi.org/10.1073/pnas.1014773107

Ramseur, J. L. (2009). *Voluntary Carbon Offsets: Overview and Assessment* (p. 15) [CRS Report for Congress]. Retrieved from Congressional Research Service website: https://fas.org/sgp/crs/misc/RL34241.pdf

Warman, R. D., & Nelson, R. A. (2016). Forest conservation, wood production intensification and leakage: An Australian case. *Land Use Policy*, *52*, 353–362. https://doi.org/10.1016/j.landusepol.2015.12.020

World Bank Corporate Responsibility Oversight Committee. (2012, November 27). *World Bank Group (WB) Guidelines/Criteria for Selection of Emission Reduction Offsets*. Retrieved from http://pubdocs.worldbank.org/en/789581443802484010/pdf/WB-Carbon-Offset-Guidelines-Public.pdf