CARBON CREDIT FINANCING FOR PRODUCTIVE USE APPLIANCE MARKETS

MAY 2025

Efficiency for Access Coalition

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ABBREVIATIONS

CO2e	Carbon Dioxide equivalent
CDM	Clean Development Mechanism
dMRV	Digital Monitoring, Reporting, and Verification
ER	Emissions Reduction
GHG	Greenhouse Gas
ITMOS	Internationally Transferred Mitigation Outcomes
MRV	Monitoring, Reporting, and Verification
NDCs	Nationally Determined Contributions
PAYG	pay-as-you-go
PUAs	Productive Use Appliances
SPV	Special Purpose Vehicle
SDGs	Sustainable Development Goals
VCMs	Voluntary Carbon Markets

ACKNOWLEDGEMENTS

The report was authored by Verst Carbon, Greenmax Capital, and CLASP.

We are grateful to all the industry experts and stakeholders for their invaluable contributions to the learnings and insights shared in this report. The report was made possible through their comprehensive and thoughtful feedback and data. The authors are thankful to the following contributors and reviewers for their guidance and feedback throughout the project:

- CLASP: Sam Grant, Albert Letting
- Energy Saving Trust: Jakub Vrba

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Front cover image: Fredrick Otieno Ogwang from WeTu loads tomatoes into a cold storage refrigerator in Mbita, Homa Bay county, Kenya. The unit helps keep produce fresh for vendors at Mbita Market. *Credit:* CLASP

Efficiency for Access is a global coalition dedicated to advancing high efficiency appliances to enhance clean energy access for the world's most impoverished communities. Current EforA Coalition members have programs and initiatives spanning 62 countries and 34 key technologies. The coalition is cochaired by UK aid and the IKEA Foundation and funded by UK aid from the UK government, via the Transforming Energy Access platform. This material has been funded by UK aid from the UK government; however, the views expressed do not necessarily reflect the UK government's official policies.

EXECUTIVE SUMMARY

Long-term, sustainable growth in solar-powered appliance and equipment markets will require a significant increase in the total amount of financing available to companies and customers. Carbon finance is one mechanism that could drive funding to this market, making solar-powered appliance and equipment more affordable. However, the current infrastructure for carbon finance in this sector is not fit for purpose and needs an upgrade.

KEY FINDINGS

- A review of existing methodologies for carbon projects involving solar Productive Use Appliances (PUAs) revealed significant gaps, especially in terms of regional applicability, data consistency, and monitoring accuracy.
- These gaps limit the effectiveness of the methodologies, making it difficult to capture the true emissions reduction potential of solar PUA projects across different regions, particularly in Africa.

RECOMMENDATIONS

- Develop a new, consolidated solar PUA carbon methodology
- Conduct robust, standardized baseline studies
- Support innovation around digital monitoring, reporting, and evaluation
- Develop and adopt an emission reduction calculation tool

An aerial view of Jungle Harvest farm in Thika, Kenya, with the solar-powered cold storage room in view.
Credit: CLASP

BACKGROUND

Carbon finance can support wider adoption of solar-powered PUAs. When applied with strong methodologies and oversight, carbon finance can strengthen markets, support credible emissions reductions, and improve access to critical energy services.

Addressing the affordability gap

A crucial aspect of scaling off-grid solar markets is addressing the affordability gap for consumers. Despite the potential benefits of solar-powered PUAs, high upfront costs can be prohibitive for low-income households and small businesses in underserved areas. Therefore, diverse financing options are essential to bridge this gap and make these technologies accessible and affordable.

Creating revenue through carbon credits

Carbon offsets are reductions in greenhouse gas (GHG) emissions achieved by implementing climate mitigation projects, such as deploying solar-powered PUAs. These projects lead to avoided, reduced, or removed GHG emissions from the atmosphere.[1] Each ton of carbon dioxide equivalent (CO2e) that is reduced or avoided by these projects can be quantified and converted into carbon credits using scientific methodologies.[2] These credits can then be sold in carbon markets, generating revenue that can be reinvested in further project development.

Attracting investment to solar infrastructure

Carbon credits make solar projects more attractive to private investors, development finance institutions, and impact investors by providing a predictable and additional revenue stream. This influx of capital can drive the expansion of solar infrastructure, support research and development of new technologies, and enable the scaling of successful business models.

Blending carbon finance with other funding mechanisms

Integrating carbon finance with other funding mechanisms, such as grants, debt, and equity, can create a compelling financial package to stimulate market entry and growth. For instance, subsidies derived from carbon credit revenues can reduce the upfront costs for consumers, while pay-as-you-go (PAYG) models and microloans provide flexible payment options. This multi-faceted approach can expand access to solar technologies for even the most financially constrained households and businesses, driving broader adoption and unlocking impact.

Strengthening monitoring and social safeguards

To maximize the impact of carbon finance, it is essential to integrate robust Monitoring, Reporting, and Verification (MRV) protocols and social safeguards into PUA projects. MRV protocols ensure that the emission reductions achieved by these projects are accurately measured, reported, and verified which is

[1] Angelo Gurgel, "Carbon Offsets," MIT Climate Portal (MIT, September 11, 2020), https://climate.mit.edu/explainers/carbon-offsets.
[2] World Bank Group and Kenya Private Sector Alliance, "A Carbon Market Guidebook for Kenyan Enterprises" (Washington, DC: World Bank, 2024).

essential crucial for maintaining the integrity and value of carbon credits. Digital MRV (dMRV) systems, leveraging technologies such as Internet of Things (IoT) devices, blockchain, remote sensing, and smart meters, enhance data collection and reduce reliance on manual processes.

Social safeguards, on the other hand, ensure that PUA projects deliver broader social and economic benefits, such as gender empowerment, improved air quality, and increased food security. By integrating these safeguards, PUA projects can attract additional funding from impact investors who are interested in both environmental and social returns.

Lowering costs through project aggregation

Targeted aggregation of carbon projects involving PUAs can help lower development and financing costs, making carbon markets more accessible, especially for smaller entities. Interviewees voiced strong support for collaboration with a carbon credit broker that provides comprehensive support, from project development to credit sales, to help foster market growth in the region.

Emerging aggregation efforts

Numerous efforts are underway to centralize certain activities by aggregating projects into tranches to help offset the steep costs associated project development and financing, which often limit participation for smaller entities or previously disaggregated activities. Other sectors, such as forestry, pioneered the development of aggregation guidelines.

Recently, Mirova SunFunder proposed establishing a Special Purpose Vehicle (SPV) to aggregate carbon credits from clean energy companies in East Africa. By pooling carbon credits from similar companies, the SPV would attract larger investments, reduce project setup costs, and streamline the process of generating and selling carbon credits.[3]

Voluntary carbon markets and alignment with national commitments

Voluntary Carbon Markets (VCMs) are platforms where companies, governments, and individuals voluntarily purchase carbon credits to offset their GHG emissions. These are distinct from compliance markets, which are regulated by government policies such as the EU Emission Trading Scheme.

VCMs aim to help companies offset their emissions by purchasing carbon credits. However, the market faces significant scrutiny due to several persistent challenges, such as inconsistent quality standards, concerns about additionality, and the risk of double counting emission reductions.

In parallel, Article 6.2 of the Paris Agreement provides a framework for countries to collaborate by exchanging Internationally Transferred Mitigation Outcomes (ITMOs) to achieve Nationally Determined Contributions (NDCs). The World Bank's Climate Warehouse Program provides the legal frameworks for these cooperative approaches. Eligible carbon offset activities are identified, approved, validated, and verified to align with NDCs. ITMO transfers require host country approval to align with NDCs.

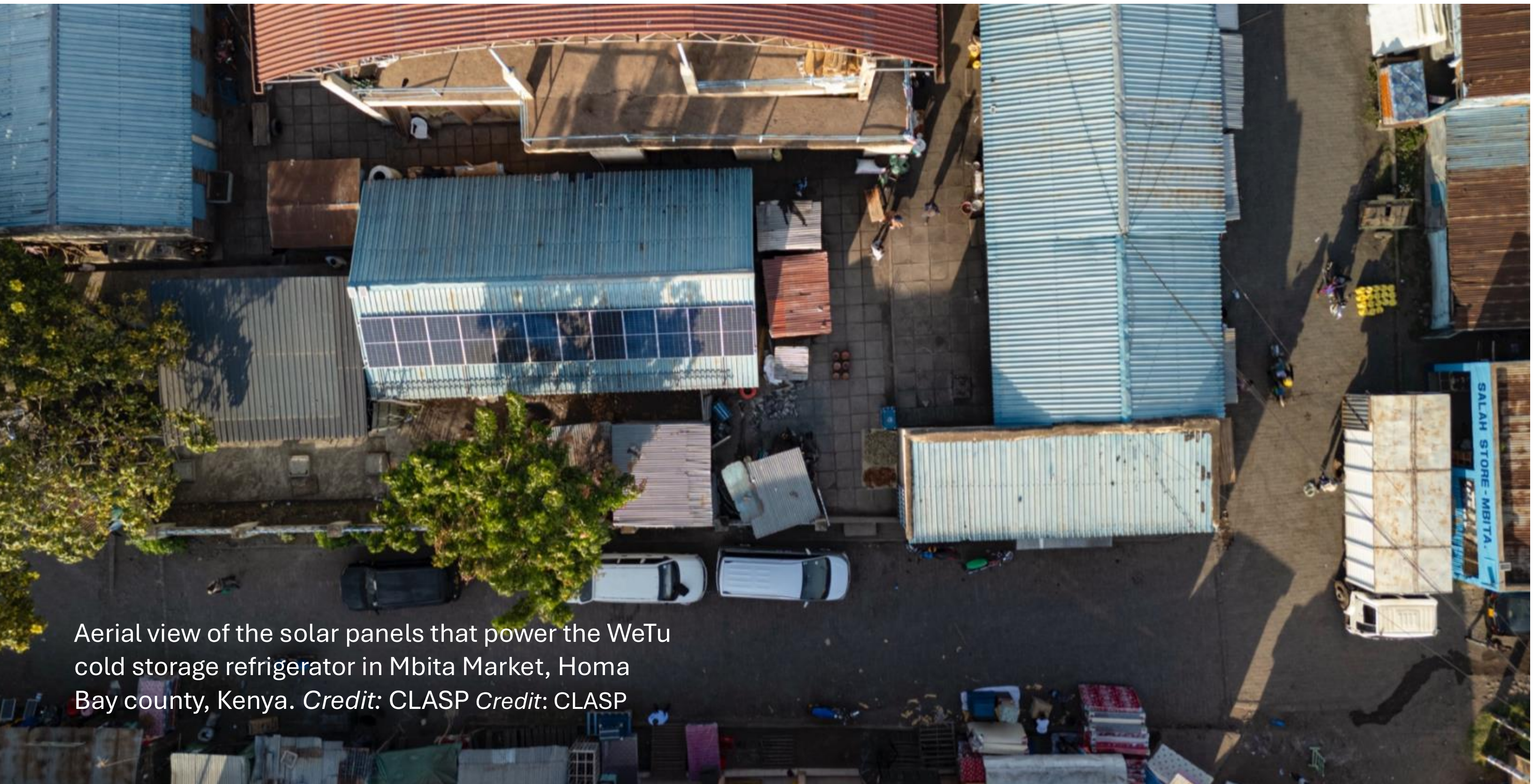
[3] Mirova SunFunder. "Carbon Credit Aggregator Platform." In "CAP Financial Innovation Challenge," United Nations Development Programme (UNDP), 2024.

Key challenges facing PUA companies trying to access the carbon markets are summarized in the table below.

Key Challenge	Details
Barriers to carbon market participation for small scale players	• **Setup costs** are prohibitively high, ranging from $100-200k • Small/new developers with low projected credit volumes **can't access financing at small scale** • **Burdensome processes** for credit issuance, MRV & fundraising
New technologies & innovative initiatives are overlooked	• **Old Methodologies** in current VCMs favour existing project types • **Registries are capacity constrained** and can't generate new methodologies quickly • Investors purchase credits from large scale, existing projects
New developer entrants not launching new projects	• **Price volatility** in the carbon market increases financial risk for developers • Barriers to investors means limited access to seed capital
Suppressed Climate Investment	• **Low integrity credits** deters future investment • Low integrity credits persist because of the **lack of industry & regulatory oversight** • **Regulatory uncertainty** around carbon taxation & Article 6.2 limit investor interest

Carbon credit financing for productive use appliance markets

This report outlines a strategic approach for improving carbon credit financing into the PUA sector in Africa, with a particular focus on solar-powered irrigation, cooling, and milling. It provides a comprehensive review of existing carbon methodologies applicable to PUAs and offers practical recommendations for their improvement. The review uses a novel evaluative framework and analyzes each methodology's use of baseline studies, monitoring, reporting and verification, integration of social and environmental safeguards, and alignment with both the voluntary and the compliance carbon markets.



Aerial view of the solar panels that power the WeTu cold storage refrigerator in Mbita Market, Homa Bay county, Kenya. *Credit:* CLASP *Credit*: CLASP

RESEARCH METHODOLOGY

To generate credible and effective carbon credits from solar PUA projects, it is essential to **use robust methodologies, establish reliable monitoring frameworks, address additionality, and mitigate leakage.**

Five methodologies from the Clean Development Mechanism (CDM), Verra, and Gold Standard were analyzed for their applicability to solar PUAs. The selection focused on their relevance to renewable energy, adaptability to small-scale decentralized systems, and alignment with emission reduction goals in off-grid areas. A novel evaluation matrix was designed based on the attributes in section 1.1 of the Annex which assigns a score to each methodology.

In addition to the desk review, in-depth interviews and stakeholder workshops were conducted to explore diverse perspectives on integrating solar PUAs into carbon markets, leveraging digital MRV systems, navigating regulatory frameworks, and understanding the social and environmental safeguards essential to sustainable development.

The annex of this report provides additional detail on the following areas:

- Methodology review
    - Methods assessed
    - Scoring matrix
- Deep dive on:
    - digital Monitoring, Reporting, and Verification (dMRV)
    - Social and environmental safeguards
    - Government and policy considerations
- Takeaways from key informant interview

RECOMMENDATIONS

The methodologies analyzed for carbon projects involving solar PUAs revealed significant gaps, especially in regional applicability, data consistency, and monitoring accuracy. These gaps limit the effectiveness of current methodologies, making it difficult to capture the true emissions reduction potential of solar PUA projects across regions, particularly in Africa. To address these challenges, four key recommendations are proposed, each targeting specific areas where improvement is needed to strengthen the methodologies and enhance project scalability and impact.

Recommendations	Justification	What is required
Develop a New Consolidated Solar PUA Carbon Methodology	Having evaluated available methodologies from Gold Standard, Verra and CDM, we have found out that those methodologies only support solar PUA devices in silos. Key problems identified: • Suppressed demand • Leakage prevention • Device lifespan considerations • Social and environmental safeguards • Diverse solar PUA applications	• Technical Research • Stakeholder Engagement: • Pilot Projects: • Legal and Regulatory Alignment: • Financial Resources • Capacity Building • Consultation with Methodology Approval Bodies
Develop Standardized Baselines	Drawing from the interviews with relevant stakeholders and assessment of methodologies, we found out that conducting a sampling procedure for the baseline is not adequate for solar PUAs.	• Data Collection and Analysis • Energy Modeling Experts • Regional Workshops/Consultations • Pilot Projects • Financial Resources • Collaboration with Standardization Bodies
Creation of Calculation Tool for Emission Reductions	Out of the methodologies evaluated, we found out that Gold Standard methodologies are more robust based on the MAC and interestingly have their own calculation tool that would allow developers to quantify the emission reductions (ERs).	• Activities: Developing the tool, testing across multiple project scenarios, integrating feedback for improvements • People: Software developers, carbon market experts, regional energy specialists • Finance: Investment in tool development, pilot testing, and integration with existing methodologies
Incubation Hub for dMRV Systems	One of the significant limitations identified across all methodologies is the reliance on traditional MRV methods. Absence of digital MRV (dMRV) tools leads to inaccuracies in emissions reduction data, hinders project scaling, and compromises the reliability of carbon credits.	• Research and Development Team • Partnership with Technology Firms • Pilot Testing of dMRV Tools • Open-Source Platform Development • Financial Investment • Capacity Building

The team from Hesao Integrated operating an efficient mill in Kisumu, Kenya, tested by Kijani Testing Lab.
Credit: CLASP

FINDINGS

DEVELOPMENT OF STANDARDIZED BASELINES

What are we solving for?

A critical gap observed across all five methodologies is the inconsistent and non-tailored approach to baseline emissions, particularly for solar Productive Use Appliances (PUAs). Existing methodologies do not account for the significant variation in energy access, infrastructure quality, and resource availability across African regions. For example, solar cold chains in rural Kenya may operate under entirely different conditions compared to those in West Africa, where the energy access situation is more severe. Without standardized baselines, it's challenging for project developers to establish accurate emissions reductions for solar PUA projects. This challenge is more pronounced in rural or off-grid regions, where collecting energy data is difficult, leading to uncertainties in baseline assumptions and emissions calculations.

Many regions also face suppressed demand, where actual energy consumption does not reflect teal need due to limited access. For instance, rural communities relying on solar irrigation or agro-processing systems may not use as much energy as urban or grid-connected regions, but they have latent demand that remains unmet. Failing to account for these dynamics results in skewed baseline scenarios, which may result in under- or overestimation of emissions reductions, and thus carbon credits.

Recommendation

Developing standardized baselines is essential for generating accurate and consistent emissions calculations across regions. These baselines should be tailored to reflect country specific conditions in Africa, starting with Kenya, which has distinct energy consumption patterns and infrastructure challenges, and then expanding to other countries across the continent. Standardized baselines would make carbon credit methodologies more regionally appropriate, reducing the burden on project developers to establish bespoke baselines for each project.

The baselines should factor in:

- **Energy access conditions** (e.g., grid availability, off-grid penetration, and reliability).
- **Energy consumption patterns** (e.g., household, agricultural, commercial energy use).
- **Suppressed demand in underserved areas (**e.g., potential energy demand if access was improved).
- **Infrastructure limitations** (e.g., unreliable electricity grids, lack of storage, weak distribution networks).

Standardized baselines will streamline project validation and improve the consistency of emissions reduction estimates. Having pre-defined, region-specific data sets would make it easier for developers to meet the requirements for carbon credit issuance, thus attracting more investment into solar PUA projects and contribute to the overall creditability of the carbon credit market.

DEVELOP A NEW CONSOLIDATED SOLAR PUA CARBON METHODOLOGY

What are we solving for?

The methodologies currently analyzed demonstrate strengths in specific areas but lack a comprehensive approach to solar PUAs in key sectors like irrigation, cold chains, and agro-processing. These shortcomings limit the applicability of the methodologies for carbon projects aiming to address diverse solar PUA applications in different regions.

Key problems identified include:

- **Suppressed demand** is either poorly integrated or completely omitted, despite being critical for regions with latent energy needs, particularly in off-grid and underdeveloped areas.
- **Leakage prevention** is inadequately addressed, leading to the potential for displaced fossil-fuel-based systems, like diesel generators, to be reused or resold, which can negate some emissions reductions.
- **Device lifespan considerations** are often ignored, potentially leading to systems breaking down before the crediting period ends, undermining the sustainability of emissions reductions.
- **Social and environmental safeguards** are inconsistently applied, reducing the overall long-term impact and attractiveness of projects, particularly in vulnerable rural communities.
- **Diverse solar PUA applications** are treated generically, without the nuance needed to accurately measure emissions reductions and impacts specific to each type of technology, such as irrigation, agro-processing, and cold chains.

These limitations reduce the utility of the current methodologies for developing long-term, scalable carbon projects and fail to capture the broader socio-environmental co-benefits that such projects can deliver.

Recommendation

Support the development of a new consolidated solar PUA carbon methodology that builds on the strengths of the existing methodologies while addressing their current gaps. This new methodology should provide a more comprehensive and adaptable framework, ensuring that solar PUA projects are both technically robust and better positioned to deliver long-term social, environmental, and economic benefits.

Key areas the methodology should cover:

- **GHG assessment:** Develop tailored GHG assessments for solar irrigation, cold chains, and agro-processing systems, with accurate baseline emissions data and clear, sector-specific emissions reduction targets.
- **Suppressed demand:** Incorporate detailed analysis of suppressed demand, especially for off-grid and underserved communities where energy needs are significantly underreported. This would help capture future energy consumption and produce more accurate emissions reduction estimates.
- **Leakage prevention:** Establish mechanisms to prevent leakage, including guidelines for decommissioning displaced fossil fuel-based equipment. This would reduce the risk of resale and reuse of diesel generators and other legacy systems that could undermining project outcomes.

- **Social and environmental safeguards:** Fully integrate the Sustainable Development Goals (SDGs) to ensure projects not only reduce emissions but also improve local livelihoods, promote gender equality, and foster long-term socio-economic development in vulnerable regions.
- **Device lifespan:** Define requirements to help solar PUA systems remain operational throughout the crediting period. This could include maintenance protocols and replacement plans to minimize or prevent breakdowns that could disrupt emissions reductions.
- **Flexible Application:** Design the methodology to accommodate a variety of solar PUA systems, ranging from small-scale irrigation systems to large agro-processing units, enabling scalability across diverse projects in Africa.

This consolidated methodology would ensure that solar PUA projects are not only emissions-reduction vehicles but also deliver long-term, scalable impacts. It will align with global carbon market standards and attract more investors by offering a framework that is technically sound, socially inclusive, and environmentally sustainable.

A farmer using solar-powered water pump to irrigate her farm in Ethiopia. *Credit:* CLASP

INCUBATION HUB FOR DMRV SYSTEMS

What are we solving for?

A key limitation across all methodologies is their reliance on traditional MRV methods. These are often time-consuming, costly, and prone to human error, making them poorly suited for large-scale or geographically dispersed solar PUA projects. This limitation is particularly pronounced in remote or rural areas, where data collection is challenging, and real-time monitoring is rarely available. The absence of MRV tools contributes to inaccuracies in emissions reduction data, hinders project scaling, and compromises the reliability of carbon credits. Without timely, accurate monitoring, project developers face challenges in adjusting operations or optimizing project performance, which reduces the credibility of reported emissions reductions.

Recommendation

Investing in establishing an incubation hub for dMRV Systems is critical. This hub would focus on research and development of digital MRV tools specifically designed for solar PUAs. These systems enable real-time data collection, remote monitoring, and automated reporting, capabilities that are essential for delivering accurate and timely emissions reductions data in geographically dispersed or rural projects. In addition to improving data accuracy, dMRV tools can also reduce the costs associated with manual MRV processes.

The incubation hub would work to standardize dMRV systems and ensure their integration into the proposed new consolidated methodology for solar PUAs. The tools developed through this initiative should be open source, allowing project developers across the globe to adopt and customize the tools for their specific needs.

Beyond improving technical processes, the incubation hub for dMRV Systems would help modernize and scale the MRV practices, particularly for solar PUA projects in rural and underserved regions. The open-source model will also contribute to global efforts to improve MRV processes and support the growth of the carbon credit market.

DEVELOP AN EMISSION REDUCTION (ER) CALCULATION TOOL

What are we solving for?

Current carbon methodologies do not provide simple, user-friendly tools for calculating emissions reductions in solar PUA projects. This presents significant challenges for project developers, especially in regions with limited access to technical expertise. Accurate emissions calculations are often difficult due to the varying energy demands, equipment lifespans, and local conditions. Additionally, critical factors like leakage scenarios, suppressed demand, and device efficiency are often overlooked in current methodologies. These limitations hinder the scalability of solar PUA projects and make it difficult to determine the full emissions reduction potential. A streamlined emissions reduction (ER) calculation tool would help project developers navigate these challenges and produce accurate, verifiable emissions reductions.

Recommendation

Develop a dedicated ER calculation tool tailored to solar PUA projects to simplify emissions calculations and make it more accessible for both large and small project developers.

The tool should incorporate the following key elements:

- **Device lifespans and energy efficiency:** Account for the lifespan of the solar devices, ensuring that they operate effectively throughout the crediting period, and integrate efficiency data to optimize emissions reduction calculations.
- **Suppressed demand:** Reflect potential energy use in areas with limited or unreliable energy access to provide a more accurate and inclusive emissions reduction baseline.
- **Leakage scenarios:** Address the risk of emissions displacement by including protocols for decommissioning or replacing baseline fossil systems, such as diesel generators.
- **Standardized emission factors and regional baselines**: Incorporate standardized emission factors, adapted to different regions and conditions, to improve accuracy and comparability of emissions reduction calculations across diverse contexts.

A user-friendly, adaptable ER calculation tool will help project developers more easily calculate and verify emissions reductions, supporting the design of solar PUA projects that meet carbon market requirements. The tool could be integrated with the new consolidated solar PUA methodology to promote consistency and reliability across different regions and project types. This approach would help scale solar PUA projects while ensuring they deliver meaningful and verifiable emissions reductions.

POTENTIAL BENEFITS OF PROPOSED RECOMMENDATIONS

Key Benefit	Details
1. Consistency & Accuracy	• Standardized baselines and a tailored ER calculation tool ensure reliable, **accurate emissions reductions across regions**.
2. Scalability	• Simplified tools, standardized frameworks, and streamlined processes **enable project developers to scale** solar PUA projects across multiple regions more **efficiently**.
3. Improved Investor Confidence	• Standardization and verified data enhance credibility, **attracting more investment** into solar PUA projects.
4. Reduced Costs & Timelines	• dMRV systems and simplified calculation tools **lower costs and time** associated with MRV.
5. Support Suppressed Demand	• Accounting for future energy needs ensures more accurate projections in **underserved areas**.
6. Long-term Sustainability	• Addressing **device lifespan** and incorporating **maintenance** supports the longevity of solar systems throughout the crediting period.
7. Enhanced Socio-Environmental Impact	• Integration of social and environmental safeguards, aligned with SDGs, ensures **broader socio-economic and environmental benefits**.
8. Global Impact & Flexibility	• Open-source dMRV tools and flexible methodologies allow **widespread global adoption** and adaptation.

ANNEX

SECTION 1

1. METHODOLOGY ANALYSIS

The application of solar Productive Use Appliances (PUAs) offers significant opportunities to reduce greenhouse gas (GHG) emissions while advancing sustainable development. By replacing fossil fuels, solar energy delivers economic and social benefits, particularly in rural communities, fostering both environmental and socio-economic progress.

To generate credible and effective carbon credits from solar PUA projects, it is essential to **use robust methodologies, establish reliable monitoring frameworks, address additionality, and mitigate leakage.**

Suitability of methodologies: Five methodologies from the CDM, Verra, and Gold Standard were analyzed for their applicability to solar Productive Use Appliances (PUAs). The selection focused on their relevance to renewable energy, adaptability to small-scale decentralized systems, and alignment with emission reduction goals in off-grid areas.

Methodologies	Description
AMS-1.A. Electricity Generation by the User	This methodology applies to renewable electricity generation for individual households or groups, particularly in off-grid rural communities. • **Solar Irrigation Systems**: Suitable for projects that switch from diesel to solar-powered irrigation pumps. Limited to a total installed capacity of **15 MW**. • **Solar Cold Chains**: Suitable for projects that replace diesel-powered refrigeration units with solar alternatives. Solar capacity capped at **15 MW**. • **Solar Agro-Processing**: Enables replacement of diesel-powered mills with solar-powered options, with a maximum renewable capacity of **15 MW**. • Maximum installed capacity refers to the installed capacity of all the appliances which would be registered under one project.
AMS-1.B. Mechanical Energy for the User	Applicable to projects that install renewable technologies for mechanical energy, such as water pumps and milling systems, which would otherwise rely on fossil fuels. • **Solar Irrigation Systems**: Directly replaces diesel pumps with solar-powered pumps; cumulative capacity capped at **15 MW**. • **Solar Agro-Processing**: Uses solar-powered mills or grinders to replace diesel-powered equipment, with a capacity limit of **15 MW**. **Solar Cold Chains**: **Not applicable** under this methodology.

AMS-1.L. Electrification of Rural Communities Using Renewable Energy	Focuses on providing renewable electricity to rural areas with limited or no prior access to electricity. • **Solar Irrigation**: Applies where solar pumps replace diesel or bring electricity to communities lacking power (75% of users must be households). • **Solar Cold Chains**: Suitable for replacing diesel generators in rural refrigeration, supporting both new installations and upgrades. The upgrades focus on reducing GHG emissions through installation of low-carbon refrigeration. • **Solar Agro-Processing**: Applies to permanent solar mills/dryers replacing diesel in isolated areas.
Gold Standard – Suppressed Demand Small Scale Methodology for Low GHG Food Preservation	Focuses on low-emission technologies for food preservation, replacing diesel-powered refrigeration in agriculture to reduce post-harvest losses. • **Solar Cold Chains**: Applicable to solar refrigeration/freezing units, replacing diesel to prevent food spoilage. • **Solar Agro-Processing**: Supports solar-powered dryers/mills to improve food preservation and extend shelf life. • **Solar Irrigation**: **Not applicable**. • This methodology comprises of project activities that provide food preservation with lower associated greenhouses gas emissions and expand food preservation beyond pre-project levels. Specifically, this is evaluated on increased energy efficiency, amount of food preserved and duration of preservation versus baseline.
Gold Standard – Suppressed Demand Methodology Micro-Scale Electrification and Energization	Designed for small-scale renewable projects in areas with limited or no grid access, helping communities shift from diesel to solar energy for productive uses. • **Solar Irrigation**: Supports solar pumps in areas lacking reliable irrigation power. • **Solar Cold Chains**: Applies to solar-powered refrigeration in regions with limited or no prior cold storage. • **Solar Agro-Processing**: Enables solar mills/dryers in areas without prior energy access for processing.

Table 1: A summary of assessed methodologies

1.1. Scoring Matrix & Outcomes

Relevance to PUA Sector	• Applicability • Scope • Previous Applications • Best Practices
Accuracy & Robustness	• Quantification of Emissions Reductions • Baseline & Additionality
Compliance with Standards	• Alignment with UNFCC • Technical Feasibility
Practicality & Ease of Implementation	• Cost Effectiveness
Monitoring, Reporting, & Verification (MRV)	• MRV Requirements • Frequency & Duration
Social & Environmental Safeguards	• Community Impact • Environmental Integrity
Scalability & Replicability	• Adaptability • Transferability
Innovative Elements	• Technical Innovation • Co-Benefits

Table 2: List of scoring attributes

49.4% — AMS I.A Electricity generation by the user

- ✓ **Strength**: Additionality and accuracy in emissions calculations.
- ✓ **Key gaps**: Lacks provisions for social and environmental safeguards and device longevity.

64.8% — AMS I.B Mechanical energy for the

- ✓ Moderate strength for solar PUA projects, particularly in irrigation and agro-processing.
- ✓ **Key gaps**: leakage, lack of social and environmental safeguards, and absence of unique identifiers

73% — AMS I.L Electrification of rural communities using renewable

- ✓ Well-suited for rural electrification projects, particularly for communities reliant on fossil fuels.
- ✓ **Strengths**: baseline and additionality provisions
- ✓ Key gaps: addressing leakage, integrating digital MRV tools, and incorporating social safeguards like SDG assessments.

80.7% — GS Suppressed Demand Methodology

- ✓ Strength: Applicable in regions with suppressed demand like Kenya's ASAL.
- ✓ Key gaps: lacks integration of dMRV tools and unique identifiers.
- ✓ Well-aligned with SDGs and offers clear social and environmental benefits

82% — GS Suppressed Demand Small-scale Methodology

- ✓ Strong performance in addressing GHG emissions for food preservation, especially in regions with suppressed demand like Kenya's Arid and Semi-Arid Lands (ASAL).
- ✓ Strengths: baseline, emissions calculations, and UNFCCC aligned
- ✓ Key gaps: Lacks integration of digital MRV tools and unique identifiers.
- ✓ Well-aligned with SDGs and offers clear social and environmental benefits

Table 3: Summary list of applicable methodologies for solar PUA carbon projects

List of available methodologies	Typical Project	Type of Mitigation Activity
AMS-I.A.: Electricity generation by the user	Renewable electricity generation by individual households/users or groups of households/users	Displacement of more-GHG-intensive, non-renewable electricity applications by introducing renewable energy technologies.
AMS-I.B.: Mechanical energy for the user with or without electrical energy	Installation of renewable energy technologies that provide mechanical energy that otherwise would have been supplied with fossil-fuel-based energy	Displacement of more GHG intensive fossil-fuel-based generation of mechanical power
AMS-I.L.: Electrification of rural communities using renewable energy	Communities which did not have electricity prior to project implementation are supplied with electricity from renewable based systems	Displacement of fossil fuel use through installation of renewable electricity generation systems

Gold Standard – Suppressed Demand Methodology Micro-Scale Electrification and Energization	Renewable energy generation and electrification of communities without access to grid power	Incorporating renewable energy sources to communities with no or 50% grid availability allowing for fossil fuel back-up power generation.
Gold Standard – Suppressed Demand Small-scale Methodology for Low GHG Food Preservation	Project activities that provide low GHG Emitting food preservation technologies	Suppressed displacement of more GHG intensive food preservation methods/technologies

Table 4: Summary of assessed methodologies

1.2. Monitoring, Reporting, and Verification (dMRV)

An effective MRV system guarantees that the data collected is **robust, verifiable, and aligned with international carbon standards**, such as those set by the Clean Development Mechanism (CDM), Verra, and Gold Standard.

Digital MRV (dMRV) Tools: dMRV systems use a variety of advanced technologies such as IoT (Internet of Things) devices, blockchain, remote sensing, and smart meters to automatically capture data, reducing the reliance on manual processes.

There are several PUA companies that utilize digital MRV protocols during implementation of the project device applications.

Company	PUA	dMRV technology
SunCulture	Solar Water Pumps	IoT
Davis & Shirtliff	Solar Water Pumps	iDayliff IoT
Agsol	Solar Mills	IoT
Adili Solar Hubs	Solar Cold Chain	Smart meters

Table 5: Companies that utilize digital MRV protocols

Emerging Challenges with dMRV for Energy Projects

- **Scaling Digital Solutions:** Implementing dMRV systems across diverse project sizes and types is challenging, especially for smaller, decentralized projects in areas with limited infrastructure. High costs and varying technological needs hinder equal access to digital monitoring.
- **Technological Limitations:** Poor internet, unreliable power, and limited technical skills in developing and remote regions restrict dMRV deployment, often requiring hybrid approaches that blend digital and traditional data methods.

Digital MRV as a Catalyst for Carbon Market Participation	
Streamlined Validation	Digital MRV systems reduce monitoring costs, enhance transparency, and simplify data collection for solar devices, enabling easier carbon credit validation.
Real-Time Monitoring	IoT-enabled MRV tools track performance metrics, improve maintenance, and support aggregated data collection, making carbon credits feasible even for small or rural PUAs.
Improved Access	Digital MRV platforms integrate multiple data points to validate energy savings and emissions reductions, expanding market participation for diverse PUA projects.

Table 6: Digital MRV as a catalyst of carbon market participation

To certify carbon projects, standard setters rely on independent auditors, known as Validation and Verification Bodies (VVBs), selected by project developers, and accredited by the standard setter. VVBs have two key roles: validating the project design (ex-ante) and verifying the project's actual benefits (ex post).

However, the scarcity of these auditors poses significant challenges in the carbon market.

- **Auditor Scarcity:** The rapid growth of the carbon market has outpaced the number of trained, accredited auditors (VVBs). With around 40 VVBs accredited by Verra and Gold Standard, only six have offices in Africa, creating a bottleneck for timely project validations and verifications.

- **High Costs and Delays:** Limited auditor availability raises costs due to competition for services, and delays in verification can slow carbon credit issuance, impacting cash flow for project developers.

- **Potential for Subjectivity or Bias:** Manual auditing allows room for subjective data interpretation. High workloads and limited sector expertise among auditors can lead to inconsistencies in project verification.

1.3. Social and Environmental Safeguards

Social safeguards are critical tools designed to prevent and reduce unintended harm to people throughout the development process as defined by the Food and Agriculture Organization of the United Nations.

During project planning, social safeguards play a crucial role in assessing potential social risks and impacts, both positive and negative, ensuring that development initiatives do not unintentionally harm communities.

International standards require that carbon project developers prioritize community benefits. This includes conducting Environmental Impact Assessments (EIA) with thorough consultations involving affected communities, particularly in Kenya, where certified NEMA experts lead the process to align projects with community needs.

- Solar-powered devices are transforming the agricultural sector, enhancing food security, and promoting economic stability.
- By boosting crop yields and reducing dependence on traditional energy sources, they play a crucial role in alleviating poverty in rural areas.
- However, deploying solar-powered Productive Use Appliances (PUAs) requires a focus on social safeguards to protect local communities.
- Agricultural projects can carry risks, making social safeguards essential to prevent harm, ensure fair compensation, and restore livelihoods impacted by development initiatives.

Evidently, much of the insight drawn from this literature would imply that social safeguards should have the following key elements.

- **Affordability and Access for Low-Income Communities:** Flexible financing models, subsidies, and cost reduction strategies help overcome upfront cost barriers:
  - **Paygo Financing**: Flexible, mobile-based payment systems align with irregular income streams, increasing accessibility for small-scale farmers and low-income users.
  - **Carbon Credit Subsidies:** Revenue from carbon credits lowers upfront costs, making solar puas more affordable for last-mile customers.
  - **Cost Sensitivity:** Subsidies and funding are critical to addressing high upfront costs for devices like solar refrigeration, enhancing affordability for small businesses

- **Community Engagement and Awareness:** Community trust and education are crucial for adoption and long-term use of PUAs:
  - **User Education:** Training users on device maintenance prevents underutilization and abandonment, ensuring sustained social and environmental impact.
  - **Local Partnerships:** Collaborations with trusted community partners improve distribution and retention of PUAs while promoting economic empowerment.
  - **Community Consultations:** Engaging communities builds local ownership and ensures understanding of the social and economic benefits of PUAs.

- **Addressing Social and Gender Equity:** Solar PUAs promote social equity and economic empowerment, particularly for women:
  - **Income Generation:** PUAs support livelihood activities, enabling women to increase food production and generate income.
  - **Gender-Specific Safeguards:** Tailored financing and support address barriers women face in accessing and maintaining PUAs, enhancing inclusion.

- **Environmental Safeguards and Sustainable Design:** Sustainability in PUA projects ensures long-term environmental and social benefits:
  - **Durability and Support:** High-quality design and accessible maintenance services enhance product lifespan and reduce waste.
  - **Replacing Polluting Alternatives:** PUAs reduce reliance on diesel generators and kerosene lamps, improving emissions and air quality.
  - **Recycling and Disposal:** Responsible end-of-life practices support a circular economy and prevent environmental degradation.

- **Safeguards in Digital MRV and Data Privacy:** Ethical data collection and privacy safeguards are essential for digital MRV adoption:
  - **Data Privacy:** Ensuring user consent and secure data practices builds trust and compliance with regulations.
  - **Transparent Communication:** Educating customers on monitoring benefits fosters acceptance of digital MRV systems.

1.4. Government and Regulatory Considerations

Governments in Africa are supporting through enacting policies that potentially support PUA carbon market goals, in the following ways.

- **Policy Alignment and National Support for Solar PUAs**
  - **Inclusion in NDCs:** Explicitly incorporating solar PUAs into Nationally Determined Contributions (NDCs) supports financing and integration with renewable energy goals.
  - **Local Partnerships:** Collaborating with local governments simplifies regulatory navigation and fosters compliance in regions with fragmented policies like solar refrigeration, enhancing affordability for small businesses.

- **Incentives and Subsidies for Solar PUAs**
  - **Subsidy Support:** Government subsidies for carbon-linked projects lower end-user costs, boosting affordability and adoption of PUAs like solar refrigeration.
  - **Tax Reforms:** VAT exemptions and reduced tariffs for renewable energy appliances improve accessibility and affordability, especially in rural areas.

- **Leveraging Article 6 and International Standards**
  - **Article 6 Compliance:** Aligning with Article 6 frameworks can unlock new carbon financing opportunities for PUAs, requiring investments in MRV systems and methodologies.
  - **International Standards:** Adopting globally recognized standards, such as Peace Renewable Energy Credits (P-RECs), attracts socially responsible investors seeking high impact projects.

- **Local Capacity Building and Regulatory Partnerships**
  - **Training and Expertise:** Developing local MRV capacity ensures accurate data collection and project compliance with carbon market standards.
  - **Government Collaboration:** Engaging governments early in project design aligns policies with renewable energy goals, supporting broader PUA adoption.

- **Harmonizing regulatory challenges**
  - **Fragmented Regulations:** Inconsistent policies and unpredictable taxes hinder solar PUA adoption, particularly in regions with complex governance structures.
  - **Import Barriers:** High tariffs and strict import regulations on renewable energy equipment increase costs and reduce market viability.

SECTION 2

2. Key Informant Interviews (KIIs)

Through in-depth interviews, this report explores diverse perspectives on integrating solar PUAs into carbon markets, leveraging digital MRV systems, navigating regulatory frameworks, and understanding the social and environmental safeguards essential to sustainable development.

2.1. Key Informant Insights on Carbon Credit Financing for Solar PUAs

The respondents provided diverse insights on the role of carbon credit financing for solar productive use appliances (PUAs). These insights highlight the potential of carbon credits to enhance financial viability, the opportunities for scaling solar PUAs, and the challenges companies face in leveraging carbon markets.

2.1.1. Financial Viability and Revenue Potential for Scaling

Carbon credits can help make solar PUAs financially viable by providing a supplemental revenue stream that offsets the high upfront costs associated with renewable energy appliances. Moreover, Carbon credits have the potential to scale solar PUAs, especially in markets where diesel-based appliances remain the norm. By using carbon credits to support clean energy alternatives, companies can scale PUAs and reduce reliance on fossil fuels. For example:

- **Namene** uses carbon credits to subsidize solar lights for underserved populations, aiming to bridge the affordability gap. However, Bernard noted that, for smaller appliances like lights, generating enough carbon credits to make a significant financial impact requires substantial scale.

- **ENGIE Energy Access**, represented by Mathieu, noted that digital MRV systems, such as those deployed within CarbonClear, allow for faster credit issuance, providing a stable revenue stream that benefits cash flow and can be reinvested into expanding energy access projects.

- **Davis & Shirtliff** is exploring partnerships to bring their solar water pumps into carbon markets, focusing on reducing diesel dependency in agricultural settings. They see potential for aggregated carbon credits across their solar pumping systems, which would encourage further investment in the sector.

- **Koolboks** similarly highlighted the emissions reduction benefits of replacing diesel-powered refrigeration with solar fridges. Ayoola noted that carbon credits could make their solar fridges more affordable for last-mile consumers, creating a cleaner alternative for food preservation in off-grid areas.

- Scaling is further supported by frameworks like **Energy Peace Partners'** Peace Renewable Energy Credits (P-RECs). According to Linda, P-RECs not only fund renewable energy projects in conflict-affected regions but also align with social impact goals, enabling solar PUAs to contribute to peacebuilding initiatives while attracting premium financing from socially responsible investors.

- However, not all informants found carbon credits immediately profitable. **Bboxx**, for instance, has leveraged Gold Standard certification for clean cooking and solar home systems but observed that the financial benefits of carbon credits for solar home systems are often minimal, particularly in high-cost, low-margin settings like the Democratic Republic of Congo.

2.1.2. Barriers to Carbon Credit Adoption

Despite the potential benefits, numerous barriers impede the adoption of carbon credits for solar PUAs. Informants highlighted several key challenges:

- **High Initial Costs and Complexity**: Most companies cited the high costs of certification, monitoring, and reporting as prohibitive. **Futurepump's** Helen Yapp noted that the bureaucratic demands and costs associated with certification prevent small-scale PUA projects from tapping into carbon credits, especially for products like solar irrigation systems.

- **Market Volatility and Unpredictable Revenue**: **Energrow's** Aaron explained that price volatility in carbon credits makes them unreliable as a primary financing strategy. Without market stability, companies face challenges securing consistent revenue through carbon credits.

- **Methodological Gaps**: Many PUAs, like solar-powered mills, cold chains, and irrigation pumps, lack standardized carbon credit methodologies, making it difficult to validate their carbon savings. **SureChill's** Rodolphe pointed out that solar refrigeration lacks precedent in carbon markets, leaving companies to pioneer methodologies or face exclusion.

- **Bboxx**'s experience in DRC showed that limited regulatory support, taxation on carbon credits, and fragmented policies add another layer of difficulty for solar PUA projects.

2.1.3. Digital MRV as a Catalyst for Carbon Market Participation

Digital MRV (Monitoring, Reporting, and Verification) systems are emerging as a valuable tool for improving access to carbon markets by enhancing transparency and reducing monitoring costs:

- **Access to Energy Institute (A2EI)**, represented by Stefan, has developed the Prospect platform, which uses digital MRV to streamline data collection for solar devices. This platform integrates multiple data points, including inverter and smart meter information, to track energy savings and emissions reductions, making it easier to validate carbon credits for solar PUAs.

- **Davis & Shirtliff** also employs digital MRV in its iDayliff IoT system for real-time monitoring of solar pumps. This approach allows them to monitor performance metrics and conduct predictive maintenance, which not only improves customer experience but could also enhance carbon credit validation processes.

- Digital MRV enables aggregated data collection, which is crucial for smaller PUAs. For example, **Agsol**'s Matt mentioned that IoT-enabled MRV systems allow them to collect power usage data for solar-powered mills, making it feasible to generate carbon credits even for individual devices deployed in rural areas.

2.1.4. Aggregation Models and the Need for Standardized Approaches

The interviews underscored a strong need for aggregation models, which allow companies to pool emissions reductions across multiple units or regions to reach the critical mass necessary for carbon financing:

- **Epicenter's** Mary suggested that by aggregating smaller projects, solar PUAs in agriculture could achieve economies of scale, making carbon financing feasible for rural communities reliant on solar irrigation.

- **Aggregation** models would particularly benefit small, distributed PUAs like solar lighting. **Namene's** Bernard noted that while each solar light generates minimal credits, pooling credits across a large distribution network could support viable project financing.

Overall, informants expressed optimism about the role of carbon credits in financing and scaling solar PUAs, especially when supported by digital MRV systems and aggregation models. However, the path to adoption remains complex, with significant financial, technical, and regulatory barriers that need to be addressed. As methodologies and technologies evolve, there is potential for solar PUAs to play a larger role in carbon markets, contributing to both climate and social goals.

2.2. Methodological Insights

The integration of solar PUAs into carbon markets requires methodologies that accurately capture emissions reductions while accounting for the unique operational characteristics of these devices. Informants discussed several methodological challenges and proposed improvements, particularly regarding data collection, aggregation, and adapting existing methodologies to fit PUAs.

2.2.1. Limitations of Existing Methodologies for Solar PUAs

Most current carbon credit methodologies are not tailored to the specificities of solar PUAs, particularly small, distributed devices. Informants highlighted specific gaps:

- **Lack of PUA-Specific Methodologies**: Existing methodologies are often designed for large-scale projects and fail to capture the unique emissions profiles of PUAs. **Futurepump's** Helen Yap emphasized that current methodologies are better suited for devices with consistent energy outputs, like solar lights, and struggle to accurately measure savings from fluctuating-use devices like irrigation pumps.

- **Overly Conservative Baselines**: Some methodologies apply conservative default factors that underestimate the carbon savings of PUAs, reducing the potential credits. **ENGIE Energy Access**'s Mathieu noted that CarbonClear's more adaptive baseline system provides a more accurate reflection of savings than traditional Gold Standard methods, highlighting the need for more flexible baselines.

- **Complexity in Diesel Replacement Measurement**: For PUAs that replace diesel engines, such as solar pumps or mills, establishing accurate diesel displacement baselines is challenging. **Agsol's** Matt shared that without standardized baselines for diesel replacement, the carbon impact of solar-powered mills is difficult to quantify reliably.

2.2.2. Need for Digital MRV-Enabled Methodologies

Many informants advocated digital MRV as a critical improvement for PUA carbon methodologies, enabling more precise, cost-effective data collection and verification:

- **Enhanced Data Collection and Accuracy**: **Access to Energy Institute (A2EI)**, through its Prospect platform, integrates data from IoT devices to continuously monitor energy usage and emissions reductions. Stefan explained that digital MRV enables real-time data collection from dispersed devices, facilitating aggregated carbon reporting and reducing reliance on manual reporting.

- **Support for Distributed Small-Scale Devices**: IoT-enabled MRV allows for consistent tracking of dispersed PUAs like solar fridges, water pumps, and egg incubators. **Davis & Shirtliff's** iDayliff system, for example, allows them to collect real-time data from their solar water pumps, supporting predictive maintenance and potentially providing accurate energy use data for carbon credits.

- **Cost-Effectiveness and Accessibility**: For smaller organizations, digital MRV can lower the barrier to carbon credit entry by reducing monitoring and verification costs. **Namene's** Bernard noted that digital MRV could make carbon credits more accessible to small solar lighting projects, where high certification costs otherwise offset potential revenue from credits.

2.2.3. Aggregation Models and Methodological Standardization

Aggregation models are critical to scaling PUA projects in carbon markets. Aggregating data not only improves feasibility but also aligns methodologies with the operational realities of PUAs, which are typically deployed in decentralized locations with limited access to conventional energy sources. Informants emphasized the need for methodologies that support the aggregation of data from multiple devices or units:

- **Pooling Emissions Reductions Across Devices**: **Verst Carbon's Jaffer** proposed developing methodologies that allow multiple small devices, like solar water pumps, to pool emissions reductions across a network. By aggregating data, carbon credits can be issued at scale, lowering certification costs, and improving feasibility for smaller players.

- **Developing Regional Baselines**: **Epicenter's** Mary suggested that standardized regional baselines for emissions factors, particularly for diesel replacement, would support aggregation. This approach would help smaller solar PUA projects operating in similar regions streamline carbon credit calculations and avoid complex, costly data collection on an individual device basis.

2.2.4. Methodological Gaps in Addressing Black Carbon and Non-CO2 Emissions

Several informants highlighted the need to expand methodologies to capture non-CO2 pollutants, especially in applications where solar PUAs replace highly polluting alternatives:

- **Inclusion of Black Carbon**: **Unite to Light's** Megan Bernie Rudert noted that current methodologies, like AMS-III.AR, omit black carbon emissions, which are a major byproduct of kerosene lamps and other fossil-based lighting. Including black carbon and other pollutants would provide a more accurate assessment of the true environmental benefits of solar lighting and similar PUAs.

- **Pollutants from Diesel-Dependent Devices**: For PUAs that displace diesel-powered engines, including emissions like particulate matter and sulfur oxides would better capture the public health and environmental benefits. **Koolboks's** Ayoola recommended that methodologies account for these pollutants in solar refrigeration projects to make the credits more attractive to socially responsible investors.

2.2.5. Simplification and Cost Reduction in Certification Processes

Many informants called for simplification of the certification and reporting requirements, which currently impose high costs that reduce project viability:

- **Reducing Documentation Complexity**: **Futurepump's** Helen and **SureChill's** Diana Sasi both described the certification processes as overly bureaucratic and time-consuming, with complex documentation requirements that are costly for small and medium enterprises. Streamlining reporting processes would encourage more companies to participate in carbon markets.

- **Pre-Consultation with Carbon Buyers**: **Energrow's** Aaron suggested pre-consulting with carbon buyers to tailor methodologies and monitoring processes to meet demand thresholds, particularly for aggregated projects. This approach would ensure methodologies align with market requirements, thereby improving project viability from the outset.

Overall, informants emphasized that for solar PUAs to achieve scalable integration into carbon markets, methodologies must adapt to the distinct characteristics of PUAs, incorporate digital MRV for reliable data collection, and support aggregation models that lower per-unit certification costs. Expanding methodologies to include pollutants like black carbon, simplifying reporting, and engaging carbon buyers early in the process are additional improvements that would make solar PUAs more attractive in carbon markets.

2.3. Social and Environmental Safeguards

Social and environmental safeguards are crucial for ensuring that solar PUAs not only achieve emissions reductions but also provide tangible benefits to the communities they serve. Informants emphasized the importance of affordability, accessibility, community engagement, and environmental sustainability, highlighting specific strategies and challenges associated with these safeguards.

2.3.1. Affordability and Access for Low-Income Communities

Ensuring affordability is fundamental to successful PUA projects, particularly in underserved, low-income areas. Informants underscored the role of subsidies, financing models, and customer support:

- **PayGo Financing Models**: The **PayGo** model has been instrumental in improving access to solar PUAs by allowing payments to align with seasonal or irregular income streams. **Davis & Shirtliff's** Philip Holi shared that their solar water pumps are accessible through flexible PayGo options integrated with mobile payments like M-Pesa, which helps small-scale farmers overcome the upfront cost barrier.

- **Subsidizing Costs Through Carbon Credits: Namene's** Bernard emphasized that carbon credits can serve as a "hidden subsidy," allowing for reduced upfront costs. By directing the revenue from credits to lower the cost of solar lights, Namene helps last-mile customers afford these devices, enhancing accessibility and uptake.

- **Addressing Cost Sensitivity: SureChill's** Rodolph discussed the importance of keeping solar refrigeration affordable for small business owners. High upfront costs pose significant barriers, and subsidies from carbon credits or other funding sources are critical to bridging the affordability gap.

2.3.2. Community Engagement and Awareness

Community engagement and education are essential to promote the adoption and sustained use of solar PUAs. Informants stressed the need to build trust and awareness, particularly in rural and low-income areas:

- **User Education for Device Maintenance: Futurepump's** Helen Yap noted the importance of educating users on device maintenance to prevent abandonment. Many PUA projects suffer when users lack the resources or knowledge to manage repairs. This can lead to devices being underused or left idle, affecting both social impact and carbon credit generation.

- **Local Partnerships to Build Trust: Unite to Light** partners with Solar Sister, which employs female entrepreneurs to distribute solar lights in rural communities. Megan Bernie Rudert highlighted that this model not only enhances women's economic empowerment but also builds trust with customers, ensuring devices reach and are retained by end-users.

- **Community Consultations: Energy Peace Partners'** Linda shared that for projects involving Peace Renewable Energy Credits (P-RECs), local consultations are integral. These consultations ensure that communities understand the social and economic benefits, which helps in building local ownership and long-term commitment to using PUAs).

2.3.3. Addressing Social and Gender Equity

Informants emphasized the role of PUAs in promoting social equity, particularly regarding gender inclusion, by supporting female entrepreneurs and enhancing livelihood opportunities:

- **Economic Empowerment Through Productive Use**: Solar PUAs like water pumps, mills, and refrigeration systems directly support income-generating activities for women in rural areas. **Impact Pumps'** Kai Williams explained that their solar irrigation pumps allow women to grow and sell produce more effectively, which not only improves food security but also generates income for families.

- **Inclusion of Gender-Specific Safeguards: Epicenter's** Mary shared that projects targeting women in agriculture should include gender-specific safeguards, such as tailored financing options or support services, to address barriers that women face in accessing and maintaining PUAs.

2.3.4. Environmental Safeguards and Sustainable Design

Ensuring environmental sustainability is a priority in PUA projects, especially when it comes to device durability, responsible disposal, and reducing dependence on harmful alternatives:

- **Durability and Long-Term Support**: **Davis & Shirtliff** emphasizes product durability and ongoing support, using high-quality components and offering local maintenance through a wide network of service branches. This approach ensures that PUAs like solar pumps can function sustainably in challenging environments, minimizing waste and replacement costs.

- **Replacing Polluting Alternatives**: Solar PUAs like refrigerators and water pumps help reduce reliance on diesel generators and kerosene lamps, which are common in rural areas without grid access. **Koolboks's** Ayoola highlighted the reduction in emissions and improvement in air quality when vendors switch from diesel-powered cooling systems to solar-powered alternatives.

- **Responsible Disposal and Recycling Initiatives**: **Unite to Light** implements recycling and responsible disposal practices for end-of-life products, ensuring solar lighting systems do not contribute to local pollution. Megan noted that recycling initiatives are incorporated into the project design to support a circular economy and prevent environmental degradation.

2.3.5. Safeguards in Digital MRV and Data Privacy

As digital MRV becomes more integral to PUA carbon financing, companies must ensure data privacy and ethical monitoring practices to protect users:

- **Data Privacy and Consent**: **Access to Energy Institute (A2EI)** employs digital MRV for tracking solar PUA usage and performance. Stefan explained that A2EI prioritizes user consent and data security, particularly when collecting personal information through IoT devices. This builds trust and ensures compliance with data privacy regulations.

- **Transparent Communication on Monitoring**: Companies like **Bboxx** ensure transparency with customers by explaining how IoT monitoring systems work and the benefits of continuous performance tracking. Xavier noted that keeping customers informed prevents potential misunderstandings and promotes acceptance of digital MRV systems.

Social and environmental safeguards are essential to ensuring that solar PUAs deliver on both social impact and sustainability goals. By prioritizing affordability, building local trust, promoting gender equity, and embedding durable, environmentally friendly practices, these projects contribute to long-term community development and environmental health. Safeguards around digital MRV, including data privacy and transparent communication, are also crucial for gaining customer acceptance and ensuring ethical data collection practices.

2.4. Government and Regulatory Considerations

Effective government engagement and supportive regulatory frameworks are essential for integrating solar PUAs into carbon markets and scaling these technologies. Informants highlighted the need for policy alignment, regulatory clarity, incentives, and international standards to facilitate the development and financing of solar PUAs. Challenges related to inconsistent policies, complex regulatory environments, and the emerging role of Article 6 compliance were also discussed.

2.4.1. Policy Alignment and National Support for Solar PUAs

Alignment between national policies and PUA carbon market goals is crucial for successful project implementation. Several informants emphasized the need for government engagement to create enabling conditions for solar PUAs:

- **Alignment with National Renewable Energy Goals**: **NDC Partnership's** Saeeda highlighted that while many countries' NDCs (Nationally Determined Contributions) emphasize renewable energy, solar PUAs are often not specified. She advocated for governments to explicitly include solar PUAs, like agro-processing and irrigation, within NDCs to signal support for these technologies and facilitate financing.

- **Partnerships with Local Governments for Community Buy-In**: **Bboxx** has collaborated with local government agencies to navigate complex regulatory environments in regions like the DRC. Xavier noted that local partnerships help streamline processes and secure regulatory compliance, which is critical in regions with fragmented policies and overlapping regulatory bodies.

2.4.2. Incentives and Subsidies for Solar PUAs

Government incentives, such as tax exemptions and subsidies, can make solar PUAs more affordable and attractive for investors. Informants emphasized the positive impact of such incentives on scaling projects:

- **Subsidies for Carbon-Credit-Linked Projects**: **SureChill's** Diana Sashi highlighted that government-backed subsidies on solar refrigeration could make their products accessible to underserved populations. This approach, coupled with carbon credits, would reduce the end-user cost, supporting market penetration for solar refrigeration solutions.

- **VAT Exemptions and Fiscal Reforms**: **Futurepump's** Helen Yap suggested that tax exemptions for renewable energy appliances, like solar irrigation pumps, could reduce costs significantly. Such exemptions would be particularly beneficial in markets where high taxes increase the price of imported equipment, making PUAs less accessible to rural communities.

2.4.3. Regulatory Challenges and Complexity

Regulatory hurdles, including inconsistent policies and complex tax structures, complicate carbon credit projects for solar PUAs. Informants shared challenges they faced when navigating these issues:

- **Fragmented Regulations and Taxation**: In the DRC, **Bboxx** encountered a fragmented regulatory environment, with inconsistent policies across different regions. Xavier shared that this complexity, coupled with unpredictable tax policies on carbon credits, creates additional financial burdens and reduces the profitability of solar PUAs in carbon markets.

- **Barriers to Importing Renewable Energy Equipment**: **Davis & Shirtliff's** Philip Holi noted that stringent import regulations and high tariffs on solar products deter PUA adoption. Simplifying import processes and aligning regulatory frameworks with carbon market goals would facilitate broader access to solar technologies.

2.4.4. Leveraging Article 6 and International Standards

The potential for Article 6 compliance and alignment with international standards presents both opportunities and challenges for solar PUAs in carbon markets. Informants discussed how emerging international frameworks might support their projects:

- **Opportunities in Article 6 for Carbon Financing**: **ENGIE Energy Access**'s Mathieu highlighted the potential of Article 6 for expanding carbon financing in solar PUAs. Compliance with international standards under Article 6 would make carbon credits more attractive to investors, especially as countries work to meet their emissions targets. However, this requires investment in developing compatible MRV systems and methodologies.

- **Adopting Internationally Recognized Standards**: **Energy Peace Partners** integrates Peace Renewable Energy Credits (P-RECs) into projects that meet international social impact and renewable energy standards. Linda Wamune explained that aligning P-RECs with international standards enables projects in fragile areas to attract investors seeking verified, high-impact investments.

2.4.5. Local Capacity Building and Regulatory Partnerships

Several participants highlighted the importance of local capacity building and partnerships to address regulatory challenges and support long-term PUA projects:

- **Building Local Capacity for MRV Systems**: **Access to Energy Institute (A2EI)** works on building local capacity for digital MRV in regions with limited infrastructure. Stefan emphasized that by training local technicians and developing regional expertise, A2EI can ensure projects comply with carbon market standards and maintain data accuracy over time.

- **Collaborations with Government Bodies**: **Verst Carbon's** Jaffer noted that working closely with regulatory bodies to align carbon credit projects with national priorities is crucial. Engaging governments in the project design phase helps ensure policies support, rather than hinder, solar PUAs and renewable energy adoption.

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