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Evidence of non-additional pig manure offset projects

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Abstract. Each carbon offset represents the claim that one ton of CO_2 emissions has been avoided or removed from the atmosphere. For offsets to deliver real climate benefits, the emission reductions they represent must be "additional," meaning they would not have occurred without financial support from the carbon market. Despite its importance, additionality has proven difficult to achieve in practice. Prior research and investigative reporting have documented widespread non-additionality throughout the carbon market, yet quantitative assessments of additionality remain rare. Here, we use offset project documentation and government statistics to evaluate the financial additionality of pig manure management projects in China that capture and burn manure-derived methane. We find that 31 percent of the anticipated annual offset credits (5.95 million of 19.2 million) from the 74 projects we analyzed are likely non-additional because they ignore the financial benefits associated with generating energy from captured methane. Notably, our analysis relies only on project-reported data and publicly available government statistics, requiring no modeled counterfactuals. Our findings suggest that current market rules require significant reform to ensure that offsets represent real climate benefits.

Keywords: ACM0010, Additionality, Carbon Offsets, Clean Development Mechanism

1. Introduction

Questions of additionality have plagued carbon offset markets since their inception. A carbon offset represents a promise to counteract the climate damage of burning fossil fuels. The only way to fulfill that promise is to produce new, "additional" climate benefits — benefits that would not have occurred without the financing provided by selling offset credits (Gillenwater 2012). Non-additional offsets cannot deliver on their promise. Instead, the use of non-additional offset credits threatens to increase fossil emissions in the long run. This makes offsets a high-risk approach, as anything less than perfect implementation means trading the certain damages of ongoing fossil emissions for the uncertain benefits promised by offsets (Macintosh et al. 2024).

As important as additionality is to the logic of offsetting, it has proven difficult to evaluate in practice. That is because additionality claims depend on unobservable counterfactual scenarios — what might have happened in a world without offsets. Many studies assess offset additionality using case studies to document how the prevailing regulatory or economic landscape calls into question claims of additionality (Haya 2009; Haya and Parekh 2011; van Kooten et al. 2015; Wara 2007). A related body of literature has applied a more theoretical (Aldy and Stavins 2012) or broad survey approach (Cames et al. 2016; Haya et al. 2020; Michaelowa 2009) to scrutinize the actual (or proposed) additionality rules used by offsetting programs. Outside of the academic literature, journalists have provided some of the clearest examples of non-additionality in the process of investigating the global carbon market (Elgin 2020; Koberstein and Applegate 2021; Song and Temple 2021). Together, these lines of inquiry provide evidence that existing oversight mechanisms often fail to ensure that offset credits generate additional climate benefits.

A handful of studies have quantitatively assessed additionality claims. That is because quantifying unobserved counterfactual scenarios usually requires exploiting some sort of natural experiment or creatively analyzing project data. Calel et al. (2025) exemplifies the natural experiment approach, comparing wind energy projects in India that received offset credits with less financially attractive projects that did not. This experimental framework showed that at least 52 percent of wind energy projects developed in India under the Clean Development Mechanism are likely non-additional. Schneider (2011) quantified non-additionality using project time series data, demonstrating how certain industrial gas-destruction offset projects strategically manipulated their production of greenhouse gases to minimize costs while maximizing offset credit generation.

Here, we quantitatively assess the additionality of pig manure management offset projects located in China. The projects we analyze all use the ACM0010 offset methodology — the Consolidated Methodology for GHG [greenhouse gas] Emission Reductions From Manure Management Systems — which was originally developed under the Clean Development Mechanism (CDM). Until recently, ACM0010 was rarely used. Between 2006 and 2021, only 34 projects had ever been proposed, representing an average of around 2 projects per year. That changed in 2021 when a surge of new ACM0010 projects appeared (Figure 1). Almost all the new growth (96 of 102 projects) involved pig manure projects in China.

This manuscript documents inconsistencies in the paperwork of Chinese pig manure offset projects enrolled under ACM0010. Our analysis focuses on project-reported cash flows and the widespread failure to account for the economic benefits of collecting and burning manure-derived methane. Specifically, many projects report generating and using heat or electricity from captured methane, but few account for the cost savings of reduced energy purchases. We show that properly accounting for these benefits renders 31 percent of projects non-additional.

Below, we provide background about pig manure management projects, their participation in the voluntary carbon market, and their impact on the carbon cycle. We then describe our methods for evaluating additionality using data from project paperwork and Chinese government statistics. Finally, we present project- and protocol-level findings of non-additionality and discuss how our results contribute to broader evidence that carbon offset protocols often fail to ensure credit quality.

1.1. Pig manure offset projects

Manure management projects earn credits for reducing methane emissions in comparison to conventional manure management practices. Prospective projects can earn offset credits via a number of crediting protocols. In our analysis, we focus on projects developed using ACM0010, the Consolidated Methodology for GHG Emission Reductions from Manure Management Systems. The protocol awards offset credits for the improved management of manure from all types of livestock, including cattle, pigs, and chickens.

ACM0010 was developed under the CDM, the carbon offset program established in the late 1990s under the Kyoto Protocol. In recent years, Verra and Gold Standard, two of the largest issuers of offsets in the voluntary carbon market, have allowed new projects to enroll using ACM0010. Accordingly, almost all recent development under ACM0010 has taken place within the voluntary market. Projects seeking credits under ACM0010 must establish that the new manure management system would not have been installed in the absence of offset credit revenue, following the Combined Tool to Identify the Baseline

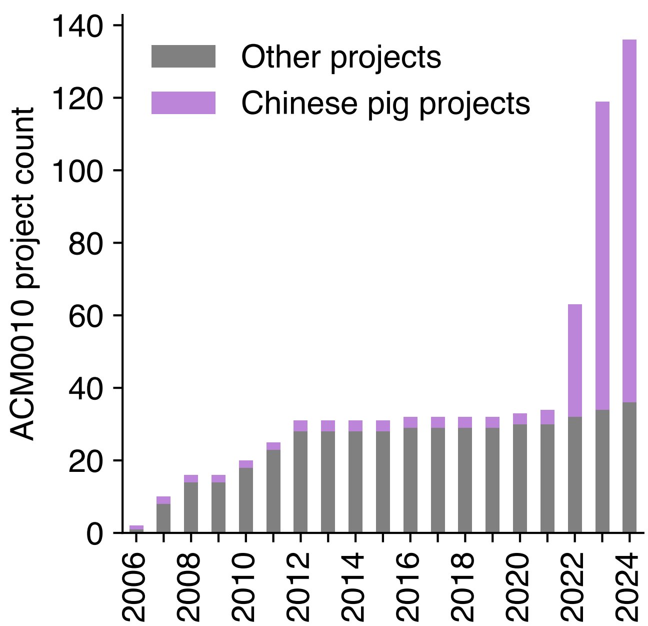

Figure 1: Cumulative number of offset projects proposed under ACM0010. ACM0010 projects started under the Clean Development Mechanism in 2006. The protocol was later adopted by the voluntary market, but remained little used for years. The number of proposed projects, especially in China, rapidly grew between 2022 and 2024. Seven projects are not shown due to insufficient information about when they started. Data from CarbonPlan (2024) and CDM Executive Board (2025).

Scenario and Demonstrate Additionality (UNFCCC 2017). ACM0010 and its related additionality tool are maintained by the UN body that oversees the CDM, and were last updated in 2013 and 2017, respectively.

Decomposing manure emits methane (CH_4) and nitrous oxide (N_2O), both of which are powerful greenhouse gases. Methane, in particular, has become a major focus of international greenhouse gas mitigation efforts due to its high global warming potential and rapidly increasing atmospheric concentrations (e.g., Global Methane Pledge n.d.). Over a 100-year time period, methane traps about 27 times more heat than carbon dioxide (Szopa et al. 2021). Decomposition of pig manure emits 10.5 $MtCH_4$ per year (283 $MtCO_2e$ using a 100-year global warming potential), making it the largest source of greenhouse gas emissions from pig husbandry (FAO 2022). A large portion of these emissions originate from China, which is thought to be home to nearly half the world's pig population (Ritchie et al. 2019).

The leading approach for reducing methane emissions from pig manure involves capturing and destroying methane instead of venting it to the atmosphere. Most conventional manure management systems use water to flush manure from pig barns and collect it in open ponds. There, submerged manure decomposes under anaerobic conditions, which produces methane that is then released to the atmosphere. Manure management projects attempt to reduce these emissions by capturing and destroying methane before it escapes. The simplest approach involves covering existing manure ponds to trap and divert the methane to a flare, boiler, or electric generator for combustion. Burning methane transforms it into CO_2 and water, reducing the immediate warming effects of decomposing manure. More advanced manure management systems, such as anaerobic digesters, use reaction chambers that provide a controlled environment (i.e., higher, constant temperature) to accelerate and maximize methane production prior to combustion.

2. Methods

Our analysis considers 74 pig manure management offset projects that capture and combust methane from decomposing pig manure. 49 of those projects claim to use biogas-derived energy in the normal operation of associated pig barns, but fail to account for those energy cost savings in their additionality analysis. We quantitatively evaluated the additionality of these 49 projects by comparing the monetary value of each project's unaccounted-for energy savings to the income the project claimed it needed from selling carbon offsets in order to justify changing its manure management practices.

Our analysis relied on three pieces of information. First, we quantified energy demand — the amount of energy each project needs to raise pigs in its normal course of operation. We estimated this value using government-provided statistics on the energy cost of pig production on a province-by-province basis.

Second, we quantified energy supplied from the proposed manure management project, as reported in project paperwork. This value allowed us to estimate the energy cost savings of using electric or thermal energy from biogas rather than buying electricity or coal. Finally, we estimated a project's "additionality revenue threshold" (or "revenue threshold" for short) — the amount of additional revenue the project claims it needed to justify collecting and destroying methane. We calculated revenue thresholds based solely on self-reported data from each project's offset registry paperwork, taking into account all other revenue sources claimed by offset projects, including the sale of fertilizer derived from pig manure.

We categorized projects as non-additional when the new energy supplied by methane capture and combustion satisfies enough of the project's energy demand that the value of the displaced energy exceeds the project's claimed revenue threshold.

2.1. Energy demand

We sourced data about the energy requirements of raising pigs in China from the 2021 Compilation of National Agricultural Product Cost and Benefit Data, which is assembled by China's National Development and Reform Commission (NDRC; NDRC (2021)). NDRC data provide estimates of the amount of money (Chinese yuan; CNY) spent on electricity and coal to produce a pig in each province of China. We combined these values with project-reported pig production numbers to estimate the energy demand of each offset project site. As a sensitivity analysis, we repeated our analysis using the 2024 Compilation of National Agricultural Product Cost and Benefit Data.

Most projects reported the total number of market pigs produced per year (variable $N_{p,LT}$ in project paperwork). In some cases, projects only reported their average daily stock of market and breeding pigs. For these projects, we converted between average daily stock and the annual number of pigs produced by assuming market pigs spend 180 days in a barn prior to slaughter, which is the mode of pigs' barn residence time for projects that report the value.

2.2. Energy supply

We identified two types of pig manure projects: electric and thermal. Electric projects use biogas to generate electricity, which can substitute for electricity previously purchased from the regional grid for things like heating, ventilation, and lighting. We identified a project as electric if the project paperwork explicitly mentioned the existence of an electric generator. Thermal projects, however, burn biogas to produce heat, which has more limited applications. If a project did not explicitly describe the existence of an electric generator, we conservatively assumed it only used collected biogas to produce thermal energy. Thermal projects represented the majority of projects we examined (27 of 49). Among thermal projects, only 10 reported the amount of heat produced (GJ) from burning biogas. For consistency, we instead calculated thermal energy generation from per-project biogas production (variable Q_{CH4} in project paperwork), which all 27 thermal projects reported. We then calculated net methane production (net Q_{CH4}) by applying project-specific estimates of methane leakage and flaring. Finally, we multiplied net methane production by the energy content of methane (55 GJ per tonne; International Energy Association (2024)) and, to ensure a conservative estimate, we assumed that only 60 percent of calculated thermal energy was available for use.

2.3. Additionality revenue thresholds

ACM0010 requires that projects establish their additionality using a procedure called the Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality (UNFCCC (2013); see §5.2). These rules require an "investment analysis" in which projects disclose expected cash flows and demonstrate that, without revenue from credit sales, the project's financial return falls below the threshold for an attractive investment (UNFCCC 2017). These rules also require a sensitivity analysis "to assess whether the conclusion regarding the financial attractiveness is robust to reasonable variations in the critical assumptions" (UNFCCC (2017); see §4.4, paragraph 32).

We used cash flow and sensitivity analysis data to derive per-project additionality revenue thresholds. In theory, the cash flow and sensitivity analysis revenue thresholds should be identical, as this would demonstrate internal consistency across values reported in project paperwork. In practice, they often diverge — sometimes significantly (Figure S1). For projects that provide sufficient information (36 of 49 projects), we calculated both thresholds and used the higher of the two in our core analysis — a conservative choice that maximizes the likelihood of classifying a project as additional.

2.3.1. Cash flow revenue threshold As part of the ACM0010 investment analysis, projects report revenues, such as fertilizer sales and subsidy income, and expenses, such as the costs of construction and ongoing operation and maintenance. They also establish a minimum net present value (NPV) or internal rate of return (IRR) that constitutes an attractive investment. We refer to this as an investment benchmark. Of the 49 projects included in our quantitative analysis, 36 adopted an IRR-based investment benchmark of 9.5 percent. Two projects reported an IRR benchmark of 8.58 percent. The remaining projects either did not report an IRR benchmark or did not provide detailed cash flow information, so we did not calculate a cash flow revenue threshold for them. Starting with reported cash flow, we used binary search to calculate the amount of additional annual revenue each project needed over the project lifetime to exceed each project's reported IRR benchmark. We used NumPy Financial to calculate IRR (NumPy-Financial Developers 2019).

2.3.2. Sensitivity analysis revenue threshold We calculated a revenue threshold from sensitivity analysis data for all 49 projects analyzed in this study. To do so, we extracted the annual revenue each project expected to receive from selling the fertilizer it would produce as a consequence of changing its manure management practices. We also extracted the percent by which this revenue would have to increase for each project to exceed its chosen investment benchmark (i.e., IRR or NPV threshold), a value that projects report. We calculated the sensitivity analysis revenue threshold by multiplying these two values.

2.4. A worked example

Examining a specific project — GLD11674 — illustrates our method. According to paperwork submitted to the offset registry Gold Standard, the project required carbon financing to justify the installation of new manure management systems at eight farms in Guangdong province. The project was deemed additional by the registry and is eligible to receive credits for the estimated 423,531 tCO_2e of methane reductions it purportedly achieves each year.

Starting with energy demand, government data indicate that pig farms in Guangdong province spend 0 CNY on coal and 14.07 CNY on electricity per pig raised. Project paperwork indicates that the farms associated with GLD11674 produce a total of 852,884 market pigs per year, in addition to maintaining a population of 61,300 breeding pigs. We therefore calculated the cost of the farms' energy demand as 12.86 million CNY per year (14.07 x 914,184).

Moving to energy supply, project paperwork states that each farm has installed an electric generator powered by captured biogas. Across the eight farms, these generators are expected to generate 59,435 MWh per year. The paperwork explicitly states that "power generated are [*sic*] all used by the AWMSs [advanced waste management systems] and the 8 swine farms and will not be connected to another user or to the regional power grid." Assuming electricity costs 0.3 CNY per kWh, those generators could entirely satisfy the pig farms' electricity needs.

Finally, we determined the project's additionality revenue threshold using the sensitivity analysis approach. GLD11674 reports anticipate fertilizer sales of 19.80 million CNY per year and claims that the project would be financially viable without carbon financing if fertilizer sales were to increase by

17.46 percent. That makes the project's revenue threshold 3.46 million CNY (0.1746 x 19.80 million CNY). GLD11674 did not provide an IRR benchmark in its investment analysis, so we only calculated a single revenue threshold for the project.

GLD11674 does not account for energy cost savings in its financial additionality assessment. Instead, the project lists only the following categories of positive cash flows: revenue from fertilizer sales, subsidy income, fixed asset residue value, and recovered current capital. The data described above indicate that even if the project's pig barns only used 20 percent of the new electricity produced — well below what appears feasible — the energy savings would exceed the project's revenue threshold. These results indicate that GLD11674 is non-additional, meaning the 701,764 credits issued to date and projected to be issued in the future (423,531 per year) provide no real climate benefits.

2.5. Project data

We identified 113 projects developed under ACM0010, 104 of which were located in China, across the voluntary carbon market as of our study cutoff date of December 31, 2024. In identifying projects, we looked for projects in five of the largest voluntary offset registries using OffsetsDB (CarbonPlan 2024). We also looked for projects listed at the Global Carbon Council, a rapidly expanding offset registry. Across these six registries, we only found ACM0010 projects listed at the Verra and Gold Standard offset registries.

We reviewed project paperwork for all 104 ACM0010 projects in China. We excluded seven projects that either lacked public project paperwork or did not involve pigs, leaving 97 projects. Of those, 23 projects had insufficient data for analysis. Among the remaining 74 projects considered by our analysis, 25 either did not generate usable energy (e.g., flare-only projects) or explicitly accounted for energy savings. As a result, our study considers 74 projects and quantitatively assesses the additionality of 49 projects. The Supplementary Text includes the language from each project's paperwork stating its intent to use biogas-derived energy for on-farm purposes (Table S1).

Because most of the analyzed projects were recently developed, few have received credits, as registration, verification, and crediting can take several years. To account for this, we report our results in terms of the number of credits projects anticipate receiving annually (Figure 2). The 74 projects we considered have received 11.59 million credits to date, but anticipate receiving 19.2 million credits per year. Because some projects are still under development, the actual number of credits that might eventually enter the market could change.

Figure 2: Summary of projects and credits analyzed in this study. We identified 97 pig manure projects located in China (26.6 million credits) that participate in the voluntary carbon market under ACM0010. Due to insufficient data in their project paperwork, we excluded 23 projects. Our core analysis therefore considers 74 projects (19.2 million credits), of which we quantitatively analyze the additionality of 49 projects (16.0 million credits) that do not account for energy generated from burning biogas in their cash flow analyses. Credit numbers reflect anticipated annual credit issuance.

2.6. Digitized project records

For each project, we transcribed data about the number of pigs housed by the project, estimates of manure and biogas production, and the amount of energy (thermal or electric) produced by burning that biogas. We recorded the project owner and the province in which each project is located. We also collected details about net cash flow, fertilizer sales, and the results of the project's additionality sensitivity analysis. A full copy of the data, along with the project documentation analyzed is available in CarbonPlan (2026).

2.7. Open science

We used Python to conduct the analyses described here. Our workflow relied on the following open source software packages: Jupyter (Kluyver et al. 2016), Matplotlib (Hunter 2007), NumPy (Harris et al. 2020), NumPy Financial (NumPy-Financial Developers 2019), Pandas (McKinney 2010; Pandas Development Team 2020), and Pint (Pint Developers 2024). The code used to produce this manuscript is available on GitHub (https://github.com/carbonplan/acm0010-additionality-analysis).

3. Results and discussion

We identified 18 projects that failed to meet ACM0010's additionality criteria after taking into account the energy savings from burning biogas (Figure 3). On a crediting basis, these projects could generate 5.95 million non-additional credits per year. Overall, 24.3 percent of all projects considered (18 of 74) were non-additional, representing 31 percent of the potential annual credit supply (5.95 million of 19.2 million). These estimates exclude the 23 projects which did not provide cash flow data. If all the projects with missing data are assumed to be additional, then 18.5 percent of Chinese ACM0010 projects (18 of

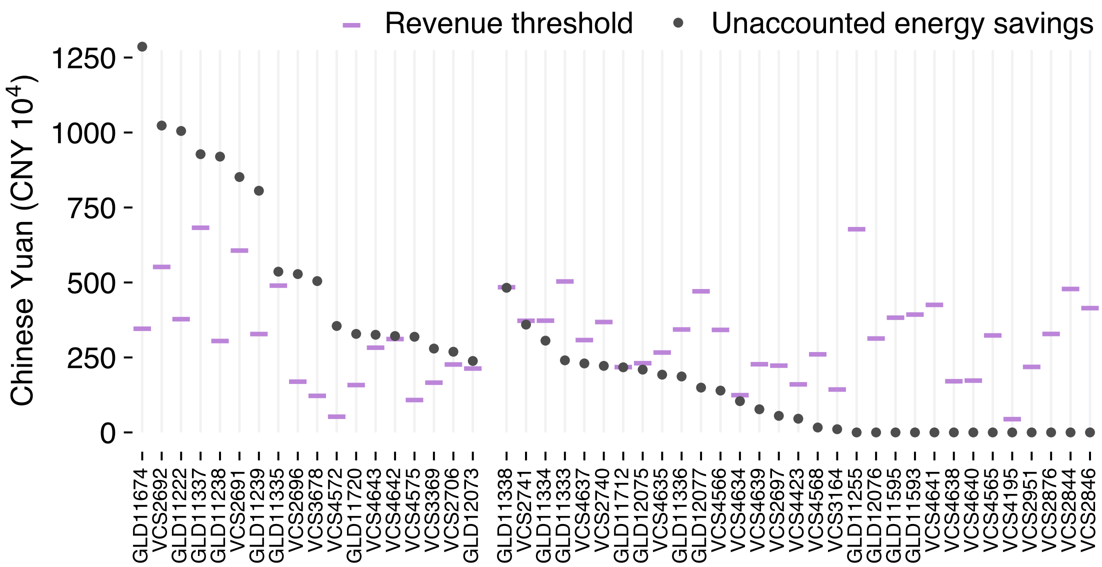

Figure 3: Additionality evaluated by project. We compared unaccounted-for energy savings per project (grey dot) against each project's additionality revenue threshold (purple line) — the amount of additional money project paperwork asserts each project requires for operation. Projects where energy savings exceeded the revenue threshold were deemed non-additional (left side of Figure). On an annual crediting basis, we found that 31 percent of credits are non-additional.

97) would be non-additional, representing 22.4 percent of annual credit issuance (5.95 million of 26.6 million). This provides a lower bound estimate of non-additionality. We repeated our analysis using 2024 NDRC data and, on a portfolio level, found similar levels of non-additionality. That said, the specifics about project-level additionality sometimes differed between the two analyses (see Supplementary Text).

Non-additionality varied by project type. Of the 27 thermal projects analyzed, only 4 (14.8 percent) were non-additional, compared to 14 of 22 electric projects (63.6 percent). These stark differences stem partly from the energy demand data used in our analysis. Government-provided statistics about pig farm energy demand indicate that coal makes up only a small fraction of the total energy costs of raising pigs in China. In fact, the data suggests pig farms in 9 of the 20 provinces that host ACM0010 projects use no coal at all. Because we assumed thermal projects can only replace coal, and coal usage rates are low according to the government data, our estimated energy savings for thermal projects rarely exceeded their additionality revenue thresholds. However, this method likely underestimates the energy cost savings of thermal projects. For example, VCS2844, a thermal project, states that the 706,302 GJ of energy it will generate from burning biogas will "all [be] used by the operation of AWMSs and the 11 swine farms, which was provided by the coal-fired boiler without the proposed project." Yet government data indicate no coal is used by pig farms in the Henan province where VCS2844 is located. As a result, our analysis assumed that no energy savings were achieved and we categorized the project as additional.

To quantify this effect, we conducted a sensitivity analysis in which we allowed thermal projects to displace up to 10 percent of electricity costs with thermal energy from biogas combustion. The rationale was that at least some of the electricity used for heating could be replaced by biogas-derived thermal energy. This change doubled the number of thermal projects we assessed as non-additional, from 4 to 8 projects. Annual non-additional credits supply increased from 1.42 million to 3.16 million — more than a 120 percent increase. Given these results, our estimate of non-additionality for thermal projects should be considered a conservative lower bound.

Several additional lines of evidence indicate our estimate is likely conservative. First, the NDRC data on energy requirements for raising a single pig appear to exclude the energy costs of farrowing and weaning piglets. The NDRC data also refer to "livestock costs", which we interpret to mean the data pertain only to the energy costs of raising market pigs and exclude the energy costs of raising piglets. This interpretation is supported by Gale (2017), who noted in a report for United States Department of Agriculture's Economic Research Service that NDRC data "has no comprehensive statistical data on costs of farrowing and nursery stages of swine production." Such an omission would be noteworthy because piglets require significant energy, particularly for heating, as they struggle to regulate their temperature (Dong et al. 2007; Qi et al. 2023). If these heating demands are indeed excluded from the NDRC data, our analysis likely underestimates total energy demand, another indication of its conservativeness.

Project paperwork provides more evidence that our approach likely misses non-additional projects. For some projects we analyzed — such as VCS3981, VCS4011, and GLD11336 — project paperwork acknowledges possible energy savings from using biogas rather than purchasing energy, only to omit those savings from their cash flow and additionality analyses. In fact, GLD11336, a project covering nine farms in Guangxi province, explicitly estimates energy savings. Its paperwork states that electricity costs about 0.50 CNY per kWh, and that the project's biogas-powered generators will produce 33,100,600 kWh of electricity per year — totalling over 16 million CNY in potential annual energy savings. However, these savings are absent from the project's reported cash flow. In our analysis, GLD11336 had an additionality revenue threshold of 3.43 million CNY, far below the project's own estimate of energy savings. Even so, our analysis did not identify GLD11336 as non-additional because the NDRC data show the project having an energy demand of only 1.86 million CNY, which is less than the project's additionality revenue threshold. This case underscores both the surprising inconsistencies in project paperwork and the conservative nature of our core analysis.

Other inconsistencies were more troubling. With accurate paperwork we would expect to derive identical or nearly identical additionality revenue thresholds from either cash flow data or sensitivity analysis results. Instead, we found significant divergences between the two metrics (Figure S1). This indicates a lack of internal consistency within project paperwork and raises questions about the quality controls of the voluntary carbon market (Giles and Coglianese 2025).

While many factors suggest our estimates are conservative, ambiguities about project-level energy use also introduce the possibility of overestimating the prevalence of non-additionality. Ideally, project paperwork would specify the exact amount of biogas-derived energy each project planned to use in its pig barns. No project provided this type of detailed accounting. Instead, project paperwork provided only vague details about how biogas-derived energy might be used (see Table S1). So when projects state they will use biogas-derived energy, our analysis treats those claims as true and assumes that projects will use as much biogas-derived energy as possible to replace existing on-farm energy consumption, up to the total amount of thermal or electric energy demand detailed by NDRC data. If projects systemically use less biogas-derived energy, our analysis could overestimate non-additionality. Quantifying this possibility would require on-the-ground information about project energy usage.

At a minimum, our results highlight the need to strengthen the financial analysis test in the CDM's Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality. The inconsistent treatment of biogas-derived energy cost savings across ACM0010 projects underscores the rule's shortcomings. Why do some projects account for these savings while others do not? VCS3128, for example, explicitly includes "[a]nnual coal saved revenue" in its cash flow analysis, detailing both tonnes of coal saved per year and the cost per tonne — unlike the 49 projects we assessed that failed to do so. One possible explanation is ambiguity in the CDM's additionality tool, which does not explicitly require a complete cost-benefit analysis that considers all significant cash flows. Alternatively, the issue may stem from inadequate enforcement by verifiers and registries. Regardless of the cause, we recommend revising the rules to explicitly require consideration of energy savings.

4. Conclusion

Our results provide quantitative evidence of non-additional outcomes within the global carbon market. Proper functioning of the market requires that projects accurately report the outcomes of the real actions they implement as a result of carbon financing; that verifiers provide meaningful oversight that uncovers errors; and that offset registry approval guarantees real climate benefits. In theory, all of those assumptions should apply to the ACM0010 projects we examined. Yet even our basic analysis, which takes multiple steps to ensure conservative results, indicates that nearly a third of pig manure projects analyzed failed to deliver additional climate benefits.

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Conflict of Interest

The authors declare no conflicts, financial or otherwise, that influenced or could be perceived as influencing the research described here.

Author Contributions

Grayson and Freya designed the research, collected and analyzed the data, and wrote the manuscript.

Data availability statement

The code used to generate all figures and numbers reported in the text is available at https://github.com/carbonplan/acm0010-additionality-analysis. An archive of data on individual projects, in addition to a copy of project paperwork, is available from CarbonPlan (2026).

Supplementary text

In addition to the 2021 NDRC data used in the Main Text, we repeated our analysis using NDRC data from 2024. Overall, the newer data show projects using relatively less coal and relatively more electricity for rearing pigs across China. Exactly reproducing the core results reported in the Main Text, but using the 2024 NDRC data instead:

> We identified 19 projects that failed to meet ACM0010's additionality criteria
>
> On a crediting basis, these projects could generate 5.33 million non-additional credits per year. Overall, 25.6 percent of all projects considered (19 of 74) were non-additional, representing 27.8 percent of the potential annual credit supply (5.33 million of 19.2 million). These estimates exclude the 23 projects which did not provide cash flow data. If all the projects with missing data are assumed to be additional, then 19.6 percent of Chinese ACM0010 projects (19 of 97) would be non-additional, representing 20 percent of annual credit issuance (5.33 million of 26.6 million).
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> Of the 27 thermal projects analyzed, only 3 (11.1 percent) were non-additional, compared to 16 of 22 electric projects (72.7 percent).

Below, we note specific projects where our assessment of additionality differed between the 2021 and 2024 (Table S1).

Project ID	Project Type	2021 NDRC	2024 NDRC
GLD11334	thermal	additional	non-additional
VCS4643	thermal	non-additional	additional
VCS4642	thermal	non-additional	additional
GLD11337	electric	non-additional	additional
GLD11712	electric	additional	non-additional
GLD11338	electric	additional	non-additional
VCS2741	electric	additional	non-additional
VCS2740	electric	additional	non-additional
VCS2691	electric	non-additional	additional

Some changes in NDRC data were especially modest, and yet, were enough to change our additionality classification. For example, VCS4642 and VCS4643 are two projects located in Shanxi province, which saw expenditures on coal per pig rise from 0 CNY in the 2021 data to 0.67 CNY per head in 2024 data. Other changes were more dramatic. Electricity usage per pig increased from 4.9 CNY per head to 9.08 CNY per head in Guizhuo province — a change of 85 percent.

Across both analyses, we found at least 20 percent over-crediting on a portfolio-wide basis when using even our most conservative approach for assessing additionality. Our sensitivity analysis, however, highlights that projects would need to be reevaluated on a case-by-case by auditors with access to project-specific data.

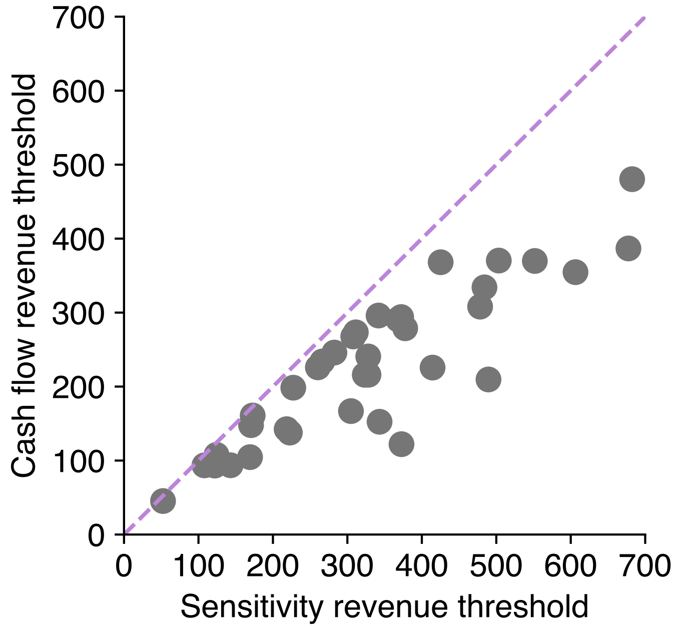

Figure S1: Comparison of sensitivity and cash flow derived additionality revenue thresholds. Each point represents a project. Projects with internally consistent paperwork fall near the one-to-one line. The existence of several projects with diverging revenue thresholds raises questions about the robustness of the carbon market's quality control processes.

Project ID	Energy Usage
GLD11222	”The electricity generated are all used by the AWMSs and the swine farms” ”The annual average electricity generation is 105,690.39 MWh, all of which will be used by the AWMSs and 10 swine farms.” ”The electricity generated by the project will be used firstly for the operation of AWMSs normally, then the excess electricity will be supplied to the swine farms”
GLD11238	”The annual average electricity generation 90,061.49MWh, all of which will be used by the AWMSs and 9 swine farms.” ”The electricity generated by the project will be used firstly for the operation of AWMSs normally, then the excess electricity will be supplied to the swine farms.”
GLD11239	”The annual average electricity generation of 87,303.42MWh, all of which will be used by the AWMSs and 9 swine farms.” ”The electricity generated by the project will be used firstly for the operation of AWMSs normally, then the excess electricity will be supplied to the swine farms.”
GLD11255	”And all the heat generated are used by the swine farms, which was provided by the coal-fired boiler without the proposed project. Since all the heat is used by the AWMSs and swine farms, therefore the baseline emissions associated with heat generation will not be claimed, which is conservative.”
GLD11334	”And all the heat generated are all used by the AWMSs and the 7 swine farms, which was provided by the coal-fired boiler without the proposed project.” ”For the use of heat energy by the AWMS is mainly reflected in the temperature maintenance of the anaerobic tank. For the swine farm, the heat energy is mainly used to supply the heat energy for the pig house and Staff living area.”
GLD11335	”Total installed capacity of the proposed project is 5.42 MW with an annual average electricity generation of 35,593.87MWh, all of which will be used by the AWMSs and the 9 swine farms.”
GLD11336	”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
GLD11337	”The biogas generated during the treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and the 15 swine farms, which was supplied by the grid company without the project.”

GLD11338	”The biogas generated during the treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and the 10 swine farms, which is supplied by the grid company in baseline scenario.”
GLD11674	”[T]he electricity generated are all used by the operation of AWMSs and the 8 swine farms” ”The biogas generated during the treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and swine farms, which is supplied by the grid company in baseline scenario”
GLD12076	”And all the heat generated are used by the operation of AMMSs and swine farms, which was provided by the coal-fired boiler without the proposed project. Since all the heat is used by the operation of AMMSs and swine farms, therefore the baseline emissions associated with heat generation will not be claimed, which is conservative.”
GLD12077	”And all the heat generated are used by the operation of AMMSs and swine farms, which was provided by the coal-fired boiler without the proposed project. Since all the heat is used by the operation of AMMSs and swine farms” ”The biogas generated during the treatment process will be captured for heat generation, the heat generated are all used by the AMMSs and swine farms, which was provided by the coal-fired boiler without the proposed project. ”
GLD12075	”The electricity generated are all used by the operation of AWMS and the swine farm.” ”[T]he electricity generated are all used by the operation of AWMS and swine farm, which is supplied by the grid company in baseline scenario. The grid company is dominated by thermal power generation. Therefore, the project activity will reduce of GHG and provide clean energy, which is in line with SGD 13(Climate Action) and SGD 7(Affordable and Clean Energy).”
GLD12073	”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
GLD11720	”The power generated are all used by the AWMSs and the 4 swine farms and will not be connected to another user or to the regional power grid and the baseline emissions associated with electricity generation will not be claimed.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”

GLD11712 ”the power generated are all used by the operation of AWMSs and the swine farms, which was provided by the region power grid.”

”The biogas generated during the treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and swine farms, which is supplied by the grid company in baseline scenario. The grid company is dominated by thermal power generation.”

GLD11595 ”And all the heat generated are used by the operation of AWMSs and swine farms, which was provided by the coal-fired boiler without the proposed project.”

”[T]he heat generated are all used by the AWMSs and swine farms, which was provided by the coal-fired boiler without the proposed project.”

GLD11593 ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”

”The biogas generated during the treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and swine farms, which is supplied by the grid company in baseline scenario.”

GLD11333 ”The biogas generated during the anaerobic digestion treatment process will be captured for power generation, the electricity generated are all used by the operation of AWMSs and the swine farms, which is supplied by the grid company in baseline scenario.”

”In baseline situation, no biogas can be generated and utilized. No clean energy can be generated in baseline situation. The electricity consumption of the swine farm is supplied by the grid company, which is dominated by thermal power generation.”

”surplus electricity will be supplied to the swine farm”

VCS4641 ”the biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms”

”biogas incineration saves fossil fuels used to generate heat and contributes to sustainable development”

VCS4642 ”the biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared.”

VCS4643 ”the biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared.”

VCS4634 ”biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared”

VCS4635 ”the biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared”

VCS4637 ”biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared.”

”for conservativeness, baseline emissions from heat generation are neglected.” ”biogas generated during the treatment process will be used as fuel for the canteens of each swine farm, which result in less GHG emissions.”

VCS4638 ”biogas released during the anaerobic digestion will be used as fuel for the canteens of swine farms, and the remaining biogas will be flared.”

VCS4639 ”The biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared. For conservativeness, baseline emissions from heat generation are neglected.”

VCS4640 ”The biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared. For conservativeness, baseline emissions from heat generation are neglected.”

VCS4565 ” the biogas generated during the treatment process will be used as fuel for the canteens of each swine farm, which result in less GHG emissions.”

VCS4566 ”Biogas collected from the fully enclosed anaerobic pond will be purified by biogas purification device firstly, and then the biogas released during the anaerobic digestion will be used as fuel for the boilers and canteens of each swine farm, and the remaining biogas will be flared.”

VCS4568 ”The biogas released during the anaerobic digestion will be partly used as fuel for the canteens of swine farms, partly for the biogas boiler for the feedlot, and the remaining biogas will be flared. For conservativeness, baseline emissions from heat generation are neglected.”

VCS4572 ”In addition, the biogas generated during the treatment process in this project will be used as fuel for the canteens of swine farms, partly for the natural gas/biogas boiler for the feedlot, and the remaining biogas will be flared.”

VCS4575 ”The liquid will be treated through anaerobic digestion and the biogas released during the anaerobic digestion will be used as fuel for the canteens of swine farms”

VCS4423	”The biogas will be captured and utilized for heat generation, the heat will be only used for the daily operation of the AWMSs and the 3 swine farms and will not be produced to other users.” ”The project makes use of biogas recovered from the animal waste treatment system for heat generation and supplies clean thermal energy, which replaces the fossil fuel fired energy.”
VCS4195	”The project avoids GHG emission of methane from the uncovered open lagoons and CO2 emissions from the fossil fuel-based boiler through recovery and utilization of biogas for heat generation.” ”The project will provide heat with generated biogas to displace equivalent heat generated from fossil fuel based boilers”
VCS3678	”The biogas generated during the treatment process will be captured and sent to the power generator. All the electricity generated will be used for the operation of the AWMSs and the swine farm, and the excess biogas will be destroyed (if any) by a flaring system.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
VCS3369	”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
VCS3164	”All biogas generated after project implementation is used for heat generation. The generated heat is only used for daily operation of AWMS and this swine farm itself and cannot be connected to other users” ”The heat energy generated by biogas boilers is used for farms’ heating system”
VCS2951	”Also, the generated heat is only used for daily operation of AWMSs and 10 swine farms themselves and cannot be connected to other users. For conservativeness, baseline emissions from heat generation are neglected.” ”All the energy generated through the burning process will be used in swine farms and AWMSs merely.” ”The biogas generated during the treatment process is captured for heat generation, the heat generated are all used by the operation of AWMSs and the 10 swine farms, which was provided by the coal-fired boiler without the proposed project. ”
VCS2876	”Also, the generated heat is only used for daily operation of AWMSs and 7 swine farms themselves and cannot be connected to other users. For conservativeness, baseline emissions from heat generation are neglected.” ”The biogas captured for heat generation, which is used for swine farms.”

VCS2844	”The biogas generated during the treatment process is captured for heat generation, the heat generated are all used by the operation of AWMSs and the 11 swine farms, which was provided by the coal-fired boiler without the proposed project”
VCS2846	”The biogas generated during the treatment process is captured for heat generation, the heat generated are all used by the operation of AWMSs and the 9 swine farms, which was provided by the coal-fired boiler in baseline scenario.”
VCS2740	”Also, the generated electricity is only used for daily operation of AWMSs and 10 swine farms themselves and cannot be connected to the region power grid or other users. For conservativeness, baseline emissions from power generation are neglected.” ”In addition, biogas incineration saves fossil fuels used to generate electricity and contributes to sustainable development.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
VCS2741	”As biogas is produced during the anaerobic treatment of the project, and the biogas is collected for power generation and all the power is used for the operation of AWMSs firstly and then surplus electricity will be supplied to the swine farms.”
VCS2706	”In addition, biogas incineration saves fossil fuels used to generate electricity and contributes to sustainable development.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
VCS2696	”Also, the generated electricity is only used for daily operation of AWMSs and 3 swine farms themselves and cannot be connected to the region grid net or other users. For conservativeness, baseline emissions from power generation are neglected.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”
VCS2697	”Also, the generated electricity is only used for daily operation of AWMSs and 4 swine farms themselves and cannot be connected to the region grid net or other users. For conservativeness, baseline emissions from power generation are neglected.” ”In addition, biogas incineration saves fossil fuels used to generate electricity and contributes to sustainable development.” ”The electricity generated by the project was used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms.”

VCS2691	”The biogas generated during the treatment process is captured for power generation, the electricity generated are all used by the operation of AWMSs and the 9 swine farms, which is supplied by the grid company in baseline scenario. The grid company is dominated by thermal power generation. Therefore, the project activity reduces of GHG and provide clean energy.” ”The electricity generated by the project will be used firstly for the operation of AWMSs normally, then the excess electricity was supplied to the swine farms. ”
VCS2692	”Also, the generated electricity will be only used for daily operation of the AWMS and the 9 swine farms themselves and will not be connected to the region grid net or other users.” ”As biogas will be produced during the anaerobic treatment of the project, and the biogas will be collected for power generation and all the power will be used for the operation of AWMS firstly and then surplus electricity will be supplied to the swine farm.”

Table S1: Details from project paperwork describing how biogas-derived energy will be used.

References

Aldy, Joseph E., and Robert N. Stavins. 2012. "The Promise and Problems of Pricing Carbon: Theory and Experience." *The Journal of Environment & Development* 21 (2): 152–80. https://doi.org/10.1177/1070496512442508.

Calel, Raphael, Jonathan Colmer, Antoine Dechezleprêtre, and Matthieu Glachant. 2025. "Do Carbon Offsets Offset Carbon?" *American Economic Journal: Applied Economics* 17 (1): 1–40. https://doi.org/10.1257/app.20230052.

Cames, Martin, Ralph O Harthan, Dr Jürg Füssler, et al. 2016. *How Additional Is the Clean Development Mechanism?* Öko-Institut e.V. https://www.oeko.de/publikation/how-additional-is-the-clean-development-mechanism/.

CarbonPlan. 2024. https://carbonplan.org/research/offsets-db.

CarbonPlan. 2026. "Data for: Evidence of Non-Additional Pig Manure Offset Projects." Zenodo. https://doi.org/10.5281/zenodo.19559011.

CDM Executive Board. 2025. *"Database for PAs and PoAs"*. https://cdm.unfccc.int/contest/Projects/projsearch.html.

Dong, H., Z. Zhu, B. Shang, G. Kang, H. Zhu, and H. Xin. 2007. "Greenhouse Gas Emissions from Swine Barns of Various Production Stages in Suburban Beijing, China." *Atmospheric Environment* 41 (11): 2391–99. https://doi.org/10.1016/j.atmosenv.2006.11.005.

Elgin, Ben. 2020. "These Trees Are Not What They Seem: How the Nature Conservancy, the World's Biggest Environmental Group, Became a Dealer of Meaningless Carbon Offsets." *Bloomberg*, December. https://www.bloomberg.com/features/2020-nature-conservancy-carbon-offsets-trees/.

FAO. 2022. *GLEAM 3 Dashboard*. https://foodandagricultureorganization.shinyapps.io/GLEAMV3_Public/.

Gale, Fred. 2017. "China's Pork Imports Rise Along with Production Costs." *Economic Research Service Report*. https://www.ers.usda.gov/publications/pub-details?pubid=81943.

Giles, Cynthia, and Cary Coglianese. 2025. "Auditors Can't Save Carbon Offsets." *Science* 389 (6756): 107–7. https://doi.org/10.1126/science.ady4864.

Gillenwater, Michael. 2012. *What Is Additionality? Part 1*. Greenhouse Gas Management Institute. https://ghginstitute.org/wp-content/uploads/2015/04/AdditionalityPaper_Part-1ver3FINAL.pdf.

Harris, Charles R, K Jarrod Millman, Stéfan J van der Walt, et al. 2020. "Array Programming with NumPy." *Nature* 585 (7825): 357–62. https://doi.org/10.1038/s41586-020-2649-2.

Haya, Barbara. 2009. "Measuring Emissions Against an Alternative Future: Fundamental Flaws in the Structure of the Kyoto Protocol's Clean Development Mechanism." *University of California, Berkeley Energy and Resources Group Working Paper No. ERG09-001*, ahead of print. https://doi.org/10.2139/ssrn.1562065.

Haya, Barbara, Danny Cullenward, Aaron L. Strong, et al. 2020. "Managing Uncertainty in Carbon Offsets: Insights from California's Standardized Approach." *Climate Policy* 20 (9): 1112–26. https://doi.org/10.1080/14693062.2020.1781035.

Haya, Barbara, and Payal Parekh. 2011. "Hydropower in the CDM: Examining Additionality and Criteria for Sustainability." *SSRN Electronic Journal*, ahead of print. https://doi.org/10.2139/ssrn.2120862.

Hunter, John D. 2007. "Matplotlib: A 2D Graphics Environment." *Computing in Science & Engineering* 9 (3): 90–95. https://doi.org/10.1109/MCSE.2007.55.

International Energy Association. 2024. *Global Methane Tracker*. https://iea.blob.core.windows.net/assets/d42fc095-f706-422a-9008-6b9e4e1ee616/GlobalMethaneTracker_Documentation.pdf.

Kluyver, Thomas, Benjamin Ragan-Kelley, Fernando Pérez, et al. 2016. "Jupyter Notebooks – a Publishing Format for Reproducible Computational Workflows." In *Positioning and Power in Academic Publishing: Players, Agents and Agendas*, edited by F. Loizides and B. Schmidt. IOS Press. https://doi.org/10.

3233/978-1-61499-649-1-87.

Koberstein, Paul, and Jessica Applegate. 2021. "Carbon Conundrum." *Earth Island Journal*. https://www.earthisland.org/journal/index.php/magazine/entry/carbon-conundrum.

Macintosh, Andrew, Don Butler, Pablo Larraondo, et al. 2024. "Australian Human-Induced Native Forest Regeneration Carbon Offset Projects Have Limited Impact on Changes in Woody Vegetation Cover and Carbon Removals." *Communications Earth & Environment* 5 (1): 149. https://doi.org/10.1038/s43247-024-01313-x.

McKinney, Wes. 2010. "Data Structures for Statistical Computing in Python." In *Proceedings of the 9th Python in Science Conference*, edited by Stéfan van der Walt and Jarrod Millman. https://doi.org/10.25080/Majora-92bf1922-00a .

Michaelowa, Axel. 2009. "Interpreting the Additionality of CDM Projects: Changes in Additionality Definitions and Regulatory Practices over Time." In *Legal Aspects of Carbon Trading*, 1st ed., edited by David Freestone and Charlotte Streck. Oxford University PressOxford. https://doi.org/10.1093/acprof:oso/9780199565931.003.0012.

NDRC. 2021. *Compilation of National Product Cost and Benefits*. https://www.zgtjnj.org/navibooklist-n3022010404-1.html.

NumPy-Financial Developers. 2019. *NumPy-Financial*. https://github.com/numpy/numpy-financial.

Pandas Development Team. 2020. *Pandas-Dev/Pandas: Pandas*. Zenodo. https://doi.org/10.5281/zenodo.3509134.

Pint Developers. 2024. *Pint*. https://github.com/hgrecco/pint.

Qi, Fei, Hao Li, Xuedong Zhao, Jinjun Huang, and Zhengxiang Shi. 2023. "Investigation on Minimum Ventilation, Heating, and Energy Consumption of Pig Buildings in China During Winter." *Agriculture* 13 (2): 319. https://doi.org/10.3390/agriculture13020319.

Ritchie, Hannah, Pablo Rosado, and Max Roser. 2019. "Meat and Dairy Production." *Our World in Data*. https://ourworldindata.org/meat-production.

Schneider, Lambert Richard. 2011. "Perverse Incentives Under the CDM: An Evaluation of HFC-23 Destruction Projects." *Climate Policy* 11 (2): 851–64. https://doi.org/10.3763/cpol.2010.0096.

Song, Lisa, and James Temple. 2021. "A Nonprofit Promised to Preserve Wildlife. Then It Made Millions Claiming It Could Cut Down Trees." *ProPublica*. https://www.propublica.org/article/a-nonprofit-promised-to-preserve-wildlife-then-it-made-millions-claiming-it-could-cut-down-trees.

Szopa, Sophie, Vaishali Naik, Bhupesh Adhikary, et al. 2021. "Short-Lived Climate Forcers (Chapter 6)." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157896.008.

UNFCCC. 2013. *GHG Emission Reductions from Manure Management Systems, Version 8*. https://cdm.unfccc.int/methodologies/DB/99QRTE6N5QJEBOV2XP374B25SSIXBB.

UNFCCC. 2017. *Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality, Version 7*. https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf.

van Kooten, Gerrit Cornelis, Timothy N. Bogle, and Frans P. de Vries. 2015. "Forest Carbon Offsets Revisited: Shedding Light on Darkwoods." *Forest Science* 61 (2): 370–80. https://doi.org/10.5849/forsci.13-183.

Wara, Michael. 2007. "Measuring the Clean Development Mechanism's Performance and Potential." *UCLA Law Review* 55: 1759. https://www.uclalawreview.org/measuring-the-clean-development-mechanisms-performance-and-potential/.