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Aligning science and practice to strengthen carbon accounting

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Results-based climate finance mobilizes private capital to public goods by paying for verified climate outcomes,[1] yet reports of large gaps between credited and independently estimated impacts have chilled confidence.[2–9] We introduce a framework that separates discrepancies into two sources: (i) implementation, what projects do and how outcomes are measured, under developer control and (ii) the state of the science, the parameters that translate observations to emissions reductions and evolve with evidence. Applied to clean cooking, the framework shows that claims of sectorwide overcrediting are largely explained by downward revisions to science parameters after reporting, not pervasive malfeasance. Projects that directly measure household fuel use best align with independent estimates; default-based protocols report several-fold larger savings. We show how future protocols will narrow remaining gaps. The approach generalizes across sectors in the voluntary carbon market. Projects and protocols that align implementation with science better reflect atmospheric outcomes and sustain finance.

Results-based climate finance is a multi-billion-dollar instrument shaping climate policy and investment.[10–13] By tying payment to verified emissions reductions or sequestration, it mobilizes private capital—often faster than public funds—across renewable energy, forest protection, and household energy projects.[12,14] It is embedded in international strategies, especially in low-income settings where projects would otherwise go unfunded. Recent evaluations report large gaps between credited and independently estimated reductions, raising doubts about whether these systems deliver real mitigation.[2–6] The design objective is clear: design accurate accounting so the mechanism consistently finances additional mitigation that lacks alternative funding.

Improved cookstoves are a focal case. A recent analysis (Gill-Wiehl, Kammen, and Haya, 2024; hereafter GKH) estimated that issuance exceeded actual reductions by ninefold.[6]

Prices and demand fell, and the Integrity Council for the Voluntary Carbon Market (ICVCM) found that most existing methodologies did not meet quality standards.[18] New approaches, such as the Clean Cooking and Climate Consortium's CLEAR methodology, tighten monitoring and defaults. Yet without attributing gaps to project practice versus scientific parameters, reforms risk over-correcting where delivery is sound and under-correcting where it is not.

This surfaces a broader challenge: audits and methodologies often blur two distinct sources of error. One concerns delivery and measurement—what projects actually do and how outcomes are observed—where corrective action is possible. The other concerns the state of the science—the parameters that translate those observations (e.g., fuel use) into CO2e—which should evolve as evidence improves. Mixing these obscures which fixes matter and slows effective reform.

We develop a diagnostic to attribute and quantify discrepancies across these dimensions. In clean-cooking projects, those that directly measure household fuel use closely match independent estimates, whereas default-based protocols report severalfold higher savings. Updating shared science parameters explains much of the reported over-crediting and narrows residual variation under conservative defaults. This approach reframes a question of credibility as one of calibration—aligning crediting with empirical reality while preserving a mechanism that directs capital to otherwise unfunded mitigation. The same reasoning extends to other mitigation sectors like forests, renewables, and methane capture.

Cookstoves offer a difficult and consequential test for carbon crediting because outcomes depend on human behavior as much as on technology, and field-verified data are limited. Reliable accounting will determine whether results-based finance can mobilize private capital toward verifiable mitigation in the world's most resource-constrained regions.[19]

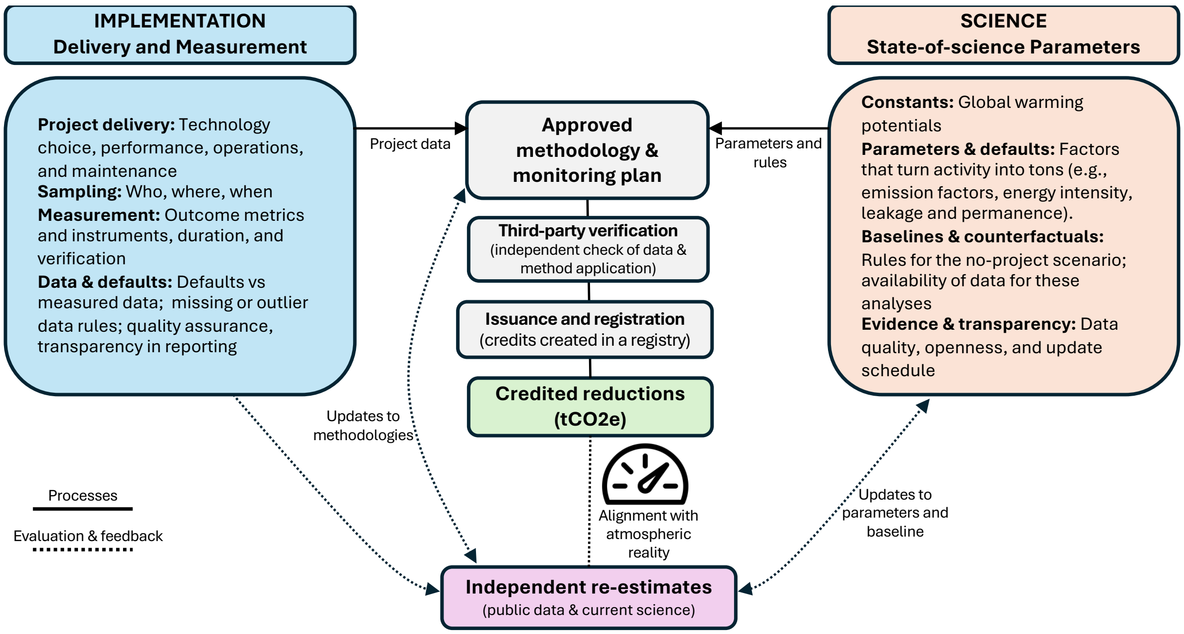
Independent verification in carbon offsets: the cookstove challenge

Carbon offset projects promise measurable, verifiable climate benefits, with one credit representing one metric ton of CO2-equivalent avoided or removed. Projects span from forest protection to landfill methane capture, each built on a chain of measurements and engineering relationships.[12] In principle, crediting is straightforward: establish a baseline, measure the intervention's impact, and claim the difference. In practice, it runs through protocols that specify data, defaults, and sampling. Figure 1a illustrates how project measurements and shared scientific parameters flow into these steps and the standards used to calculate credits. Accredited third-party auditors validate compliance with methods set by carbon standards (e.g., Gold Standard, Verra), yet fully compliant projects can still over- or under-credit when method-compliant defaults, measurement protocols, or sampling designs misestimate baselines, usage, leakage, or decay. Across sectors, integrity rests on five elements: additionality, no double counting, permanence, leakage, and accurate quantification.[20]

Independent evaluations assess these elements with outside data and explicit counterfactuals.[2,21] Figure 1b outlines the crediting workflow, common threats to accuracy, and the principal data sources by sector. In avoided deforestation, high-frequency satellite imagery allows evaluators to reconstruct quasi-experimental controls to compare forest loss inside and outside project areas.[4,5] In improved forest management, plot-level inventories of stocks and growth are used to test project baselines and permanence.[22,23] For industrial gas analyses, independent studies reconstruct plant-level logs from regulatory and market data to probe incentives in crediting formulas and confirm reported destruction and uptime against independent records.[24] Renewable energy analyses use policy archives and market statistics to test additionality against non-project trends.[3] In these sectors, external data largely mirror what developers can access, making verification relatively direct.

Cookstove projects differ. Household stove use cannot be observed from satellites, plant logs, or grid meters, so credits cannot be cross-checked with the same external records. Independent evaluations of carbon-financed cookstove projects are rare (three peer-reviewed studies).[25–27] In their absence, buyers and reviewers rely on the broader academic literature to set expectations for adoption, use, and fuel savings. Those studies are informative but not equivalent to project monitoring: they follow different protocols, target different households, and estimate different quantities. Projects optimize to deliver under crediting rules: they target households likely to adopt (often with higher baseline fuel use), invest in follow-up and repairs, and manage for performance targets. Academic studies optimize for inference: they prioritize clean identification, limit researcher influence, and sample to learn about specific behaviors. Substituting one for the other leads to poor comparisons.

A



B

Sector	How credits are calculated	Threats to accurate crediting	Public data to re-analyze crediting	Data–project match	Share of issued credits (2020-2024)
Renewable Energy (grid wind, solar, hydropower)	Electricity generated × grid emission factor	I: Additionality S: Grid emission factors I/S: Counterfactual dispatch	Public planning/policy docs to assess the no-project case, and auditable plant and grid records.	●● (grid data is public; project finance details often private)	47%
Forestry & Land Use (REDD+, ARR, improved forest management)	Expected land-use emissions without the project minus what happened, then adjust for leakage and later losses.	I: Quality of land cover change data S: Baseline (loss rate) I/S: Leakage (pressures moved elsewhere) and reversals	Time-series satellite images, fire/storm maps, clear project boundaries, and auditable forest measurements.	●● (baselines often ●●●; leakage, permanence ●●)	31%
Household Energy (stoves)	Fuel/energy saved × emission factor × share of non-renewable biomass	I: Real stove use S: non-renewability of biomass; fuel-charcoal yields; in-field stove performance	Academic studies from non-crediting projects; regional non-renewability of biomass data; spotty data on wood-charcoal yields	●	10%
Chemical / Industrial Gases (HFC-23, N_2O, process)	Amount destroyed × climate impact per unit, minus any baseline allowance.	I: Destruction performance I/S: Baseline and incentives (do rules create more waste-gas production); downtime and maintenance rules	Plant records and regulator audits, run-time and destruction test results, and simple production/throughput data.	●●● (where logs exist)	7%
Energy Efficiency & Fuel Switching (industry/buildings)	[Energy use before − after] × emissions factor	I: Measurement and verification of use S: Additionality; rebound; grid emission factors	Meter/utility readings before and after, simple records of what was installed and when, and current grid/fuel emissions rates.	●● (limited by private measurement and verification)	4%
Waste Disposal (landfill and wastewater methane)	Modeled methane produced × share captured and burned − methane oxidized	I: Uptime and capture S: Choice of methane generation models and oxidation	Gas flow and methane-percent readings, flare/engine runtime logs, records of waste received and its composition, and published parameter ranges/local studies	●● (often ●●● in US)	2%

I = Implementation, S = State-of-science parameters
ARR = Afforestation, reforestation, and regeneration
Match = how closely public, independent data align with project monitoring today (usable to re-compute). ●●● High ●● Medium ● Low

Figure 1. Separating implementation from science clarifies crediting and threats to accurate crediting from projects in the voluntary market. (A) Verified carbon credits are

based on an approved methodology that combines implementation data (what was built, done, or measured) with science-based parameters (how those activities translate into tons of CO2-equivalent). Implementation risks include poor metering, non-representative sampling, or reporting gaps. Even fully compliant projects can misstate outcomes if baselines and counterfactuals, emission factors, or permanence/leakage rules diverge from reality, or if field measurement or sampling is weak. Independent re-estimates use public datasets and today's science to recalculate outcomes; their work guides revisions to monitoring rules and parameters. (B) Major credit categories differ in how credits are computed, where claims are most sensitive, and how well public data can support re-analysis.[3,4,6,24,28–30] For example, renewable energy credits hinge on assumptions about grid emissions and what generation was displaced, while forestry credits depend heavily on baseline setting, leakage, and permanence assumptions. Public data such as satellite imagery, grid records, or plant logs offer varying degrees of reanalysis potential. The final column shows each category's share of issued credits from 2020–2024.[31]

How on the ground cookstove projects turn into avoided emissions

Clean cooking projects aim to replace smoky, inefficient stoves with cleaner technologies. Most operate in sub-Saharan Africa, South Asia, and Latin America, where solid fuel use remains common; roughly 2% of global CO2e from household biomass combustion.[32–37] Traditional cooking practices also drive large health burdens, and despite progress, projections suggest that one-third of the global population will continue to lack access to modern cooking fuels (gas and electricity) by 2030.[38–42] Intermittent use of project stoves can blunt anticipated health, air-quality, environmental, and climate gains.[43–45] Affordability, fuel access, device quality, and user preferences shape sustained use,[46–48] complicating verification.

Crediting converts observed changes in cooking practices to avoided CO2e through two parameter classes. Implementation parameters reflect project decisions: which households are targeted, the technology delivered, and how use is tracked. Projects also choose how to monitor outcomes: whom to sample and when, whether stove use is tracked using surveys or sensors, and how fuel consumption is measured. Within compliant protocols, choices about sampling, attrition handling, and analysis can move credited outcomes. Together, these elements quantify per-household fuel savings and the intensity and duration of use (stove-days) that drive credits.

State-of-science parameters then convert fuel savings into CO2e using emission factors, the fraction of non-renewable biomass (fNRB), charcoal conversion ratios, and greenhouse-gas global warming potentials (GWPs). Some parameters straddle the line: the true fNRB in a project region is scientific, but the choice among spatial layers, defaults, and update frequency is an implementation choice. Maintaining this separation clarifies accountability, isolates near-term operational remedies, and indicates when sector-wide parameter updates are appropriate.

Definition-consistent evidence for cookstove crediting

Estimates of the gap between credited and realized emissions reductions depend on both measurement and definitions. In clean cooking, the key implementation metrics are stove adoption, usage, and stacking. GKH define *adoption* as the share of distributed stoves still actively used, *usage* as the share of meals cooked on the project stove, and *stacking* as the share of meals cooked using both traditional and project stoves together. Adoption and usage increase credited savings; stacking reduces them. GKH contend that projects systematically misreport these behaviors.

In the literature, these terms are not standardized. “Adoption” may mean any use within a week or being the primary stove; timing matters because equipment fails and substitutes exist.

Stacking is defined at meal, day, or household scales. This heterogeneity requires evaluators to choose clear definitions and then use evidence consistent with those definitions.

GKH use the academic literature to benchmark adoption, usage, and stacking , assuming well-measured projects should converge to published values. Treating project reports and research studies as directly comparable places substantial weight on literature selection and definitions. Given a heterogeneous evidence base, transparent search and inclusion rules are essential; GKH do not report a search strategy or inclusion criteria.

For adoption, GKH assemble nine studies; only five match their own definition (Fig 2a; Table S1). Several measure purchase rather than use, others come from purposive low-uptake samples, and some values are untraceable. For example, Ruiz-Mercado et al. (2011)[49] are cited by GKH at 50% adoption, though the study reports 90–95% active use and 50% continued use of traditional stoves. Burwen and Levine (2012)[50] are cited at 49% adoption; excluding cases where usage could not be ascertained, adoption is 65%. In four of the five definitionally compliant studies, GKH select the lowest plausible estimate.

For usage and stacking, definitional mismatch is greater. Only one of nine usage citations measures the share of meals on the project stove; several reuse adoption values, and others are untraceable (Fig 2b; Table S2). None of the 24 stacking estimates capture simultaneous meal-level use; most record whether a household reports to use both stoves at any time (Fig 2c; Table S3).

To construct a more representative benchmark, we screened more than 150 peer-reviewed studies identified from six systematic reviews[47,51–55], database searches, and citation chaining (Methods). We retained field studies with quantitative measures of adoption, usage, or stacking and excluded purely qualitative work, acquisition-only outcomes, and metrics not consistent with our (and GKH's) definitions. This yielded 60 adoption and 20 usage estimates (Tables S4, S5). No study reported the percentage of meals with simultaneous use of both stoves (GKH's stacking definition), but meal-share or cooking-minutes usage metrics implicitly capture most overlapping use.

Meta-analytic benchmarks for adoption, usage, and stacking

We fit a random-effects meta-analysis (REMA) to the 60 adoption observations, using logit transformation and inverse-variance weights. Back-transforming, the fitted distribution yields a mean adoption of 0.75 and a median of 0.80 (IQR 0.63–0.91) (Fig 2a-c), well above GKH's 0.55 from nine studies. For usage, the one study that matches GKH's rules reports 0.70 (vs. their 0.52). Extending the REMA to our 20 usage estimates yields a median of 0.55 (IQR

0.37–0.71), with a broader distribution than GKH’s. To bound any residual within-meal co-use not captured by meal-share metrics, we apply a 0–5% stacking discount.

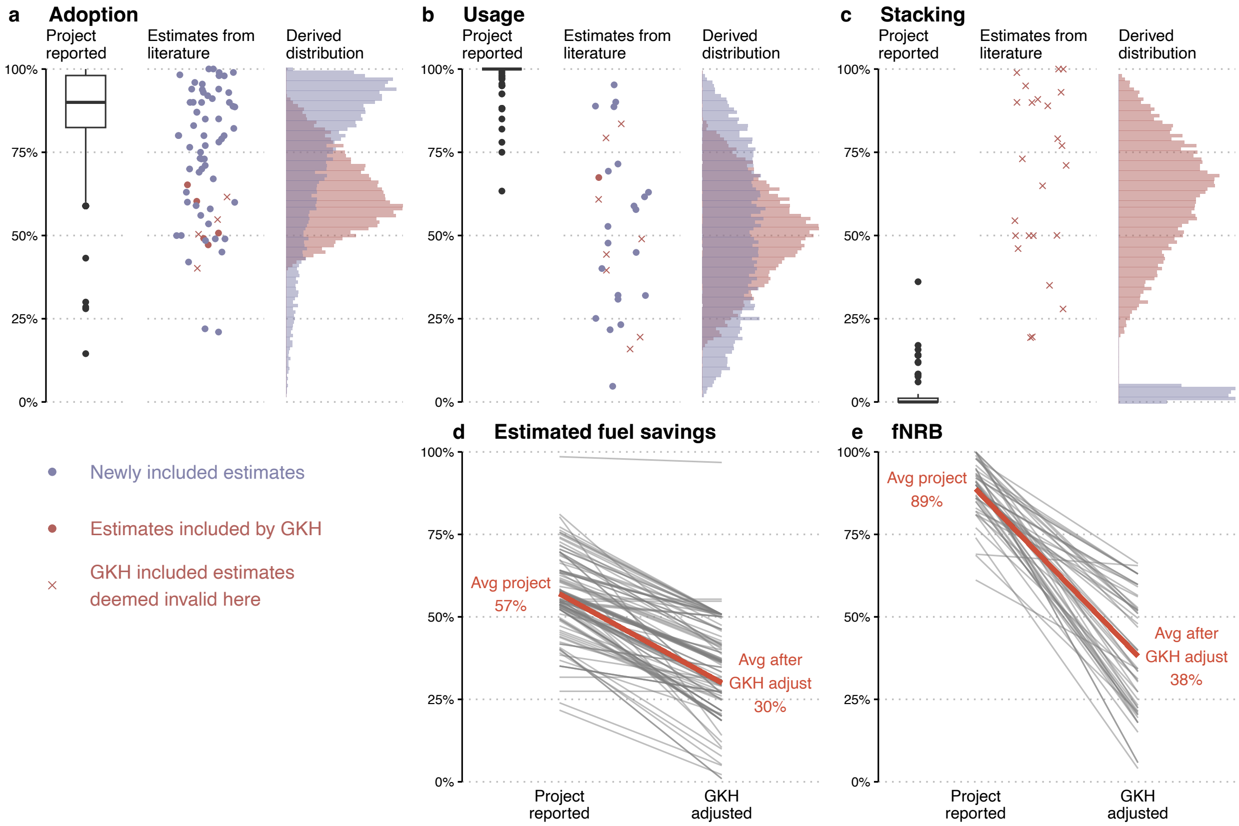


Figure 2. Widely used cookstove parameters in evaluations of the sector are biased low and poorly supported by evidence and post hoc state-of-science references reduce credits. Commonly used parameter estimates for independent estimates of commercial cookstove project adoption, usage, and stacking are drawn from studies that are inappropriate and lead to systematic underestimation of stove uptake. Boxplots represent project-reported values across 151 protocols from 51 projects. Points indicate individual study estimates for adoption (n=9), usage (n=9), and stacking (n=24). For the GKH distribution, estimates were used to generate 10,000 bootstrapped estimates from a triangle distribution (where mode was taken as the average of the estimates). For the distribution of estimates for this study, we generate 10,000 simulations from the fitted random-effects distributions to summarize central tendencies and dispersion. Because stacking had no appropriate estimates, we apply a uniform distribution between 0% and 5% to allow for some discounting from under-reported joint fuel use during individual meals not already captured by usage estimates. (d) shows shifts in reported fuel savings for projects that do not switch fuels comparing project-reported values with those after application of GKH's universal 2–4 MJ/person/day bound (grey lines) and the sample-wide average (red line). (e) shows analogous adjustments for the fraction of non-renewable biomass

(fNRB) using updated spatial models and illustrate their influence on average credited emissions reductions across the project sample.

Fuel-use measurement and adjustment

Adoption and usage affect emissions only through how much less fuel each household burns. Fuel use is estimated by: (i) efficiency-based models using laboratory tests; (ii) direct, in-home measurement (KPTs or sensors); and (iii) back-calculation that infers baseline from project-period use assuming constant cooking services. Each produces natural-unit consumption (e.g., kg wood day^{-1}) for the same households, yielding baseline, project, and the difference that determines credited CO2e.

To address noisy or implausible values, GKH impose a universal 2–4 MJ $person^{-1}$ day^{-1} bound on both baseline and project use. While intended to manage outliers, a single band risks masking real heterogeneity: diet and simmer time, fuel type and moisture, climate, household size, and season all shift energy demand; reported values frequently lie outside this band.[56–58]

Applied to the 51-project sample, the constraint pushes most baselines down and project use up: 46 projects are adjusted; baselines fall in 28 and project use rises in 19 (Table S6), cutting implied savings nearly in half—from 57% to 30% on average (excluding fuel-switchers) (Fig. 2d).

Bounding baseline and project consumption independently ignores that both measurements come from the same households and instruments. When errors are shared, clamping each value independently biases the observed savings ratio. We therefore adopt a ratio-preserving approach: bound one period within 2–4 MJ $person^{-1}$ day^{-1} and infer the other from the measured percent reduction (Methods). For example, baseline from 6 to 3 MJ $person^{-1}$ day^{-1} (50%) becomes from 4 to 2, not from 4 to 3 (25%). Likewise, baseline from 3 to 1.5 (50%) becomes from 4 to 2, not from 3 to 2 (33%). If both periods require adjustment, we clamp baseline and project in turn, preserve the ratio in each case, and take the more conservative result. Current methodologies do not require these checks; all projects reported fuel use with accepted tools.

State-of-science parameters: why updates matter for crediting

Some inputs to crediting are scientific rather than implementation choices. They describe physical conditions in a place and time and should be revised as evidence improves. The fraction of non-renewable biomass (fNRB) is one such input: it converts avoided firewood use into CO2e. Early practice often used national defaults of 80–90%.[59] With improved spatial datasets and models, many regions now exhibit markedly lower fNRB—at times one-third of earlier estimates and in some areas below 10%—reducing creditable savings.[60,61] In GKH, substituting newer values was the single largest driver of overcrediting (Fig 2e). Modern methodologies increasingly favor region-specific, model-based values with a conservative 30% default where local evidence is lacking.[18]

Charcoal yields tell a similar story. The wood-to-charcoal conversion ratio (mass of wood required per unit charcoal) varies by kiln design, feedstock, and handling; field measurements span from 3:1 to more than 10:1.[62,63] Earlier methodologies routinely defaulted to 6:1, which could bias credits up or down. Newer approaches either apply upstream emission factors per kilogram of charcoal, implicitly capturing kiln and handling losses, or require region- and technology-specific yields, with a conservative 4:1 default when data are absent.

This evolution is not unique to cookstoves. In avoided deforestation, standards have shifted from project-history baselines to jurisdictional, risk-based baselines using shared, high-resolution satellite data. Methane and N2O accounting likewise adopt the latest IPCC global warming potentials and updated waste-sector parameters.[64–66] These changes can open gaps between historical project reports and contemporary re-estimates even when nothing changed on the ground—a signal of science moving forward, not misconduct. Updating science inputs improves accounting fidelity and brings credited outcomes closer to the atmospheric ledger that ultimately determines warming.

Evaluating cookstove carbon crediting

We reanalyze the 51 cookstove projects examined by Gill, Wiehl, and Kammen (GKH), who reported that credited emissions reductions exceeded independent estimates by roughly ninefold. We read that figure as a historical snapshot—one sample, one moment, one set of definitions—rather than a claim about the sector. Using the same cross-section, we ask: (i) does the headline replicate under the original rules? and (ii) conditional on replication, how much of the gap reflects choices projects control versus parameters that science has since updated?

Using GKH’s assumptions reproduces their result (9.24×; Fig. 3a,b). A minor coding correction has negligible effect (Methods). We then decompose the gap. Implementing definition-consistent priors for adoption, usage, and stacking, ratio-preserving fuel bounds, and current methodological rules reduces the mean discrepancy between project values and our estimates to 4.5×, driven by our updated literature synthesis and the removal of post-hoc energy bounds.

Variation across projects is large. The median project lies ~2.5× above our benchmark; several are indistinguishable from parity, and a few exceed 50× (Fig. 3c). Where household fuel use is measured (in-home weighing or metering), project reporting approximates our estimates; where protocols permit defaults, estimates tend to sit several-fold higher.

Method and fuel interact. Modern fuels are easier to meter—electricity via smart sensors, LPG via cylinder refills, pellets via hopper/bag counts—whereas firewood and charcoal are harder to quantify given ad-hoc collection, weighing challenges, and variable properties. To avoid conflating technology with measurement, we emphasize within-fuel contrasts and estimate protocol effects conditional on fuel (Fig 3d). Charcoal under tighter, measurement-forward rules tighten toward 2–3×, while charcoal credited from defaults remains 5–6×; firewood shows a similar split. Metered pellet projects are near 1×; LPG displays wider dispersion that traces largely to method choice rather than the fuel itself. Across these comparisons, how outcomes are measured matters more for alignment than stove technology.

Portfolio composition underlies the historical picture. In this sample, charcoal (75%) and firewood (19%) dominate issued credits, predominantly via legacy default-based pathways—the farthest from our estimates. The smaller number of metered projects demonstrates that, with consistent definitions and observed fuel use, discrepancies narrow and reported outcomes align with independent estimates.

Prospectively, alignment should improve under current rules. To isolate the contribution of evolving science, we apply identical science inputs to both sides. Under ICVCM guidance, projects must use a 30% default fNRB or an approved spatial model; imposing fNRB = 0.30 symmetrically on the historical sample reduces credited volumes and lowers the mean discrepancy to 2.1×. From 9.24× to 2.1×, approximately two-thirds of the decline is attributable to state-of-science updates; the residual gap reflects implementation—delivery and measurement. As certification migrates to newer methodologies, both dispersion and remaining misalignment are expected to decline.

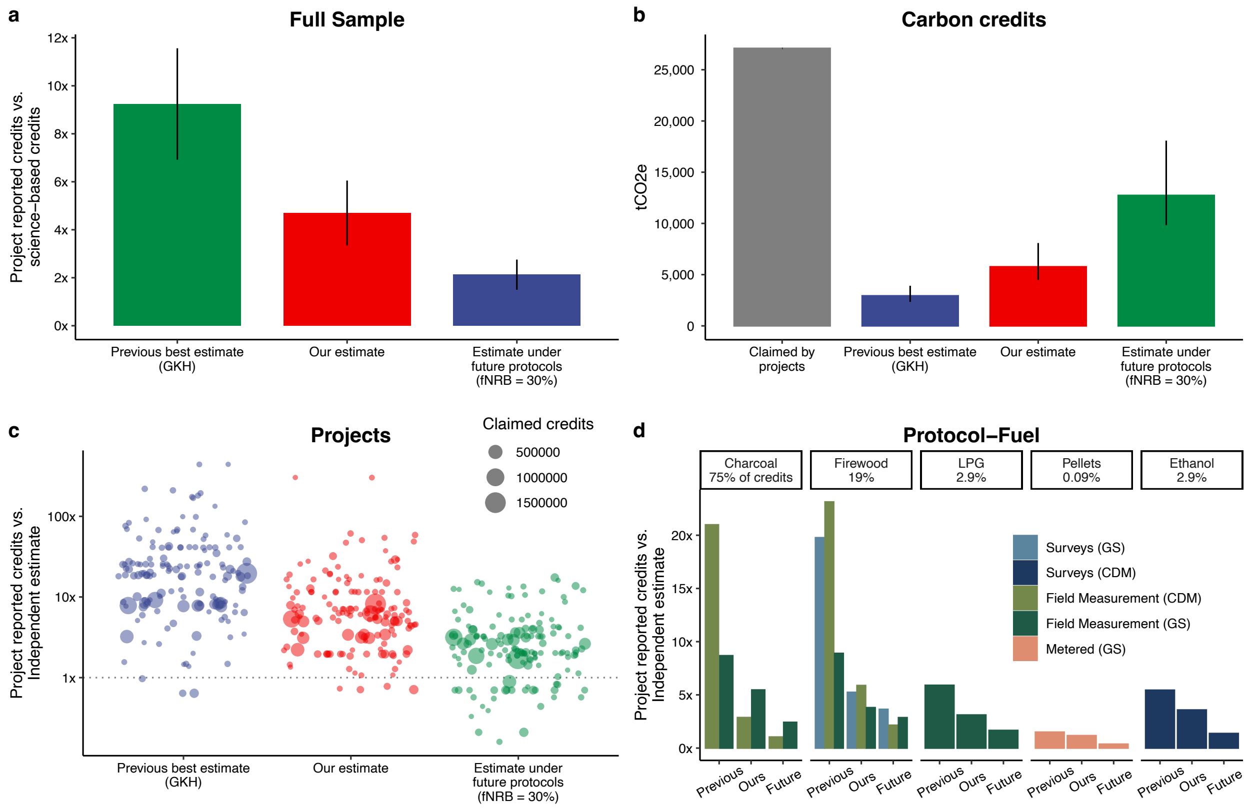


Fig 3. Alignment of cookstove project claimed credits with independent estimates: sector average, volumes, project dispersion, and protocol-fuel effects. (a) Sample-wide ratio of project-reported to independently estimated credits under three setups: prior best estimate (GKH), our implementation-focused estimate, and an ICVCM-aligned scenario fixing fNRB at 0.30 ("future"). Bars show means; whiskers show 95% CIs. (b) Aggregate tCO2e for the same sample: credits claimed by projects, and totals implied by the GKH, our, and future scenarios. (c) Project-level ratios (y-axis, log scale) under the three scenarios; point size scales with a project's claimed credits. The dotted line denotes parity (1×). (d) Ratios by protocol–fuel category, highlighting method effects conditional on fuel. Headers indicate the credit share by fuel in this sample. Colors distinguish measurement approaches (surveys/defaults vs field measurement vs metered) and standard (GS/CDM). Across panels, metered or field-measured projects cluster near parity, while default-permissive pathways remain several-fold high; updating fNRB further narrows gaps.

Conclusion

Carbon crediting rests on two inputs. Implementation covers what projects do and how outcomes are observed. State-of-science parameters convert those observations into CO2e using physical, ecological, and chemical relationships. When these are conflated, we cannot tell whether gaps arise from delivery and measurement or from updated science—problems that demand different fixes.

Cookstove projects show why these distinctions matter. The canonical integrity tests apply across sectors, but weak points vary; here, they center on behaviors that are hard to observe at scale. Our reanalysis indicates that historical discrepancies trace largely to measurement choices and restrictive priors. Projects that measure household fuel use align with independent benchmarks; projects that rely on defaults do not. Updating science inputs, especially the fraction of non-renewable biomass, closes much of the remaining distance.

Analogues from other domains show how to treat scientific updates. In the Global Burden of Disease, estimates of air-pollution mortality for the same year changed as methods and data improved; for 2010 the series spans 6.8 million, 5.5 million, 6.4 million, 6.7 million, and 7.8 million across successive releases. We do not read this as a failure of integrity or the enterprise, but as science evolving. Crediting should work the same way: audit implementation in real time, update shared parameters on a schedule, and avoid retroactive penalties for good-faith delivery.

We add clarity to a growing scholarship scrutinizing carbon crediting[8,23,67–75] by making project–academic comparisons explicit, aligning definitions, broadening the admissible evidence base, and tracing discrepancies to their sources. Recent controversies have kept attention on cookstoves,[18,76] yet two fundamentals remain: real mitigation requires stoves that people want, can afford, and will use in ways that displace polluting fuels;[47,77–79] and among common voluntary carbon market strategies, clean cooking is unusually proximate to human welfare.

Evidence remains the binding constraint. Household energy lacks the large secondary datasets that enable routine independent checks in other sectors. One exception is a recent randomized trial in Kenya[25] that found fuel savings broadly consistent with engineering estimates and reported credits. More prospective evaluation of commercial deployments would sharpen priors and narrow uncertainty; until then, claims about a single sector-wide inflation factor should be tempered by limited ground truth and heterogeneous delivery.

Our work has several practical implications. To better align science and practice, the two should use shared, definition-consistent benchmarks; protocols should require transparent monitoring; scientific inputs should update on a schedule; and safeguards should manage project-side risks without retroactively penalizing good-faith work. Across the system, open data and regular science updates should be treated as progress, not instability.

Results-based climate finance functions when accounting keeps pace with evidence. Systems that measure real behavior, apply the best available science, and update transparently can sustain trust and direct capital to verifiable climate and health gains. Because this mechanism channels capital where other finance is scarce, preserving it while improving accuracy is essential.

Methods

Our aim was to quantify the extent to which differences between credited and actual emissions reductions arise from implementation-linked parameters (e.g., adoption, usage, fuel consumption) versus state-of-science physical parameters (e.g., fraction of non-renewable biomass, emission factors). To do so, we replicated and extended the analysis of Gill-Wiehl, Kammen, and Haya (2024; hereafter GKH), who evaluated the accuracy of emissions reductions claimed by improved cookstove projects issuing voluntary carbon credits. Doing so was supported by replication data and code (https://github.com/agillwiehl/GillWiehl_et_al_Pervasive_over_crediting). GKH's core method involves comparing reported project inputs to benchmark values drawn from academic literature and simulating counterfactual emissions reductions under those benchmarks. We make three modifications to their approach: (1) data corrections and implementation refinements; (2) redefinition and reconstruction of benchmark parameter distributions based on updated empirical evidence; and (3) sensitivity tests of modeling assumptions.

Project Sample and Replication

We used the same dataset of 51 improved cookstove carbon crediting projects analyzed in GKH, covering both firewood, charcoal, and ethanol stove interventions under four common offset methodologies across 15 countries. Project-level data were derived from project design documents and compiled by reporting period, and included values for project size in stove-days, reported stove adoption, usage, and stacking, baseline and project fuel consumption, emission factors, non-renewable biomass fractions (fNRB), firewood-to-charcoal conversion factors, and verified credits issued during that period and in the project's entire lifetime. All project inputs and results were aggregated from public registries.

GKH simulate 10,000 realizations of emissions reductions for each project-year, drawing from parameter distributions for stove adoption, usage, stacking, fuel consumption, stove efficiency, rebound effects, fNRB (fraction of non-renewable biomass), and fuel-switching assumptions. These simulated reductions are then compared to project-reported emissions reductions to calculate an overcrediting ratio. Ratios are weighted by stove-days (number of stoves x days in use) and scaled by verified credits to produce project-level and sector-wide estimates. Specifically, average sector-wide and project-specific over- or under-crediting across the 10,000 estimates is calculated in the following a set of equations:

$$R_i^a = VERs_i^{academic} / VERs^{project\text{-}period}$$

$$R_{avg}^{a} = \sum R_i^{a} / \text{length}(i)$$

$$R_{pp}^{overcredit} = R_{avg}^{a} * \text{Project-Stove-Days}_{pp}$$

$$R_p^{weighted\_overcredit} = \sum R_p^{overcredit} / \sum \text{Project-Stove-Days}_p$$

$$\text{Credits}_p^{estimated} = \text{Credits}_p^{reported} / R_p^{weighted\_overcredit}$$

$$R_{total} = \sum \text{Credits}_p^{estimated} / \sum \text{Credits}_p^{reported}$$

where R_i^a is the ratio of verified estimated reductions (VERs) for protocol *a* for bootstrapped run *i* using academic studies ($VERs_i^{academic}$) to VERs from the project ($VERs^{project\text{-}period}$). R_{avg}^a represents the average ratio for all bootstrapped runs for protocol *a*. R_{avg}^a is multiplied by the total number of project stove days (the product of households receiving a stove and the number of days in the monitoring period) to yield $R_{pp}^{overcredit}$ – a way of weighting the project period contribution to overcrediting. Because some cookstove carbon projects have multiple protocols (project periods), these are summarized using a weighted average of contributed project stove days, yielding $R_p^{weighted\_overcredit}$. For each project (n=51 in GKH's analysis), GKH identify the total number of credits that have ever been verified, including some that are not directly evaluated in the project period protocols ($\text{Credits}_p^{reported}$). These are divided by $R_p^{weighted\_overcredit}$ to generate a new estimate of total credits ($\text{Credits}_p^{estimated}$). R_{total} (the total times over- or undercredited) is estimated as ratio of the sum of $\text{Credits}_p^{estimated}$ to the sum of $\text{Credits}_p^{reported}$. R_{total} can either be estimated at both the project or the sector level using the same procedure.

To estimate uncertainty around the total ratio of reported to adjusted credits, GKH computed the aggregate ratio across all included projects by dividing the sum of reported verified credits by the sum of adjusted credits, where adjusted credits were calculated by dividing each project's reported credits by its estimated project-level over-crediting factor. They approximated a 95% confidence interval using the ratio of standard deviations of reported and adjusted credit totals across projects:

$$SE = (SD_{reported} / SD_{adjusted}) \times (1.96 / \sqrt{n}),$$

where n = 51 is the number of projects. The confidence interval was then defined as:

$$95\%\ CI = [\text{Ratio} - SE, \text{Ratio} + SE]$$

To assess whether uncertainty in the aggregate overcrediting ratio is driven more by differences across projects or by within-project parameter uncertainty, we ran a two-stage nonparametric bootstrap. We resampled the 51 projects with replacement 100 times and, for each selected project, drew from its parameter distributions as in GKH. Using the resulting distribution of aggregate ratios, we decomposed variance into between-project and parameter components. Parameter uncertainty explained >90% of total variance, indicating that project resampling contributes little. Accordingly, GKH's original method adequately captures uncertainty for our purposes.

Correction of errors. In replicating GKH's code and data, we identified two related implementation errors. First, GKH misattribute credits for project GS3112, recording only 696 credits when Verra records indicate >312,000 credits issued over the 2015–2019 period. It is plausible this cell was erroneously copied from the cell of another project. Second, due to how project-level data are deduplicated, their code drops this record from the numerator (reported credits) but retains it in the denominator (simulated counterfactuals), which biases the overcrediting factor downward. Correcting both raises sector-wide overcrediting from 9.24x to 9.30x.

Project-side parameters

Evaluation of literature-derived adoption, usage, and stacking estimates

We re-examined every adoption, usage, and stacking value cited by GKH. For each paper we recorded the variable actually measured, the recall or monitoring window, the sampling strategy, and the computation used to derive the statistic. Detailed annotations appear in Supplementary Tables 1–3. Four errors recur: (i) substitution of stove purchases for stove use, (ii) reliance on purposively selected low-adoption samples, (iii) extraction of figures that cannot be located in the source text or data, and (iv) arithmetic slips that deflate reported uptake. Where possible we calculated alternative, less pessimistic estimates consistent with the authors' own data.

Additional literature review. To move beyond GKH's narrow evidence base, we assembled a candidate pool by aggregating all references contained in six prior systematic reviews, then supplemented these with targeted database searches and backward citation chaining. Title-and-abstract screening retained 152 peer-reviewed studies published before July 2025 that appeared to offer field data on adoption, usage, or stacking. We then applied four exclusion rules: the study had to (i) report quantitative outcomes, (ii) measure sustained use rather than promotional uptake (or purchase), (iii) identify households longitudinally (i.e., households that had acquired or received an improved stove at some point previously), and (iv) present metrics that could be mapped cleanly onto our operational definitions. This pruning yielded 60 adoption and 20 usage estimates; no study quantified meal-level stacking under the GKH definition. Included studies can be found in Tables S4-S5. All studies reviewed and justifications can be found in the replication archive.

Reviewing studies revealed wide variation in measurement approaches—even when the same terms are used. For instance, “adoption” in one study might indicate any use in the past week, while another counts only exclusive or primary stove use. While widely discussed in the literature, we found that studies providing quantitative estimates of usage and stacking as defined by GKH were limited. Usage was sometimes conflated with adoption or defined into general categories like “weekly,” “frequent,” or “rarely.” Valid estimates were derived from studies that reported data on cooking with the project stove (in minutes or meals) as well as estimates of all cooking. In academic literature, stacking typically meant that a household uses multiple stoves or fuels to meet their energy needs[80], but not necessarily in the same meal as required by GKH’s definition.

Timing further complicates comparisons. Stove use often declines over time due to degradation, breakage, or fuel availability.[49,81–84] But academic studies vary in when they assess usage, from weeks after distribution to several years later. A study that reports high adoption three months post-distribution may be valid, just as one that shows decline five years later may be—but they answer different questions. GKH favor the latter, long-term snapshots, which ultimately yields lower estimates of uptake.

Generating new parameter distributions for adoption, usage, and stacking. Rather than adopt the triangular distributions used by GKH—which weight all studies equally and require specifying upper and lower bounds for the distribution—we pooled estimates using random-effects meta-analysis in the ‘metafor’ package in R. Adoption and usage proportions were logit-transformed, weighted by inverse sampling variance, and combined with restricted maximum likelihood. The fitted distribution thus gives greater influence to larger studies and relaxes the assumption of a common true effect. We drew 10,000 samples from each fitted distribution to propagate uncertainty through subsequent emissions calculations. Because our usage metrics already capture most concurrent stove use, stacking is treated as a residual adjustment. In our main analysis, we apply a conservative uniform discount of 0–5% to reflect potential residual fuel use from secondary stoves.

Alternative treatment of stacking. GKH treat any stacking as fully negating creditable reductions. As a sensitivity analysis, we instead apply a fixed 50% discount in stacking scenarios, reflecting the view that partial displacement would yield half savings.

<u>Fuel consumption adjustments</u>

GKH report adjusting baseline and project-period fuel consumption values to fall within a "reasonable" energy use range (2–4 MJ per capita per day), but do not document the specific adjustment method in code or text. In their analysis, these adjustments were applied independently to baseline and project values. For firewood and charcoal projects that do not switch fuels, we test an alternative approach that scales baseline and project-period fuel use proportionally, preserving the reported percentage reduction (*r*) while constraining both values to plausible energy use ranges. We interpret "unadjusted" fuel consumption as the values used to replicate project self-reported emissions, and "adjusted" consumption as the values used in the overcrediting analysis. Even with both datasets, the intermediate calculation step used by GKH could not be deduced. We define:

$$r = \frac{W_{baseline} - W_{post}}{W_{baseline}}$$

Where W is in kilograms. Post-intervention consumption for a target reduction r was calculated as:

$$W_{post} = W_{baseline} \times (1 - r)$$

Conversely, the baseline required to achieve r from a known W_{post} was:

$$W_{baseline} = \frac{W_{post}}{1 - r}$$

All raw and adjusted project fuel consumption values are reported in Table S7.

<u>Rebound and monitoring reactivity</u>

The rebound effect is a behavioral response to higher efficiency: applied here, it suggests that when the generalized cost of cooking falls, households sometimes cook more (longer simmering, extra dishes, parallel burners), raising total energy use. GKH invoke this concept to justify a blanket 22% discount when KPTs were not used. Whereas GKH apply a uniform correction to emissions reductions, it is more suitable to apply the rebound effect to *fuel consumption*. Therefore, we first compute baseline and post-intervention fuel use across all fuels and convert these to energy units (e.g., MJ). We then apply a 22% rebound by reducing the expected energy savings by 22%, and allocate the adjusted energy use back across fuels proportionally to the original project fuel mix. Finally, we recalculate total emissions using fuel-specific emission factors. This approach preserves the physical meaning of rebound and correctly accounts for fuel switching and variation in emission intensity. When rebound is applied this way, the resulting overcrediting estimate increases to 9.47x.

For protocols that rely on KPTs (e.g. GS-TPDDTEC), GKH apply an ex-post "Hawthorne" discount by randomly drawing a reduction in usage (0–53%) and an increase in stacking (0–29%) from Simons et al. (2017)[86], then applying the combined discount directly to emissions reductions, i.e., per-stove emissions reductions x adoption % x usage % x (1 – stacking %). Under their priors, this implies that, on average, a household would need to overstate fuel savings by one-third to one-half during the KPT monitoring period—despite KPTs directly weighing fuels over multiple days. They justify this on the grounds that observation can inflate project stove use and decrease baseline stove use, i.e., that project implementation of KPTs does not capture typical behavior. Although GKH state they do not adjust GS-Metered, their code applies the same discount there; this has negligible impact because metered projects contribute very few total credits in the sample. In our analysis, we adopt a measured-protocol rule: for GS-TPDDTEC and GS-Metered, we treat usage and stacking as already embedded in the measured fuel and scale baseline and project emissions by adoption only.

State of the science parameters

<u>Fraction of non-renewable biomass (fNRB)</u>

In their main analysis, GKH replaced project-reported fNRB values with regional defaults from Bailis et al. (2015), which combine spatially explicit biomass availability data with demand estimates to quantify the proportion of harvested woody biomass that is non-renewable. While this approach standardizes across projects, it blends project implementation factors (e.g., stove adoption, usage) with ecological context (i.e., the sustainability of local biomass supply), making it difficult to attribute differences in credited versus actual emissions to one or the other.

To isolate the role of implementation-linked parameters, we simulated a scenario in which fNRB was fixed at 30% for all projects. This counterfactual holds ecological context constant, thereby attributing all variation in over- or under-crediting to differences in project performance and monitoring. By comparing this scenario with the Bailis et al. (2015) defaults and project-reported values, we quantify the extent to which state-of-science fNRB estimates drive differences in over-crediting outcomes.

Decomposition of gaps between GKH estimates and updated estimates

We use a Shapley value-based decomposition to attribute the gap between GKH's estimates and our updated estimates to implementation and science factors. Four scenarios are considered: (i) GKH replication ("Baseline"); (ii) Baseline plus only implementation updates (adoption/usage/stacking distributions, ratio-preserving fuel bounds, rebound revision; "Implementation"); (iii) Baseline plus only science updates (fix fNRB at 0.30 for both benchmark and project; "Science"); and (iv) both sets together ("Both").

For each project, we log-transform the reported over-crediting ratio to treat multiplicative changes symmetrically. Shapley-style contributions for the two factors are then calculated as the average of the two possible orderings:

$$\text{implementation contribution} = 0.5 * [(\text{Implementation} - \text{Baseline}) + (\text{Both} - \text{Science})]$$
$$\text{science contribution} = 0.5 * [(\text{Science} - \text{Baseline}) + (\text{Both} - \text{Implementation})]$$

By construction, these contributions sum to the total change (Both − Baseline). Sector aggregates are then formed as credit-weighted averages using each project's verified credits. As a robustness check, we replicate the decomposition in levels (without the log transform) and verify that sector shares remain qualitatively unchanged.

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Data and Code Availability

All data and code used in this project will be made publicly available on Zenodo upon publication.

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Competing interests

Funding for this work was provided by the High Tide Foundation. Two of High Tide's founders/directors also co-founded and serve as directors of Proyecto Mirador, a clean cookstove project in Honduras. Proyecto Mirador appears in the dataset selected by GKH; we gave it no special attention in our methods or interpretation. The funder had no role in study design, data collection, analysis, interpretation, or the decision to submit the manuscript

SUPPLEMENT

Aligning science and practice to strengthen carbon accounting

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Table of contents

1. **Review of GKH's included studies and their appropriateness for providing estimates of adoption, usage, and stacking**

Adoption

Appendix Table 1 reproduces GKH's included studies for defining their stacking range, along with identifiers for reference. Here we review each study.

[A1 Duflo] is a randomized controlled trial conducted over several years in India. GKH identify an adoption rate of 40% after two years. This parameter extracted is inappropriate for defining adoption because of a mismatched study design. The basic design of the study centers not around the effects of an improved cookstove on socioeconomic and health outcomes, but around the effect of a *lottery to have the opportunity to purchase an improved cookstove at a reduced rate*. The authors identify the impacts of this lottery on outcomes, with randomization being used as an instrumental variable for the effectiveness of the improved cookstove. As such, only just over 70 percent of households that won one of the lotteries built a project stove during the first six months of the program. The data provided seek to answer the following research question: Among households in a village offered the opportunity to purchase an improved cookstove at a subsidized rate, how many had such a stove 36 months later as compared to the fraction of households in similar villages that were not offered a stove at the subsidized rate? Here, mismatched study design stems from the fact that not all households that were offered to purchase a stove did so. The 40% adoption parameter is drawn from a regression based proportion of households that were offered the opportunity to build a stove with an improved stove 25 to 30 months after offer.

[A2 Burwen] reports results after 8 months of a randomized controlled trial in Ghana. Adoption is inferred from field observations of households that did initially acquire an improved cookstove. Burwen report results in three categories: broken (not in use), appear in use, and unclear in use. GKH define adoption as the proportion of households that fall into the category "appear in use" out of all sampled households. This is an appropriate study and an appropriate parameter for adoption, though it is perhaps *pessimistic* because an alternative option would be to remove "unclear in use" from the denominator. Doing so would change adoption from 49% to 65%.

[A3 Islam] is a randomized controlled trial conducted over several years in India. GKH identify an adoption rate of 61.9% after two years. We are unable to identify where GKH find this parameter in the referenced article and thus are unable to determine its appropriateness.

[A4 Beltramo] is a randomized controlled trial conducted over several years in Uganda. This is an appropriate study and an appropriate parameter for adoption. Beltramo et al. report the impacts of an improved cookstove on fuel use and pollution. Study enumerators then made unannounced visits three and a half years later, finding that 65% of households had a project stove with obvious signs of use. Beltramo et al. also measure project stove use within the first year of stove acquisition, which are expected to be higher than 65% adoption, though they do not provide clear adoption-related measures as they for their long-term follow up. We believe that GKH make a small math error. The calculation should yield an estimate of 67% adoption (instead of 65%). An alternative option would have been 73% self-reported to still use the Envirofit after 3.5 years.

[A5 Rosa] is a randomized controlled trial conducted among 566 households in Rwanda conducted over five months assessing the combined impacts of a water filter and an improved biomass cookstove on children's respiratory health. This article reports on the impacts on drinking water quality and household air pollution.

GKH report an adoption rate of 47.5% over six months. Rosa et al. report data on cookstove use in several different ways. They report data from 'Evaluator's surveys' – these are surveys collected by the researchers – as well as data from 'Implementer's surveys' - surveys collected by the project implementers. GKH report data from the Evaluator's surveys, which is a fair choice under the assumption that researchers might be more likely to produce least biased estimates (though both surveys yield similar results).

Rosa et al. report data separately among households that were actively cooking while the survey visit occurred from those that were not cooking. GKH report data from those that were not actively cooking, which is a fair choice. Next, Rosa et al. report whether the household reported to have used only the intervention stove (78%), both the intervention and traditional stove (19.3%), or only the traditional stove for their last stove use (2%). They also report whether the intervention stove was reported to have been used in all three of the last follow-up visits (47.5%). It is clear that GKH opt for this last parameter as their measure of adoption.

Plausibly, GKH could have also identified adoption as 98%, where adoption is identified from reporting to have used the intervention stove during their last meal. The implementer's survey is more extensive, and reports that 89.1% of households identified the intervention stove as their primary stove and 93.3% report using it 7 or more times per week. Taken together, we deem GKH's parameter extraction as appropriate and the study design is also appropriate, but the parameter extraction is also *pessimistic*.

[A6 Ruiz-Mercado] is a long term monitoring study of plancha stoves in Mexico. We are unable to identify where GKH identify an adoption rate of 50% after 10 months. The parameter extracted does not appear appropriate, though the study design is appropriate. The authors report that, after 2.6 years, 90% of stoves are still used on a daily basis (section 4.1.1, Figure 3). After three months, 95% of households responded yes to "Are you using the Plancha for cooking?" (Figure 4A).

We identify two plausible data points that led GKH to extract 50% adoption rates. First, the authors report data from an initial sample of 50 households during the initial adoption stage. Second, the authors identify that half of households continued using their traditional stoves in the long term.

[A7 Garcia-Frapolli] reports results on adoption from a different study Pine et al. 2010, but no new primary data are reported. It is not clear why GKH cite Garcia-Frapolli instead of Pine et al. 2010. Here, we discuss Pine et al., who report results from a quantitative longitudinal study of households in Mexico. GKH identify an adoption rate of 60% after two to seven years. In their Figure 2, Pine et al. report that 60% of households used their stove, defined as any reported use of the Patsari at month five, with Figure 3 reporting similar levels of any Patsari use at month 10. Plausibly these data points match GKH's definition of adoption. With that said, Pine et al. also write "Of the 259 households in the sample, 10% or 26 of the 259 did not adopt the Patsari stove at all" and "... some (17%) of the households ultimately rejected the technology by the end of the 10 month follow-up period." We are unable to identify where GKH derive their 2-7 year time frame. There is some lack of clarity as to what Pine et al. refer to when they indicate that 10-17% of households rejected the technology, but that reported usage was closer to 60% of households. GKH report the 60% figure for adoption, though one could imagine also reporting

83% adoption based on this study. Ultimately, we deem that the parameter extracted is appropriate and the study design is appropriate, though the extraction of these parameters over others is perhaps *pessimistic*.

[A8 Adrianzen] is a cross-sectional observational study in the northern Peruvian Andes. GKH identify an adoption rate of 55% after 10 months. The parameter extracted is not appropriate for defining adoption and the study design is not appropriate. First, this cross-sectional study purposefully identified a sample "where relatively low usage rates were expected." As such, it is inherently a downward biased estimate. Second, in their Table 1, Adrianzen report data on the proportion of visited beneficiaries in a village that received their improved stove but were not making use of it. The average was 55%. We believe that this is where GKH defined their adoption, erroneously interpreting the table. Were the study design to have been appropriate, GKH should have extracted an adoption rate of 45%. Adrianzen further clarify in text: "Table 1 also indicates that approximately 45% of the visited beneficiaries per village reported using the new stove as their main cooking device."

[A9 Bensch] is a randomized controlled trial conducted in rural Senegal. GKH identify an adoption rate of 51% after 3.5 years. The study design is appropriate and the parameter extracted is appropriate for defining adoption, although it may be *pessimistic*. The authors report that the expected lifetime of the stoves was one to three years. As such, adoption beyond that expected lifetime is anticipated to be low. The authors write: "Considering an expected life span of one to three years, the proportion of 49% of treatment households still using the randomized ICS can, nevertheless, be considered surprisingly high." Note a small error from GKH in reporting adoption of 51% instead of 49% after 3.5 years. Bensch's Figure 4 reports the proportion of households still using the project stove by month. At their initial follow-up, Bensch reports that there are only 2 households out of 253 that do not use the project stove. Plausibly, adoption could have been identified as 99%.

Table S1. Adoption rates from academic literature used by GKH

Adoption rates listed here reflect values reported by GKH unless otherwise noted.

Identifier	Study Title	Country	Time period (years)	Adoption Rate	Study Year (this paper)	Sample Size (this paper)	Stove type (this paper)
[A1 Duflo]	Up in smoke: The influence of household behavior on the long-run impact of improved cooking stoves.	India	2	0.4	2016	2,650	Improved Biomass Stove with Chimney
[A2 Burwen]	A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana	Ghana	0.67	0.49	2023	164	Envirofit improved biomass stove
[A3 Islam]	Assessing the Effects of Stove Use Patterns and Kitchen Chimneys on Indoor Air Quality during a Multiyear Cookstove Randomized Control Trial in Rural India	India	3.5	0.619 (estimate cannot be confirmed)	2022	480	Improved Biomass Chimney Stove, LPG, Traditional Stoves
[A4 Beltramo]	The Effects of Fuel-Efficient Cookstoves on Fuel Use, Particulate Matter, and Cooking Practices: Results from a Randomized Trial in Rural Uganda	Uganda	3.5	0.65	2024	955	Improved Charcoal Stove
[A5 Rosa]	Assessing the Impact of Water Filters and Improved Cook Stoves on Drinking Water Quality and Household Air Pollution: A Randomised Controlled Trial in Rwanda	Rwanda	0.5	0.475	2014	566	EcoZoom Dura improved biomass stove (along with water filter intervention)
[A6 Ruiz-Mercado]	Quantitative metrics of stove adoption using Stove Use Monitors (SUMs)	Guatemala	0.83	0.5	2013	80	Plancha chimney stove
[A7 García-Frapolli]	Beyond fuelwood savings: Valuing the economic benefits of introducing improved biomass cookstoves in the Purépecha region of Mexico	Mexico	2 to 7	0.6	2010	232	Patsari improved biomass cookstove

[A8 Adrianzén]	Social Capital and Improved Stoves Usage Decisions in the Northern Peruvian Andes	Peru	0.83	0.55	2010	~250–300	Iron-frame biomass stove with chimney
[A9 Bensch]	The intensive margin of technology adoption - Experimental evidence on improved cooking stoves in rural Senegal	Senegal	3.5	0.51	2014	1,000	Low-cost portable clay-metal improved biomass stove

Usage

GKH largely draw on a previous review - Jeuland et al. - for their identification of usage rates. They additionally include one other study. While not explicitly referenced in GKH's appendix or elsewhere, we believe this study is Ruiz-Mercado (2012).

[U1 Rosa] is a randomized controlled trial conducted over several years in Rwanda. It is the same as [A5 Rosa]. This parameter extracted is inappropriate for defining usage because it more closely matches GKH's definition for adoption.

[U2 Ruiz-Mercado] The study by Ruiz-Mercado et al. (2012) uses Stove Use Monitors (SUMs) to measure stove usage in 80 rural Guatemalan households over 32 months. The study defines usage metrics based on daily stove use, counting the percentage of days in use, the number of meals cooked per day, and the total stove-hours recorded. The reported usage rate of 50% refers to the percentage of monitored stoves actively in use during the study period. While the study tracks sustained stove use, it does not directly quantify how often traditional stoves are used for meal preparation versus the improved stove, which is critical for GKH's definition. Therefore, this measurement method does not fully align with GKH's definition of usage rate.

[U3 Hanna] is the same as [A1 Hanna]. This parameter extracted is inappropriate for defining usage because. Please see above discussion under the adoption section for an explanation of the study design, and its lack of suitability for adoption and also usage.

[U4 Traction] is an unknown study.

[U5 Garcia-Frapolli] is an study that focuses on the costs and benefits of the Patsari Cookstove among Purépecha regions. The study disseminated 1,672 Patsari stoves to randomly selected households from 2003 to 2008. The study found that "60% or 1,003 stoves were being used on a sustained long-term basis". This study design is inappropriate for defining usage because it lacks meal-specific tracking or measures of total stove use completed by the project stove.

[U6 Adrianzen] This study examines the role of social capital in the adoption and usage of improved cookstoves in the Northern Peruvian Andes. The reported usage rate of 45% was determined through household surveys conducted 8–12 months after stove distribution, where beneficiaries self-reported whether they used the improved stove as their primary cooking device. This study design is inappropriate for defining usage because it lacks meal-specific tracking or measures of total stove use completed by the project stove.

[U7 Bensch] is a randomized controlled trial conducted from 2009 to 2013. The study employs various measurement methods, including household surveys, firewood measurement, and health indicators, to evaluate the effectiveness of a low-cost, maintenance-free portable clay-metal stove (ICS) and its impact on health. The study reports a utilization rate of 69.1% among the treatment group using the ICS at follow-up. The parameters and study design are appropriate for accurately measuring the usage rate.

[U8 Traction] is an unknown study.

[U9 Ruiz-Mercado] It is unclear how GKH's reported 85% usage rate was determined. The study primarily focuses on measuring the sustained use of improved cookstoves using stove use monitors. The key metric presented by Ruiz-Mercado is the "percent stove-days in use," which quantifies the number of days the improved stove was used relative to the monitoring period. However, GKH's definition of usage rate would require clear data on the proportion of total cooking done on the improved stove versus the traditional stove. Since this study does not explicitly quantify the continued use of traditional stoves or the proportion of meals cooked on them, it is inappropriate for defining usage.

Table S2. Usage rates from academic literature used by GKH[a]

Identifier	Study Title	Country	Time period (years)	Usage Rate
[U1 Rosa]	Assessing the Impact of Water Filters and Improved Cook Stoves on Drinking Water Quality and Household Air Pollution: A Randomised Controlled Trial in Rwanda	Rwanda	0.5	0.8
[U2 Ruiz-Mercado]	Adoption and sustained use of improved cookstoves	Mexico	0.83	0.5
[U3 Hanna]	Up in smoke: The influence of household behavior on the long-run impact of improved cooking stoves.	India	2	0.4
[U4 Traction]	Unknown	India	Unknown	0.2
[U5 García-Frapolli]	Beyond fuelwood savings: Valuing the economic benefits of introducing improved biomass cookstoves in the Purépecha region of Mexico	Mexico	2 to 7	0.6
[U6 Adrianzén]	Social Capital and Improved Stoves Usage Decisions in the Northern Peruvian Andes	Peru	0.83	0.45
[U7 Bensch]	The intensive margin of technology adoption - Experimental evidence on improved cooking stoves in rural Senegal	Senegal	3.5	0.69
[U8 Traction]	Unknown	India	Unknown	0.16
[U9 Ruiz-Mercado]	The Stove Adoption Process: Quantification Using Stove Use Monitors (SUMs) in Households Cooking with Fuelwood	Guatemala	2.67	0.85

[a] Studies U1-U8 are from Jeuland et al. whereas study U9 is added by GKH.

Stacking

Recall that GKH define stacking as the percentage of meals where the traditional stove and the project stove are used in tandem. We review specific studies cited by GKH for their ranges of stacking and whether they meet this definition.

[S1 Asante] report data that are now published under the title 'Experiences with the Mass Distribution of LPG Stoves in Rural Communities of Ghana' by Carrion et al. This study is a cross-sectional that reports that, after 9 months, less than 5% of households used LPG for cooking their main meals the previous day based on self-reported survey data. GKH cite a stacking rate of 100%. Given the data reported in Carrion et al., this is not appropriate because their reported data do not match GKH's definition of stacking.

[S2 Pollard] This study evaluates Peru's Fondo de Inclusión Social Energético (FISE) program, which promoted the adoption of liquefied petroleum gas (LPG) through a voucher system subsidizing half the cost of one LPG cylinder per month for eligible households. The study reports a stacking rate of 95%, which was determined through household surveys conducted in rural Puno, where participants self-reported their stove use patterns. This study's approach captures whether households used multiple stoves within a given period but does not track whether both stoves were actively used together for the same meal; therefore, the reported stacking rate is inconsistent with GKH's definition.

[S3 Gould] This study is a cross-sectional observational study that reports a stacking rate of 79%, with households in a very rural area of Ecuador using woodfuel weekly or more frequently despite having LPG stoves. The stacking rate of 79% comes from the survey data indicating that woodfuel is frequently used as a secondary fuel, with 86% of households using woodfuel alongside LPG. GKH cite this stacking rate based on the survey data that measures woodfuel use. However, this is not appropriate because the measure used—reporting woodfuel use weekly or more frequently—does not align with GKH's definition of stacking, which focuses on the concurrent use of traditional and project stoves for cooking meals.

[S4 Thoday] The study by Thoday, which reports a stacking rate of 73% in various provinces of Indonesia, calculates this rate using survey questions like "Which stoves have you used in the last three days?" and "List all stoves you have in the household." The 73% stacking rate indicates that a majority of households are using multiple stoves, including both LPG and traditional stoves. However, this measurement doesn't align with GKH's definition of stacking, which focuses specifically on the percentage of meals where both traditional and project stoves are used simultaneously.

[S5-S6 Bruce] This study evaluates the government-led initiative for LPG scale-up in Cameroon. The reported stacking rates of 90% and 99% were derived from household surveys conducted in peri-urban and rural areas, as part of the LPG Adoption in Cameroon Evaluation (LACE) studies. The survey questions focused on whether households used multiple fuels and how often LPG was refilled. Since the reported stacking rates were found through self-reported fuel use surveys and refill frequency data, which indicate continued use of traditional stoves but do not capture concurrent stove usage during meal preparation, this measure does not align with GKH's definition of stacking.

[S7 Ozier] This study evaluates a commercial pilot program promoting ethanol-methanol CleanCook stoves in Lagos, Nigeria. The reported stacking rate of 65% was determined through a combination of household surveys, stove use monitors, and fuel canister sales data collected from 30 experimental households over five months. The surveys asked households whether they continued using traditional stoves, while stove use monitors (SUMs) tracked temperature changes as a proxy for use. This study's approach to measure stacking captures overall stove usage patterns over time rather than whether both stoves were actively used together for the same meal; therefore, it does not match GKH's definition of stacking. However, this measure does not align with GKH's definition of stacking, which focuses on the percentage of meals where both the traditional and project stoves are used in tandem.

[S8 Benka-Coker] This study is a randomized controlled trial and pilot study that reports a stacking rate of 65% in Lagos, Nigeria, where CleanCook ethanol-methanol stoves were introduced. GKH cite this stacking rate based on a combination of surveys and stove use monitors, which show households using both CleanCook stoves and traditional stoves. However, this measure is uncertain in terms of fully aligning with GKH's definition of stacking, as it is based on indirect indicators like fuel canister usage rather than directly measuring the percentage of meals cooked using both stove types in tandem.

[S9 Carter] In the study by Carter et al., the reported stacking rate of 77% in southwestern China is based on a before-and-after intervention that introduced semi-gasifier stoves and biomass pellets. This rate was calculated by observing the continued use of traditional wood chimney stoves alongside the new stoves. However, this measure reflects general stove usage over time rather than concurrent use during meal preparation, which is how GKH defines stacking. Therefore, it is not appropriate for use as a metric for tracking stacking.

[S10-S12 Clemens] This study is a cross-sectional one-time survey that reports a stacking rate of 46% in Kenya, where households with biodigesters use both biogas and traditional fuels for cooking. GKH cite this stacking rate based on data showing that while 54% of households use biogas exclusively, 46% stack biogas with other fuels. However, this is not appropriate because the measure used—percentages of households exclusively or partially using biogas—does not align with GKH's definition of stacking, which focuses on the concurrent use of traditional and project stoves for cooking meals.

[S13-S14 Hyman] This study evaluates a national biodigester program in Cambodia and reports two stacking rates: 28% and 50%. The stacking rate was determined through household surveys and stove use monitors, which tracked household fuel use and cooking patterns. Surveys asked respondents about their primary and secondary stove use, while stove use monitors recorded temperature fluctuations on traditional and biodigester stoves as a proxy for stove usage. Additionally, observational data collected from a subset of households indicated that while biogas was used for primary cooking, many households continued to rely on traditional stoves, particularly for cooking tasks requiring high heat or large pots. Therefore, since the reported stacking rate in this study was found through a combination of survey self-reports and indirect monitoring methods that did not specifically capture simultaneous stove use during meal preparation, it does not meet GKH's definition.

[S15 Rosa] This is a parallel household RCT conducted over a year in three rural villages in Rwanda. The study reports a stacking rate of 19.3% among 585 participating households. This rate does not align with GKH's definition because it reflects the percentage of households using traditional and improved cooking stoves together during the study, rather than the percentage of meals prepared with both stoves. Additionally, the 19.3% stacking rate is different from the researchers' observations, where only 4.3% of households used both stoves simultaneously during their visit.

[S16-S17 Ruiz-Mercado] Reports data from a Master's thesis by Zamora. This study uses sensor-based monitors to observe the adoption process and impacts of the improved cookstove program implemented in Purepecha and Mestizo villages in Mexico. The study reports a stacking rate of 90% among Purepecha participants, indicating that "90% now stack the TSF with Patsaris, LPG stoves, and microwaves (MW)." It also reveals a stacking rate of 50% among Mestizos, who "continue using the three-stone fire (TSF) with gas (LPG) stoves and even microwaves (MW)." These stacking rates do not meet GKH's definition because they focus on overall usage across households, rather than within households from meal to meal. We note that GKH report these race/ethnic group stratification statistics in reverse.

[S18 Hanna] This study evaluates the long-term effects of an improved cookstove intervention in India, examining behavioral patterns and sustained use of traditional stoves. The reported stacking rate of 93% was derived from household surveys and direct observations conducted over a two-year period. Surveys captured self-reported stove usage, while field observations tracked cooking behaviors in randomly selected households. Since the reported rate primarily reflects stove ownership and continued use rather than the percentage of meals cooked using both traditional and project stoves in tandem, it does not match GKH's definition of stacking.

[S19 Bensch] This is a randomized controlled trial conducted in rural Senegal from 2009 to 2013. The study evaluates the usage of improved cookstoves and their potential impacts on participants' health. Based on surveys of 253 randomly selected households, the study reports that 19.5% of the treatment group continue to use open fires (three-stone stoves or open fires) for cooking. This data suggests that the treatment group "stacks" project stoves with open-fire stoves. However, this data does not exactly reflect concurrent stove usage during meal preparation, but it rather provides a general overview of stove usage patterns among households. Therefore, it does not meet GKH's definition of stacking.

[S20 Pattanayak] This is a multiphase randomized controlled study assessing the implementation and adoption of improved biomass stoves and LPG stoves. It involves about 1,000 households from the Indian Himalayas. The study does not explicitly discuss the stacking rate, but it does report that the treatment group had an average daily use of 231.6 minutes for traditional cooking stoves (TCS) three months after the intervention. Additionally, the supplementary information indicates that 26.6% of the control group and 54.5% of the treatment group used improved stoves in the past week. However, this measure is not an appropriate parameter for stacking. It does not meet GKH's definition, which focuses on the concurrent use of project stoves and traditional stoves.

[S21 Pine] This study evaluates the adoption and sustained use of Patsari improved biomass cookstoves in rural Mexico. The reported stacking rate of 35% was determined through a combination of structured household surveys, follow-up interviews, and observational data. Households were classified into different stove usage groups based on self-reported cooking practices and physical evidence of stove use gathered during home visits. The study captures broader patterns of stove use over time without explicitly tracking concurrent use for the same meal; therefore, it does not match GKH's definition which requires measuring the percentage of meals where both stoves are used simultaneously.

[S22 Burwen] This is a randomized controlled study conducted in rural Ghana that examines the impacts of improved cookstoves. The study uses stove usage monitors, field observations, and self-reported surveys. The results show that the treatment group uses the improved cookstoves more frequently than traditional cookstoves but continues to use the traditional ones during their cooking events. The stove usage monitors indicate that "50% of improved cookstoves remained in use" within the treatment group. However, this measure is not an appropriate parameter for stacking and does not meet GKH's definition of stacking.

[S23 Beltramo] This study is a randomized controlled trial conducted in Uganda that assesses the impact of fuel-efficient cookstoves on fuel use, particulate matter exposure, and cooking behaviors. The study reports a stacking rate of 90.9%, which was determined through a combination of self-reported surveys and temperature-based stove use monitoring. Households were given improved cookstoves, and researchers tracked their cooking behaviors using stove use monitors, which recorded temperature fluctuations to infer stove usage. However, this measure does not align with GKH's definition of stacking, which focuses on the percentage of meals where both the traditional and project stoves are used in tandem.

[S24 Ruiz-Mercado] The study by Ruiz-Mercado et al. evaluates the sustained adoption and usage patterns of improved cookstoves in rural Guatemala. The reported stacking rate of 50% is derived from stove use monitors, which recorded temperature fluctuations in 80 households over 32 months. The SUMs tracked daily cooking events, defining "fueling events" based on temperature spikes, which were clustered into cooking events or "meals." The study found that while 90% of stove-days involved the use of the improved chimney stove, 50% of households continued to use open cookfires alongside it. The reported stacking rate in this study was found through general household-level stove usage patterns, meaning it captures whether a household continued using both stoves but does not specify if both were used for the same meal; therefore, this measure does not align with GKH's definition of stacking.

Table S3. Table of stacking rates used by GKH

Identifier	Study Title	Stacking Rate
[S1 Asante]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Ghana	100.00%
[S2 Pollard]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Peru	95.00%
[S3 Gould]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Ecuador	79.00%
[S4 Thoday]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Indonesia	73.00%
[S5 Bruce]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Cameroon (2 values reported)	90.00%
[S6 Bruce]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Cameroon (2 values reported)	99.00%
[S7 Ozier]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Nigeria	65.00%
[S8 Benka-Coker]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Ethiopia	100.00%
[S9 Carter]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - China	77.00%
[S10 Clemens]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Kenya	46.00%

[S11 Clemens]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Tanzania	71.00%
[S12 Clemens]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Uganda	89.00%
[S13 Hyman]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Cambodia (two values reported)	28.00%
[S14 Hyman]	Everybody Stacks: Lessons from household energy case studies to inform design principles for clean energy transitions: Case Study - Cambodia (two values reported)	50.00%
[S15 Rosa]	Assessing the Impact of Water Filters and Improved Cook Stoves on Drinking Water Quality and Household Air Pollution: A Randomised Controlled Trial in Rwanda	19.30%
[S16 Ruiz-Mercado]	Adoption and sustained use of improved cookstoves: Purepecha	50.00%
[S17 Ruiz-Mercado]	Adoption and sustained use of improved cookstoves: Mestizo	90.00%
[S18 Hanna]	Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves	93.00%
[S19 Bensch]	The intensive margin of technology adoption — Experimental evidence on improved cooking stoves in rural Senegal	19.50%
[S20 Pattanayak]	Experimental evidence on promotion of electric and improved biomass cookstoves	54.50%
[S21 Pine]	Adoption and use of improved biomass stoves in Rural Mexico	35.00%
[S22 Burwen]	A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana	50.00%
[S23 Beltramo]	The Effects of Fuel-Efficient Cookstoves on Fuel Use, Particulate Matter, and Cooking Practices: Results from a Randomized Trial in Rural Uganda	90.90%
[S24 Ruiz-Mercado]	Quantitative metrics of stove adoption using Stove Use Monitors (SUMs)	50.00%

Table S4. Table of adoption rates drawn from the academic literature used in this study.

Author-Year	URL	Stove	Sample Size	Adoption	Adoption_alt	Reason
Abdulai-2018	https://link.springer.com/article/10.1007/s10393-018-1369-7	LPG	200	0.42	0.42	Use very low (5%), but my opinion is that adoption is at 42%.Fig 4 reports that 58% did not refill their stoves more than once.
Adrianzen-2013	https://doi.org/10.1016/j.ecolecon.2013.02.010	Improved biomass	163	0.79		Use of stove without problem vs. problem with stove from iron frame causing stopped usage. 129 vs. 34.
Adrianzen-2014	https://doi.org/10.1016/j.worlddev.2013.07.004	Improved biomass	26	0.45		Sample size is uncertain. Results reporting is unusual and not straightforward (average percent at village level). It reproduces the above study table on adoption. Table 1 also indicates that approximately 45% of the visited beneficiaries per village reported using the new stove as their main cooking device.
Alem-2015	https://www.theigc.org/sites/default/files/2018/02/Alem-et-al-final-report.pdf	LPG	296	0.75		Reported use within the last week.
Alexander-2017	https://www.sciencedirect.com/science/article/pii/S0160412017312448#bb0160	Ethanol	162	0.83		83% continue to use ethanol after conclusion of study period
Aung-2016	https://pubs.acs.org/doi/10.1021/acs.est.5b06208	Improved biomass	96	0.85		Supplement indicates that 14/96 intervention HHs dropped out because they didn't want the stoves. Other adoption estimates unlikely to be useful (60% exclusive but 40% are still partial users).
Bailis-2020	https://iopscience.iop.org/article/10.1088/1748-9326/ab865a	Gasifier	83	0.67	0.93	Estimated from Supplemental Information Fig S6 (1-Never Used SUMS). Alt from surveys
Barstow-2014	https://doi.org/10.1371/journal.pone.0092403	Improved biomass	1479	0.9	0.9	Intervention study, adoption tracked. Table 5.
Bensch-2015a	https://doi.org/10.1016/j.jebo.2015.04.023	Improved biomass	377	0.886		Most households have LPG. ICS sometimes used as backup. Reports that 15% and 1% in two villages do not use ICS. Implies adoption of at least 85% - calculated at 88.6% after weighting.

Bensch-2015b	https://doi.org/10.1016/j.jhealeco.2015.03.006	Improved biomass	1000	0.49	0.99	
Berkouwer-2023	http://www.susannaberkouwer.com/files/theme/BerkouwerJMP.pdf	Charcoal	517	0.98		Out of the 517 stove adopters resurveyed on year later, 508 (98 percent) still had the Jokokoa.
Betina-2022	https://www.sciencedirect.com/science/article/abs/pii/S0973082622000989	Improved biomass	134	0.8881		Table 3.
Beyene-2015	https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2616555	Improved biomass	300	0.9115		1-year of follow up
Bonan-2021	https://doi.org/10.1016/j.worlddev.2021.105467	Improved biomass	75	0.73	0.73	Focused on how to increase purchase of stove rather than stove us after acquisition. Still, reports 55 of 75 women used ICS at least once. Plausibly could also use 85% as adoption (9.5% use rarely and 5% never; remainder more frequent)
Burwen-2012	https://www.sciencedirect.com/science/article/abs/pii/S0973082612000208	Improved biomass	768	0.49	0.65	In GKH – kept. Unclear in use = not adopted vs. omitted
Checkley-2021	https://pmc.ncbi.nlm.nih.gov/articles/PMC8456540/	LPG	90	0.99		LPG + free fuel. Use = 0.98
Christiansen-2012	https://doi.org/10.1017/S1355770X13000375	Biogas	610	0.93		93% satisfied; 93% use it for cooking. Reports interruptions that are technical in. nautre and frequently resolved.
Clark-2017	https://iopscience.iop.org/article/10.1088/1748-9326/aa751e/pdf	Gasifier	89	0.92		% of households that 'tried' stove still using it 5-10 months later. Sample size is 89
Diaz-Vasquez-2020	https://doi.org/10.1177/1757975920945248	Improved biomass	52	0.8		After 9 years, 52% use improved stove regularly. 35% of sample had stove destroyed by external circumstances and should be removed from sample .
Dickinson-2019	https://www.sciencedirect.com/science/article/abs/pii/S0301421518308036	Improved biomass	50	0.8	0.6	3-month mark; 3-year mark; Total sample size is 200 across four groups
Dickinson-2019	https://www.sciencedirect.com/science/article/abs/pii/S0301421518308036	Improved biomass	50	0.59	0.2	3-month mark; 3-year mark

Dohoo-2013	https://www.nature.com/articles/jes201342#Tab1	Biogas	31	0.77		24 households 77% say biogas is principal fuel source. I would consider this the lower bound on adoption.
Fankhouser-2019	https://www.tandfonline.com/doi/full/10.1080/23311843.2019.1625481#abstract	Improved biomass	77417	0.938	0.769	Cross-sectional follow up of households that had received an improved biomass stove. Of the 77,417 households 93.8% report using stove. Of the 11,137 households cooking at the time of visit, 76.9% were using intervention stove. Requiring observed use at time of visit is too aggressive for adoption (one could still use the stove at other times), but self report is plausibly an overestimate.
Gitau-2021	https://www.sciencedirect.com/science/article/pii/S0973082618308913	Gasifier	50	0.96		48 out of 50 use at least weekly 2-3 months after adoption
Gupta-2020	10.1007/s11356-020-11011-8	Improved biomass	65	0.535		Although methods for adoption/use are not clear, my best guess is that the sentence broadly refers to adoption as in reasonably consistent use of project stove among study households. Improved adoption and usage of NEERDHUR ICS was found to be 53% and 54% in Charanka and Fangli, respectively.
Hankey-2015	https://www.sciencedirect.com/science/article/abs/pii/S0973082614001306	Improved biomass	32	1		From Table S3, no households with suitable data report 0 use of the intervention stove. 1-month adoption rates.
Hing-2023	https://doi.org/10.1016/j.deveng.2023.100111	Improved biomass	120	0.765	0.765	Table 1. Free trial data
Hing-2023	https://doi.org/10.1016/j.deveng.2023.100111	Improved biomass	69	0.21	0.21	Table 1. Follow up purchase group after 1 year reporting use in last month. Sensor-based.
Jack-2021	https://gh.bmj.com/content/6/8/e005599.full	Improved biomass	527	0.69		Across the study period, participants reported using their intervention stoves to cook their main meal the previous day during approximately 87% of weekly visits to households in the LPG study arm (~25 000 visits) and 69% of visits to households in the improved biomass study arm (~34 000 visits); Likely a lower bound.

Jack-2021	https://gh.bmj.com/content/6/8/e005599.full	LPG	361	0.87	Across the study period, participants reported using their intervention stoves to cook their main meal the previous day during approximately 87% of weekly visits to households in the LPG study arm (~25 000 visits) and 69% of visits to households in the improved biomass study arm (~34 000 visits); Likely a lower bound.
Jagger-2017	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4918052/	Improved biomass	121	0.8	After 6 months, visited random sample of 121 households. 80% actively using. 63% using for all cooking events.
Keese-2016	https://www.tandfonline.com/doi/full/10.1080/09614524.2017.1257565	Improved biomass	43	0.7	30% of households were non-adopters.
Kirby-2019	https://pubmed.ncbi.nlm.nih.gov/31158266/	Improved biomass	718	0.822	Sample size varies across study periods.
Kongani-2019	https://doi.org/10.53537/jsep.2019.02.004	Improved biomass	28	0.5	Cross-sectional follow up of households that had received an improved biomass stove. Was established that 28 households (93%) of the respondents received the improved stoves from these programmes. Further investigation was undertaken to establish the use of these improved stoves and it emerged that 50% of those who received the improved stoves were using them at some point.
Lafave-2021	https://www.sciencedirect.com/science/article/abs/pii/S0305750X20304599	Improved biomass	480	0.6	3.5 years later. "This causal estimate includes both the 60 percent who continued using the Mirt stove and the 40 percent who had stopped using it at some point during the prior three and a half years."
Lohani-2025	https://doi.org/10.1016/j.erss.2025.104027	Improved biomass	55	0.22	Participants did not like the stoves. Nepal.
Lung-2019	https://doi.org/10.1016/j.esd.2018.12.004	Improved biomass	464	0.929	The proportion of households using stoves (i.e. usage rate) for stoves of all ages averaged 95.8% and declined with age of stove from 98.4% for stoves less than two years old to 92.9% for stoves four years and older.. # of households visited not totally clear

Matavel-2023	https://doi.org/10.1016/j.erss.2023.103082	Improved biomass	357	0.58	0.58	Fig 3, exclude never adopters. % adoption = those that did not abandon .
Medina-2019	https://www.mdpi.com/2073-4433/10/11/693	Improved biomass	257	0.63		37% rely exclusively on three stone fire (after substantial number of years. Between 7 and 9)
Mortimer-2017	https://www.thelancet.com/action/showPdf?pii=S0140-6736%2816%2932507-7	Improved biomass	1427	0.781	0.921	Table 3. 24 months after intervention 21.9% no meals cooked with stove.; Alt is after 3 months
Mudombi-2018	https://doi.org/10.1016/j.esd.2018.03.004	Ethanol	99	0.56	0.56	Plausibly 56% adoption of ethanol stove. 44% described as ethanol abandoners. Sample size = 341*.29 (17+12). From section "Ethanol stove adoption and use"
Northcross-2014	https://doi.org/10.1016/j.esd.2016.05.003	Ethanol	25	0.9		Stove used 90% of stove-days. Kerosene fell down to 5%. Adoption at 90% would be an underestimate. Usage at 90% hard to pinpoint.
Pakravan-2018	https://doi.org/10.1109/GHTC.2018.8601900	Improved biomass	390	0.85		2 month follow up. 90% stove in usable condition. 85% report primary. 73% reported use last week.
Pattanayak-2019	https://www.pnas.org/doi/10.1073/pnas.1808827116	Various	358	0.7		70% feels like an acceptable adoption rate "In the postintervention first-round follow-up (~3 mo after the intervention), most households that had purchased intervention stoves still owned them (Fig. 3), and nearly 70% of owners reported using them in the week before the survey". Also: "Because past work has typically only examined impacts on immediate use, we implemented a second shorter survey to examine ownership and use ∼15 mo after the intervention. Even at this stage, ownership rates of intervention stoves remained largely unchanged". It's not obvious which choices one would make using individual level data to extract an adoption estimate. The takeaway from the study, though, appears to be that adoption was reasonably high.
Pillarisetti-2014	https://doi.org/10.1021/es504624c	Improved biomass	146	0.94		6% reported no cooking with phillips according to SUMS 2-3 months post intervention (Table 1). 60% use.

Pine-2011	https://doi.org/10.1016/j.esd.2011.04.001	Improved biomass	259	0.6	0.83	In GKH – kept. 0.6 or 0.83 "usage" vs. did not adopt.
Qu-2025	https://www.sciencedirect.com/science/article/abs/pii/S0973082625000420?via%3Dihub	Ethanol	400	0.94		Around 94 % of the households in the treatment group and 0 % in the comparison group reported that they had taken up ethanol as their primary stove.. Likely underestimate.
Ramanathan-2016	https://www.nature.com/articles/nclimate3141#Sec1	Improved biomass	456	0.73		17 months. Inferred from Figure 2 - roughly 26-29% of folks are at 0 daily cooking in the later time period.
Romieu-2009	https://doi.org/10.1164/rccm.200810-1556OC	Improved biomass	283	0.5		RCT. 50% classified as primarily using Patsari or mixed use. Remainder are classified as mainly traditional. Not specified if this means 0 patsari use. Could be underestimate.
Rosa-2014	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091011	Improved biomass	566	0.485	0.933	
RuizMercado-2013	https://doi.org/10.1016/j.biombioe.2013.07.002	Improved biomass	80	0.9	0.95	In GKH – kept.
RuizMercado-2015	https://link.springer.com/article/10.1007/s10393-015-1009-4#Sec6	Improved biomass	100	0.9		Implied from Fig 4 that 10% of homes don't use chimney stove at all.
Schillman-2019	https://doi.org/10.1016/j.envint.2019.105013	Improved biomass	257	0.8	0.8	Long term follow up stoves installed. Estimates provided over the course of 9 years. Eyeballed at 80% after 2 years. 50% after 4 years. 15% after 9 years.
Thomas-2013	https://pubs.acs.org/doi/abs/10.1021/es403412x	Improved biomass	118	0.732		"The adoption rate interpreted by the sensors varied from the household reporting: 90.5% of households reported primarily using the intervention stove, while the sensors interpreted 73.2% use, and 96.5% of households reported using the intervention filter regularly, while the sensors interpreted no more than 90.2%." For EHO survey data, ratio of households reporting using the improved stove as their primary stove. For sensor data, ratio of installations for which at least .2 uses were detected

Usmani-2017	https://iopscience.iop.org/article/10.1088/1748-9326/aa6008	Improved biomass	45	0.955		Focused more on impact of economic incentives on stove adoption/use patterns, so reporting of the descriptives is not quite clear for our purpose here. However, the authors note that two treatment households faced a non-zero final stove price. This implies that all but two households had 'adopted' the stoves for our purposes.
Williams-2023	https://www.sciencedirect.com/science/article/pii/S0160412023004336	LPG	1590	0.99		Plausibly an underestimate. This might subsume Quinn-2021. LPG+fuel.
Williams-2023b	https://doi.org/10.1016/j.esd.2023.01.005	LPG	83	1		Use = 0.63 minutes; 0.77 events. All participants purchased LPG cylinder refill at some point in the year following intervention.
Wilson-2016	https://sci-hub.scrongyao.com/10.1021/acs.est.6b02899	Improved biomass	122	0.71	0.79	71% use the stove >10% of days; follow-up increases 'adoption' up to ~79%
Wolf-2017	https://www.mdpi.com/1660-4601/14/7/745	Improved biomass	1033	0.871	0.95	Plausibly Primary + Seconday = 95% for Alt
Young-2023	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10688445/	Improved biomass	230	0.98		"In our 3-year randomized cookstove intervention in rural Honduras, we observed substantially reduced 24-hour concentrations of BC from Justa stoves compared to traditional stoves for personal and kitchen exposures, with exceptional uptake of Justa stoves (98%, based on self-report among those assigned to use the Justa), despite some ongoing use of traditional stoves."

Table S5. Table of usage rates drawn from the academic literature used in this study.

Author-Year	URL	Stove	Sample size	Usage	Usage (alt)	Reason
Barstow-2014	https://doi.org/10.1371/journal.pone.0092403	Improved biomass	1479	0.712		71.2% of cooking events - Table 5.
Bensch-2015b	https://doi.org/10.1016/j.jhealeco.2015.03.006	Improved biomass	1000	0.691		Table 2. The shares represent the ratio between the number of times the respective stove type is used and the total number of stove applications per household and week.
Burwen-2012	https://www.sciencedirect.com/science/article/abs/pii/S0973082612000208	Improved biomass	768	0.22		SUMs cooking improved / improved+traditional. Table 2. 2.6 / (2.6+9.2)
Dohoo-2013	https://www.nature.com/articles/jes201342#Tab1	Biogas	31	0.4		Table 2. Minutes with 'exposure'
Hankey-2015	https://www.sciencedirect.com/science/article/abs/pii/S0973082614001306	Improved biomass	32	0.58		Fig 5 panel D. Ballpark 210 minutes + 150 minutes (traditional)
Jagoe-2020	https://www.sciencedirect.com/science/article/pii/S2214629619306668	Improved biomass	55	0.311		30% usage; Adoption appears to be 100%?
Kumar-2022	https://doi.org/10.3390/earth3010019	LPG	58	0.45		Use estimate is viably 0.45; Adoption not estimated in terms of % of households using.
Lafave-2021	https://www.sciencedirect.com/science/article/abs/pii/S0305750X20304599	Improved biomass	480	0.89		3.5 years later; a sort of combined adoption/usage measure, in my opinion. It's a Mirt stove for cooking injera. I think that use is quite high. Reported cooking events in line with traditional cooking patterns of injera. This use estimate combines stopping time of folks that stopped but gives them partial credit. I think it's not perfectly right, but it seems close.
Lozier-2016	https://doi.org/10.1021/acs.est.5b06141	Improved biomass	45	0.48		cooking events per day with ICS range from 0.45 to 0.7 of cooking events depending on stove. Weighted average at 0.48
Northcross-2014	https://doi.org/10.1016/j.esd.2016.05.003	Ethanol	25	0.9		Stove used 90% of stove-days. Kerosene fell down to 5%. 85% gave away kerosene stove. Usage at 90% hard to pinpoint, but it's fairly close I think.

Piedrahita-2016	https://www.sciencedirect.com/science/article/abs/pii/S0973082616302137	Improved biomass	50	0.615		Gyapa/Gyapa % of total cooking
Piedrahita-2016	https://www.sciencedirect.com/science/article/abs/pii/S0973082616302137	Improved biomass	50	0.59		Gyapa/Phillips
Piedrahita-2016	https://www.sciencedirect.com/science/article/abs/pii/S0973082616302137	Improved biomass	50	0.32		Phillips/Phillips
Pillarisetti-2014	https://doi.org/10.1021/es504624c	Improved biomass	146	0.25		Minutes cooking phillips / (phillps + trad). Fig 3 middle panel.
Qu-2025	https://www.sciencedirect.com/science/article/abs/pii/S0973082625000420	Ethanol	400	0.23		40 min use bioethanol; 177 minutes total use. Around 94 % of the households in the treatment group and 0 % in the comparison group reported that they had taken up ethanol as their primary stove.
RuizMercado-2015	https://link.springer.com/article/10.1007/s10393-015-1009-4	Improved biomass	100	0.53		Sample weighted average of hours of use from Fig 3, i.e., 10% of sample uses open fire 5.9 hours (.1*5.9) + (.2*6.1) … etc
Saleh-2022	https://doi.org/10.12688/wellcomeopenres.17544.3	Improved biomass	18	0.95		Use at 0.95. Adoption estimates not reported. Can be expected to be high, but no specific number is provided.
Simons-2017	https://www.sciencedirect.com/science/article/pii/S0095069617303170	Improved biomass	103	0.32		Total envirofit usage / Total usage of stoves from Table 3 (w/out observation)
Williams-2023b	https://doi.org/10.1016/j.esd.2023.01.005	LPG	83	0.63	0.77	Use = 0.63 minutes; 0.77 events. All participants purchased LPG cylinder refill at some point in the year following intervention.
Paulsen-2019	http://pubs.acs.org/action/showCitFormats?doi=10.1021/acsomega.8b03596	Improved biomass	15	0.89	0.89	89% of cooking time; 93% of cooking events from SUMs with Poyo. Fig 2. 6 weeks after adoption I think.

2. Cookstove projects included in the study

Table S6. Cookstove projects included in the study and their descriptions

Project ID	Project Name	Developer	Voluntary Registry	VPA/PoA	Methodology	Country/Context/Scope	Implementation Model	Pre-Project Fuel/Technology
GS 447	Improved Cookstoves for Social Impact in Ugandan Communities	Impact carbon	GOLD	Standalone	GS TPDDTEC v2	Uganda; 95% rely on solid fuels. Charcoal in urban, wood in rural. Sold through partners.	Retail stove sales	Charcoal, wood, inefficient stoves
GS 500	Darfur Efficient Cook-stove Project	Carbon clear	GOLD	Standalone	AMS-II.G. v5	El Fashir, Sudan. Households use non-renewable biomass with inefficient stoves. LPG network expanded.	LPG distribution network	Charcoal, wood, inefficient stoves
GS 2564	Expanding access to LPG in Haiti through microfinance services	Entrepreneurs du Monde	GOLD	Standalone	AMS-II.G. v3	Port au Prince, Haiti. >90% use charcoal. Microfinance enables LPG stove access.	Microfinance stove purchase model	Charcoal, inefficient stoves
GS 2094	Man and Man Enterprise Improved Cooking Stoves Programme	Man and Man Enterprise	GOLD	PoA 1385	AMS-II.G. v3	Ghana (urban). ICS sold directly and via vendors.	Direct and vendor sales	Charcoal, unimproved stoves
VCS 1719	Improved Cookstoves Project for Malawi and Mozambique	C-Quest Capital	VCS	Standalone	AMS-II.G. v3	All of Malawi. ICS for rural households. Pre-project: firewood.	Direct distribution	Firewood, inefficient stoves
VCS 1721	ONIL Stoves Guatemala Uspantan	C-Quest Capital	VCS	Grouped	AMS-I.E. v9	Guatemala. Used solid fuels in open fires. Manufacturer-distributor model.	Manufacture and distribution	Firewood, open fires
VCS 1216	Distribution of ONIL Stoves - Mexico	C-Quest Capital	VCS	Grouped	AMS-I.E. v9	Mexico. Similar to Guatemala model. Distributed across communities.	Manufacture and distribution	Firewood, inefficient stoves
GS 10974	Improved Cooking Stoves in Bangladesh (CPA No.12)	Bangladesh Bondhu Foundation	GOLD	PoA 10833	GS TPDDTEC v3.1	Bangladesh. Households use firewood in inefficient stoves.	Stove construction program	Firewood, inefficient stoves
GS 10884	KOKO Kenya - Ethanol Cookstoves Program	KOKO Network Limited	GOLD	PoA - 10884	GS Methodology for Improved Cookstoves v2	Kenya. Promotes portable ethanol stoves.	Ethanol stove distribution	Charcoal, firewood
GS 7312	Promoting Improved Cooking practices in Nigeria	Toyola Energy Services Limited	GOLD	Standalone	GS TPDDTEC v2	Nigeria (nationwide). Implements improved stove construction with artisans.	Local artisan-based construction	Solid fuel, inefficient stoves or open fires
GS 7438	Improved Cookstove Project in Uganda	South Pole Ltd	GOLD	Standalone	GS TPDDTEC v2	Uganda. Managed distribution and marketing of improved stoves.	Partner coordination, distribution, promotion	Woody biomass, inefficient stoves

Project ID	Project Name	Developer	Voluntary Registry	VPA/PoA	Methodology	Country/Context/Scope	Implementation Model	Pre-Project Fuel/Technology
GS 1060	Improved Cook Stoves programme for Rwanda	Atmosfair gGmbH	GOLD	PoA 1023	AMS-II.G. v3	Rwanda (all regions). Disseminates improved biomass cookstoves.	National dissemination	Firewood and/or charcoal
GS 1094	WWF Mamize Firewood-Saving Cook Stove Project I	South Pole Ltd	GOLD	Standalone	AMS-II.G. v3	Sichuan, China (Maxize Nature Reserve). 400 households using firewood. Stoves deployed for free.	Free deployment	Firewood, inefficient stoves
GS 2744	Project Activity for Local Improved Cookstoves in Bamako	GERES	GOLD	PoA 2486	AMS-II.G. v5	Mali (Bamako). Local production and dissemination network for improved stoves.	Local production and retail	Charcoal and firewood, inefficient stoves
GS 4291	The Breathing Space ICS Programme, India – VPA 10 Envirofit	Envirofit International, Ltd.	GOLD	PoA 916	AMS-II.G. v3	India. Dissemination of ICS to replace inefficient "chulhas".	Commercial distribution	Traditional chulhas
GS 6604	Energy efficiency project with SD impacts (Uganda)	Pacific Engineering Services Limited	GOLD	Standalone	AMS-II.G. v9	Uganda. Dissemination of improved stoves.	Distribution	Firewood, open fires
GS 1267	Improved Kitchen Regimes: Bugesera, Rwanda	CO2balance UK Ltd	GOLD	PoA 1247	GS TPDDTEC v1	Rwanda (Bugesera). Installs subsidized stoves in households.	Subsidized installation	Firewood, open fires
GS 2439	Utsil Naj – Casa saludable para todos VPA2 (Guatemala)	MICROSOL SAS	GOLD	PoA 1377	GS TPDDTEC v1	Guatemala (7 departments). Partner-led stove promotion and distribution.	Local partner promotion and distribution	Firewood, charcoal
GS 2441	Utsil Naj – Casa saludable para todos VPA4 (Mexico)	MICROSOL SAS	GOLD	PoA 1377	GS TPDDTEC v1	Mexico (6 states). Local partners manage manufacturing and dissemination.	Local partner promotion and distribution	Firewood, inefficient stoves
GS 5003	Bamako Clean Cookstoves – Sahel region	Swiss Carbon Value Ltd	GOLD	Standalone	GS TPDDTEC v2	Mali (urban and peri-urban Bamako, expanding nationally).	Commission agent retail network	Charcoal, firewood, inefficient stoves
GS 2445	African Biomass Energy Conservation PoA Malawi	Hestian Innovation	GOLD	PoA 1265	GS TPDDTEC v1	Malawi (Northern, Central, and Southern Districts). Disseminates firewood stoves to households using charcoal and firewood.	National dissemination	Firewood, charcoal, inefficient stoves
GS 3112	Bondhu Chula ICS in Bangladesh (PoA)	Bangladesh Bondhu Foundation	GOLD	PoA 3112	GS MS Simplified Methodology v1	Bangladesh. Bondhu Foundation leads manufacturing and subsidized installation of ICS.	Partner network with subsidized installation	Solid biomass, three-stone fires
GS 2456	Efficient cookstoves in Burkina Faso – tiipaalga F3PA (various VPAs under GS1340)	tiipaalga (with Livelihoods Fund SICAV SIF/1Carbon partners)	GOLD	PoA (GS1340)	GS MS Simplified Methodology for Efficient Cookstoves v1	Burkina Faso (multiple provinces incl. Bam, Loroum, Nahouri)	Local partner-led construction & dissemination (F3PA)	Firewood/charcoal on open fires or traditional stoves. (SAP, Carbset Marketplace, Akvo Foundation)

Project ID	Project Name	Developer	Voluntary Registry	VPA/PoA	Methodology	Country/Context/Scope	Implementation Model	Pre-Project Fuel/Technology
GS 2513	CleanStar Mozambique – Maputo Ethanol Cookstove & Cooking Fuel Project 1	CleanStar Mozambique (CleanStar Ventures & partners)	GOLD	Standalone	AMS-I.E. (CDM) – Switch from non-renewable biomass	Mozambique (Maputo, urban/peri-urban); ethanol fuel & stove program	Sale of ethanol stoves + retail fuel supply ("NDZiLO")	Households predominantly using charcoal. (State of Green, Ethanol Producer, Scientific American)
GS 2896	Fuel Efficient Stoves for North Darfur Women	Haggar Group (with Women Development Association Network – WDAN)	GOLD	Standalone	GS Simplified ICS methodology (project docs describe efficient biomass stoves)	Sudan (North Darfur; El Fasher and surrounding communities)	Community distribution through women's associations; subsidised uptake	Firewood/charcoal on inefficient stoves/open fires. (goclimate.com, Goldman School of Public Policy)
GS 3018	Improved Cook Stove Project with Carbon Finance (ICF), Nepal	SNV Netherlands Development Organisation (with CRT/N; Eneco as buyer)	GOLD	Micro-scale project	GS MS Simplified Methodology for Efficient Cookstoves	Nepal (rural/household ICS dissemination)	Local manufacture & installation; credit finance supports scale-up	Firewood on three-stone or traditional stoves.
GS 3422	Improved Cook Stoves in Pastoral & Agro-Pastoral Communities in Southern Ethiopia	Carbon Sink Group S.r.l.	GOLD	Standalone	GS MS Simplified Methodology v1	Ethiopia (pastoral/agro-pastoral communities in the south)	Production & dissemination of ICS through local partners	Firewood burned in traditional stoves.
GS 4677	Project Gaia Cook Stove PoA – CPA0003 Ethiopia	Project Gaia Inc. (CME; Carbon Africa as consultant)	GOLD	PoA 10340	AMS-I.E. (CDM) – Switch from non-renewable biomass	Ethiopia (households incl. refugee camps)	Distribution of ethanol clean-cooking stoves; fuel supply chain	Firewood/charcoal open-fire cooking.
GS 6129	Myanmar Stoves Campaign – Soneva in Myanmar – VPA No. 007	QK TS Pvt. Ltd. (programme implementer)	GOLD	PoA 1729 (Myanmar Stoves Campaign)	GS MS Simplified Methodology for Efficient Cookstoves v1	Myanmar (urban & rural households via the MSC PoA)	Retail stove sales with instalment options; local partner network	Firewood in traditional stoves
GS 11352	Kenya Biomass Gasification for Clean Cooking (EcoSafi)	Better Cooking Company (EcoSafi)	GOLD	Standalone	GS Methodology for Metered & Measured Energy Cooking Devices (v1+)	Kenya (nationwide sales of pellet gasifier stoves)	Commercial sales of biomass gasifier stoves + pellet supply; device usage metered	Charcoal/wood on traditional stoves
GS 11507	Advanced Biomass Cooking Solutions by BioMassters – Rwanda (VPA1 under FCF PoA GS11506)	FairClimateFund (developer) with BioMassters	GOLD	PoA (GS11506) – VPA1	GS Methodology for Metered & Measured Energy Cooking Devices	Rwanda (household pellet gasifier rollout)	Sale of biomass gasifier stoves + pellet distribution; metered usage	Urban charcoal & rural firewood baseline.
GS 11509	Clean Cooking with Biomass Gasification in Zambia – VPA1	Emerging Cooking Solutions (ECS / SupaMoto)	GOLD	PoA/Grouped (first VPA)	GS Methodology for Metered & Measured Energy	Zambia (urban/peri-urban; pellet fuel switch)	Sale/servicing of metered pellet gasifier stoves + fuel	Predominantly charcoal (also firewood) in traditional stoves.

Project ID	Project Name	Developer	Voluntary Registry	VPA/PoA	Methodology	Country/Context/Scope	Implementation Model	Pre-Project Fuel/Technology
					Cooking Devices			
GS 407	Gyapa Cook Stoves Project in Ghana	Relief International	GOLD	Standalone	GS TPDDTEC v2	Ghana. Expanded from Greater Accra to national reach.	Commercial retail and distribution	Charcoal, inefficient stoves
GS 913	Efficient Wood Fuel Stove-Sets, Lesotho	Atmosfair gGmbH	GOLD	Standalone	AMS-II.G. v3	Lesotho (multiple districts). Dissemination of improved firewood stoves at subsidized prices.	Subsidized sales	Firewood, inefficient stoves
GS 6212	Promoting Clean Cooking Solutions – Nepal	Value Network Venture Advisory Services Pte. Ltd.	GOLD	Standalone	AMS-II.G. v9	Nepal (8 districts in Terai). ICS distributed free; costs recovered via carbon revenue.	Free distribution + carbon finance	Firewood, inefficient stoves
GS 2758	Proyecto Mirador – Honduras	Proyecto Mirador	GOLD	PoA 1988	GS TPDDTEC v2	Honduras. Locally built Dos por Tres chimney stoves replace fogón cookstoves.	Local training and installation workforce	Fogón (open biomass)
GS 5642	Burn Stoves Project in Kenya	ECOA Climate Capital	GOLD	Standalone	GS TPDDTEC v2	Kenya. Develops retail networks for locally appropriate ICS.	Market-based distribution model	Firewood, charcoal, LPG
GS 1146	Expanding LPG Access in Burkina Faso via Microfranchises	Entrepreneurs du Monde	GOLD	PoA	GS TPDDTEC v3.1	Burkina Faso (Kadiogo Province). Nafa Naana social micro-franchise distributes improved charcoal, wood, and LPG stoves.	Microfranchised distribution	Wood, charcoal, inefficient stoves
GS 11330	Circle Gas LPG Smart Meter Program	Climate Impact Partners Limited	GOLD	PoA	GS TPDDTEC v3.1	Kenya. Nationwide distribution of LPG cookstoves with smart meters to monitor usage.	Metered LPG stove distribution	Wood, charcoal, kerosene
GS 7578	Garner Mozambique – Bioethanol Cookstoves CPA1	Garner Advisors LLC	GOLD	PoA 7577	AMS-I.E. v10	Mozambique (Maputo and Matola). Ethanol stoves distributed in urban/peri-urban areas.	Ethanol stove distribution	Biomass (charcoal, wood)
GS 1028	Efficient Cookstoves in Bahia II – Santo Amaro	Instituto Perene	GOLD	Standalone	GS MS Simplified Methodology v1	Brazil (Bahia – rural areas of Recôncavo). ICS built with local materials to replace wood combustion in traditional stoves.	Local stove construction	Wood
GS 3071	Micro Energy PoA – VPA 2 West Cameroon	QK TS Pvt. Ltd.	GOLD	PoA 1366	GS TPDDTEC v1	Cameroon (Western Region – 8 departments). ICS built with local materials to replace three-stone fires.	Local stove construction	Three-stone fires
GS 10777	Efficient Cookstoves – Urban Maputo, Mozambique (VPA 22)	Carbonsink Group S.r.I.	GOLD	PoA 5658	GS TPDDTEC v3.1	Mozambique (Maputo and Matola). Distributed door-to-door to replace charcoal stoves.	Direct sales	Charcoal, traditional stoves
GS 10886	African ICS Programme – Zambia (Peace Parks and Simalaha VPA01)	Commonland B.V.	GOLD	PoA 10874	GS TPDDTEC v3.1	Zambia (Simalaha region; national scope). ICS distributed by BURN Manufacturing.	Commercial ICS distribution	Traditional biomass stoves

Project ID	Project Name	Developer	Voluntary Registry	VPA/PoA	Methodology	Country/Context/Scope	Implementation Model	Pre-Project Fuel/Technology
GS 5107	Qori Q'oncha ICS Programme – Peru (VPA 5)	Livelihoods Fund SICAV SIF	GOLD	PoA 1005	GS TPDDTEC v2	Peru (Huancavelica and Ayacucho). ICS installed and users trained.	Installation + education	Wood
GS 11195	BioLite HomeStove in Kenya (CPA 041)	BioLite, Inc.	GOLD	PoA 11191	AMS-II.G. v3	Kenya (national). Distribution of improved cookstoves replacing biomass in traditional models.	Retail distribution	Biomass
VCS 2077	Tuik Ruch Lew ICS Project – Lake Atitlan, Guatemala	Asociacion Tuik Ruch Lew	VCS	Standalone	AMS-II.G. v11.1	Guatemala (Lake Atitlan region – Tz'utujil Maya). NGO subsidizes stove cost and provides education and maintenance.	NGO-based distribution, training	Open fires
GS 411	Efficient Fuel Wood Stoves for Nigeria	Atsmosfair gGmbH	GOLD	Standalone	AMS-II.G. v1	Nigeria (Savannah Zone: 10 states including FCT). Program subsidizes heat retention cookers for households using traditional fires.	Subsidized sales	Inefficient wood fires
GS 10914	UpEnergy ICS Programme – Uganda	UpEnergy Group	GOLD	PoA 10898	AMS-II.G. v12	Uganda (national). Project focuses on marketing, awareness, and distribution of ICS for low-income households.	Marketing + distribution	Biomass, traditional stoves
GS 10781	ICS in Burkina Faso – VPA-17 (tiipaalga F3PA, Nahouri)	Tipaalga	GOLD	PoA 1340	GS MS Simplified Methodology v1	Burkina Faso (Nahouri). Rural women trained to build, maintain, and use ICS with local materials. Training includes climate and hygiene education.	Local women-led construction	Open fires
GS 5660	Myanmar Stoves Campaign – Soneva in Myanmar – VPA No. 004	QK TS Pvt. Ltd.	GOLD	PoA 1729	GS MS Simplified Methodology v1	Myanmar. Households purchase stoves through lump sum (15,000 MMK) or 5-month installment (17,000 MMK).	Retail sales with payment options	Firewood, inefficient burning

3. Understanding fuel consumption adjustments

There is no replicable procedure for understanding the fuel consumption adjustments made by GKH. Changes can be inferred, with some irregularity, by comparing two excel files in the replication archive:

- 'Raw' fuel consumption was obtained from "9_27_23_python_inputs_project_recreation_gillwiehl_et_al.xlsx".
- 'Adjusted' fuel consumption was obtained from "9_27_23_python_inputs_charc_firewood_baseline_adjusted_gillwiehl_et_al.xlsx"

In an excel file in the replication archive, we found the following table which we reproduce unaltered.

Table S7. Fuel adjustments made by GKH, with reported justifications.

Protocol ID	Adjustment Explanation
GS10974	This project has a low baseline; therefore, we adjusted the baseline up and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
VCS1216	This project has a high baseline; therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
GS2094	This project has a high baseline; Therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
VCS1719	This project has a low project consumption; therefore, we adjusted the project consumption up to be within the range.
VCS1721	This project has a high baseline; therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
GS7312	In the 2020 crediting period, the project has both a high baseline and a low project consumption. Therefore, we both adjust the baseline down and the project consumption up to be within the 2-4MJ/capita/day range. In the 2021 crediting period, the project has a low project consumption. When we adjust it up to 2MJ/capita/day, it is larger than the reported baseline. Therefore, we adjust the project consumption up, and then add the original differential that the project reported to that adjusted project consumption to obtain the baseline consumption.
GS500	This project has a low baseline; therefore, we adjust the baseline up to within the range.
GS10884	This project has a low project consumption; therefore, we adjust the project consumption up to within the range.

GS447	This project frames it as biomass savings and combined domestic and commercial values to obtain that biomass saved. We do not adjust commercial consumption and we refered back to their excel "GS 447 Round II Submission" to ensure that their kg/capita/day was within the range of ~2-4MJ/capita/day. Therefore, no adjustment was made.
GS2564	Not adjusted; the project's baseline and project includes multiple fuels and in total does not exceed 4MJ/capita/day.
GS7438	This project has a high baseline and a low project consumption value; therefore, we adjust the baseline down and the project consumption value up to stay in the range. For charcoal, the project has a low project consumption. When we adjust it up to 2MJ/capita/day, it is larger than the reported baseline. Therefore, we adjust the project consumption up, and then add the original differential that the project reported to that adjusted project consumption to obtain the baseline consumption.
GS913	This project has a high baseline and a low project consumption value; therefore, we adjust the baseline up and the project consumption value up to stay in the range.
GS6212	This project has a high baseline; therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
GS2758	This project has a high baseline; therefore, we adjusted the baseline down.
GS3112	The project has a low project consumption. When we adjust it up to 2MJ/capita/day, it is larger than the reported baseline. Therefore, we adjust the project consumption up, and then add the original differential that the project reported to that adjusted project consumption to obtain the baseline consumption.
GS5642	For the first crediting period, the project has a low project consumption value; therefore, we adjust this value up. For the second crediting period, we adjust the fireword down to keep the 2-4 MJ/capita/day total in the project scenario.
GS1060	The project has a low project consumption. When we adjust it up to 2MJ/capita/day, it is larger than the reported baseline. Therefore, we adjust the project consumption up, and then add the original differential that the

	project reported to that adjusted project consumption to obtain the baseline consumption.
GS2744	Not adjusted
GS1094	This project has a high baseline; therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
GS4291	This project has a high baseline; therefore, we adjusted the baseline down and then we utilized the stove's efficiency to find the project consumption from subtracting baseline savings (from the water boil test efficiency).This is the same approach that the protocol implements.
GS6604	The project has a low project consumption. So we adjust the project consumption up to be within the range.
GS1267	This project has a high baseline and a low project consumption value; therefore, we adjust the baseline up and the project consumption value up to stay in the range.
GS2439	This project has a high baseline; therefore, we adjusted the baseline down.
GS2445	This project has a high baseline; therefore, we adjusted the baseline down.
GS7578	Not adjusted
GS2513	Not adjusted
GS4677	This project has a high baseline; therefore, we adjusted the baseline down.
GS2441	This project has a high baseline; therefore, we adjusted the baseline down.
GS5003	Scaled back project charcoal as total baseline and project consumption was over 4MJ/capita/day across firewood and charcoal. Therefore, we took a combination of firewood and charcoal based on the KPT ratio that would have

	the combination stay under the range, then subtracted the charcoal savings from that new baseline value for the project scenario.
GS6129	This project has a high baseline and a low project consumption value; therefore, we adjust the baseline up and the project consumption value up to stay in the range.
GS407	The project has a low project consumption. We thus adjust it up to 2MJ/capita/day. We do not adjust the commercial stoves.
GS11509	This project has a low project consumption; therefore, we adjust the project consumption up to within the range.
GS11352	This project has a low project consumption; therefore, we adjust the project consumption up to within the range.
GS11507	This project has a low project consumption; therefore, we adjust the project consumption up to within the range.
GS1146	In the exclusive LPG scenario, the project has a low project consumption value, so we adjust it up to stay within the range. The other scenarios are already within the range. We do not adjust the commercial scenario.
GS 11330	This project has a low project consumption; therefore, we adjust the project consumption up to within the range.
GS 3071	This project has a high baseline; therefore, we adjusted the baseline down.
GS 10777	This project has a high baseline; therefore, we adjusted the baseline down.
GS 10886	This project has a high baseline; therefore, we adjusted the baseline down.
GS 5107	This project has a high baseline; therefore, we adjusted the baseline down.
GS 11195	This project has a high baseline; therefore, we adjusted the baseline down.
GS 2077	This project has a high baseline; therefore, we adjusted the baseline down.

GS 411	This project has a high baseline; therefore, we adjusted the baseline down.
GS 10914	This project has a high baseline; therefore, we adjusted the baseline down.
GS 10781	This project has a high baseline; therefore, we adjusted the baseline down.
GS 5660	This project has a high baseline; therefore, we adjusted the baseline down.

Some projects that were noted as not having been changed, appear to have different fuel consumption values between what we interpreted as the ‘raw’ fuel consumption and the ‘adjusted’ fuel consumption.

4. Supplemental results

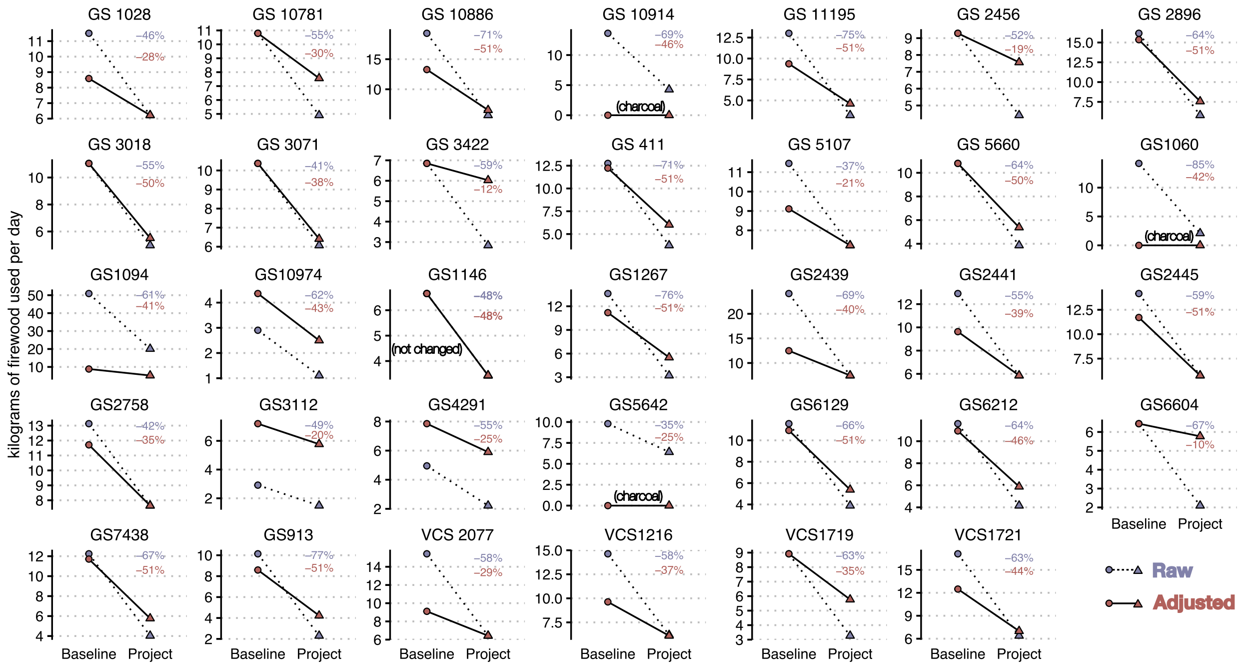

Fig S1. Placing bounds on 'reasonable' energy use systematically reduced apparent fuel savings in cookstove projects.

Baseline and project fuel consumption estimates in kilograms of firewood used per day are shown from improved firewood cookstove projects. Adjustments were made by GKH so that both baseline and project fuel consumption estimates fit within a 'reasonable' range of energy consumption of 2-4 MJ/capita/day. In large part, baseline fuel consumption was lowered and project fuel consumption, when changed, was increased. Consequently, implied fuel consumption reductions were reduced. Purple annotations are raw (unadjusted) estimates of declines in fuel consumption due to project stoves and red are estimated fuel consumption declines following GKH's adjustments.

Table S8. Estimated overcrediting under all alternative assumptions

#	Model description	Sample overcrediting[a] (x higher; 95% CI)	Project overcrediting (Median [IQR])
	Replication and Basic Corrections Confirmation of overcrediting and accounting errors without altering basic assumptions.		
1	**Replication:** Confirmation that we can reproduce original findings	9.24 (6.92-11.57)	16.15 (7.96-31.45)
2	**Credit accounting fix**: Corrects error in total credits for project GS3112	9.30 (6.99-11.60)	16.15 (7.96-31.45)
3	**Rebound correction**: Proposes more appropriate calculation of rebound on energy efficiency gains as opposed to *ex post* penalty on credits + Model 2	9.83 (7.38-12.28)	18.79 (8.25-31.54)
4	**Partial stacking discount**: Applies a 50% discount (vs. 100%) for meals cooked with both stoves + Models 2-3	9.27 (6.82-11.73)	11.80 (7.46-26.37)
	Implementation-Linked Parameters Replaces behavioral and engineering assumptions under project control with evidence-based values.		
5	**Lower rebound**: Applies a 10% rebound effect instead of original 22% + Models 2-4	8.73 (6.36-11.09)	10.23 (7.05-21.70)
6	**New adoption, stacking, and usage estimates:** Based on systematic literature search + Models 2-4	6.73 (4.80-8.66)	7.27 (5.05-16.98)
7	**No ex-post Hawthorne discount on measured protocols:** Omit GKH's *ex post* haircut to KPT-derived emissions reductions + Models 2–4	5.39 (3.92-6.86)	6.76 (4.20-15.39)
8	**Alternative fuel adjustment (with established adjusted baseline fuel consumption)**: Retains estimated energy efficiency gains from project stoves while bounding to adjusted total energy delivered per day per person + Models 2-4	6.20 (4.38-8.01)	7.27 (4.52-16.94)
9	**Alternative fuel adjustment (with established adjusted project fuel consumption)**: Retains estimated energy efficiency gains from project stoves while bounding to adjusted total energy delivered per day per person + Models 2-4	5.88 (4.18-7.57)	7.27 (4.52-17.00)
10	**Joint implementation of models 2-6**	6.27 (4.43-8.10)	6.79 (4.71-14.04)
11	**Joint implementation of models 2-6 + 7**	5.05 (3.64-6.46)	6.13 (3.64-12.98)
12	**Joint implementation of models 2-6 + 7 + 8**	4.70 (3.35-6.05)	5.86 (3.43-12.99)
13	**Joint implementation of models 2-6 + 7 + 9**	4.49 (3.20-5.77)	5.86 (3.43-12.99)
	State-of-Science Parameters Isolation of physical-science inputs outside immediate project control		
14	**Assume fNRB = 30%**: Removes penalties related to non-renewable biomass estimation and isolates factors under project control[c] + Models 2-4	3.13 (2.16-4.10)	3.21 (1.99-5.45)
	Joint Scenarios Combines implementation-linked and state-of-science adjustments to assess cumulative effects.		
15	**Joint implementation of models 12 + 14[c]**	2.13 (1.50-2.76)	2.57 (1.45-4.32)
16	**Joint implementation of models 13 + 14[c]**	2.01 (1.43-2.59)	2.57 (1.45-4.32)

[a] "Estimated Overcrediting" refers to the factor by which credits may have been overstated. For example, a factor of 9.24 suggests credits were overcounted by more than 9x.

[b] Median project-specific overcrediting and interquartile range. Differs from total sector wide overcrediting, which considers the size of the project as well as project specific overcrediting.

[c] Compares against project-reported emissions had they also reported 30% fNRB.

Table S9. Project and period protocol specific overcrediting observed across various model specifications in this study.

protocol_id	protocl type	monitoring_period	stove_year_cohort	total verified credits	credits per stove_year_cohort	Replication	New adoption, usage, and stacking	Models 2-6 + 9	Models 2-6 + 7 + 9	fNRB = 30%	Model 11b + Measured
GS10974	CDM AMS II G	2	domestic	69556	16258.34792	25.50 (-1248.48-1299.49)	2.17 (2.16-2.18)	1.88 (1.87-1.89)	1.87 (1.86-1.88)	0.96 (0.95-0.96)	0.83 (0.83-0.84)
GS10974	CDM AMS II G	2	commercial	69556	8463.65208	1.48 (1.47-1.48)	1.48 (1.48-1.48)	1.28 (1.28-1.28)	1.28 (1.28-1.28)	0.65 (0.65-0.65)	0.57 (0.57-0.57)
GS10974	CDM AMS II G	3	domestic	69556	29387.01516	25.30 (-1149.87-1200.48)	2.15 (2.14-2.16)	1.86 (1.85-1.87)	1.85 (1.84-1.86)	0.95 (0.94-0.95)	0.82 (0.82-0.83)
GS10974	CDM AMS II G	3	commercial	69556	8294.984842	1.48 (1.48-1.48)	1.48 (1.48-1.48)	1.28 (1.28-1.28)	1.28 (1.28-1.28)	0.65 (0.65-0.65)	0.57 (0.57-0.57)
VCS1216	CDM AMS II G	2019	2010	414109	5212.980379	41.22 (39.87-42.57)	13.33 (12.62-14.04)	11.51 (10.91-12.11)	11.53 (10.91-12.16)	3.75 (3.57-3.94)	3.25 (3.09-3.41)
VCS1216	CDM AMS II G	2020	2010	414109	5178.908612	41.37 (40.03-42.71)	13.31 (12.61-14.02)	11.59 (11.00-12.19)	11.55 (10.92-12.18)	3.75 (3.57-3.94)	3.25 (3.09-3.41)
VCS1216	CDM AMS II G	2019	2011	414109	10233.20708	41.08 (39.74-42.42)	13.27 (12.61-13.93)	11.50 (10.92-12.09)	11.50 (10.93-12.08)	3.73 (3.55-3.92)	3.24 (3.08-3.39)
VCS1216	CDM AMS II G	2020	2011	414109	10166.32337	41.06 (39.69-42.42)	13.24 (12.52-13.95)	11.47 (10.89-12.05)	11.49 (10.87-12.11)	3.73 (3.55-3.92)	3.24 (3.08-3.39)
VCS1216	CDM AMS II G	2019	2013	414109	4627.157386	41.41 (40.03-42.78)	13.40 (12.75-14.06)	11.63 (11.00-12.25)	11.58 (10.97-12.18)	3.77 (3.59-3.96)	3.27 (3.11-3.43)
VCS1216	CDM AMS II G	2020	2013	414109	4596.914527	41.47 (40.10-42.85)	13.39 (12.70-14.07)	11.59 (10.99-12.19)	11.59 (10.96-12.23)	3.77 (3.59-3.96)	3.27 (3.11-3.43)
VCS1216	CDM AMS II G	2019	2014	414109	7115.233169	40.89 (39.56-42.23)	13.15 (12.46-13.85)	11.44 (10.88-12.00)	11.43 (10.83-12.03)	3.71 (3.53-3.89)	3.22 (3.06-3.37)
VCS1216	CDM AMS II G	2020	2014	414109	7068.728378	40.79 (39.46-42.12)	13.14 (12.50-13.79)	11.42 (10.85-11.99)	11.40 (10.84-11.96)	3.71 (3.53-3.89)	3.22 (3.06-3.37)
VCS1216	CDM AMS II G	2019	2015	414109	4872.054036	41.22 (39.87-42.57)	13.29 (12.59-13.98)	11.49 (10.92-12.07)	11.50 (10.90-12.11)	3.74 (3.56-3.93)	3.24 (3.09-3.40)
VCS1216	CDM AMS II G	2020	2015	414109	4840.210546	41.24 (39.83-42.66)	13.32 (12.64-14.00)	11.48 (10.88-12.09)	11.53 (10.93-12.13)	3.74 (3.56-3.93)	3.24 (3.09-3.40)
VCS1216	CDM AMS II G	2019	2016	414109	5272.579404	41.60 (40.20-43.00)	13.44 (12.72-14.16)	11.64 (11.04-12.24)	11.65 (11.06-12.23)	3.79 (3.60-3.97)	3.28 (3.12-3.44)
VCS1216	CDM AMS II G	2020	2016	414109	5238.118101	41.68 (40.31-43.04)	13.49 (12.76-14.22)	11.67 (11.07-12.26)	11.64 (11.00-12.28)	3.79 (3.60-3.97)	3.28 (3.12-3.44)
VCS1216	CDM AMS II G	2017	2010	414109	2671.794166	25.72 (24.87-26.57)	8.26 (7.85-8.67)	7.18 (6.83-7.53)	7.18 (6.82-7.53)	2.33 (2.22-2.45)	2.02 (1.92-2.12)
VCS1216	CDM AMS II G	2018	2010	414109	3702.093877	25.64 (24.80-26.48)	8.28 (7.86-8.69)	7.19 (6.84-7.55)	7.16 (6.80-7.53)	2.33 (2.22-2.45)	2.02 (1.92-2.12)
VCS1216	CDM AMS II G	2017	2011	414109	5160.025768	26.21 (25.37-27.05)	8.43 (7.99-8.88)	7.35 (6.96-7.75)	7.31 (6.94-7.68)	2.38 (2.26-2.50)	2.06 (1.96-2.16)
VCS1216	CDM AMS II G	2018	2011	414109	7149.839626	26.19 (25.29-27.08)	8.48 (8.06-8.90)	7.34 (6.96-7.72)	7.34 (6.97-7.71)	2.38 (2.26-2.50)	2.06 (1.96-2.16)
VCS1216	CDM AMS II G	2017	2013	414109	2392.363284	25.46 (24.63-26.30)	8.18 (7.78-8.59)	7.11 (6.75-7.46)	7.12 (6.76-7.47)	2.31 (2.20-2.42)	2.00 (1.91-2.10)
VCS1216	CDM AMS II G	2018	2013	414109	3314.908602	25.39 (24.57-26.21)	8.23 (7.80-8.66)	7.12 (6.76-7.47)	7.14 (6.76-7.52)	2.31 (2.20-2.42)	2.00 (1.91-2.10)
VCS1216	CDM AMS II G	2017	2014	414109	3642.279386	25.35 (24.50-26.19)	8.19 (7.77-8.61)	7.08 (6.73-7.43)	7.07 (6.71-7.44)	2.30 (2.19-2.42)	2.00 (1.90-2.09)
VCS1216	CDM AMS II G	2018	2014	414109	5046.818496	25.28 (24.46-26.11)	8.17 (7.75-8.59)	7.08 (6.73-7.42)	7.09 (6.75-7.43)	2.30 (2.19-2.42)	2.00 (1.90-2.09)
VCS1216	CDM AMS II G	2017	2015	414109	2510.703435	25.30 (24.49-26.10)	8.16 (7.74-8.58)	7.08 (6.73-7.43)	7.07 (6.71-7.43)	2.30 (2.19-2.42)	2.00 (1.90-2.09)

VCS1216	CDM AMS II G	2018	2015	414109	3478.88319	25.30 (24.44-26.16)	8.16 (7.71-8.61)	7.09 (6.72-7.46)	7.09 (6.74-7.43)	2.30 (2.19-2.42)	2.00 (1.90-2.09)
VCS1216	CDM AMS II G	2017	2016	414109	2825.59913	24.23 (23.37-25.08)	7.81 (7.41-8.21)	6.77 (6.43-7.10)	6.74 (6.38-7.11)	2.20 (2.09-2.30)	1.90 (1.81-2.00)
VCS1216	CDM AMS II G	2018	2016	414109	3915.209251	24.28 (23.44-25.13)	7.81 (7.42-8.21)	6.74 (6.38-7.10)	6.76 (6.42-7.10)	2.20 (2.09-2.30)	1.90 (1.81-2.00)
GS2094	CDM AMS II G	2020	2015	1932086	9826.95461	17.79 (17.23-18.34)	5.74 (5.46-6.02)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.06 (1.96-2.16)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2015	1932086	19735.12372	17.79 (17.23-18.35)	5.74 (5.46-6.02)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.06 (1.96-2.16)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2020	2016	1932086	19232.47215	18.34 (17.77-18.91)	5.92 (5.63-6.21)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.12 (2.02-2.23)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2016	1932086	38623.89034	18.33 (17.76-18.90)	5.92 (5.63-6.21)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.12 (2.02-2.23)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2020	2017	1932086	17657.08796	18.73 (18.14-19.32)	6.05 (5.75-6.34)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.17 (2.06-2.28)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2017	1932086	35460.10227	18.72 (18.13-19.31)	6.05 (5.75-6.34)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.17 (2.06-2.28)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2020	2018	1932086	16997.79348	20.22 (19.58-20.85)	6.52 (6.20-6.84)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.34 (2.23-2.46)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2018	1932086	34136.06459	20.22 (19.58-20.85)	6.52 (6.21-6.84)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.34 (2.23-2.46)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2020	2019	1932086	44354.89968	22.10 (21.41-22.80)	7.13 (6.78-7.48)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.56 (2.43-2.69)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2019	1932086	89076.36877	22.10 (21.41-22.79)	7.13 (6.78-7.48)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	2.56 (2.43-2.69)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2020	2020	1932086	38026.45974	27.41 (26.55-28.27)	8.85 (8.41-9.29)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	3.18 (3.02-3.33)	0.70 (0.67-0.74)
GS2094	CDM AMS II G	2021	2020	1932086	76367.18774	27.42 (26.56-28.28)	8.85 (8.42-9.28)	1.96 (1.87-2.06)	1.96 (1.87-2.06)	3.18 (3.02-3.33)	0.70 (0.67-0.74)
VCS1719	CDM AMS II G	2016/2017	NA	6761	6631.44026	23.20 (22.47-23.93)	7.48 (7.11-7.85)	6.49 (6.16-6.81)	6.48 (6.16-6.81)	3.01 (2.86-3.15)	2.61 (2.48-2.73)
VCS1721	CDM AMS II G	2016/2018	NA	508680	37509	21.93 (21.24-22.62)	7.08 (6.73-7.42)	6.14 (5.83-6.44)	6.13 (5.83-6.43)	2.53 (2.41-2.65)	2.19 (2.08-2.30)
GS7312	GS TPDDTEC	3	2020	3045660	919166.4918	7.83 (7.79-7.88)	8.41 (8.22-8.59)	7.29 (7.12-7.45)	5.35 (5.24-5.46)	4.95 (4.85-5.06)	3.16 (3.10-3.23)
GS7312	GS TPDDTEC	3	2021	3045660	166356.558	7.81 (7.76-7.86)	8.36 (8.17-8.54)	7.26 (7.09-7.42)	5.35 (5.24-5.46)	4.95 (4.84-5.06)	3.16 (3.10-3.23)
GS500	GS TPDDTEC	8th	NA	329887	46709	34.92 (34.62-35.23)	104.09 (-22.26-230.45)	43.87 (41.90-45.83)	32.13 (31.19-33.06)	29.35 (28.65-30.05)	13.71 (13.43-13.99)
GS10884	CDM AMS I E	PDD	domestic	167182	135509.5206	3.29 (3.26-3.32)	2.28 (2.17-2.39)	2.20 (2.09-2.31)	2.20 (2.09-2.31)	1.33 (1.26-1.39)	1.25 (1.19-1.31)
GS10884	CDM AMS I E	PDD	commercial	167182	21548.16573	0.97 (0.96-0.97)	0.81 (0.80-0.81)	0.78 (0.78-0.78)	0.78 (0.78-0.78)	0.47 (0.47-0.47)	0.44 (0.44-0.44)
GS447	GS TPDDTEC	2020	NA	7506609	266312	8.06 (8.01-8.11)	6.77 (6.62-6.92)	6.77 (6.60-6.94)	4.97 (4.86-5.07)	4.91 (4.80-5.02)	3.60 (3.52-3.67)
GS447	GS TPDDTEC	2021	NA	7506609	157844	8.14 (8.09-8.19)	6.86 (6.71-7.01)	6.85 (6.70-7.00)	5.03 (4.92-5.13)	4.96 (4.85-5.07)	3.64 (3.57-3.72)
GS2564	GS TPDDTEC	2019/2021	NA	124931	99774	11.14 (11.08-11.21)	9.80 (9.56-10.04)	9.55 (9.34-9.77)	6.18 (6.05-6.31)	5.38 (5.25-5.51)	3.35 (3.28-3.42)
GS7438	GS TPDDTEC	2019	NA	103512	32837.24205	4.71 (4.68-4.73)	5.08 (4.96-5.20)	4.39 (4.29-4.49)	3.22 (3.16-3.29)	4.19 (4.09-4.28)	2.67 (2.62-2.73)
GS7438	GS TPDDTEC	2019	NA	103512	70289.4315	42.47 (42.21-42.72)	45.72 (44.68-46.77)	39.37 (38.48-40.26)	29.10 (28.50-29.70)	27.32 (26.74-27.89)	17.43 (17.07-17.79)
GS913	CDM AMS II G	9	domestic	229704	25316	19.46 (18.85-20.07)	6.29 (5.98-6.59)	5.45 (5.19-5.71)	5.44 (5.17-5.71)	2.59 (2.47-2.72)	2.25 (2.14-2.36)
GS6212	CDM AMS II G	5	domestic	143692	19872	12.03 (11.65-12.41)	3.88 (3.69-4.07)	3.36 (3.20-3.53)	3.36 (3.20-3.53)	1.98 (1.88-2.07)	1.71 (1.63-1.80)

GS6212	CDM AMS II G	2	domestic	143692	34135	13.37 (12.95-13.79)	4.32 (4.10-4.53)	3.74 (3.56-3.92)	3.74 (3.56-3.92)	2.20 (2.09-2.30)	1.90 (1.81-2.00)
GS2758	GS TPDDTEC	Dec 2015-Nov 2016	domestic	2119324	279029.12	7.63 (-38.97-54.23)	3.56 (3.54-3.58)	3.08 (3.07-3.10)	3.10 (3.08-3.11)	3.03 (3.01-3.05)	2.63 (2.61-2.64)
GS2758	GS TPDDTEC	Dec 2016-Nov 2017	domestic	2119324	312520	7.70 (-32.58-47.97)	3.58 (3.56-3.60)	3.11 (3.09-3.13)	3.11 (3.09-3.12)	3.05 (3.03-3.06)	2.64 (2.62-2.65)
GS2758	GS TPDDTEC	Dec 2017-Nov 2018	domestic	2119324	311998	7.80 (-40.56-56.16)	3.64 (3.62-3.66)	3.14 (3.13-3.16)	3.15 (3.13-3.16)	3.00 (2.99-3.02)	2.61 (2.59-2.62)
GS2758	GS TPDDTEC	Dec 2018-Nov 2019	domestic	2119324	282475	8.43 (-47.23-64.10)	3.93 (3.91-3.95)	3.40 (3.38-3.42)	3.40 (3.38-3.42)	3.38 (3.37-3.40)	2.93 (2.92-2.95)
GS2758	GS TPDDTEC	Dec 2019-Nov 2020	domestic	2119324	269044	8.41 (-34.79-51.60)	3.93 (3.91-3.95)	3.41 (3.39-3.42)	3.42 (3.40-3.44)	3.40 (3.38-3.42)	2.96 (2.95-2.98)
GS2758	GS TPDDTEC	Dec 2020-Nov 2021	domestic	2119324	277430	8.47 (-31.59-48.53)	3.96 (3.93-3.98)	3.43 (3.41-3.45)	3.42 (3.41-3.44)	3.42 (3.40-3.44)	2.96 (2.94-2.98)
GS3112	GS Simplified	1	1-2 years	312478	36049.30979	18.56 (17.98-19.15)	5.99 (5.69-6.29)	5.19 (4.94-5.45)	5.19 (4.94-5.44)	4.70 (4.47-4.93)	4.07 (3.87-4.27)
GS3112	GS Simplified	1	2-3 years	312478	92361.75333	18.13 (17.56-18.70)	5.85 (5.56-6.13)	5.07 (4.82-5.31)	5.07 (4.82-5.31)	4.58 (4.36-4.81)	3.97 (3.78-4.17)
GS3112	GS Simplified	2	2-3 years	312478	60498.1326	18.10 (17.53-18.67)	5.85 (5.56-6.13)	5.07 (4.82-5.31)	5.06 (4.81-5.31)	4.58 (4.36-4.81)	3.97 (3.78-4.16)
GS3112	GS Simplified	2	3-4 years	312478	123838.8886	17.80 (17.25-18.36)	5.75 (5.47-6.03)	4.98 (4.73-5.23)	4.98 (4.74-5.22)	4.50 (4.28-4.73)	3.90 (3.71-4.10)
GS5642	GS TPDDTEC	26/04/2017 to 30/09/2018	domestic	2057512	435613	3.23 (3.21-3.25)	3.48 (3.40-3.56)	3.03 (2.95-3.10)	2.22 (2.17-2.26)	1.40 (1.37-1.42)	0.89 (0.87-0.91)
GS5642	GS TPDDTEC	01/06/2020 to 31/03/2022	domestic	2057512	1535469	19.63 (19.51-19.74)	8.02 (7.84-8.19)	11.13 (10.88-11.39)	8.19 (8.02-8.36)	1.89 (1.85-1.94)	1.72 (1.69-1.76)
GS1060	CDM AMS II G	MP9	scenario 1	249400	6234	19.87 (19.25-20.49)	6.41 (6.10-6.73)	5.56 (5.29-5.83)	5.56 (5.29-5.83)	2.39 (2.27-2.51)	2.07 (1.97-2.17)
GS1060	CDM AMS II G	MP9	scenario 2	249400	3866	21.02 (20.36-21.68)	6.78 (6.45-7.12)	5.88 (5.59-6.17)	5.88 (5.59-6.17)	2.53 (2.40-2.65)	2.19 (2.08-2.30)
GS1060	CDM AMS II G	MP9	scenario 3	249400	7653	18.07 (17.50-18.63)	5.83 (5.55-6.12)	5.05 (4.81-5.30)	5.05 (4.81-5.30)	2.17 (2.07-2.28)	1.88 (1.79-1.97)
GS1060	CDM AMS II G	MP8	scenario 1	249400	6337	19.87 (19.25-20.49)	6.41 (6.10-6.73)	5.56 (5.29-5.83)	5.56 (5.29-5.83)	2.39 (2.27-2.51)	2.07 (1.97-2.17)
GS1060	CDM AMS II G	MP8	scenario 2	249400	3930	21.02 (20.36-21.68)	6.78 (6.45-7.11)	5.88 (5.59-6.17)	5.88 (5.59-6.16)	2.53 (2.40-2.65)	2.19 (2.08-2.30)
GS1060	CDM AMS II G	MP8	scenario 3	249400	7780	18.07 (17.50-18.64)	5.83 (5.55-6.12)	5.05 (4.81-5.30)	5.05 (4.81-5.30)	2.17 (2.07-2.28)	1.88 (1.79-1.97)
GS2744	CDM AMS II G	new CP	wassa large	33637	0.434	133.53 (129.13-137.92)	42.98 (40.74-45.22)	37.36 (35.42-39.31)	37.37 (35.52-39.22)	14.92 (14.19-15.65)	12.93 (12.30-13.56)
GS2744	CDM AMS II G	new CP	wassa super	38512	0.479	64.14 (61.96-66.33)	20.72 (19.70-21.74)	17.89 (16.98-18.80)	17.94 (17.05-18.82)	7.16 (6.81-7.51)	6.21 (5.90-6.51)
GS1094	CDM AMS II G	1	0	39067	4761	174.13 (168.65-179.60)	56.27 (53.48-59.05)	48.70 (46.27-51.13)	48.71 (46.27-51.15)	14.00 (13.31-14.68)	12.13 (11.54-12.72)
GS1094	CDM AMS II G	2	0	39067	4998	168.79 (163.49-174.09)	54.46 (51.81-57.10)	47.25 (44.94-49.56)	47.14 (44.80-49.48)	13.56 (12.90-14.22)	11.75 (11.18-12.33)

GS1094	CDM AMS II G	3	0	39067	5257	181.00 (175.33-186.67)	58.41 (55.56-61.27)	50.58 (48.11-53.05)	50.59 (48.02-53.16)	14.54 (13.83-15.25)	12.60 (11.98-13.21)
GS1094	CDM AMS II G	4	0	39067	4983	193.80 (187.78-199.83)	62.58 (59.51-65.64)	54.22 (51.58-56.85)	54.20 (51.53-56.87)	15.57 (14.81-16.34)	13.50 (12.84-14.16)
GS1094	CDM AMS II G	5	0	39067	9649	219.38 (212.34-226.41)	70.72 (67.22-74.21)	61.31 (58.30-64.32)	61.32 (58.32-64.32)	17.61 (16.75-18.47)	15.26 (14.52-16.01)
GS1094	CDM AMS II G	6	0	39067	9429	210.05 (203.43-216.67)	67.90 (64.61-71.19)	58.78 (55.90-61.66)	58.73 (55.86-61.60)	16.89 (16.06-17.72)	14.64 (13.92-15.35)
GS4291	CDM AMS II G	MR 3 - 2019	0	169804	13630	22.50 (21.80-23.21)	7.25 (6.89-7.61)	6.28 (5.97-6.60)	6.29 (5.97-6.61)	1.91 (1.81-2.00)	1.65 (1.57-1.73)
GS4291	CDM AMS II G	MR 3-2020	0	169804	12896	22.51 (21.79-23.23)	7.28 (6.92-7.65)	6.31 (6.00-6.62)	6.31 (5.99-6.63)	1.91 (1.82-2.00)	1.65 (1.57-1.74)
GS6604	CDM AMS II G		0	75317	33024	53.32 (51.62-55.02)	17.20 (16.35-18.05)	14.92 (14.20-15.64)	14.92 (14.17-15.66)	8.02 (7.63-8.42)	6.95 (6.61-7.29)
GS 2896	GS Simplified	1st MR 2019-2020	0	38512	31185	30.27 (29.26-31.27)	9.78 (9.28-10.28)	8.49 (8.06-8.93)	8.48 (8.06-8.90)	3.82 (3.63-4.00)	3.31 (3.15-3.47)
GS 3422	GS Simplified	5th MR 2020	0	45989	7180	53.18 (51.47-54.88)	17.17 (16.34-18.00)	14.90 (14.15-15.64)	14.89 (14.17-15.61)	11.81 (11.23-12.39)	10.24 (9.73-10.74)
GS 2456	GS Simplified	6th MR	AG 4-5	46382	2577	69.48 (67.29-71.66)	22.42 (21.32-23.51)	19.44 (18.49-20.38)	19.44 (18.48-20.39)	10.03 (9.54-10.52)	8.70 (8.27-9.12)
GS 2456	GS Simplified	6th MR	AG 3-4	46382	3217	83.18 (80.58-85.79)	26.84 (25.52-28.15)	23.27 (22.13-24.40)	23.27 (22.13-24.40)	12.01 (11.43-12.60)	10.41 (9.90-10.92)
GS 2456	GS Simplified	6th MR	AG 2-3	46382	522	91.68 (88.79-94.56)	29.59 (28.13-31.04)	25.63 (24.38-26.88)	25.64 (24.39-26.89)	13.24 (12.59-13.89)	11.48 (10.91-12.04)
GS 2456	GS Simplified	6th MR	AG 1-2	46382	11.7	99.14 (96.04-102.25)	31.99 (30.42-33.56)	27.73 (26.37-29.09)	27.72 (26.36-29.08)	14.32 (13.62-15.02)	12.41 (11.80-13.01)
GS 2456	GS Simplified	6th MR	AG 0-1	46382	2073	84.67 (82.01-87.34)	27.33 (25.99-28.68)	23.69 (22.54-24.84)	23.68 (22.53-24.84)	12.23 (11.63-12.83)	10.60 (10.08-11.12)
GS 1028	GS Simplified	2016	2016	29330	710	65.53 (63.39-67.68)	21.12 (20.07-22.17)	18.32 (17.39-19.24)	18.34 (17.44-19.24)	7.68 (7.30-8.05)	6.65 (6.33-6.98)
GS 1028	GS Simplified	2017	2017	29330	621	58.91 (57.03-60.79)	18.99 (18.05-19.92)	16.47 (15.66-17.28)	16.50 (15.68-17.31)	6.91 (6.57-7.25)	5.99 (5.70-6.28)
GS 1028	GS Simplified	2018	2018	29330	1615	58.12 (56.27-59.96)	18.78 (17.82-19.75)	16.25 (15.45-17.05)	16.23 (15.44-17.02)	6.80 (6.47-7.14)	5.90 (5.61-6.19)
GS 1028	GS Simplified	2019	2019	29330	4023	98.46 (95.30-101.61)	31.83 (30.29-33.38)	27.58 (26.24-28.92)	27.58 (26.17-28.98)	11.55 (10.99-12.12)	10.01 (9.52-10.50)
GS 1028	GS Simplified	2020	2020	29330	4354	29.80 (28.85-30.75)	9.60 (9.13-10.07)	8.33 (7.92-8.74)	8.34 (7.90-8.77)	3.49 (3.32-3.66)	3.02 (2.88-3.17)
GS 3018	GS Simplified	2nd MR 2015-2017	Age 1-2	27096	157	7.88 (7.63-8.12)	2.54 (2.42-2.67)	2.20 (2.10-2.31)	2.20 (2.10-2.31)	1.98 (1.89-2.08)	1.72 (1.64-1.80)
GS 3018	GS Simplified	2nd MR 2015-2017	Age 2-3	27096	4403	5.20 (5.04-5.36)	1.68 (1.60-1.76)	1.45 (1.38-1.53)	1.45 (1.38-1.53)	1.31 (1.25-1.37)	1.13 (1.08-1.19)
GS 3018	GS Simplified	2nd MR 2015-2017	Age 3-4	27096	3035	2.61 (2.53-2.69)	0.84 (0.80-0.88)	0.73 (0.69-0.77)	0.73 (0.69-0.77)	0.66 (0.63-0.69)	0.57 (0.54-0.60)
GS1267	GS TPDDTEC	1st	0	59891	6515	6.67 (6.63-6.71)	7.17 (7.01-7.34)	6.24 (6.10-6.38)	4.57 (4.48-4.67)	3.72 (3.63-3.80)	2.37 (2.32-2.42)
GS1267	GS TPDDTEC	2nd	0	59891	3527	6.48 (6.44-6.52)	7.00 (6.83-7.17)	6.04 (5.90-6.19)	4.44 (4.35-4.54)	3.61 (3.53-3.69)	2.30 (2.26-2.35)
GS1267	GS TPDDTEC	3rd	0	59891	26147	6.41 (6.38-6.45)	6.89 (6.75-7.03)	5.95 (5.83-6.08)	4.38 (4.29-4.47)	3.57 (3.48-3.66)	2.27 (2.22-2.32)
GS1267	GS TPDDTEC	4th	0	59891	11617	5.95 (5.92-5.99)	6.41 (6.26-6.56)	5.57 (5.44-5.69)	4.08 (3.99-4.16)	3.31 (3.23-3.39)	2.11 (2.07-2.16)
GS1267	GS TPDDTEC	5th	0	59891	10996	5.63 (5.60-5.67)	6.04 (5.91-6.17)	5.26 (5.14-5.37)	3.86 (3.78-3.94)	3.13 (3.06-3.20)	2.00 (1.96-2.04)
GS1267	GS TPDDTEC	6th	0	59891	3083	1.56 (1.55-1.57)	1.68 (1.64-1.72)	1.45 (1.42-1.49)	1.07 (1.05-1.09)	0.87 (0.85-0.89)	0.55 (0.54-0.57)

GS2439	GS TPDDTEC	1st 2012	ecocina	30313	172	10.17 (10.11-10.23)	10.93 (10.67-11.19)	9.51 (9.29-9.73)	6.97 (6.83-7.11)	6.51 (6.34-6.67)	4.15 (4.07-4.24)
GS2439	GS TPDDTEC	1st 2013	ecocina	30313	4754	9.99 (9.93-10.05)	10.73 (10.50-10.95)	9.32 (9.11-9.52)	6.85 (6.71-6.99)	6.40 (6.27-6.54)	4.08 (4.00-4.16)
GS2439	GS TPDDTEC	1st 2014	ecocina	30313	8973	10.17 (10.10-10.23)	10.91 (10.64-11.18)	9.47 (9.25-9.68)	6.96 (6.82-7.11)	6.49 (6.36-6.63)	4.15 (4.06-4.23)
GS2439	GS TPDDTEC	1st 2012	ecoplancha	30313	1443	8.26 (8.21-8.31)	8.89 (8.68-9.10)	7.69 (7.51-7.86)	5.65 (5.53-5.77)	5.28 (5.17-5.40)	3.36 (3.29-3.43)
GS2439	GS TPDDTEC	1st 2013	ecoplancha	30313	4775	8.14 (8.09-8.19)	8.80 (8.61-8.99)	7.59 (7.40-7.77)	5.58 (5.47-5.70)	5.24 (5.11-5.36)	3.32 (3.26-3.39)
GS2439	GS TPDDTEC	1st 2014	ecoplancha	30313	10196	8.65 (8.60-8.70)	9.34 (9.11-9.56)	8.09 (7.89-8.28)	5.94 (5.82-6.06)	5.55 (5.43-5.67)	3.54 (3.46-3.61)
GS2445	GS TPDDTEC	per stove per day in 1st MR	0	250634	0.007791435	6.55 (6.51-6.59)	7.05 (6.90-7.21)	6.14 (6.00-6.27)	2.85 (2.79-2.91)	4.59 (4.48-4.70)	1.85 (1.81-1.89)
GS7578	CDM AMS I E	PDD	0	356309	96658	7.53 (7.46-7.59)	4.89 (4.64-5.14)	4.89 (4.64-5.14)	4.90 (4.65-5.14)	1.43 (1.36-1.50)	1.43 (1.36-1.50)
GS2513	CDM AMS I E	PDD	0	174984	6.75	8.74 (8.66-8.81)	5.68 (5.39-5.96)	5.67 (5.38-5.95)	5.68 (5.40-5.96)	1.55 (1.48-1.63)	1.55 (1.48-1.63)
GS4677	CDM AMS I E	PDD	0	73181	4.2	3.47 (3.44-3.50)	2.26 (2.15-2.37)	2.26 (2.15-2.37)	2.26 (2.15-2.37)	1.24 (1.18-1.30)	1.24 (1.18-1.30)
GS2441	GS TPDDTEC	1st	Ecocina 2013	172720	314	9.20 (9.11-9.28)	9.98 (7.30-12.66)	8.51 (7.00-10.03)	6.07 (5.11-7.03)	3.04 (1.87-4.21)	1.86 (1.66-2.06)
GS2441	GS TPDDTEC	1st	Ecocina 2014	172720	578	9.47 (9.39-9.56)	10.24 (8.40-12.08)	8.81 (7.08-10.54)	6.36 (5.57-7.14)	3.17 (2.39-3.94)	1.98 (1.38-2.59)
GS2441	GS TPDDTEC	1st	Plancha 2011	172720	30	441.67 (438.26-445.07)	473.54 (461.54-485.53)	410.31 (401.04-419.59)	303.23 (296.68-309.78)	151.10 (147.74-154.45)	96.19 (94.21-98.18)
GS2441	GS TPDDTEC	1st	Plancha 2012	172720	2456	440.34 (437.01-443.67)	474.53 (462.52-486.54)	410.81 (401.68-419.93)	302.19 (295.42-308.95)	150.77 (147.38-154.16)	96.04 (94.06-98.02)
GS2441	GS TPDDTEC	1st	ONIL 2011	172720	51	24.16 (23.98-24.34)	25.89 (25.28-26.50)	22.36 (21.81-22.90)	16.53 (16.13-16.92)	8.26 (8.08-8.44)	5.25 (5.14-5.36)
GS2441	GS TPDDTEC	1st	ONIL 2012	172720	3564	24.00 (23.82-24.18)	25.91 (25.29-26.53)	22.52 (21.99-23.04)	16.51 (16.15-16.87)	8.23 (8.06-8.41)	5.25 (5.14-5.36)
GS2441	GS TPDDTEC	1st	ONIL 2013	172720	3823	24.02 (23.84-24.20)	25.98 (25.34-26.61)	22.39 (21.77-23.02)	16.53 (16.18-16.89)	8.25 (8.07-8.43)	5.25 (5.14-5.36)
GS2441	GS TPDDTEC	1st	ONIL 2013	172720	3729	24.07 (23.89-24.26)	25.84 (25.17-26.51)	22.45 (21.92-22.98)	16.52 (16.16-16.88)	8.24 (8.05-8.43)	5.25 (5.14-5.36)
GS5003	GS TPDDTEC	1st	SGF	165127	6.82	37.73 (37.50-37.95)	57.99 (56.59-59.39)	39.83 (38.86-40.79)	29.24 (28.64-29.84)	32.82 (32.08-33.55)	16.09 (15.76-16.43)
GS5003	GS TPDDTEC	1st	GF	165127	4.29	4.98 (4.95-5.01)	5.16 (5.04-5.29)	4.57 (4.46-4.67)	3.37 (3.30-3.43)	2.68 (2.62-2.73)	1.74 (1.71-1.78)
GS5003	GS TPDDTEC	1st	GF	165127	3.22	5.11 (5.08-5.14)	5.33 (5.21-5.44)	4.71 (4.60-4.82)	3.46 (3.38-3.53)	2.76 (2.69-2.82)	1.79 (1.75-1.83)
GS6129	GS Simplified	1st	0	25186	9090	76.07 (73.68-78.45)	24.54 (23.34-25.75)	21.27 (20.23-22.31)	21.27 (20.23-22.31)	5.49 (5.23-5.76)	4.76 (4.53-5.00)
GS6129	GS Simplified	2nd	0	25186	7997	67.68 (65.56-69.81)	21.85 (20.78-22.92)	18.93 (18.01-19.86)	18.94 (18.01-19.86)	4.89 (4.65-5.13)	4.24 (4.03-4.45)
GS6129	GS Simplified	3rd	0	25186	8099	68.53 (66.38-70.68)	22.12 (21.04-23.20)	19.17 (18.24-20.11)	19.17 (18.23-20.11)	4.95 (4.71-5.19)	4.29 (4.08-4.50)
GS407	GS TPDDTEC	2018	small domestic	5156577	86526.4424	10.10 (10.04-10.16)	10.85 (10.59-11.11)	9.39 (9.18-9.61)	6.91 (6.77-7.06)	3.23 (3.15-3.30)	2.05 (2.01-2.10)
GS407	GS TPDDTEC	2018	medium domestic	5156577	777114.0775	9.17 (9.12-9.22)	9.80 (9.58-10.03)	8.49 (8.29-8.69)	6.25 (6.12-6.37)	2.93 (2.86-2.99)	1.86 (1.82-1.89)
GS407	GS TPDDTEC	2018	commercial	5156577	107848.5298	0.64 (0.64-0.64)	0.82 (0.82-0.82)	0.71 (0.71-0.71)	0.71 (0.71-0.71)	0.24 (0.24-0.24)	0.21 (0.21-0.21)
GS407	GS TPDDTEC	2018	commercial	5156577	30269.03146	0.64 (0.64-0.64)	0.82 (0.82-0.82)	0.71 (0.71-0.71)	0.71 (0.71-0.71)	0.24 (0.24-0.24)	0.21 (0.21-0.21)

GS11509	GS Metered	PDD	0	8952	4.74	1.38 (1.38-1.38)	1.08 (1.08-1.08)	1.08 (1.08-1.08)	1.08 (1.08-1.08)	0.33 (0.33-0.33)	0.33 (0.33-0.33)
GS11352	GS Metered	PDD	0	4348	3.4	2.00 (2.00-2.00)	1.57 (1.57-1.57)	1.56 (1.56-1.56)	1.56 (1.56-1.56)	0.44 (0.44-0.44)	0.44 (0.44-0.44)
GS11507	GS Metered	PDD	0	9642	4.02	1.46 (1.46-1.46)	1.14 (1.14-1.14)	1.14 (1.14-1.14)	1.14 (1.14-1.14)	0.39 (0.39-0.39)	0.39 (0.39-0.39)
GS1146	GS TPDDTEC	MP4	monitoring firewood	30055	601.64	12.27 (0.86-23.67)	24.90 (-47.14-96.94)	13.98 (3.80-24.16)	9.73 (-5.10-24.55)	2.70 (2.64-2.76)	1.42 (1.39-1.45)
GS1146	GS TPDDTEC	MP4	monitoring charcoal	30055	6557.32	4.07 (4.04-4.09)	4.31 (4.22-4.40)	3.77 (3.68-3.86)	2.63 (2.57-2.68)	0.26 (0.25-0.26)	0.16 (0.16-0.16)
GS1146	GS TPDDTEC	MP4	monitoring LPG only	30055	4716.27	9.13 (9.04-9.22)	31.06 (-37.56-99.69)	11.61 (1.83-21.39)	8.12 (6.69-9.56)	4.42 (4.32-4.51)	2.01 (1.97-2.05)
GS1146	GS TPDDTEC	MP4	commercial	30055	60.77	7.70 (5.02-10.39)	18.40 (-12.31-49.11)	10.44 (5.09-15.78)	9.99 (4.28-15.71)	2.02 (2.02-2.02)	1.45 (1.45-1.45)
GS 11330	GS TPDDTEC	PDD	0	288563	0.0051	2.72 (2.70-2.73)	2.69 (2.62-2.76)	2.45 (2.39-2.50)	1.35 (1.33-1.38)	1.61 (1.58-1.65)	0.77 (0.76-0.79)
GS 3071	GS TPDDTEC	MP 1	small	2493	2493	3.17 (3.15-3.19)	3.41 (3.34-3.48)	2.98 (2.91-3.04)	2.18 (2.13-2.22)	2.27 (2.22-2.32)	1.45 (1.42-1.48)
GS 10777	GS TPDDTEC	MR 2023	small	4547	4563	11.77 (11.69-11.84)	12.59 (12.31-12.87)	10.96 (10.71-11.20)	6.27 (6.14-6.39)	4.33 (4.22-4.43)	2.16 (2.11-2.20)
GS 10886	GS TPDDTEC	MR1	small	78329	78329	11.52 (11.45-11.59)	12.37 (12.08-12.66)	10.77 (10.52-11.01)	7.90 (7.73-8.07)	6.15 (6.01-6.29)	3.92 (3.84-4.00)
GS 5107	GS TPDDTEC	MP2 2018-2019	small	203533	59827	18.64 (18.53-18.75)	20.10 (19.66-20.54)	17.39 (16.99-17.78)	12.78 (12.51-13.04)	4.11 (4.02-4.21)	2.62 (2.56-2.67)
GS 11195	CDM AMS II G	MR4	small	696	696	18.79 (18.19-19.39)	6.07 (5.77-6.37)	5.26 (5.00-5.51)	5.25 (4.99-5.51)	3.36 (3.19-3.52)	2.91 (2.77-3.05)
GS 2077	CDM AMS II G	MR 2018-2020	small	975	175	48.13 (46.62-49.65)	15.53 (14.77-16.29)	13.46 (12.80-14.12)	13.47 (12.81-14.13)	5.02 (4.77-5.27)	4.35 (4.14-4.56)
GS 411	CDM AMS II G	MR5	small	97297	3016	16.15 (15.65-16.66)	5.21 (4.96-5.47)	4.52 (4.29-4.74)	4.52 (4.30-4.74)	2.08 (1.98-2.18)	1.80 (1.71-1.89)
GS 10914	CDM AMS II G	MP2	small	61013	18752	8.59 (8.33-8.86)	2.77 (2.64-2.91)	2.40 (2.29-2.52)	2.40 (2.29-2.52)	1.19 (1.13-1.25)	1.03 (0.98-1.08)
GS 10781	GS Simplified	MP6	small	2344	2345	52.21 (50.55-53.88)	16.86 (16.04-17.68)	14.60 (13.90-15.30)	7.71 (7.33-8.08)	7.91 (7.52-8.29)	7.91 (7.52-8.29)
GS 5660	GS Simplified	MR1	small	3397	2771	68.44 (66.29-70.59)	22.09 (21.01-23.17)	19.15 (18.21-20.08)	4.46 (4.24-4.68)	4.29 (4.08-4.50)	4.29 (4.08-4.50)