Name of the enquirer:	Nathan Gachugi
Organization:	Burn Manufacturing
Affiliation:	Project Developer
Subject:	***Revisiting the Wood-to-Charcoal Conversion Factor (WCCF) and Direct Charcoal Emission Factors: A Science-Based Call for Accurate Carbon Accounting and Equitable Finance***
Contact Information:	nathan.gachugi@burnmfg.com
Date (DD/MM/YYYY)	31/07/2026

Background: A Call for Accuracy over Conservatism - WCCF and EF Revisions

This submission addresses two parameters central to the Integrity Council for the Voluntary Carbon Market's (ICVCM) ongoing review of cookstove methodologies against the Core Carbon Principles (CCP) Assessment Framework: the Wood-to-Charcoal Conversion Factor ("WCCF") and the direct charcoal Emission Factors (EFs). The Gold Standard's publication on 05/05/2026 of its revised methodologies, RECH v5.0 (formerly TPDDTEC) and MECD v2.0, provides a timely opportunity to revisit how these parameters are calibrated. Both GS methodologies move away from the legacy CDM 4:1 default toward a field-grounded WCCF of 6:1. At the same time, over the last few months a range of direct charcoal emission factors has been proposed under differing assumptions; although these are all intended to represent the same physical effect, the resulting values diverge significantly. We therefore strongly encourage the ICVCM to align with the Gold Standard's revised WCCF and to adopt the corresponding parameters, while urging a more conservative, evidence-anchored approach to direct emission factors, for the reasons set out below.

In line with the recently published GS4GG cookstove methodologies, we consider that sufficient empirical evidence has been shared for the ICVCM to revise the default value for the quantity of wood required to produce one unit of charcoal. The default should be regionalised so that a ratio of 6:1 is treated as conservative for Sub-Saharan Africa. The 4:1 default originates in CDM Methodological Tool 33, where the CDM Methodologies Panel introduced it on a conservative interpretation of the academic studies referenced, a value that departs from the earlier IPCC-based reference of 6:1. The ICVCM has since adopted the same figure: under its Core Carbon Principles (CCP) Assessment Framework, and most recently in its 7 March 2025 cookstove methodology decisions, charcoal projects must apply either a direct charcoal emission factor or a 4:1 WCCF to qualify for the CCP label. The factor therefore directly governs which clean-cooking credits the ICVCM recognises as high-integrity, giving it influence well beyond the CDM.

However, defaulting to figures inconsistent with regional empirical data introduces systematic under-crediting risks for Sub-Saharan Africa, contrary to the principles of scientific rigor and environmental integrity. More than ten independent field studies and reviews spanning Malawi, Ghana, Kenya, Tanzania, Mozambique, the Democratic Republic of Congo, Zambia and Uganda find that traditional kilns operate at just 8-20% efficiency, averaging around 10%, and report real-world WCCFs ranging from 6:1 to 10:1. Direct field measurements on 24 traditional kilns in Malawi and Ghana (Oregon State University, 2025) recorded effective WCCFs of 7:1 to 8:1. The 4:1 default is not anchored in any of this evidence; it derives from a conservative misreading of the 1996 IPCC Guidelines, which themselves referenced traditional kilns closer to 6:1.

Turning to direct emission factors: while we support the Gold Standard's revised adoption of a 6:1 WCCF, we do not adopt the high direct emission factors set out in its revised methodologies; we instead recommend a direct charcoal emission factor anchored to the total emission factor set out in

the CLEAR methodology. Anchoring the direct emission factor on a recognised, peer-reviewed reference value ensures that upstream production emissions are captured rather than excluded. This will give every CCP-labelled project a common, physically consistent basis on which to model emission reductions.

This submission argues that parameter-setting should be governed by **data accuracy** and **full-system-boundary** accounting rather than blanket conservatism, and that where the evidence overwhelmingly establishes the dominance of a particular production technique, prescriptive global defaults should give way to regionally grounded values.

1. Wood to Charcoal Conversion Factor (WCCF)

Rationale : Methodological Weakness: Incomplete System Boundary

The existing 4:1 WCCF is calculated on a **mass basis at the kiln level only**. This understates real wood used twice over: it overstates the efficiency of the kiln itself, and it ignores the substantial biomass lost before carbonization even begins: during tree felling, wood drying and handling. Because these upstream losses fall outside the kiln-only boundary, the wood, and therefore the baseline emissions attributable to each tonne of charcoal is systematically understated, directly suppressing the verifiable emission reductions a clean-cooking project can claim.

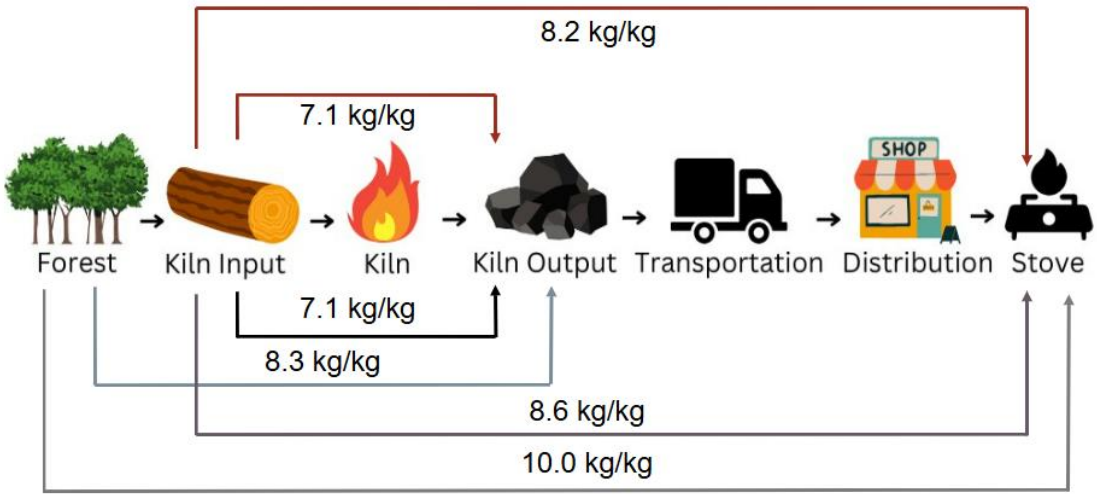

Figure 1: Urban J., et al. (2025) *Quantifying conversion factors for the value chain of charcoal production in Malawi and Ghana* Oregon State University https://ir.library.oregonstate.edu/concern/technical_reports/2f75rj10q

Justification:

a. Key Evidence from Field Studies and Academic Literature

While the value-chain evidence above indicates effective WCCFs of 7:1 to 8:1 once pre-carbonization losses are counted, this submission anchors its kiln-level recommendation at 6:1 - a value already

adopted by Gold Standard's RECH v5.0, the CLEAR methodology and the PACM SB - and addresses upstream losses through the emission-factor recommendation in Section 2, so that the system boundary is closed without double counting.

The primary charcoal production method in Sub-Saharan Africa is the traditional earth mound carbonization technique, whose kiln efficiency in real-world practice is typically lower than 17%.

Kiln Efficiency (%) = Mass of Charcoal Produced ÷ Mass of Wood Input × 100

WCCF (kg wood / kg charcoal) = 1 ÷ Kiln Efficiency

Where:

Kiln efficiency = 17% -> 0.17

WCCF = 1 ÷ 0.17 = 6:1

Field studies, synthesis reports and analyses across Sub-Saharan Africa document kiln yields of traditional earth mound kilns as low as 8%, with an average of around 10% reported consistently across studies. On this basis, a WCCF of 6:1 is both accurate and conservative for Sub-Saharan African countries.

Kiln Summaries and WCCF across Sub-Saharan Africa

Kiln Type	**Kiln Yield**	**WCCF Range**	**Prevalence**
Traditional earth mound	8 - 20%	5.0 - 12.5 kg wood/kg charcoal	Most common
17% efficiency (IPCC control)	17%	5.88 kg wood/kg charcoal	Control
Drum kiln	20 - 30%	3.3 - 5.0 kg wood/kg charcoal	Rare
Brick/concrete kiln	20 - 30%	3.3 - 5.0 kg wood/kg charcoal	Rare
Retort kiln	22 - 40%	2.5 - 4.5 kg wood/kg charcoal	Rare

More information on kiln yield and summaries based on field research is provided in ***Appendix 1.***

Comparative Methodology Alignment

- New methodologies, such as Verra's VMR0050, Gold Standard's RECH v**5.0** and the **CLEAR methodology** for cooking energy transitions, apply WCCFs of **6:1,** better aligned with field data.

- Against this backdrop, the CDM and ICVCM CCP requirements are the outliers, retaining the 4:1 factor and creating inconsistency across the standards that project developers must work within.
- The PACM SB itself is revising the parameters underpinning these methodologies under the Paris Agreement Crediting Mechanism (PACM). The PACM SB and MEP have already accepted the use of the MoFuSS fNRB model, which uses a WCCF of 6:1. These parallel moves confirm that the legacy CDM defaults are being actively superseded by field-grounded science, the same direction this submission urges for the WCCF.

2. Direct Charcoal Emission Factors (EFs)

Rationale

Under the ICVCM's current CCP Assessment Framework, charcoal projects may already apply a direct charcoal emission factor, an approach we support and recommend retaining. However, the concern is not whether direct emission factors are used, but the scientific basis for the values they rest on: where a direct emission factor excludes upstream production emissions, the result is a direct emission factor that understates the true climate impact of charcoal produced in the low-efficiency traditional kilns that dominate Sub-Saharan Africa. Anchoring a direct charcoal emission factor to a recognised, field-grounded reference value, such as the total emission factor set out in the CLEAR methodology, would capture both upstream production and point-of-use emissions, correct this systematic underestimation, and give all CCP-labelled projects a common, physically consistent basis for modelling emission reductions.

a. Support for the CLEAR Methodology

Although the Gold Standard's revised methodologies (RECH v5.0 and MECD v2.0) adopt their own direct charcoal emission factors, with direct emission factors exceeding 300 tCO_2e/TJ, we have not seen sufficient empirical grounds for values of that magnitude and do not recommend their adoption. We instead support the direct charcoal emission factors for Sub-Saharan Africa set out in the CLEAR methodology (Appendices 4 and 5), and recommend that the ICVCM adopt them. These factors are grounded in peer-reviewed field research on the low-efficiency traditional kilns that dominate the region, which makes them a more accurate and defensible basis for charcoal carbon accounting and keeps the ICVCM framework consistent with the underlying science.

The CLEAR methodology sets these factors out in full, separating upstream production emissions from point-of-use emissions so that the two are not double counted. For traditional kilns, the upstream emission factor (Appendix 4) is 130 tonnes CO_2, 3.0 tonnes CH_4 and 0.005 tonnes N_2O per TJ.

Table 1: Upstream emissions from charcoal production in tonnes/TJ (CLEAR methodology, Appendix 4).

Fuel	CO_2	CH_4	N_2O
Charcoal (traditional kiln assuming 6:1 conversion)	130	3.0	0.005
Charcoal (traditional kiln assuming 4:1 conversion)	72	1.7	0.005

Note: CO_2 values must be multiplied by the relevant fNRB before adding to CO_2e.

The matching point-of-use factors (Appendix 5) apply a 0.0295 TJ/tonne net calorific value, a 25% stove thermal efficiency, and 78.5 tonnes CO_2, 0.2 tonnes CH_4 and 0.008 tonnes N_2O per TJ.

Table 2: Net calorific values, thermal efficiencies and emission factors for charcoal (CLEAR methodology).

Fuel	**Net Calorific Value (TJ/tonnes)**	**Thermal efficiency**	**CO_2 Emission Factor (tonnes/TJ)**	**CH_4 Emission Factor (tonnes/TJ)**	**N2O Emission Factor (tonnes/TJ)**
Charcoal	0.0295	25%	78.5	0.2	0.008

Together they give a complete and transparent account of the emissions attributable to each tonne of charcoal produced and used in Sub-Saharan Africa.[1]

We recommend that the ICVCM adopt the CLEAR methodology direct emission factors for charcoal in Sub-Saharan Africa. By capturing both upstream production and point-of-use emissions on a field-grounded basis, they provide a complete and empirically defensible account of charcoal's climate impact. Adopting them would align the ICVCM framework with the best available science and with the other major standards already moving in this direction, and would correct the systematic under-crediting that current defaults impose on the region's clean-cooking projects.

3. Recommendations for the ICVCM

To improve emissions integrity and equitable credit allocation, we recommend that the Integrity Council for the Voluntary Carbon Market (ICVCM) adopt the following within its Core Carbon Principles (CCP) Assessment Framework and the conditions it applies to cookstove and charcoal methodologies:

1. Revise the WCCF required under the CCP Assessment Framework from 4:1 to 6:1, grounded in peer-reviewed field data on kiln yields in Sub-Saharan Africa.
2. Adopt direct charcoal emission factors that incorporate production emissions and are anchored in peer-reviewed field research, such as the values set out in the CLEAR methodology (computed against a WCCF of 1:6). We do not support the substantially higher direct emission factors adopted in the Gold Standard's revised methodologies, for which we have not seen sufficient empirical justification. A common, peer-reviewed reference factor would give all CCP-labelled projects a consistent and comparable basis for modelling emission reductions.
3. Encourage region-specific WCCF and Charcoal Production Emission Factor estimates, where feasible, using field-based measurement protocols and emerging digital monitoring tools.
4. Ensure cross-registry harmonization, aligning ICVCM, Verra, Gold Standard, CDM and PACM methodologies to uphold environmental integrity and comparability.

Conclusion

The field evidence points in one direction: for the traditional kilns that dominate Sub-Saharan Africa, real-world WCCFs of 6:1 or greater are the norm, not the exception. Continued reliance on a 4:1 value underestimates real emissions, suppresses the value of clean cooking projects in Sub-Saharan

[1] Ref: CLEAR methodology page 95

African countries, and may inadvertently bias carbon finance away from the regions and technologies that need it most.

On direct emission factors, we support the CLEAR methodology values, which capture both upstream and point-of-use emissions on a field-grounded basis and give the ICVCM a complete, empirically defensible alternative to the current defaults. We do not endorse the substantially higher direct emission factors adopted in the Gold Standard's revised methodologies, for which we have not seen sufficient empirical justification.

Revising these parameters presents an opportunity for the ICVCM and affiliated mechanisms to strengthen climate accounting standards through **empirical evidence and full system transparency**.

Appendix 1: Research on Kiln Yields

a) Field Research by Oregon State University (MacCarty et al., 2025) (Link)

- Field studies conducted on 24 traditional Earth Mound kilns in Malawi and Ghana recorded effective WCCFs between **7:1 and 8:1**.
- Kiln only conversion ratios (i.e., excluding pre and post-processing losses) averaged **≥6.5:1**.
- When total system losses (e.g., moisture content variability, fines, handling waste) were included, actual biomass use per kg of charcoal exceeded 7:1.
- These findings support adjusting the default WCCF upward to reflect real-world practices.

b) Synthesis Study by World Agroforestry (Link)

- Analysis of published studies, reports, and data on Kenya's charcoal sector spanning 20 years (2000 - 2020)
- Supports that carbonization in Kenya is primarily undertaken using traditional earth mound kilns: 90-99% of charcoal in Kenya.
- Kiln efficiency rates: the inefficient kilns used for carbonization in Kenya have efficiency yields of **8% to 20%** with 10% commonly being used in official calculations.
- On WCCF, the report clarifies that in Kenya, "about 8-10 tonnes of wood is required to produce a tonne of charcoal" signifying WCCFs between **8:1 and 10:1.**
- The study supports the adjustment of the WCCF upward to reflect actual/real-world practices.

c) Field Research by World Agroforestry / CIFOR-ICRAF, in collaboration with the University of Nairobi (Link)

- Field study across 384 randomly selected charcoal producers in actual charcoal production areas in Kenya.
- Reports that 99% of charcoal producers in Baringo County, use traditional kilns for carbonization.
- Kiln efficiency rates: the report cites that the inefficient traditional kilns have yield ranging from 10%-14%, with up to 80% of the wood lost in the process.
- A yield of 10-14% kiln yield conversely implies a WCCF of approximately **between 7:1 and 10:1** tonnes of wood per tonne of charcoal. This WCCF is based on internal calculation (1 ÷ kiln efficiency), as the study reports kiln yield rather than a conversion factor directly.
- The field research supports the adjustment of the WCCF upward to reflect real-world charcoal production and conversion factors.

d) Literature Review and Synthesis Publication by the Food and Agriculture Organization (FAO) (Link)

- Analysis of data, literature and case studies from around the world.
- Report underscores that the main carbonization technique is the traditional earth-mound kiln especially in the Sub-Saharan Africa and developing countries.
- Kiln efficiency rates: highlighting that the most common carbonization technique is the traditional earth mound kiln, the efficiency rates particularly in Kenya range from 10% to15% and estimated at 15.6% for Uganda.
- The report also assesses on the impact of low kiln efficiencies on the WCCF, where modern improved kilns have WCCFs of about 3:1 while the traditional mundane carbonization techniques have WCCFs of up to 12:1.

- Seeing that charcoal in SSA is produced using the traditional earth mound kilns as referenced, revising WCCF upward enhances accuracy and consistency as pertains to reporting on SSA carbonization.

e) Field Research and Literature Review by EES Engineers / GreenLight Mozambique (De Koning & Atanassov, 2013) (Link)

- Literature review and field study of the Mozambican charcoal value chain (Maputo, Gaza and Inhambane Provinces), commissioned under the UNFCCC climate-financing framework.
- Confirms that charcoal in Mozambique is produced almost entirely using traditional earth kilns, with only about 5% of the sector formalised.
- Kiln efficiency rates: the report confirms that the traditional earth kilns used in Mozambique operate at 10 - 20% efficiency, with an average of 14%.
- On WCCF, the report states that the average earth kiln uses “7 kg of wood for the production of 1 kg charcoal”, i.e. a WCCF of 7:1, a ratio it applies consistently in its national wood-demand estimates.
- The study supports adjusting the WCCF upward to reflect real-world traditional production.

f) Review and Field Research by the Center for International Forestry Research (Schure et al., 2019) (Link)

- Review of carbonization efficiency across Sub-Saharan Africa, combined with field data from two production areas in the Democratic Republic of Congo (Yangambi and the Bateke Plateau).
- Confirms that production is dominated by traditional earth kilns, whose low efficiency is the principal constraint on the value chain.
- Kiln efficiency rates: traditional earth kilns measured at 10% (Lubumbashi) and 12.8% (Yangambi Biosphere Reserve); improved agroforestry kilns at Mampu reach about 20% and the savannah Bateke Plateau up to 28.1%.
- On WCCF, a traditional earth-kiln efficiency of about 12.8% implies a WCCF of approximately 7.8:1, while improved techniques can raise conversion two- to three-fold.
- The study supports revising the WCCF upward for traditional systems, while noting that efficiency gains also depend on improved technique and enabling institutional capacity.

g) Life Cycle Assessment by Quantis for the Tanzania Traditional Charcoal Project / TFCG (2014) (Link)

- Life-cycle assessment of the traditional charcoal value chain in Kilosa District (Morogoro region), Tanzania.
- Confirms that the basic earth mound kiln is “the most commonly used traditional charcoal kiln throughout East Africa”.
- Kiln efficiency rates: a review of the most commonly used kilns reports conversion rates of 11.8 - 25.7% (average 18.8%), with the field-measured value at the Kilosa site at 13.1%.
- On WCCF, the field-measured 13.1% efficiency corresponds to a modelled wood input of 7.64 kg wood per kg charcoal (approximately 7.6:1), versus 3.64 kg (approximately 3.6:1) for the more efficient improved scenario.
- The study supports adjusting the WCCF upward to reflect the dominant, low-efficiency earth mound kiln.

h) Policy and Political Ecology Study by Kansanga, Banda, Mkandawire et al. (2025) (Link)

- A policy-focused political ecology study of the deforestation and charcoal conundrum in Malawi, drawing on a synthesis of published literature on the country's charcoal sector and its governance.
- Confirms that charcoal production in Malawi relies overwhelmingly on traditional pit and earth-mound kilns.
- Kiln efficiency rates: cites an average efficiency of about 10% for the traditional pit/mound kilns that dominate production.
- On WCCF, a 10% kiln efficiency implies a WCCF of approximately 10:1 (about 10 kg of wood per kg of charcoal).
- The study supports adjusting the WCCF upward to reflect the low-efficiency traditional kilns prevalent across Sub Saharan Africa.

i) Regional Overview and Synthesis by Falcão (2008) (Link)

- A historical overview and synthesis of charcoal production and use across four southern African (SADC) countries: Mozambique, Malawi, Tanzania and Zambia, covering production technologies, markets and management systems.
- Confirms that charcoal in these countries is produced predominantly using traditional earth/mound kilns.
- Kiln efficiency rates: reports that charcoal production efficiency in the study countries varies between 10% and 25%, with only the more advanced kilns (e.g. Mark IV, Cusab and Gayland retort kilns) reaching the upper (25%+) end.
- On WCCF, traditional kilns at the lower end (about 10% efficiency) imply a WCCF of up to approximately 10:1, while the most efficient kilns (about 25%) correspond to roughly 4:1.
- The study supports adjusting the WCCF upward to reflect the low-efficiency traditional kilns that dominate production.

j) Review Publication by the Food and Agriculture Organization (FAO) - Mozambique Charcoal Studies (Link)

- An FAO review of existing studies on fuelwood and charcoal in Mozambique, drawing together survey and production data for the sector.
- Confirms that all charcoal consumed in Mozambique is produced by the traditional earth kiln method.
- Kiln efficiency rates: reports earth-kiln yields of about 12% to 16% on a weight basis for professional producers.
- On WCCF, a 12 - 16% kiln efficiency implies a WCCF of approximately 6:1 to 8:1 (about 6 - 8 kg of wood per kg of charcoal). This WCCF is based on internal calculation (1 ÷ kiln efficiency), as the study reports kiln efficiency rather than a conversion factor directly.
- The study supports adjusting the WCCF upward to reflect real-world traditional earth-kiln production.

k) Literature Review and Modelling by Bailis (SEI, 2024) (Link)

- The 4:1 value is based on selective interpretation of the **1996 IPCC Guidelines**, which referenced traditional kilns with WCCFs closer to 6:1.
- Emissions modelling indicates that WCCF is linearly correlated with direct charcoal emission factors. A 4:1 WCCF yields ~123 tCO_2e/TJ, while a 6:1 ratio yields ~221 tCO_2e/TJ illustrating a substantial underestimation when using the lower value.

l) Methodology Revision and Supplementary Information by the Gold Standard (RECH v5.0 and MECD v2.0, 2026) (Link)

- The Gold Standard's 2026 revisions to its core cookstove methodologies - RECH v5.0 (formerly TPDDTEC) and MECD v2.0 moved away from the legacy CDM 4:1 default toward a field-grounded WCCF of 6:1 to 6.5:1.

- The revision broadened the accounting boundary to capture cradle-to-gate embodied emissions through a dual-pathway rule.

- It is underpinned by a published Supplementary Information package setting out the scientific basis for the updated direct emission factors and embodied-emissions factors.

- This precedent demonstrates that a 6:1 default is both empirically defensible and operationally workable within an established crediting standard. We endorse this WCCF precedent; on emission factors, however, we support the more conservative, peer-reviewed CLEAR values, for the reasons set out in Section 2.