Appendix A:

Making Inclusion Metrics More Meaningful

Standard gender metrics (and inclusion metrics more broadly) in solar energy programmes tend to measure numbers of people attending/trained rather than its impact. For example, how many women/persons with a disability are enrolled, employed, or reached. The following framework, drawn from the case evidence, suggests a richer approach:

Move beyond headcounts: Assess the quality of participation, not just its quantity. Are women in leadership roles? Are their voices shaping design and resource decisions? Are benefits distributed equitably?

Use disaggregated and intersectional data: Collect and report data by gender, age, disability, ethnicity, socio-economic status, and location. Overlapping exclusions are invisible in aggregate data.

Measure recognition and agency: Include indicators for whether local knowledge is respected and integrated - not just whether local people are present.

Track procedural inclusion: Report on decision-making processes: are marginalised groups consulted meaningfully? Are there mechanisms for feedback, co-design, and grievance redress?

Assess distribution of benefits and risks: Who gains from solar interventions? Who bears the risks? Distributive justice requires examining both.

Contextualise to local realities: Avoid universal benchmarks. Tailor indicators to local histories, cultures, and power dynamics (especially in postcolonial contexts).

Include qualitative narratives: Complement metrics with testimony and case evidence. Data tells you what happened; stories tell you why.

Appendix B: Cases Mapped Against Barriers to Inclusivity

The table below maps each delivery case study against the structural barriers identified in Paper 1

Structural Barrier (Paper 1)	4.1 Inclusive Market Research	4.2 SUNSAFE	4.3 Kijani Testing	4.4 POWERE	4.5 ENACT
Epistemic injustice & tech dependency	Embedded user perspectives into early-stage design, ensuring technologies reflect lived realities rather than externally assumed needs.	SUNSAFE embeds engineering knowledge in an accessible tool, challenging knowledge gatekeeping;	Kijani integrates user and technician knowledge through living labs, repositioning local actors as contributors to product design.	Women's Action Learning Groups surface lived experience and local priorities, shaping both system design and implementation.	Local knowledge is mapped alongside technical feasibility, with participatory processes recognising informal expertise as a basis for decision-making.
Financial exclusion	Market insights identify affordability constraints and inform business	SUNSAFE builds local technical capacity, reducing reliance on external	Kijani's repair model and Energy as a service (EaaS)-type approaches reduce lifecycle	Women's SHGs as co-owners link energy access directly to income generation	Financial consideration is embedded in community planning processes, linking system

Structural Barrier (Paper 1)	4.1 Inclusive Market Research	4.2 SUNSAFE	4.3 Kijani Testing	4.4 POWERE	4.5 ENACT
	models aligned with income variability and user priorities.	service provision;	costs, lower upfront barriers, and spread financial risk over time.	(e.g. seaweed processing), enabling participation in value creation rather than only consumption.	design to locally viable payment and management structures.
Procedural marginalisation	Inclusive research processes ensure under-represented groups shape early decision-making, not only downstream engagement.	Gender-data and user engagement are built into tool deployment, informing iterative design and enabling women's participation in technical decision-making spaces.	Living lab environment create structured spaces where users, agents, and technicians feed into product testing, though influence over wider system design and governance remains limited.	Three-phase model makes community governance a precondition of deployment, not optional, ensure women's participation in operational and strategic decision-making processes.	A structured, phased approach makes community governance a precondition of deployment, embedding decision-making authority locally.
Gender segmentation & masculine	Gendered roles and constraints are identified at the research	Women-only training spaces, peer champions, and	Inclusion emerges more indirectly through repair ecosystems, with	Women's Action Learning Groups; inter-structural lens; care	Participatory governance creates openings for women's

Structural Barrier (Paper 1)	**4.1 Inclusive Market Research**	**4.2 SUNSAFE**	**4.3 Kijani Testing**	**4.4 POWERE**	**4.5 ENACT**
workplace cultures	stage, shaping design choices that reduce exclusion before systems are introduced.	accessible diagnostic tools reduce reliance on male-dominated technical expertise and support entry into technical roles.	some opportunities for broader participation, but without an explicit focus on transforming gendered labour divisions.	responsibilities mapped and accommodated	involvement, though deeply embedded social norms can still constrain participation.
Colonial spatial patterns & data gaps	Context-specific, ground-level research challenges assumptions embedded in standardised market and feasibility models	Generates sex-disaggregated and usage data through deployment, improving visibility of differentiated user experiences within existing system structures.	Living labs surface performance and usage realities that are often invisible in standard testing environments, feeding local conditions back into product development	Ethnographic and community-led approaches reveal power dynamics and spatial inequalities not captured in conventional data collection.	Participatory mapping and planning processes surface local priorities often excluded from top-down system design.

Appendix C: Full Case Studies

The case studies are presented here in their extended versions, retaining the authors' original work with only minimal formatting and reframing. They provide in-depth analysis of context, methodology, and outcomes, offering detail beyond the summaries included in the main report. The structure and content have been retained to preserve the integrity of each contribution.

Case Study 4.1 – Inclusive market research for next-generation solar adoption

Uttar Pradesh, India | Urban and Peri-urban Households

ORGANISATION / LOCATION	VALUE CHAIN STAGE	INCLUSION MECHANISM
IIT Kanpur; Uttar Pradesh, India (urban and peri-urban)	Upstream design & market development (technology adoption, product design, policy alignment)	Discrete Choice Experiment (DCE) to simulate real-world decision-making (Pilot + Main Survey)

Framing note

This case study frames inclusion as process, not just outcome. Rather than centring on perovskite vs silicon, it positions the research as embedding consumer voice into solar technology design and policy **before markets exist** - making it transferable across contexts and technologies. Perovskite-based solar panels have not yet been commercially deployed in India, meaning market preferences are still undeveloped. This study prioritises inclusivity by engaging with households before the technology is available, ensuring decisions reflect real user priorities rather than expert assumptions.

Community Engagement & Participation

What was done

- In-person household surveys across urban and rural wards
- Pilot testing to ensure comprehension and relevance
- Explicit training of enumerators to guide respondents through complex trade-offs

The pilot survey took place in December 2025 across four residential areas of Kanpur Nagar: Jajmau, Kalyanpur, Kamalpur, and Umri Bujurg. It involved 90 respondents in face-to-face interviews engaging both urban and rural communities, ensuring clear understanding of the questions. The purpose was to assess the clarity and relevance of the attributes and choice tasks, leading to minor adjustments based on participant feedback. Enumerators received thorough training to help respondents navigate the choice tasks, allowing even those with limited technical knowledge to answer confidently.

Why this matters for inclusion

- Avoids elite or expert-only assumptions about what users value
- Makes low-income and non-technical households visible in early-stage innovation

The pilot approach directly incorporated household perspectives into the research process instead of relying on expert assumptions about technology preferences. By involving everyday households, it revealed what users truly value in solar technologies. This method also ensured that the voices of low-income and non-technical households were included in early-stage innovation discussions, which are often overlooked.

Actionable takeaway

Inclusion can start before deployment — by investing in survey design, piloting, and enumerator training.

The study prioritised inclusion before deploying technology by carefully preparing the survey process. A pilot survey tested respondent comprehension, allowing for refinement of the questions and tools. Enumerators were trained to clearly explain options and guide respondents. This preparation ensured that households could understand the technological options and share their preferences, demonstrating that inclusion can start before technology enters the market.

Attribute design: translating technology into lived realities

What was done

- Attributes were defined around what households experience: cost, lifespan, subsidy, bill reduction, social adoption, and efficiency
- Forced trade-offs reflect real constraints, not idealised choices

The study considered five key attributes: 1) cost, 2) lifespan, 3) subsidy, 4) bill reduction, and 5) social adoption, along with efficiency. Choice sets required respondents to select between two solar technology options, better capturing the realistic trade-offs households face rather than relying on idealised responses from separate attribute inquiries.

Why this matters

- Challenges the assumption that higher efficiency = higher social value
- Reveals that durability and affordability matter more than marginal technical gains

The pilot results indicate that efficiency is statistically insignificant ($\beta = 0.009$, $p = 0.735$). In contrast, lifespan ($\beta = 0.04$, $p = 0.0008$) emerges as the only important technical attribute, with households valuing each additional year of lifespan at ₹1,152. Cost ($\beta = -0.35$) and subsidy ($\beta = +0.37$) are the dominant factors, both statistically significant at $p < 0.001$. This confirms that affordability and durability are far more important than marginal efficiency gains when households make decisions.

Actionable takeaway

Inclusive design requires translating technical options into lived realities.

Asking respondents to choose between competing full profiles, rather than rating each attribute in isolation, is what highlights these trade-offs in a way a standard survey cannot replicate.

Distribution, Trust, and Adoption Pathways

What was done

- Tested the role of community adoption and peer effects
- Identified where social signalling does not outweigh economic risk

Community adoption rate was included as a discrete choice attribute, with levels set at 10–20% for silicon and 1–10% for perovskite, reflecting that perovskite is not yet commercially deployed in India. This setup allows for a meaningful comparison of realistic penetration scenarios. The pilot results indicate that adoption rate has a coefficient of 0.00056 ($p = 0.961$), which is statistically insignificant, with a marginal effect of only 0.0001 per percentage point change. This confirms that peer effects do not significantly influence household choices when economic risk has not been addressed.

Why this matters

- Prevents over-reliance on awareness campaigns when structural affordability is the real barrier

The pilot results show that affordability is the main barrier for households. This suggests that financial support mechanisms such as subsidies or cost reductions are likely to be more effective than awareness campaigns alone in promoting adoption.

Actionable takeaway

Inclusion means not blaming communities for low uptake when systems don't meet their priorities.

The pilot results indicate that low adoption rates are mainly influenced by financial barriers rather than a lack of interest from households. Cost ($\beta = -0.35$) and subsidy ($\beta = +0.37$) have a significant impact on household choices ($p < 0.001$). Uptake is more likely to increase when the financial structure aligns with household priorities.

Data, Governance, and Policy Feedback Loops

What was done

- Generated quantitative WTP estimates that policymakers and manufacturers can act on
- Designed results to inform subsidy design, guarantees, and risk-sharing mechanisms

Quantitative estimates of household preferences and willingness to pay were derived from the pilot analysis. These estimates provide measurable indicators to guide technology development and policy decisions, and directly support discussions on subsidy design, product features, and risk-sharing mechanisms.

Why this matters

- Moves inclusion from consultation to decision-shaping evidence

These estimates enhance inclusion by transforming household preferences into evidence that is relevant for decision-making. Rather than merely demonstrating that households favour lower costs or longer lifespans, the analysis highlights the relative importance of various attributes thus enabling policymakers and manufacturers to identify which features need financial support, design improvements, or policy intervention.

Actionable takeaway

> **Inclusive data systems should directly influence funding and policy design.**
>
> These estimates advance inclusion beyond basic consultation by transforming household preferences into evidence pertinent to decision-making. The analysis enables policymakers and manufacturers to identify which features need financial support, design enhancements, or policy intervention.

Study Context: Where, Who, and Why

Study location — Uttar Pradesh, India

The proposed study takes place in Uttar Pradesh, India's most populous state, making it an ideal setting for examining household energy preferences at scale. With a population exceeding 200 million, the state is home to a diverse mix of urban and rural households, allowing the study to capture variations in income levels, housing types, and electricity access conditions within a single region.

Uttar Pradesh has a relatively low per capita electricity consumption compared to the national average, and many areas face issues with power supply and reliability. As a result, decentralised energy solutions such as rooftop solar are particularly relevant for households in this region. Insights gained from this study could also be relevant for other densely populated states in India.

Sample design

For the main survey, four districts have been identified: Kanpur Nagar, Kanpur Dehat, Lucknow, and Bara Banki. Within each district, six locations will be selected from villages and urban wards using a Probability Proportional to Size sampling approach based on population data. In each selected location, 50 households will be surveyed, resulting in a planned sample of 300 households per district and a total sample size of 1,200 households.

Inclusive mechanism – how voices are gathered and supported

Household voices are supported through carefully designed field interaction procedures that ensure respondents can clearly understand and express their preferences. Enumerators conduct interviews in Hindi and local regional languages, explaining survey questions and solar technology concepts in simple terms so that respondents with varying levels of education can participate comfortably.

To maintain consistency, all enumerators receive standardised training and a detailed survey script before fieldwork begins, minimising the chance that differences in wording or explanations could influence responses. Survey implementation is monitored in real time: the research team regularly reviews progress to identify unusually fast responses, missing information, or logically inconsistent answers, with enumerators staying in continuous contact throughout.

These procedures help ensure that responses accurately reflect household preferences rather than misunderstandings or variations in how questions are asked — enabling respondents to meaningfully participate in evaluating future solar technology options.

What Changed – Decisions, Insights, and Surprises

The study is expected to yield several important decisions, insights, and potential surprises following completion of the main survey with 1,200 households.

Decisions informed by the research

Results will aid in decision-making related to the design of solar technology and the development of policy support mechanisms. By evaluating the relative importance of attributes such as system cost, lifespan, subsidy, emission reduction, community adoption, and efficiency, the study will help policymakers and manufacturers understand which features households prioritise most - and what features need financial support, design improvements, or policy intervention.

Mid-pilot adjustment — a live example of inclusion in practice

During the pilot phase, bill reduction was found to be statistically insignificant, indicating that respondents did not strongly differentiate options based on this factor. However, many respondents expressed interest in discussing the environmental impacts of solar technologies. This led to the inclusion of emission reduction as an attribute in the main survey and allowing the study to capture whether environmental considerations affect household choices alongside financial and technical factors. This is **inclusion as a process**: the research adapting in response to what households actually raised.

Novel insights into pre-commercial technology evaluation

The research will yield novel insights into how households assess emerging solar technologies before they become widely available. By analysing how respondents weigh trade-offs among different attributes, the study will enhance understanding of the factors that influence adoption decisions, highlighting the relative significance of financial, technical, and social considerations.

Potential surprises

The study may uncover unexpected patterns in household preferences. Some attributes commonly thought to significantly impact adoption may play a smaller role, while others may prove more influential than anticipated. The results may also demonstrate that households can effectively evaluate future technologies when the options are clearly articulated; a finding with implications for how pre-commercial research is conducted more broadly.

Transferable Lessons — What Others Can Replicate

- **Engage households before technology enters the market.** A DCE can capture user preferences even when the product is not yet commercially available, helping researchers and policymakers understand what people value early in the design stage.
- **Validate attributes with end users before the main survey.** Conducting pre-pilot consultations and a pilot survey helps identify which factors households consider

important, reducing researcher assumptions and improving the quality of the final choice experiment.

- **Use structured and transparent sampling.** Selecting locations using Probability Proportional to Size and conducting a fixed number of household interviews in each location ensures that the sample is systematic and replicable in other large, diverse regions.
- **Use in-person surveys with trained enumerators.** Face-to-face interviews help respondents understand unfamiliar technologies and make informed choices, allowing even households with limited technical knowledge to participate meaningfully.
- **Use choice experiments to reveal real trade-offs.** Asking respondents to choose between two technological options provides clearer insights into preferences than simple opinion or awareness questions.
- **Translate findings into practical policy insights.** Preference results and willingness-to-pay estimates can guide technology design, subsidy structures, and programme targeting — making research useful for both policymakers and technology developers.

Author: Dr Deepika Swami (IIT Kanpur)

Case study 4.2 - Embedding Gender Equality and Social Inclusion Across the Solar Value Chain through PREO[i]-SUNSAFE[ii]

A GESI-informed digital decision-support tool for solar system sizing

ORGANISATION / LOCATION	VALUE CHAIN STAGE	INCLUSION MECHANISM
PREO-SUNSAFE, Strathmore University;	Full value chain: design, retail & distribution,	GESI-informed app design; women-only training;

Machakos and Makueni Counties, Kenya	installation, household decision-making	gender-disaggregated data; peer-led champions

Key Actors: Women technicians, retailers, households, OEM[iii]s, distributors

The Background: When Solar Expertise Does Not Reach Where Solar Is Needed Most

In many of Kenya's rural communities, solar photovoltaic (PV) systems are installed with high expectations, yet the results often lead to disappointment. Families invest scarce income into panels and batteries meant to last for years, only to find that months later, lights dim, power fails, and trust in solar technology erodes. Through years of research into Kenya's electricity and appliance quality ecosystem, Anne Wambugu observed a clear pattern behind these failures. While solar PV is promoted as the answer to off-grid electrification, the expertise required to design and size systems correctly is rarely available where it is needed most. Technicians who gain formal training and licenses tend to migrate to urban centres in search of better opportunities, leaving rural areas dependent on overstretched or informal installers with limited tools.

The Intervention: The PREO-SUNSAFE Partnership

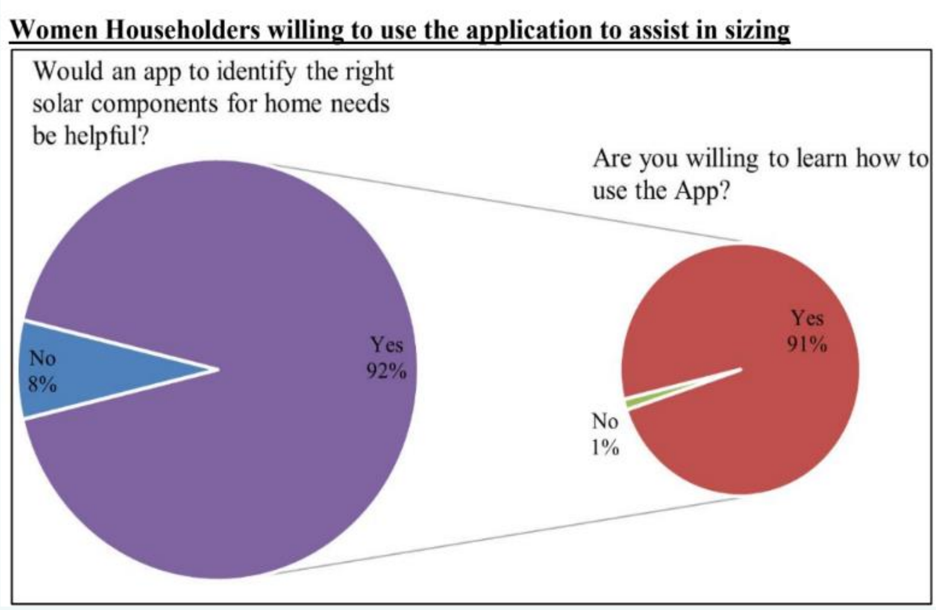
This gap between promise and performance is precisely where the SUNSAFE initiative was conceived. Recognizing that a significant portion of system failures resulted not from faulty technology but from the absence of accessible sizing expertise, SUNSAFE was developed to place critical design knowledge directly into the hands of those installing and selling solar systems at the last mile. To bring this vision to life, the Powering Renewable Energy Opportunities (PREO) programme partnered with SUNSAFE to engineer a solution that was both technical and social. PREO served as the strategic enabler, providing the essential funding and ecosystem support needed to prove that high technical standards are a prerequisite for the productive use of renewable energy. Under this mandate, SUNSAFE provided the technical intervention by deploying a web- and Android-based application designed to correctly size and configure

Component-Based Solar Systems (CBSS). By automating complex calculations, the tool effectively reduces the errors that lead to safety risks, financial loss, and erosion of consumer trust.

The Strategy: Inclusion by Design

From its inception, the project integrated a Gender Equality and Social Inclusion (GESI) lens, acknowledging that women and other marginalized groups are often the most affected by poor-quality installations while simultaneously facing the greatest barriers to participating in technical roles within the solar sector. SUNSAFE was therefore designed not merely as a technical diagnostic tool, but as **an enabler of safer, more equitable participation** across the solar value chain. This case study demonstrates how GESI can be practically embedded across the sector, using the PREO–SUNSAFE project in Kenya as a real-world example. It details how inclusive approaches were intentionally integrated to improve both social and technical outcomes through four specific entry points: *i* inclusive system design and digital access; *ii* women-led distribution and entrepreneurship; *iii* installation, repair, and technical services; and *iv* the generation of data to inform governance. Together, these elements illustrate how addressing technical gaps through inclusive innovation can strengthen system reliability, expand livelihoods, and rebuild trust in solar energy in Kenya's rural communities.

Figure 1.0 — Women Householders willingness to use the application for sizing



The figure presents responses from the surveyed women householders (n = 158). The first chart shows that 92% of respondents indicated that an application to identify appropriate solar components for household needs would be helpful. The second chart represents a follow-up question posed to those respondents, assessing their willingness to learn how to use the application. Among this group, 91% expressed willingness to learn how to use the app.

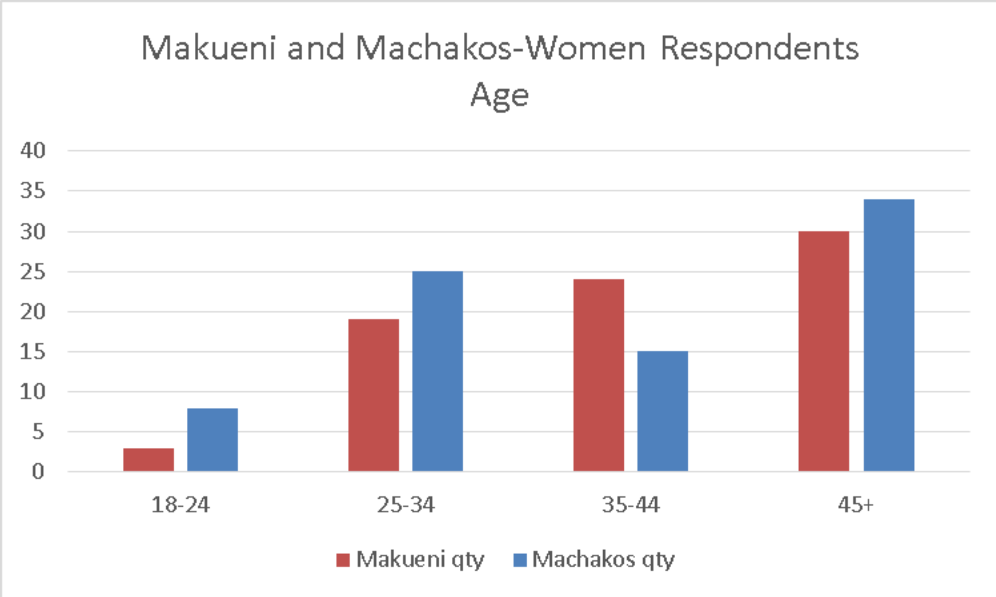


Figure 2 — Age range of women respondents: Makueni and Machakos Counties

The figure illustrates the age distribution of women household respondents across Makueni and Machakos counties. The respondents are predominantly within the older age categories, with the highest representation observed in the 45+ age group in both counties. In Machakos, this group constitutes the largest share, followed by those aged 25–34, while in Makueni, the 45+ and 35–44 groups are most prominent. Younger respondents (18–24 years) are the least represented in both counties.

A core insight of SUNSAFE:

.. is that ensuring system reliability should not require every rural retailer to become a certified solar engineer. Instead, the initiative adopts a digital-assisted approach to capacity building. By embedding complex engineering logic and sizing calculations directly into the SUNSAFE app, the project shifts the burden of technical precision from the individual to the tool. This allows retailers, particularly women who may lack formal technical background to configure and sell expert-level systems with confidence, effectively democratizing access to technical accuracy.

Data Insights

SUNSAFE aims to make reliable solar energy tools accessible to everyone, especially women who are often excluded from technical roles in the solar sector. This made a Gender Equality and Social Inclusion strategy essential from the outset.

Fieldwork carried out in Machakos and Makueni Counties in 2023 revealed strong gender imbalances across the solar value chain. Over 80% of technicians were men, while most women were found in retail and sales roles. Many women retailers reported that they did not have enough technical knowledge to correctly size solar systems, which put them at risk when systems failed and reduced trust in component based solar solutions.

These challenges were also clear during training sessions. Very few women attended technical training, with only one female participant in Makueni County and four in Machakos. One woman arrived with her infant and was unsure if she could stay. Support from other women allowed her to participate, showing how childcare responsibilities affect women's ability to access technical training. Most training formats do not consider these realities and unintentionally exclude women.

Past experience from previous training work by Anne and the UNESCO Chair team helped explain these patterns. Women-only training spaces consistently improved participation and learning outcomes. In these settings, participants reported feeling more comfortable asking questions, admitting gaps in knowledge, and building confidence in solar system sizing and installation. Facilitators also observed that these spaces encouraged more active participation in women-only sessions which suggested reduced intimidation and stronger engagement with technical content.

The findings showed that women are not excluded because of lack of interest or ability, but because of structural and cultural barriers. These include limited access to training, workplace power dynamics, childcare responsibilities, and social norms that label technical work as men's work (Patriarchy). Many women retailers said they wanted to gain installation skills but faced barriers such as lack of time, employer restrictions, and limited training options.

Key barriers and risks identified

Key barriers identified (structural and cultural)

- Childcare responsibilities
- Limited access to technical training
- Workplace power dynamics
- Social norms framing technical work as male

Key risk identified:

- Retailers without technical sizing knowledge faced reputational and financial risks when systems failed

The data insights presented here draw on a mixed qualitative research approach designed to capture lived experiences of gendered participation in solar energy adoption. Fieldwork was conducted in Machakos and Makueni Counties and engaged 158 women household consumers, 22 solar retailers, and 33 solar installers. Data were collected through in-home observations, in-depth face-to-face interviews, and focus group discussions with installers and retailers. This approach enabled the study to move beyond surface-level gender disaggregation and uncover structural, cultural, and practical barriers shaping women's participation across the solar value chain.

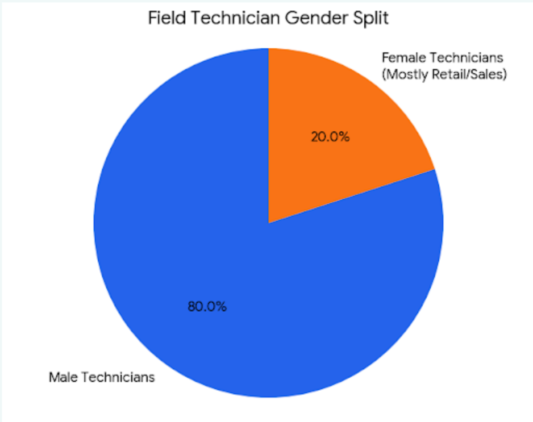


Figure 2.0 — Gender distribution of roles in the solar value chain

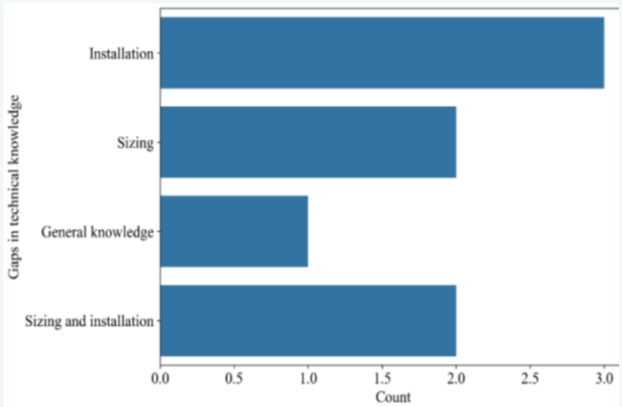


Figure 3.0 — Learning outcomes in women-only training sessions

Solar Value Chain with Gendered Barriers

By embedding GESI at multiple entry points, the PREO–SUNSAFE project in Kenya has strengthened women's participation in technical and entrepreneurial roles, enhanced the reliability and safety of solar systems, increased market trust, and contributed to the long-term sustainability of solar investments. It offers actionable lessons for policymakers, practitioners, investors, and development partners seeking to operationalize inclusion in renewable energy programming and support an energy transition that is both clean and equitable.

Design & Information	Retail & Distribution	Installation & Repair	Household decision making
• Low access to sizing knowledge • Technical confidence is mainly male dominated • System design based on guesswork	• Women present but under-skilled • Reliance on suppliers/men • Limited progression pathways	• <0.05% women installers • Hostile work environments • Inflexible training models	• Women primary energy users • Men control purchases • Women bear consequences of failure

The SUNSAFE-PREO Response: Impact on Women, Youth, and Market Actors

SUNSAFE embeds inclusion directly into how component-based solar systems are designed, sold, and supported. The SUNSAFE application simplifies system sizing using clear language, guided steps, QR code scanning, and basic manual inputs, allowing retailers and installers with limited technical training to size systems accurately and confidently. This shifts sizing from a specialist task to a shared capability across the value chain, contributing to SDG 7 — Access to affordable, reliable, sustainable and modern energy for all.

For women who face barriers to attending formal training, the app acts as a practical learning tool, reinforcing correct sizing decisions during everyday work. Retailers noted that this reduces reliance on male technicians and suppliers while strengthening their technical credibility.

SUNSAFE also integrates gender-disaggregated data into its design and rollout, creating evidence for more inclusive policy and accountability over time. Finally, the project supports peer-led adoption by working with trusted installers as SUNSAFE champions, helping normalise women's technical participation and build confidence within local solar markets.

Key Lessons Learnt

1	Effective inclusion starts with design. Tools must reflect the realities of users with limited time, mobility, and formal training.
2	Participation in retail alone does not equal empowerment; meaningful inclusion requires access to technical skills and decision-making power.
3	Training models must adapt, using flexible and tool-supported approaches to unlock women's participation.

4	Gender-disaggregated data plays a critical role in shaping responsive policy, guiding investment, and strengthening accountability.
5	Inclusion is cultural as well as technical: visible women technicians and supportive workplaces can shift entrenched norms across the solar value chain.

Authors: Anne Wacera Wambugu, Jovia Bogere Nampewo, Kirsten Erica Dass, Augusta Njogo, Maryvelma Nafula

Case study 4.3 – Kijani Testing: Building repair ecosystems for inclusive solar futures

When solar products break, who fixes them? Kijani Testing is rebuilding the repair ecosystem from the ground up.

ORGANISATION/ LOCATION	VALUE CHAIN STAGES	INCLUSION MECHANISM
Kijani Testing; Kenya (Kakuma refugee settlement and rural/peri-urban communities)	Downstream (aftersales, repair, and maintenance) through to end-of-life; upstream influence via living labs and product co-design	Tiered repair and capacity-building model; living labs; evidence-based advocacy for spare parts availability and user education

Inclusion challenge

In Kakuma refugee settlement in northern Kenya, thousands of solar products have been distributed by humanitarian agencies over the years — lanterns, solar home systems, productive use appliances. When they break, there is nowhere to get them fixed. NGO procurement has typically prioritised getting as many products into as many hands as possible, with little attention to customer training, realistic expectations, or the aftersales infrastructure needed to keep systems working.

Kinya Kimathi, founder of Kijani Testing, has documented this pattern across Kenya through careful data collection at every repair her team undertakes. The figures are striking: over 60% of product failures are entirely preventable — caused not by faulty technology or inevitable wear and tear, but by poor installation, misuse, and lack of user awareness. A further 90% of failed products could be restored to working condition with the right spare parts, tools, and skills. Most instead sit broken in people's homes because accessible repair infrastructure simply does not exist in most rural areas.

This reframes the inclusion challenge. The barrier is not primarily product quality or affordability. It is the absence of the knowledge, skills, and local infrastructure needed to keep solar systems working — and the systematic exclusion of end users, local technicians, and repair businesses from a value chain that often ends at the point of sale.

What the data shows

- 19% of failures in Kakuma are due to lack of spare parts
- 23% due to poor installation
- 40% due to negligence or misuse — largely preventable through user education
- 42% of users try to return broken products to suppliers; only 14% dispose of them

People want to repair, not dispose. The barrier is not user attitude — it is the absence of accessible repair infrastructure.

Where and how inclusion was embedded

Kijani's work embeds inclusion at the downstream end of the solar value chain — in aftersales support, repair, maintenance, and end-of-life — while also generating evidence and advocacy that feeds back upstream into product design, procurement decisions, and policy. Inclusion here is not a component added to an existing system; it is the organising principle of the repair ecosystem Kijani is building.

The model operates at multiple levels simultaneously: educating end users as informed product owners; professionalising local freelance technicians and integrating them into trusted repair networks; and anchoring the system through service centres capable of handling complex repairs. Cutting across all three tiers is a commitment to evidence — Kijani's repair data does not just inform its own practice; it challenges assumptions across the sector about where failures occur, why, and what can be done about them.

Mechanism deployed

Tier 1: End-user education and trusted aftersales support

The first tier focuses on educating end users as informed product owners, not as technicians. This means building realistic expectations of system performance, promoting correct handling and installation practices, routine maintenance, and early fault identification. Given that the majority of failures stem from preventable causes, even modest increases in user knowledge can significantly reduce breakdowns.

Kijani provides pro bono user training to all repair customers, alongside a six-month repair warranty — reinforcing trust, accountability, and long-term product care. This tier also addresses the circulation of substandard and unsafe products. Poor wiring, low-quality components, and non-certified devices present real safety risks, and user education includes guidance on quality-certified products, recognising that cheaper options often carry higher long-term costs.

As part of a strategic shift, Kijani is increasingly working with distributors and suppliers as a trusted aftersales support provider, with its contact details included in product warranty documentation. This embeds repair, education, and quality assurance directly into the formal solar value chain rather than leaving these functions to informal networks.

Tier 2: Freelance technicians and entrepreneurial capacity

The second tier focuses on local freelance technicians who typically already possess technical skills — through certificates, diplomas, or vocational training — but lack the formal structures, recognition, and business skills needed to operate sustainably within the solar value chain. The primary constraint is not technical competence, but limited access to trusted repair networks, stable demand, and opportunities to professionalise their services.

Kijani engages these technicians on a consultancy basis, with fees that include logistical costs. This responds to the highly volatile demand for repair services while avoiding the need for a large full-time workforce. The support Kijani provides focuses on what technicians actually lack: customer communication, basic accounting and cost recovery, reporting and documentation. The goal is for technicians to function as entrepreneurs rather than precarious informal workers — with pathways into trusted, formalised repair ecosystems and visibility within the value chain.

Tier 3: Service centres and complex repairs

The third tier consists of service centres where more complex electrical and mechanical repairs are undertaken by experienced in-house technicians, with spare parts on hand and quality assurance processes in place. Service centres act as anchors for the wider repair ecosystem, supporting freelance technicians with expertise, spares, and escalation pathways, while reinforcing standards and accountability across all tiers.

Tiered documentation

Skills are built through the tiered model to match repair complexity — but even skilled technicians need clear documentation. Kijani has identified a consistent gap: manuals arrive in the wrong languages, are overly technical, lack troubleshooting guides or wiring diagrams, and contain warranty terms buried in fine print. The solution is equally tiered: simple pictorial guides for end users that work across language barriers; technical manuals with clear procedures for field technicians; comprehensive documentation with exploded diagrams and parts specifications for service centres.

Living labs and context-based co-design

What makes Kijani's approach different starts long before products break. Rather than waiting for solar devices to fail in the field, Kijani has pioneered "living labs" — real-world testing environments where products are deployed with actual users before launch to the wider market. These are not laboratory settings; they are field environments where multiple stakeholders interact with a new product simultaneously: end users give feedback on prototypes to product designers; technicians perform field repairs with limited tools; financiers test finance mechanisms with new products; investors set up demonstration sites for capacity building and data collection.

The insights are revealing. Manufacturers specify that a solar panel should face north; users place it flat on the roof because it is more practical. Training manuals written in Chinese arrive in Uganda. Products designed by engineers far from deployment contexts fail to account for local conditions, knowledge, or practices. Living labs create the space for these mismatches to surface and be resolved before they become embedded failures.

Context shapes everything. In Kenya, around 90% of customers are rural or peri-urban, with many urban residents purchasing systems for relatives in rural homes. Solar adoption is higher where people own their homes; renters in urban areas are less likely to invest. These patterns have direct implications for product design, messaging, and aftersales support — and Kijani's data makes them visible.

> *When people understand how their solar product works from day one — when they know how to clean panels and check connections, when their expectations are realistic rather than shaped by over-enthusiastic sales pitches — products last longer. That 60% of preventable failures? User training addresses most of it.*

Outcomes observed

Kijani's evidence base challenges assumptions across the solar sector. By documenting every repair, it has produced data showing not only where failures occur and why, but also that users actively want to repair their products — 42% seek out suppliers or technicians when things break; only 14% dispose of broken systems. This reframes the narrative: the problem is not user attitude or product quality alone, but the absence of accessible, affordable repair infrastructure.

The tiered model is demonstrating that sustainable repair ecosystems are possible in contexts typically written off as commercially unviable. Freelance technicians are being professionalised and integrated into formal networks. Service centres are functioning as anchors for wider ecosystems. Aftersales support is being embedded into formal product warranties rather than left to informal networks.

Living labs are generating product-level improvements and more realistic market communication strategies. Manufacturers, suppliers, and financiers who engage with the labs come away with a more grounded understanding of how products are actually used, what fails and why, and what support structures are needed to sustain them. This upstream influence — feeding evidence back into product design and procurement decisions — is one of the more significant longer-term contributions of Kijani's work.

Kijani's experience demonstrates that inclusion in the solar sector is not only about access to energy. It is about access to knowledge, quality, repair services, and livelihoods. Repair ecosystems succeed when they are designed with consumers, for local context, and with existing skills in mind.

Enabling conditions

Several conditions underpin Kijani's ability to operate at this level of depth and impact.

- **Evidence-led practice**: Systematic documentation of every repair generates the data needed to challenge sector assumptions, target interventions precisely, and make the case for upstream change. Without this evidence base, the model loses much of its persuasive force.
- **A tiered model that reflects real patterns of failure**: The three-tier structure — end users, freelance technicians, service centres — was developed from observation of how failures actually occur and how different actors in the ecosystem can most usefully respond. It is grounded in evidence, not designed from first principles.
- **Recognising what technicians already know**: Rather than assuming that local technicians need more technical training, Kijani's assessment found that most already had the hard skills needed. What they lacked were business skills, market access, and integration into trusted networks. Targeting support accurately avoids waste and builds genuine capacity.
- **Integration into formal value chain structures**: Being listed in supplier warranty documentation positions Kijani as part of the formal solar value chain, not an informal add-on. This both legitimises the repair ecosystem and creates a sustainable pipeline of customers.
- **Living labs as a shared infrastructure**: By bringing end users, technicians, suppliers, and financiers together in real-world testing environments, living labs create a space for mutual learning that no single actor could generate alone. The insights surface at the intersection of different perspectives — and they inform not just Kijani's practice but the wider sector.
- **Advocacy for systemic change**: Kijani advocates for standardised components, local spare parts hubs, and interoperability — so that parts can work across models and spare parts do not disappear when products are discontinued. These systemic changes are beyond what any single company can deliver, but Kijani's evidence base makes the case for them compellingly.

Feedback loop

The feedback loop in Kijani's model runs in both directions. Repair data informs user training content and technician support. Living lab findings feed back into product design and procurement decisions. Evidence on failure patterns and user behaviour is shared with suppliers, manufacturers, and policymakers. Each tier of the repair ecosystem learns from the others, and the model as a whole becomes more effective over time as the evidence base grows.

Author: Kinya Kimathi (Kijani Testing)

Case study 4.4. – POWERE: Institutional co-ownership in Indonesia's remote coastal communities

POWERE[iv] — Participation of Women in Renewable Energy · South Sulawesi, Indonesia

ORGANISATION/ LOCATION	VALUE CHAIN STAGE	INCLUSION MECHANISM
POWERE; Tamparang, South Sulawesi, Indonesia (remote coastal communities)	Full cycle: pre-deployment grounding, participatory co-design, post-deployment governance	Ethnography; Women's Action Learning Groups; participatory co-design; adaptive governance

POWERE

POWERE (Participation of Women in Renewable Energy) supports inclusive low-carbon transitions in off-grid remote coastal communities of the Global South. Starting in South Sulawesi, Indonesia, it introduces **near-shore floating photovoltaics** (FPV) to replace fossil fuel reliance, integrating **renewable energy with women-led groups** based in the community. Through **interdisciplinary collaboration, ethnography** and **participatory action research**, POWERE aims to position women as co-owners and managers of energy infrastructure, linking clean energy access to livelihood development, capacity building, and long-term climate resilience.

The Challenge of Sustainable Energy Transitions

Our approach begins long before installation and extends far beyond product performance. Rather than focusing solely on how technologies function in isolation, we ask: How does electricity already circulate materially and socially? Who controls it? Who maintains it? Who bears the burdens, who reaps the benefits, and who is excluded?

Fishing and seaweed farming villages on a remote Indonesian island. (Photograph by Muhammad Zamzam Fauzanafi)

Why This Matters

- Off-grid energy systems often fail due to weak governance and a lack of local ownership.
- Women play central but under-recognised roles in coastal economies and energy systems.
- Climate vulnerability in small island communities requires integrated energy-livelihood solutions that are both practical and deeply integrated in their everyday lives.
- Technology alone is insufficient—resilient infrastructure in remote contexts depends on strong, locally embedded social and institutional infrastructure.
- Peer-to-peer learning and support networks, alongside wider national and international connections, are critical for long-term sustainability and resilience.

POWERE addresses these challenges through a three-phase approach that integrates social grounding, participatory implementation, and long-term adaptive governance.

Tamparang—a pseudonym for a cluster of small mangrove-fringed islands—lies over an hour by boat from mainland Sulawesi. Fishing yields are declining, seaweed farming is seasonal and precarious, education and training facilities are insufficient, and electricity is unreliable for village residents. Communal diesel generators are instead managed by a locally selected team (manager, operator, and fee collector), appointed in a village meeting where fee amounts are also agreed. Men frequenting mosques gain easier access; women and households further from installations are often excluded. Infrastructure therefore mirrors, and can reinforce, existing hierarchies.

Understanding these dynamics requires long-term fieldwork, mapping not only electrical systems but also social, economic, and political power relations alongside livelihood patterns, seasonal rhythms, and care responsibilities. Technology adoption is treated not as a neutral event but as an intervention into an already uneven social landscape.

Therefore, the challenge is not only deploying renewable technology but embedding it socially, inclusively, institutionally, and sustainably. Without **social infrastructure** encompassing local governance, capacity building, and social grounding, floating solar units risk remaining underutilised, mismanaged or broken, echoing failures observed in other off-grid contexts globally.

Study Sites and Key Insights

In Tamparang:

- Diesel generators and patchwork solar panels provide limited electricity
- Climate vulnerability is rising—sea levels are increasing, fishing yields are declining, and extreme weather threatens livelihoods.
- The islands' 800 households are part of approximately 31,000 seaweed-farming households in South Sulawesi, 25-50% of which are managed primarily by women.
- Women invest profits directly into housing, schooling, healthcare, and food security.
- Village governments already allocate 20% of their budgets for food security, providing a ready channel for Village-Owned Enterprises (BUMDes) to invest in supportive energy.
- The village fund is administered by the village treasurer, with priorities set through the Musrenbang (annual village development planning meeting). Implementation authority rests with the village head, village secretary, and the Village Consultative Body (BPD).

This evidence underscores that barriers are not entirely about capital or leadership but more about building on existing resources, skills and social structures and connecting them to energy infrastructure.

Remote island village with street cabling connected to a diesel-fuelled communal generator. (Photograph by Raminder Kaur)

Three-Phased Research, Development and Deployment Model

POWERE applies a three-tiered social and institutional strategy, ensuring infrastructure is embedded within local practices and governance systems **before, during, and after deployment**. The programme uses an **interstructural** lens, integrating the intersections of multifaceted identities, social relations, everyday practice and infrastructural conditions rather than treating these as separate domains (Kaur et al. 2026).

Each phase contains **structured gate checks** to ensure renewable deployment is conditional on social, environmental, and institutional viability—not solely technical feasibility. For example:

- Project vision aligns with village priorities that are inclusively established
- Renewable resource availability verified
- Energy demand and consumption pathways identified, including household, productive, and community uses, alongside clear revenue and maintenance arrangements
- No environmental or regulatory show-stoppers detected
- Social acceptance and governance feasibility confirmed
- Coastal use compatibility confirmed

Phase 1: Social and Institutional Grounding (Pre-Deployment)

Objective: Ensure renewable infrastructure responds well to existing social structures, energy practices, livelihood practices, power hierarchies and spatial dynamics before installation.

This phase is founded on the premise that communities are not homogeneous. Access to infrastructure often mirrors—and can reproduce—existing inequalities. It also examines local conceptions of infrastructure, trust, and past experiences of infrastructure breakdown and/or disappointment, recognising that **(dis)enchantment** shapes willingness to adopt new systems.

Mapping and Diagnostics

Before deployment, this phase undertakes:

- Mapping of existing electricity arrangements (e.g., diesel generator, private solar, communal access)
- Identification of informal technical authority and maintenance practices
- Analysis of gendered divisions of labour and responsibility in the household, seaweed farming and other livelihood strategies

- Examination of livelihood-energy linkages and seasonal variability
- Intersectional power-mapping (that is, with reference to income, wealth, patron-client relations, land and marine ownership/tenure)
- Participatory marine spatial analysis to understand existing use of coastal space

Particular attention is paid to how electricity reorganises time and labour, especially for women balancing seaweed processing, household care, and other forms of income generation.

Participatory coastal mapping is conducted with a combination of community place-based knowledge and professional spatial verification systems to document existing livelihood uses, navigation routes, and informal marine tenure systems. Environmental and spatial assessments are integrated to ensure technical feasibility, marine compatibility, and risk minimisation.

Institutional and regulatory feasibility are assessed to identify governance capacity, permitting requirements, and potential implementation bottlenecks. Household and productive energy needs are assessed to identify supply gaps, reliability constraints, and opportunities for livelihood expansion.

Rather than operating as separate streams, social, spatial, institutional, and technical diagnostics are conducted in an integrated manner to ensure that siting and design decisions are both **technically viable and socially legitimate.**

Women learning to read the wind with the POWERE team as part of site selection feasibility studies. (Photograph by Andi Irma Saraswati)

Ethnography and Women's Action Learning Groups

Ethnographic engagement using local languages to appreciate and understand the nuances and complexities of everyday life and power mappings reveal the **social distribution of energy responsibility and technical authority**—dimensions often invisible in conventional or quick-in, quick-out feasibility studies. **Women's Action Learning Groups** -initiated through invitation of about 20 diverse women ranging from those in their late teens to their 60s, spanning low-income to elite households—provide regular and structured spaces for reflection, collective learning, and articulation of energy priorities.

Workshops are sequential and cumulative, strengthening adaptive problem-solving and collective management capacity. Expert exchanges and field-based learning activities connect local knowledge with technical insight, fostering co-learning rather than passive reception.

Action learning workshops with women and POWERE team (Photograph by Raminder Kaur)

Phase 2: Participatory Co-Design and Institutional Embedding (Implementation)

Objective: Build local ownership, operational capacity, and governance systems alongside renewable infrastructure deployment.

This phase is implemented through participatory action research with the women-led groups, enabling iterative learning, co-design, and adaptive refinement during deployment. Rather than treating infrastructure as a finished product delivered to users, the process positions communities as co-developers of both the technical infrastructure and the social infrastructure that are mutually sustaining.

The phase integrates three interdependent components:

- **Hardware**: installation of floating solar photovoltaic systems
- **Software**: energy literacy, technical training, and maintenance skills

- **Orgware**: governance structures, financial/business models, and conflict-resolution mechanisms (Quirapas Franco 2020)

These components are developed concurrently to prevent common shortcomings of infrastructure that is technically functional but institutionally unsupported.

Structured Participatory Modules

Cumulative workshops are sequenced to progressively deepen technical understanding and organisational capacity. Participants engage in action learning on:

- Practical operation and maintenance training
- Collective design of revenue-generating energy applications linked to local livelihoods
- Development of transparent financial mechanisms for system upkeep
- Co-creation of governance structures in collaboration with village institutions and enterprises
- Agreement on roles, responsibilities, and benefit-sharing arrangements

Women-led groups are engaged not only as beneficiaries, but as co-designers, co-owners, and potential operators of the FPV installations. Through hands-on engagement, peer learning, and cross-village exchanges, participants build confidence to manage infrastructure and make informed decisions about siting, maintenance, and revenue allocation.

Capacity-building extends beyond technical competence. It cultivates **individual and collective energy agency**—the ability to shape how infrastructure is governed, who benefits, and how conflicts could be resolved productively. By strengthening decision-making authority and accountability mechanisms, the programme embeds renewable energy within local institutional systems rather than leaving it detached from the community and dependent on external actors.

Peer-to-peer networks across villages further reinforce horizontal learning and enable a shift from passive reliance on outside technical support to proactive engagement with and leveraging of multi-level support mechanisms.

Women presenting their work to participants in action learning workshops. (Photograph by Raminder Kaur)

Rationale

- Technical infrastructure without robust community-based social infrastructure often fails
- Capacity-building must be cumulative and embedded in practice
- Gender-inclusive participation strengthens transparency, accountability, and long-term sustainability.

Implications

Renewable energy programmes should allocate equal attention to social infrastructure—institutional development, financial governance, and participatory processes—as to hardware procurement. *Sustainable deployment requires simultaneous investment in social as well as technical systems.*

Phase 3: Long-Term Evaluation and Adaptive Governance (Post-Deployment)

Objective: Ensure renewable systems remain functional, inclusive, and institutionally embedded over time.

This phase extends beyond installation to examine how infrastructure reshapes social relations, governance practices, and livelihood strategies. Applying the interstructural lens longitudinally, it analyses how infrastructure interacts with identities (gender, income, education, lifecycle stage etc.), sociocultural norms, and aspiration as conditions evolve.

Adaptive Monitoring and Institutional Consolidation

Post-deployment engagement focuses on how renewable systems are governed, maintained, and experienced in practice. Evaluation examines:

- Who controls and maintains infrastructure including payment structures and maintenance, repairs and renewal costs
- How responsibilities are redistributed across gender, class, age, and household structures
- The effects of energy access on livelihood flexibility and economic resilience
- Whether governance mechanisms remain transparent and accountable
- How conflicts can be managed and resolved

Attention is paid to how social position—based on income, education, marital status, and aspiration, for instance—influences ongoing engagement with infrastructure.

Monitoring combines participatory reflection sessions, troubleshooting reviews, focus groups, and cross-village peer exchanges. Periodic site visits by the research team and/or other experts can assess both technical functionality and institutional durability. Rather than treating evaluation as an external audit, this phase embeds **continuous learning** within community governance structures.

Measuring Sustainability Beyond Output

Success is not measured solely by electricity generation, but by:

- Local maintenance capacity
- Inclusive and accountable governance
- Financial viability and revenue management
- Adaptability to seasonal, environmental, and economic volatility

By embedding monitoring and reflection into everyday management, the programme strengthens adaptive governance—the capacity to respond to breakdown, social tension, and shifting livelihood conditions without external dependence.

Rationale

- Renewable systems degrade when institutional support ends
- Technical sustainability depends on social sustainability
- Adaptive governance is essential in volatile off-grid environments

Implications

Renewable energy programmes should incorporate long-term institutional accompaniment, embedded monitoring processes, social learning and adaptive governance mechanisms beyond installation timelines. *Sustainable transitions require ongoing social stewardship, not one-time deployment.*

From Installation to Transformation: Embedding Energy in Social Life

In Tamparang, technical competence does not begin in classrooms or training manuals. It develops through repeated encounters with breakdown of existing energy infrastructure, improvisation, and shared responsibility. Electricity is already embedded in everyday life—in the repair of damaged wiring, in negotiations over generator fuel, in the quiet recalibration of household routines when power fails. These informal systems of learning and adaptation form the **foundations of energy transitions.**

While electrical repair is often narrated as dangerous and masculine work, lived practice tells a more complex story. When men migrate seasonally for fishing or when systems fail, women step into maintenance and coordination roles. Their engagement with energy is rarely framed as empowerment; it is driven by necessity, autonomy, and dignity. In a context where borrowing electricity can carry social shame or discomfort, households seek greater independence wherever possible. **Energy management** becomes intertwined with reputation, resilience, and household standing.

Our approach begins from appreciating this reality nurtured through ethnographic engagements. Rather than assuming low technical literacy, we recognise and build upon existing cultures of maintenance, improvisation, and seasonal adjustment. Workshops are designed not as awareness campaigns but as **embedded and cumulative action learning spaces** where reflection, experimentation, and collective problem-solving unfold over time. Participants analyse their own energy practices, identify risks, negotiate responsibilities, and gradually develop the confidence to shape infrastructure decisions.

This process produces **ongoing collective capacity-building**: the groups' ability to adapt systems, manage conflict, allocate revenue, respond to environmental volatility, and sustain infrastructure beyond the life of a project cycle. Expert exchanges and field-based exercises do not replace local knowledge; they deepen it. Community members become **co-analysts and co-producers** of technical options and governance arrangements, strengthening ownership and long-term accountability.

Applying an interstructural lens allows us to see how infrastructure interacts with social identities, sociocultural norms and hierarchies, livelihood insecurity, seasonal migration, and individual aspirations. Energy transitions are never purely technical adjustments. They reorganise time, labour, authority, and opportunity. If introduced without understanding these dynamics, renewable systems risk reinforcing inequality or deteriorating once external support withdraws.

Embedding floating solar infrastructure in Tamparang therefore requires more than correct siting and installation. It requires

- power mapping alongside technical mapping,
- governance design alongside hardware deployment, and
- recognition of informal expertise alongside formal training.

The process requires acknowledging that communities are differentiated and politically situated, not homogeneous beneficiaries.

By sequencing social grounding before deployment, institutional embedding during implementation, and adaptive governance after installation, the programme reframes renewable energy from **a product to be tested** into **a social context to be cultivated *for* the product**. Infrastructure endures not because it is technically advanced, but because it becomes woven into everyday life, collective responsibility, and shared aspiration.

Energy transitions in off-grid contexts are not simply shifts in generation technology; they are **negotiated social transformations**. Embedding renewable energy inclusively and sustainably requires aligning infrastructure with existing social relations, governance systems, and livelihood realities rather than treating technology as a standalone solution. It demands recognition of differentiated actors, redistribution of decision-making authority, and cultivation of long-term institutional capacity alongside technical deployment. Social infrastructure must be constructed together with technical infrastructure. When renewable infrastructure is socially grounded, institutionally embedded, and adaptively governed, it becomes more than electricity supply—it becomes **a durable platform for resilience, autonomy, and collective capability**, directed by the women-led groups and rooted within the communities it is meant to serve.

Woman fixing lighting in her house. (Photograph by Diah Irawaty)

Action Learning Women

Safira is an 18-year-old married woman and a member of the Action Learning Group that has been named Bai Baine Kassa (Women's Learning Group)by them, in Rannu village. She has participated in the action learning workshops since they began in November 2025. Together with her husband, Daeng Sila, she runs a small business that specializes in repairing electronic devices, such as cellphones and televisions. In addition to repairs, they sell internet data and operate an online business offering various items, including rechargeable flashlights and small portable solar panels, which they deliver to community members who place orders. They also manage a digital financial service that helps village residents pay bills, shop online, and transfer money.

Although Safira did not complete her high school studies, she possesses valuable electrical skills. She continues to learn by experimenting hands-on with electronic devices and electricity; for instance, she successfully repaired broken bulbs and extension cables. Safira has further developed these skills alongside her husband.

She shared her workshop experiences, explaining how they have positively influenced her relationship. By frequently discussing what she learned with her husband, he began to make significant changes in his behaviour. He has become more willing to take on household chores that he had never done before. Safira expressed her joy in witnessing this transformation, stating,

> *The knowledge about gender and sharing domestic work that I shared with my husband from the meeting encouraged him to make changes in himself. I was very happy to see his progress, and it made me even more confident in sharing information from the group meetings because he accepted it so well. My husband is also knowledgeable about some topics I discuss every time I return from the women's learning group.*

Safira fixing electrical appliances in a remote island village. (Photograph by Diah Irawaty)

Authors: Chun Chun Yu, Prof Raminder Kaur, Monika Swastyastu (POWERE)

Case study 4.5 - ENACT: Community Co-Ownership of Solar Energy in Malaysia

ORGANISATION / LOCATION	VALUE CHAIN STAGE	INCLUSION MECHANISM
ENACT; Pos Titom, Pahang, Malaysia (primary); Sabah, Malaysia	Operates as a cross-cutting intervention across SVC-(community co-design), midstream (deployment governance), and downstream (productive use), with institutional embedding functioning as an ancillary, system-level enabler.	Participatory co-design; Village Energy Committees; COMET toolkit; D-RECs as community revenue mechanism

Inclusion challenge

Despite Malaysia's stated near-100% national electrification rate, around 400 villages in Sabah and 200 in West Malaysia remain under-electrified. This gap between headline statistics and on-the-ground reality reflects deeper structural issues: policy has consistently favoured grid extension over distributed energy systems, data on remote communities is often outdated, and energy and rural development agendas are not generally aligned. The result is that conventional delivery models have simply not reached many remote Indigenous communities, and where infrastructure has arrived, it has often come with limited or no governance or ownership consideration, or the capacity to sustain it.

In the villages of Pos Titom, before the current clustered solar home system installations, energy access was minimal and in some cases absent entirely. Higher-income households could afford diesel generators, but for most families these were prohibitively expensive. The majority relied on oil lamps or battery-powered lights for basic lighting. Some communities had received small solar lamps distributed by energy companies, but these offered little beyond lighting and phone charging which may be considered a gesture toward access rather than a genuine energy solution. Social mapping and ethnographic research conducted in the area confirms what this picture suggests: incomes are relatively low, and these communities routinely pay higher prices for basic amenities than their urban counterparts. Exclusion here is not just about the absence of infrastructure, it is about who bears the cost, and who is left outside the systems that determine how energy is planned, delivered, and governed.

Where and how inclusion was embedded

ENACT began working with two of the four villages now part of the project in 2019. What started as initial meetings developed into sustained engagement over several years, drawing on ethnographic methodologies including social mapping, COMET workshops, and focus group discussions. These approaches supported the gradual building of rapport, not only within the project villages but with neighbouring communities across Pos Titom. These activities surfaced the distinct context, priorities, and perspectives of each place.

Co-design with communities is central to ENACT's approach, grounded in the recognition that Indigenous communities hold deep knowledge of their land, cultures, and needs. The engagement at Pos Titom both applied and refined this practice. The trust built over this period made the pilot installations in Sempar in 2022–2023 possible, and subsequent projects, including Innovate UK's Energy Catalyst Round 10 and UNDP's Green and Resilient Recovery programme, built on that foundation, continuing to involve communities at every stage with substantive decision-making authority held locally.

Community deliberations are broadly inclusive across genders, ages, and groups within each village. Village Energy Committees, which carry operational responsibility for the systems, have tended to be predominantly male in composition and this pattern is worth noting and is one the project continues to reflect on. Women's participation is nonetheless present and meaningful, extending through productive use enterprises and household-level energy management, and represents an area for ongoing attention as the project develops.

Mechanism deployed

For communities with very little or no prior access to electricity, introducing the concept can be genuinely challenging — it is difficult to envision the use of appliances that have never been part of daily life. Rather than relying on surveys and questionnaires that may not capture the full range of possibilities, COMET[1] (developed and maintained by a separately incorporated enterprise that emerged from ENACT in 2022) offers a more intuitive way to visualise appliance and electricity usage.

A COMET workshop was held in each community as part of the social baseline assessment. A series of 24-hour simulations were conducted, each serving a different purpose: from an initial familiarisation round, where participants experimented freely with different appliances at different times of day, to a more structured round in which participants role-played a 24-hour day using the appliances they would like to own.

After each simulation, participants received a "bill" calculated against a pre-existing tariff, creating an immediate and tangible connection between usage and cost. This grounds subsequent community discussions on tariff setting and demand estimation in something concrete and personally felt, rather than abstract.

COMET was also used to simulate productive use of energy (PUE), giving communities a structured space to identify and develop potential business opportunities. In Sempar, three separate COMET PUE workshops held over the years supported the development of three of the four businesses now operating in the village (the convenience store, cold storage facility, and hair salon, with a fourth, a restaurant, having developed independently outside the workshops). Other communities have followed with their own planning, with a rice milling service under development at Kemiyan and a cold storage facility at Cerewes.

Distributed Renewable Energy Certificates (D-RECs) have been established but are not yet generating revenue due to technical issues with metering. Once operational, funds will be channelled into community funds designed to support the long-term maintenance of the systems.

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[1] A software that taps into human behaviors and interactive digital technology to provide diverse insight into energy demand, customer priorities, and more. https://www.cometapp.net

Outcomes observed

As of May 2026, all houses in the three of the four villages have been electrified save for one that is still pending their testing and commissioning. Each village has its own designated village energy committee – or VEC, which manages day-to-day operations and maintenance; monitoring system performance, collecting monthly payments, and routine maintenance such as panel cleaning. Minor technical issues are resolved by VEC technicians, trained by ENACT prior to installation, with troubleshooting support from the ENACT team where needed. Major issues - for example, inverter failures attributed to manufacturer defects - were replaced by the installer under warranty.

Adjustment to new roles and responsibilities has been a gradual process for committee members. Each VEC has a dedicated chat group where updates and issues are reported in real time, and regular field visits by the ENACT team complement this digital communication. The team also involves VECs in subsequent installation work: the first meter in each village was installed by ENACT's in-house technician, with the rest installed by VEC members after observing the process. VEC members are now confident handling basic system wiring independently.

Each household pays a monthly fee based on metered usage at a community-set tariff. Payments flow into a community fund managed by the VEC, used for repairs, replacements, and ongoing system maintenance.

Productive use enterprises operating across the villages are:

- Sempar: hair salon, convenience store, restaurant, cold storage facility
- Cerewes: cold storage facility
- Kemiyan: rice milling service, household-based restaurant

Enabling conditions

ENACT has worked in two of the featured communities since 2019, with the others drawn into the relationship subsequently through their proximity within Pos Titom. The engagement has never been uniform as each community has brought its own starting point. In Sempar, there was pre-existing interest in developing local enterprises; the hair salon, for example, had already begun operating informally from a community member's home. For communities like this, the role of a supporting organisation is less about introducing new ideas than creating the conditions for existing ones to grow. Resources in this context are not always monetary and workshops, for example, on basic business practices and hands-on working apprenticeships are equally valued, and often more directly sought after. It was this kind of sustained, responsive relationship-building that made the pilot installation in Sempar in 2022–2023 possible.

Beyond the project communities, ENACT contributes to the Sabah RE2 Roadmap as part of a consortium of five organisations, each bringing distinct strengths to the shared goal of scaling rural electrification across Sabah. ENACT's particular contribution is in policy and regulatory reform, drawing on field experience from Pos Titom and other partner communities to develop instruments such as the Levels of Service and Safety and Quality Assurance Framework, all tools designed to support larger-scale, community-centred delivery of mini-grids across the region.

Authors: Ayu Abdullah, Wan Nur Sakinah, Tia Najya Effendee (ENACT)

Case study 4.6 - Ashden: Financing refugee-led clean energy enterprises

Embedding inclusion through finance, market access, and local leadership

Based on an interview with a senior member of Ashden's international programmes team, March 2026

Inclusion challenge

Ashden's involvement in refugee-led clean energy grew from five years running the Powering Refugees and Displaced People Award (2020–2024). Applications came in from many of the major humanitarian actors including UN agencies, and iNGO's such as Mercy Corps and Practical Action, but also came from a handful of refugee-led organisations that were already working in clean energy, almost entirely without institutional support.

That handful pointed to a gap the sector was largely ignoring. Refugee-led organisations existed, had ideas, had community relationships, but they were systematically locked out of the structures needed to grow. In the humanitarian funding model, international NGOs receive implementation contracts and may subcontract a refugee-led organisation for community engagement or distribution. When that funding ends, so does the project, and the local organisation is left with none of the supplier relationships, financial track record, or institutional capacity to continue independently.

The barriers refugee-led organisations described were circular and self-perpetuating, despite strong community knowledge, there was no supplier relationships, no procurement capacity, no track record with funders and without that track record, other funders were unlikely to take the risk of supporting refugee-led organisation'. The problem was not just financial. It was structural, relational, and embedded in how the humanitarian system has continued to operate.

Where and how inclusion was embedded

Ashden joined the THEA programme (funded through FCDO's Transforming Energy Access platform) with a specific remit: to design and deliver inclusive financing mechanisms and enterprise support for refugee-led clean energy organisations. This positioned inclusion upstream of deployment, changing the structural conditions that determine who can participate in the solar value chain in the first place.

The model operates across midstream (distribution and sales), downstream (installation, maintenance, and service provision), and community levels - embedding energy systems within local governance, trust networks, and livelihoods. Inclusion here is not limited to access to technology. It extends to control, ownership, and economic participation: the ambition is for refugee-led organisations to become recognised market actors, not better-supported beneficiaries.

The question Ashden brought to the THEA programme was not how to bring refugees in as beneficiaries of clean energy delivery, but how to find what was already out there and help it grow.

Mechanism deployed

Tiered grant-making

The centrepiece of the approach was a tiered grant programme, currently supporting 18 organisations across Uganda, Kenya, and Ethiopia. Two tiers were designed in direct response to what Ashden had heard from refugee-led organisations during consultation.

The £25,000 tier was available to organisations already active in clean energy, with a customer base, some experience working with upstream partners, and a prior grant or sales agreement. The £10,000 tier was designed for a different cohort: organisations that could demonstrate activity on the ground but could not yet demonstrate it on paper. This was a direct response to a recurring observation that conventional funding rewards proposal-writing experience, while funders rarely visit applicants in person. If they did, the work would speak for itself. Ashden took that seriously: £10,000 grants were available to organisations who could evidence their work through photos, videos, or an in-person visit.

An application process built for accessibility

The application process was redesigned to lower barriers at every stage and designed to be as accessible as possible. The first stage was a limited number of questions that could be answered in writing, by voice note, photos, or video. Formal registration and bank accounts were not required to apply- if an organisation demonstrated potential -Ashden would support it through the process. Materials were available in nine languages. Shortlisted applicants had one-hour calls, mostly over WhatsApp video so they could walk assessors around their sites. Interpreters were arranged on request, and Ashden worked with shortlisted applicants to co-develop their proposals rather than simply evaluating submissions.

At least 50% of the selection panel comprised people with lived experience of forced displacement (people who had themselves spent time in the settlements where the programme operated). This grounded assessment in contextual understanding that would otherwise have been absent.

Simplified contracting

Ashden's grant agreements sit at the bottom of a funding chain running from FCDO through Carbon Trust to Mercy Corps. By the time contract terms and appendices had accumulated through each level, the documentation ran to 200–300 pages (a barrier that is rarely named but is deeply excluding for small organisations and time-poor applicants). Working with external lawyers - all critical clauses were retained -reducing contracts to around 20 pages. Ashden carries more institutional risk as a result, but grant holders are not confronted with hundreds of pages of legal complexity before they have even started.

Demand-led support and relationship-building

A field team, a programme coordinator and six project support members conducting monthly visits to projects, provides ongoing support that responds to what organisations ask for rather than prescribing systems or approaches. The focus is on building the capabilities grant holders will need to operate independently: holding supplier relationships directly, managing procurement, contacting suppliers when things go wrong. The goal is for refugee-led organisations to feel like valued customers, not troublesome side projects.

A technical assistance budget is also being used to bring finance providers into direct contact with grant holders, running lender training programmes with current grantees and, in doing so, beginning to open up lending relationships that would not otherwise have been accessible. Several providers had never considered displacement settings as a viable market; exposure to Ashden's grant holders is starting to shift that.

Advance payments

Most humanitarian funding is paid in arrears, which structurally excludes organisations without access to bridge financing. Ashden's cash flow allows it to pay grants upfront, removing a barrier that would otherwise lock out the smallest and most under-resourced organisations from day one.

Tiered grant-making

The centrepiece of the approach was a tiered grant programme, currently supporting 18 organisations across Uganda, Kenya, and Ethiopia. Two tiers were designed in direct response to what Ashden had heard from refugee-led organisations during consultation.

The £25,000 tier was available to organisations already active in clean energy, with a customer base, some experience working with upstream partners, and a prior grant or sales agreement. The £10,000 tier was designed for a different cohort: organisations that could demonstrate activity on the ground but could not yet demonstrate it on paper. This was a direct response to a recurring observation that conventional funding rewards proposal-writing experience, while funders rarely visit applicants in person. If they did, the work would speak for itself. Ashden took that seriously: £10,000 grants were available to organisations who could evidence their work through photos, videos, or an in-person visit.

An application process built for accessibility

The application process was redesigned to lower barriers at every stage and designed to be as accessible as possible. The first stage was a limited number of questions that could be answered in writing, by voice note, photos, or video. Formal registration and bank accounts were not required to apply- if an organisation demonstrated potential -Ashden would support it through the process. Materials were available in nine languages. Shortlisted applicants had one-hour calls, mostly over WhatsApp video so they could walk assessors around their sites. Interpreters were arranged on request, and Ashden worked with shortlisted applicants to co-develop their proposals rather than simply evaluating submissions.

At least 50% of the selection panel comprised people with lived experience of forced displacement (people who had themselves spent time in the settlements where the programme operated). This grounded assessment in contextual understanding that would otherwise have been absent.

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OUTCOMES OBSERVED

Ashden is currently supporting 18 organisations. Early evidence points to meaningful progress. Grant holders are building supplier relationships and developing the operational infrastructure including bookkeeping, reporting, procurement processes needed to access finance from other providers. Those engaged for a longer time, are reporting on their own sales and production capacity and managing data collection independently; those at earlier stages are doing so collaboratively with Ashden's field team.

The programme is demonstrating something important about scale in displacement contexts. Rather than expecting individual organisations to grow indefinitely, there is a natural ceiling in most settlement contexts and Ashden has geared its grants towards financial sustainability and graduation to independent lending. Scale is achieved through replication across organisations, not the growth of a single enterprise.

An additional, positive and less anticipated outcome is emerging in conversations with finance providers. Exposure to Ashden's grant holders is causing some lenders to reconsider displacement settings as a viable market and are now exploring how to engage more systematically.

On gender: of the 18 organisations currently supported, three are women-led. This reflects broader underrepresentation in energy enterprise and the channels through which the call was promoted. It is identified as an area for deliberate attention in any future round.

The aim is for refugee-led organisations to hold the relationships, the track record, and the financial infrastructure to keep going — not just for the duration of a grant, but beyond it.

ENABLING CONDITIONS

Several conditions were essential to making this approach work at the level of depth and inclusivity it achieved.

- **Institutional willingness to absorb risk:** Simplified contracting, upfront grant payments, and the staffing of a field team all require an organisation with the financial position and commitment to carry more risk than is typical. This is not easily replicable by most NGOs in the current funding climate.
- **Donor support for an inclusive model:** The THEA programme provided both the mandate and the funding to pursue this approach, including acceptance of the higher transaction costs of working with non-traditional market actors.
- **Design grounded in consultation:** The tiered structure, the light-touch application process, the use of voice notes and video, the absence of registration requirements - all

came directly from listening to refugee-led organisations about what had previously excluded them.

- **Sustained field presence:** Monthly visits and demand-led support from a locally based team are resource-intensive but fundamental to the model. The relationship between Ashden's field team and grant holders is the mechanism through which capability is built.
- **Lived experience in decision-making:** At least 50% of the selection panel having lived experience of displacement changed the nature of assessment — grounding decisions in contextual understanding rather than institutional criteria applied from a distance.
- **Values-aligned suppliers:** In displacement settings, suppliers willing to service remote communities and respond quickly when things go wrong are a critical enabling condition. Identifying and cultivating those relationships is part of what makes the model function.

Feedback loop

Learning from this phase is shaping future design. The call for applications was promoted through multiple channels. However, because it was routed primarily through not-for-profit networks, the applicant pool did not necessarily include entrepreneurial organisations already active in energy delivery or women-led enterprises. Using gender-focused networks and investing in in-settlement outreach are both now identified as priorities for any future rounds. Active conversations with finance providers are underway to ensure that the capability built through the programme translates into durable market access beyond the life of THEA funding.

Case study 4.7 - Value for Women: Strengthening gender-inclusive technical assistance across clean energy

Making gender inclusion accessible and actionable across clean energy market systems.

Based on source materials from Value for Women and TEA@SUNRISE, March 2026

ORGANISATION	VALUE CHAIN STAGES	INCLUSION MECHANISM
Value for Women (V4W); within the Transforming Energy Access (TEA)	Cross-cutting: upstream research and market development; workforce and	Portfolio-wide GEDSI capacity building; targeted gender advisory

ORGANISATION	VALUE CHAIN STAGES	INCLUSION MECHANISM
programme; Sub-Saharan Africa and South Asia.	talent pipelines; supply chains; governance and accountability.	support; peer learning and knowledge exchange.

1. Inclusion Challenge

Value for Women works with businesses, investors, and funders to make markets work better for women, through practical advisory support and scalable initiatives that shift business practices, capital flows, and incentives. Its starting point is not a theory. It is a pattern the organisation has encountered repeatedly across emerging markets and sectors: companies and programmes want to include women, but when it comes to acting on that, they don't know how. Gender sits in strategy documents, donor commitments, and annual reports. But without the tools, ownership structures, or internal capacity, organisations find it challenging to turn commitments into practice.

Clean energy is where this gap is especially visible and especially costly. The sector has grown rapidly, with significant public and private investment directed at expanding energy access across sub-Saharan Africa and South Asia. Inclusion language has followed. But across the organisations V4W has worked with (energy companies, research networks, last-mile distributors, technology developers) a consistent picture emerged: leadership committed to gender inclusion rarely had staff with the skills to implement it, market research routinely missed women as customers or decision-makers, recruitment practices were drawing from the same narrow networks, and gender targets existed in plans with no one accountable for delivering them.

The gap was not one of intent, but structural. Organisations lacked the diagnostic tools to understand where and how women were being excluded. They lacked practical frameworks to act on what they found. And they lacked the peer-learning infrastructure that would let them benefit from what others across the sector were learning. V4W's engagement with the Transforming Energy Access (TEA) platform grew from exactly this observation and was designed to close it.

2. Where and How Inclusion Was Embedded

Within the Transforming Energy Access programme, Value for Women provides specialised gender technical assistance to the platform and its delivery partners. The organisation's goal is to make gender inclusion accessible and actionable across a diverse portfolio of companies, research institutions, investors, and market builders working on clean energy access spanning across sub-Saharan Africa and South Asia.

Rather than implementing solar delivery activities directly, the organisation focused on improving the enabling conditions that shape programme effectiveness. This included supporting partners to integrate gender responsive market intelligence, strengthen inclusive workforce strategies and embed accountability mechanisms that allow inclusion commitments to be tracked and sustained.

VFW's work operates at the level of the systems that determine whether gender is embedded or sidelined: how organisations research markets, who they recruit and how, which suppliers they engage, and how they measure and account for their own progress. Inclusion here translates into how an organisation functions, in what questions it asks, what data it collects, and what it holds itself accountable for.

3. Mechanism Deployed

Portfolio-wide GEDSI capacity building

Beyond deep engagement with selected partners, V4W delivered applied training and advisory services across the wider TEA portfolio. Over two years, this included:

- Three thematic webinars reaching 78 energy access ecosystem actors;
- A three-part virtual GEDSI bootcamp attended by 38 energy companies and ecosystem organisations
- Support to 14 organisations to complete a Gender Self-Assessment and develop GEDSI roadmaps (structured blueprints capturing and prioritising the gender strategies each organisation intended to pursue).
- Engagement of 17 TEA partners to assess current levels of understanding of GEDSI, interests and
- knowledge gaps, as well as identify potential areas for capacity building support.

- Development of GEDSI toolkit in collaboration with the Global Disability Innovation Hub
- In-depth technical assistance to select organisations to identify gaps and opportunities, development of Gender Action Plans with time-bound priority strategies and actions, and hands-on advisory to support their implementation.

The training and advisory content focused on strengthening internal capability in gender-responsive market research, inclusive monitoring and evaluation systems, and practical approaches to reaching and supporting women more effectively as customers, employees, leaders and value chain actors. Alongside direct engagement, V4W developed the TEA GEDSI Toolkit in collaboration with GDI Hub. This is a practical, self-guided resource covering baseline assessment, risk management, safeguarding, action planning, inclusive procurement, and MEL indicators, designed for independent use by TEA partners at any stage of their journey.

By building institutional knowledge and confidence at scale, this strand contributed to more consistent integration of inclusion considerations across programme design and delivery.

Targeted gender advisory support

For organisations ready to go further, V4W provided structured technical GEDSI accompaniment to a cohort of delivery partners, enabling them to translate gender equality commitments into concrete operational adjustments. This support followed four stages:

- a gender diagnostic assessment informed by stakeholder interviews and document review, identifying performance gaps and areas of opportunity;
- co-development of a Gender Action Plan (GAP) setting out priority actions, activities, metrics, and timelines;
- time-bound implementation support over approximately five months; and
- closing and sustainability planning to consolidate progress and identify next steps.

Three TEA partners received this in-depth support: POPO, Natfort Energy, and TEA@SUNRISE. The diagnostic and the GAP are both structured around four domains of inclusion that V4W has found to be the most consistent pressure points across clean energy organisations:

- how they reach women as customers;
- how they recruit and develop women as workers;
- how they engage women-led businesses as suppliers; and

- how they hold themselves accountable for progress across all three.

These four domains are a diagnostic lens that shapes which questions get asked in each organisation and which actions end up in the GAP. The GAP is a management tool, not a reporting instrument. This tool makes inclusion concrete by assigning accountability for specific actions to named role owners, and it is the primary mechanism through which V4W's advisory engagement strengthens partners' capacity to implement, monitor, and sustain inclusive practices within their energy initiatives.

Peer learning and knowledge exchange

Across the portfolio, V4W created the conditions for organisations to learn from each other rather than working through inclusion challenges in isolation. This included structured knowledge-exchange events, such as a peer-share webinar on 11th March, 2026, that brought together representatives from POPO, Natfort Energy, and TEA@SUNRISE to share practical lessons on reaching women customers, building inclusive workplaces, and establishing GEDSI, MEL and accountability systems.

Within TEA@SUNRISE, this function developed a more organic dimension: the Women in Solar Energy (WISE) network grew directly from the network's own inclusion work, reaching around 40 members, and became a peer-led space for shared learning, advocacy, and mutual support across the broader sector.

Peer learning matters because it makes inclusion visible and practical to organisations across the portfolio, not only those receiving direct technical assistance. It also reduces the isolation that individual organisations often experience when working on GEDSI without external support.

4. Outcomes Observed

Within TEA, V4W's technical advisory model has focused on a specific gap: organisations that hold genuine inclusion commitments but lack the internal systems, data, and expertise to act on them consistently. The outcomes observed across the TA partnerships are early and in some cases still developing, but they point to concrete shifts in practice rather than changes in policy language alone.

- **Workforce and recruitment**. At POPO, inclusive recruitment training delivered to the leadership team led to direct changes in how the company advertised and assessed candidates. In a recruitment round launched in December 2025, 72% of applications received for new sales agent positions were from women, described by POPO's own leadership as an unprecedented result, in a company that had previously relied on referral-based hiring for 90% of its team. All participants in the inclusive recruitment training reported increased confidence in applying gender-responsive hiring practices. At Natfort Energy, V4W's support produced a structured early-career pipeline strategy for women in technical roles, including partnerships with Midlands State University and Women's University in Africa, and a first-ever target of 100% women interns in technical positions for 2026. Natfort Energy also moved from an informal intent to a deliberate, accountable approach.

- **Customer engagement and market data**. V4W developed a centralised sex-disaggregated marketing data collection tool for POPO, giving the company its first structured means of understanding how women discover and purchase its products. Data collected over three months showed that 100% of women leads and customers came through referrals, evidence that directly reshaped POPO's marketing strategy and prompted active assessment of referral incentive structures for women customers. At Natfort Energy, a pilot customer engagement approach delivered through trained agents using inclusive communications techniques and regular check-ins with a group of ten women customers resulted in 98% of participants reporting satisfaction and willingness to recommend the company. Before the intervention, only 57% of women customers said they would recommend Natfort to others.

- **Research capacity**. Within TEA@SUNRISE, inclusive market research training delivered by V4W and GDI Hub to partner institutions (including IIT Kanpur, University of KwaZulu-Natal, Universiti Kebangsaan Malaysia, and University College London) doubled participants' reported confidence in identifying who benefits from, and who is excluded from, energy access. The network subsequently embedded GEDSI indicators into its core MEL framework and partner reporting processes, so that inclusion is now tracked alongside technical and research outcomes rather than treated as a separate activity.

- **Portfolio-wide reach**. Across the broader TEA portfolio, capacity-building webinars and bootcamps reached more than 100 ecosystem actors, and gender diagnostics and roadmaps were developed with 14 organisations. These activities extended practical GEDSI knowledge to organisations not yet ready for in-depth TA, building a wider base of capability across the sector.

5. Enabling Conditions

Several conditions underpin V4W's ability to deliver systemic gender inclusion support at this scale:

- Institutional mandate combined with specialist delivery support: Value for Women's technical assistance allowed operationalising TEA's GEDSI mandate and each organisation's inclusion commitments, helping organisations convert high-level commitments into structured actions embedded within programme design, delivery models, and performance systems.
- A tiered advisory model that meets organisations where they are: Broad capacity building for the full portfolio, alongside high-touch TA for organisations ready for deeper engagement, avoids a one-size-fits-all approach and builds a pipeline of readiness across the sector. Not all organisations can absorb intensive support simultaneously; the tiered structure ensures that no organisation is left entirely unsupported.
- Making the business case for inclusion explicit: Framing gender inclusion as a market and financial opportunity instead of only a rights or compliance obligation creates stronger conditions for genuine engagement from private sector actors. Connecting inclusion directly to customer growth, employee retention, and supplier resilience gives organisations a clear reason to act.
- Tools that convert commitment into action. The four entry point framework, gender lens diagnostic, GAP methodology, and GEDSI Toolkit give practitioners specific, manageable steps. Without these, inclusion commitments frequently stall at the level of good intentions.
- Peer exchange as a learning infrastructure. Structured opportunities for organisations to share what is working and what is not accelerate learning and reduce the risk of organisations repeating avoidable mistakes in isolation.
- Feedback loop. V4W's model is explicitly adaptive. Diagnostic findings inform GAP design, ensuring actions are grounded in evidence. GAP implementation generates evidence tracked through MEL frameworks. Peer exchange surfaces emerging lessons. The wider portfolio strand (webinars, advisory resources, and the GEDSI Toolkit) feeds

learning back into how V4W designs its future support. The result is a cycle in which evidence, capacity building, and practice continuously inform each other.

Authors: Value for Women team

Case study 4.8 - Global Disability Innovation Hub: Disability-inclusive technical assistance in clean energy

Building the system-level infrastructure for disability-inclusive energy research and innovation

Based on source materials from GDI Hub, December 2025

ORGANISATION / LOCATION	VALUE CHAIN STAGES	INCLUSION MECHANISM
Global Disability Innovation Hub (GDI Hub); deployed within TEA platform and TEA@SUNRISE network; global	Cross-cutting: upstream research design and market development; workforce; governance; product design and innovation	Disability Specialist Support (DSS); OPD partnership frameworks; inclusive research methodology; GEDSI strategy and data integration

BACKGROUND: Building capacity among TEA partners

GDI Hub, with input from the Carbon Trust, designed and delivered a bespoke online training series of six modules, titled 'Disability Inclusion and Innovation for Energy Access'. Over 40 members from 30 TEA partner organisations benefited from the live sessions, with 60% reporting feeling empowered to discuss disability inclusion with their colleagues as a result.

Integrating disability inclusion in practice: Eight TEA partner organisations were engaged under the DSS technical assistance (TA) offer. The range of partners' activities include: Surveys to assess disability inclusion perception and readiness. Co-design workshops and research modules. Disability-responsive reviews of programme strategy and delivery documents. Notably, over 80 downstream members and innovators were trained through partner-organised disability innovation webinars and learning sessions.

Inclusion challenge

People with disabilities represent one in six of the global population — an estimated 1.3 billion people — yet remain among the most systematically excluded from clean energy access. The barriers are not incidental but structural: disability-related discrimination and stigma, inaccessible physical and digital environments, lack of assistive technology, and exclusion from the financial and governance systems that shape energy delivery. For people with disabilities in low- and middle-income countries, these barriers compound: energy poverty and disability poverty reinforce each other, and the absence of clean, reliable energy constrains both independence and livelihood.

In the solar sector, disability inclusion has been treated overwhelmingly as a downstream adjustment, addressed, if at all, after products are designed, systems are deployed, and workforces are trained. Research and innovation networks working on next-generation solar technologies have faced a particular gap: technical expertise has rarely been paired with the frameworks, tools, or community partnerships needed to ensure those technologies are designed for and with people with disabilities from the outset.

> *Disability inclusion in the energy sector is not a niche concern. One in six people globally lives with a disability. Designing energy systems that exclude them is designing systems that fail at scale.*

Where and how inclusion was embedded

DSS operates as a system-level enabler, its role is not to deliver solar projects directly, but to shift how energy actors design, research, and govern their work so that disability inclusion becomes structural rather than incidental. Its cross-platform delivery model for TEA partners embeds disability inclusion across the value chain through targeted technical assistance, capacity building, and the development of practical tools and frameworks. For TEA@SUNRISE network, DSS engagement moved disability inclusion from a statement of intent to planned operational practice - integrating into research methodology, project design, partner capacity, and data systems.

Within the TEA platform and TEA@SUNRISE network, GDI Hub's engagement moved from the upstream, building awareness and establishing a baseline of partner knowledge in early 2025, through to the development of practical tools, GEDSI data infrastructure, and research methodology guidance by the end of the year. The approach was adaptive: a partner survey established what the network knew and needed, and the programme of support was designed in response.

Inclusion was embedded at multiple levels simultaneously: in the GEDSI statement and strategy that TEA@SUNRISE adopted institutionally; in the research methodology guidance that individual partners can apply in their projects; and in the OPD partnership frameworks developed and shared that can open up new collaborations between energy researchers and disability-led organisations.

Mechanism deployed

Capacity building and network sensitisation

GDI Hub's engagement with TEA@SUNRISE began with a presentation at the January 2025 symposium, reaching over 20 network partners on disability inclusion and innovation in solar energy access. A parallel survey mapped priorities and identified starting points: some respondents were entirely new to considering disability in their work; others had appetite for practical tools and peer exchange. The survey findings shaped everything that followed, ensuring the programme was responsive rather than generic.

OPD partnership guidance and methodology

A central output is practical guidance on how energy researchers and businesses can identify, engage, and genuinely collaborate with Organisations of People with Disabilities (OPDs). This guidance addresses a persistent gap: OPD engagement has typically been tokenistic, with people with disabilities positioned as survey respondents rather than co-researchers. GDI Hub's framework is grounded in the 'nothing about us, without us' principle of the UN CRPD, and sets out four core principles: engage OPDs from the outset; position them as co-researchers; maintain an open feedback loop; and use accessible engagement tools.

The guidance also addresses practical barriers: how to locate OPDs using tools such as GDI Hub's Global OPD Map; how to budget for reasonable accommodation and OPD remuneration; how to navigate ethics processes; and how to ensure diversity across disability types, gender, and regional contexts.

Inclusive research methodology

GDI Hub has developed guidance for TEA@SUNRISE on delivering inclusive next-generation solar energy research — covering disability-disaggregated data collection across the whole research cycle, accessible methodologies, and the ethical dimensions of research with people with disabilities. This positions disability inclusion not as an add-on but as a methodological requirement embedded from scoping through to impact appraisal.

GEDSI strategy and data integration

GDI Hub supported TEA@SUNRISE to develop and launch a GEDSI statement, and to integrate disability metrics into the network's survey infrastructure. This institutional embedding is significant: it means disability inclusion is tracked and reported across the network, creating accountability and data that can inform adaptive practice.

Innovation exploration

Alongside the capacity-building strand, GDI Hub explored how advances in next-generation solar technologies could directly address disability-related barriers — investigating how low-light solar technologies could reduce cost and access barriers associated with hearing aid adoption in low-resource settings, in collaboration with Deaftronics. This connection illustrates the upstream potential of the approach: embedding disability needs into technology development from the outset.

Illustrative example: SolarEar

SolarEar, founded in 2002, illustrates what disability-inclusive design in the solar sector can achieve. Developed by people with hearing impairments, it is the world's first solar-powered hearing aid with rechargeable batteries. Solar batteries last up to three years, dramatically reducing the cost and maintenance burden that had made conventional hearing aids inaccessible to the estimated 460 million people globally living with hearing impairments. SolarEar has now reached 30 countries. The case illustrates a broader principle: when people with disabilities are positioned as designers and innovators rather than passive beneficiaries, they produce solutions that the solar sector, designing from the outside, had not generated.

Outcomes observed

Over 30 TEA@SUNRISE partners have been exposed to disability-inclusive research and innovation principles. TEA@SUNRISE has adopted a GEDSI statement and integrated disability metrics into its network survey infrastructure. A guidance note on delivering inclusive next-generation solar research in collaboration with OPDs has been produced and disseminated. GDI Hub has produced guidance on informant remuneration, supported the scoping of a research pilot with LIV Durban in South Africa, and begun to connect next-generation solar innovation with disability-specific use cases.

At network level, a shift in awareness is documented: partners noted that the scale of potential benefit from inclusive design was striking, and identified this as a rich area for future research. Some partners moved from having no prior engagement with disability inclusion to actively requesting tools, training, and peer exchange opportunities.

The model demonstrates a wider principle: disability inclusion at scale in the energy sector requires dedicated system-level support. Individual organisations rarely have the expertise, tools, or partnerships to embed it independently. Technical assistance that builds these capabilities across a network can shift the conditions for inclusion across many efforts simultaneously.

Enabling conditions

Several conditions enabled GDI Hub's approach to gain traction within the TEA platform.

- **A dedicated specialist function:** a DSS role with mandate, resource, and sustained presence within the platform — not a one-off training event but an ongoing advisory and capacity-building relationship.

- **Starting from evidence**: the January 2025 partner survey established a baseline of knowledge and need before any support was designed, ensuring the programme was targeted rather than assumed.
- **Adaptive programming**: survey findings directly shaped content and format of subsequent support, including the decision to prioritise practical tools and how-to guides.
- **Platform-level institutional mandate:** TEA's GEDSI strategy provided legitimacy for disability inclusion to be embedded across funded projects and tracked through data systems.
- **The 'nothing about us, without us' principle in practice**: positioning OPDs as co-researchers ensures guidance and tools produced reflect the actual needs and expertise of people with disabilities.
- **Connecting disability inclusion to innovation opportunity**: framing disability inclusion not only as a rights obligation but as a source of innovation creates a stronger case for engagement from technology-focused actors.

Feedback loop

GDI Hub's engagement with TEA@SUNRISE is structured as a feedback loop. Partner survey findings shaped programme design. Guidance note content reflected what practitioners requested. The February 2026 workshop is designed to consolidate learning and identify what is needed next — creating an adaptive cycle between evidence, capacity building, and practice.

Authors: Pollyanna Wardrop and Bala Nagendran (GDI Hub)

Appendix D -The Vignettes

The vignettes used in the body of the report are ‘taken’ from an observational report (below) from detailed field observations from an engineer with extensive experience in development activities and solar mini-grid deployment across West Africa. It provides an in-depth account of system performance over time, highlighting recurring technical, financial, and operational challenges observed across multiple sites. The report is included here in full to preserve the depth and nuance of the original observations.

Observations from West Africa 2022-2026:

In rural settlements classified as “electrified” through solar PV mini-grids, what is typically delivered is a narrow band of service lighting, phone charging, and little beyond. This is often sufficient at commissioning, but it does not remain so for long. Demand increases almost immediately. One of the earliest and most consistent changes is the introduction of refrigeration. These appliances are rarely new. They are second-hand units, often heavily used, sometimes repaired or modified locally, and almost always inefficient. Their electrical behaviour is poorly aligned with the constraints of the system. The effect is cumulative rather than immediate: rising strain on the network, voltage instability, and a gradual deterioration in reliability. In many sites, this progression ends in partial or complete system failure. What is delivered as access proves, in practice, difficult to sustain under normal patterns of use.

Solar PV mini-grids are, in technical terms, a sound solution. They are modular, scalable, and capable of supporting communities from tens to hundreds of users. Across West Africa, they have been deployed widely and, in some cases, have been in place for years. However, sustained observation across multiple sites shows a consistent pattern: many systems do not operate as intended over time. Some degrade into intermittent functionality; others cease operation altogether. These are not isolated cases. The recurrence of similar outcomes across different geographies and implementing actors suggests that the issue lies less in the technology itself and more in how it is being deployed and managed.

In most cases, deployment is led by NGOs and development agencies, operating through competitive procurement processes. The dominant metric is cost-efficiency, usually framed as the number of people reached per unit of investment. Over time, it becomes clear how strongly this shapes system design. Coverage is prioritised, while service depth is constrained. It is not uncommon for systems to be designed around minimal definitions of access sufficient to meet proposal requirements, but insufficient to support meaningful use. Where minimum service levels are clearly specified and enforced, outcomes tend to be better, but this is not consistently the case. In their absence, systems are often, from the outset, aligned more closely with funding criteria than with the realities of use.

Once installed, responsibility shifts, at least formally to local operators. These systems are typically placed in rural and deep-rural environments where prior exposure to electrical infrastructure is limited. In many instances, the individuals tasked with operating them have received only brief or highly constrained training. The gap between what the system requires and what the operator is equipped to manage becomes evident over time. Issues that are routine in more established contexts load balancing, basic fault identification, preventative maintenance become points of failure. There are also safety implications. These systems are not benign, and the risks associated with improper handling are not always fully appreciated. Across sites, operator capacity emerges repeatedly as a limiting factor, not because of lack of willingness, but because of insufficient preparation and ongoing support.

Demand, meanwhile, does not remain static. Once electricity is introduced, expectations and usage patterns shift quickly. Refrigeration is only one example, but it is a consistent one. The appliances that enter these systems are rarely suited to them. They draw more power than anticipated, cycle unpredictably, and are often in poor condition. Their presence is not anomalous; it reflects a rational response by users seeking to improve daily life or generate income. However, their cumulative impact on small, tightly balanced systems is significant. Over time, they contribute to overloading, reduced availability of power, and more frequent outages. These effects are rarely immediate, but they are persistent.

As system performance declines, so too does user confidence. In most cases, communities are required to pay ongoing fees for access. When the service is reliable, this is generally accepted. When it is not, the relationship changes. Payment continues to be expected, but the value delivered becomes uncertain. This creates tension. Users begin to disengage, either by reducing usage or by withdrawing from the system altogether. The situation is further compounded by the fact that communities often contribute materially at the outset, most commonly through the provision of land under favourable or informal terms. Where systems fail to deliver, this prior contribution is not forgotten. It shapes how the intervention is understood and remembered.

At the same time, operators are working within financial constraints that are not always visible at the user level. Tariffs are often capped by government regulation, and in many cases these caps are not adjusted in line with inflation, currency depreciation, or increases in operating costs.

Over time, this erodes the real value of revenue. As costs rise and income remains fixed, operators begin to defer maintenance, delay component replacement, or reduce service provision. This is not necessarily a matter of poor management; it is often a structural limitation. When combined with declining willingness to pay among users, the financial model becomes increasingly fragile. In a number of cases, this trajectory leads to eventual system abandonment.

Taken together, these observations point to a set of misalignments that extend beyond individual projects. There is a disconnect between how success is defined at the point of procurement and what is required for long-term functionality. There is a gap between system design assumptions and actual patterns of use. There is also a persistent underestimation of the role of local operational capacity. Financial structures, meanwhile, often constrain cost recovery while exposing systems to economic volatility.

The pattern is difficult to ignore. Many mini-grid projects, as currently implemented, are effective at demonstrating access, but far less effective at sustaining it. The result is not immediate failure, but gradual erosion technical, financial, and social. Without a shift in how these systems are specified, supported, and evaluated over time, the same outcomes are likely to repeat: nominal access at the outset, followed by declining performance, user disengagement, and, ultimately, system collapse.

A recurring observation across multiple sites suggests an additional dynamic that shall remain a hypothesis. The initial introduction of even limited electricity access creates both aspiration and, in some cases, short-term income opportunities, particularly through activities such as refrigeration. However, once service reliability deteriorates, users do not necessarily revert to pre-electrification conditions. Instead, those who have realised even modest gains often seek to retain them. Having experienced the added value of electricity, and having generated some initial income, households or small enterprises may invest in small-scale generators as an alternative. In this way, unreliable mini-grid provision can inadvertently catalyse a transition toward decentralised, fossil-fuel-based generation at the user level undermining both the economic rationale and the broader developmental and environmental objectives of the original intervention

By contrast, models that explicitly constrain energy provision at the outset can, in some contexts, achieve greater stability. Battery rental systems, such as those deployed by companies like MOPO, provide a defined and limited quantity of energy tied to specific use cases, typically lighting, small device charging and small appliances. Because the service envelope is narrow and relatively clearly communicated, user expectations are more aligned with actual system capability. Operational complexity is reduced, both at the system and user level, and the need for local technical management is minimal. While such models do not enable higher-value productive uses, they illustrate a key point: where service limits are explicit, enforced, and matched to user understanding, the risk of demand-driven system destabilisation is significantly lower.

A similar logic may apply at slightly larger scales through pico-grid configurations small, shared systems serving a limited number of households or businesses. In these arrangements, energy is constrained not only by system design but also by the small number of participants involved. This creates conditions where demand is more visible, usage patterns are more easily understood, and informal governance mechanisms can emerge. Participants are better able to coordinate consumption, negotiate priorities, and respond collectively to constraints. While such systems do not eliminate technical or financial challenges, their reduced scale can make management more tractable and expectations more grounded. In practice, this suggests that alignment between system capacity, user understanding, and local governance rather than scale alone may be a critical determinant of sustained functionality.

Appendix E: References and Resources

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Resources

Sunsafe II Project GESI – COMPONENTS-BASED SOLAR HOME SYSTEMS FIELD SURVEY REPORT- https://acrobat.adobe.com/id/urn:aaid:sc:EU:63ab15c8-952c-4fd0-81cd-45c979770483

POWERE, a UKRI Ayrton Challenge funded project, see website: https://www.sussex.ac.uk/research/projects/participation-of-women-in-renewable-energy/

[i] Powering Renewable Energy Opportunities — https://preo.org

[ii] https://sunsafe-energy.com

[iii] An original equipment manufacturer (OEM) is a company that produces parts and equipment that may be marketed by another company.

[iv] For further details on POWERE, a UKRI Ayrton Challenge funded project, see website: https://www.sussex.ac.uk/research/projects/participation-of-women-in-renewable-energy/