Caribou

Clean Energy as a Catalyst for Women's Economic Empowerment

In partnership with

Shell Foundation

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Foreword

In four years at my job, here's one lesson I've learned: Women empowered by clean energy make the world work better.

At Shell Foundation, we have seen firsthand the potential of clean energy solutions to transform women's economic lives. Women shop owners in Tanzania earn an average of US$674 more per year when empowered to electrify their shop via a local solar kit, to cite just one example. For women dairy farmers in Kenya, solar milk chillers have double earnings and introduced more predictable payment cycles, with impacts extending beyond income to reduced physical strain, significant time savings that support children's schooling, and greater agency over household financial decisions driven by increased earnings.

When designed with women's realities in mind, these solutions can increase incomes, reduce costs, improve safety, and strengthen agency. They are not just climate solutions; they are engines of economic opportunity.

Together with others investing in this space, we've learned a lot about what works. For example, it is not technology alone that empowers women to earn more. Five conditions — Agency, Relevance, Infrastructure, Skills, and Engagement (ARISE) — distinguish interventions that drive positive outcomes. Applying these lessons in the agriculture sector alone could lift 100 to 150 million people out of hunger.

Yet despite this potential, investments that integrate climate and women's economic empowerment remains limited. Climate capital and gender-focused capital are both growing, but largely in silos. Those pools of capital need to come together to perform for their investors, for women and for our planet.

This report is a step in that direction. It brings together evidence that clarifies how clean energy solutions can deliver meaningful economic outcomes for women — and where more intentional investment can unlock greater impact. We welcome your interest in this report, and your partnership in forging the future it promises.

Jonathan Berman

CEO
Shell Foundation

Executive summary

Clean energy solutions are a powerful lever for women's economic empowerment (WEE), with far greater impact potential than previously recognised. However, the evidence needed to move funders and investors from interest to action has been fragmented, incomplete, and difficult to apply.

This report, developed through a synthesis of more than 115 studies, shows the many ways clean energy solutions can significantly improve women's economic lives in emerging markets. The evidence is clear: women are using clean energy solutions. But which solutions women use, how and when they use them, and how these solutions impact WEE are the questions that this report sets out to answer. The evidence also makes a compelling case that clean energy and WEE are mutually reinforcing. Funders who invest across both with intentionality, rigour, and patience are positioned to deliver outsized returns for women, for the climate, and for the broader systems of which both are a part.

Clean energy has a multiplier effect on women's income, safety, and agency

KEY FINDING 1

Across five archetypes of women,[1] evidence points to consistent, meaningful gains when clean energy interventions are well designed. Individual examples from the research illustrate the range of these gains:

- **Increased income:** Solar milk chillers have doubled earnings for women dairy farmers,[2] and irrigation has increased women farmers' incomes by US$250 per year.[3]
- **Enhanced safety:** A 16-percentage-point reduction in domestic violence followed the introduction of clean cookstoves in Uganda.[4]

1 Women as users of cookstoves, as household energy users, as farmers, as entrepreneurs, and as workers in the clean energy sector.

2 Usagi et al., "Assessment of the Effect of Solar Powered Milk Cooling Technology on Small Holder Dairy Farmer Earnings, Siaya County, Kenya."

3 Efficiency for Access and 60 decibels, *Uses and Impacts of Solar Water Pumps*.

4 Guzmán et al., "Improved Cookstoves as a Pathway between Food Preparation and Reduced Domestic Violence in Uganda."

- **Cost savings:** Solar irrigation reduces irrigation expenses by up to 91% across five sub-Saharan African countries.[5]
- **Improved agency and control:** Over 90% of women report greater agency over spending and over 80% greater involvement in household purchasing decisions after the introduction of clean energy assets.[6]

These figures represent what is possible. Realising that potential for women consistently requires programmes designed around women's specific barriers and contexts.

KEY FINDING 2

The path to economic empowerment is not the same for every woman, and one solution can lead to cascading gains

WEE is not a single outcome but a multidimensional process spanning economic advancement, agency, and well-being. The most common ways to achieve this outcome are:

1. Through productive use technologies that directly generate economic returns for women
2. Indirectly through time savings or cost reductions, primarily in the household
3. Through employment, working within the clean energy value chain

The way women benefit further depends on their baseline socioeconomic status, the assets they use, the purposes for which they use them, and the surrounding context.

To measure the impact of clean energy assets on WEE, investors need frameworks that reflect this complexity. A cookstove may improve health, save time, and enable opportunities for entrepreneurial activities. However, a narrow assessment that focuses only on income uplift would miss most of the story. The evidence shows multiple, interacting pathways through which clean energy creates value for women: reduced drudgery, improved health, greater safety, stronger agency, and, where conditions align, increased income. Investors risk undervaluing interventions that deliver significant welfare gains, or overestimating income impact, if they track only productivity metrics.

5 Efficiency for Access and 60 decibels, *Uses and Impacts of Solar Water Pumps*.

6 Gray et al., *Turning on the Lights: Transcending Energy Poverty Through The Power of Women Entrepreneurs*.

PERSONA

Adama's story
Addressing multiple constraints unlocks compounding benefits

Adama is a 45-year-old smallholder rice farmer in rural West Africa. She spends five to six hours a day on irrigation, weeding, and processing; energy costs consume nearly a quarter of her seasonal income. Without a land title, she finds it difficult to access credit. The diesel pump she relies on for irrigation is controlled by men in her village.

A single biodigester changes the equation. Fed by agricultural waste already on her farm, it produces cooking fuel and organic fertiliser, reduces her daughters' daily firewood burden by two hours, and eases the respiratory symptoms she has learned to live with. Healthier days mean more time on the farm. The fertiliser cuts her input costs and improves her yields, generating a surplus she can sell to neighbours. Those improved margins give her something she did not previously have: collateral. She uses the biodigester to secure a loan for a solar pump. The pump enables a second growing season. A second growing season only pays if the harvest reaches the market. Post-harvest storage or drying, processes that Adama is responsible for, rather than her husband, ensures the harvest does reach the market.

For Adama, one well-designed intervention does not solve one problem in isolation, but it removes a constraint that blocked progress on several others, unlocking compounding gains across time, health, productivity, and agency.

For women, financing terms can turn a viable investment into a loss

KEY FINDING 3

Financial modelling of fifteen clean energy assets led by Caribou in this study found that baseline conditions and enabling factors determine financial viability more than the technology itself.

Under the right conditions, solar milk chillers, improved cookstoves, refrigeration for micro-entrepreneurs, and solar irrigation pumps can all deliver strong financial returns for women. But the same assets can fail under the wrong conditions or assumptions. Technically sound investments can still fail if the surrounding context hasn't been verified to ensure relevance. A solar fridge generates no revenue in a location without customer traffic; a milk chiller delivers no benefit when evening collection already exists. Investors should verify the conditions before committing, not assume them.

Productive-use technologies (those that create new revenue streams, such as solar irrigation enabling a second growing season, or milk chillers monetising evening production that would otherwise spoil) deliver stronger and more direct returns than well-being-oriented technologies like cookstoves, where realising economic gains depends on women converting time savings into paid work, which rarely happens without complementary programming. For investors, this may mean that there should be different expectations for how "success" is defined and measured in terms of return on investment for productive versus non-productive assets.

Financing terms are equally decisive: a solar irrigation system generating a 30% annual return when purchased upfront can produce a net loss under typical consumer finance or pay-as-you-go arrangements, where interest charges and premiums can exceed the income gains the technology produces. And even where returns are positive, affordability is a separate test; a technology that pays back over three years but requires monthly payments that consume 40% of household cash flow is not viable without concessional terms or subsidies during the early period. Positive return on investment is necessary, but not sufficient. These are market design problems, not inherent features of investing in women. Better-structured financing products, blended finance mechanisms, and first-loss arrangements can restore viable returns without requiring permanent subsidy.

Five enabling factors matter more than the technology itself

KEY FINDING 4

The evidence points to five conditions — Agency, Relevance, Infrastructure, Skills, and Engagement (ARISE) — that distinguish interventions that deliver positive outcomes from those that fall short. Agency, relevance, and infrastructure (including access to finance) play the largest roles in the evidence base:

- Gains stall when women lack agency and men remain default decision-makers over what solutions are adopted and how they are used. When women are empowered to participate in decision-making and have control over finances, clean energy access translates into economic change. This is also why placement matters: technologies introduced at post-harvest and processing stages, where women already have operational control, are more likely to retain gains for women than those introduced at production stages where men dominate decision-making.
- Clean energy assets have the most significant impact on WEE when they are part of a set of bundled solutions that address women's interconnected needs. This means assets designed to serve multiple purposes, layered assets that build on each other, or the bundling of energy assets with complementary support, such as training and financing. Single-asset interventions rarely deliver the transformative change needed; bundled solutions do. A solar pump paired with zero energy cold storage, a women's savings group and agronomic training for example outperforms the pump alone.
- When financing products offer flexible terms that are responsive to women's needs, they can open pathways to assets that didn't previously exist.

Closing the gap between women's economic empowerment and climate investment requires deliberate action

Too often, WEE and climate agendas operate in silos, with separate strategies, metrics, and funding streams, due to a perceived complexity of climate outcomes. Bridging this divide could simultaneously advance climate goals and transform women's economic lives.

To capitalise on this opportunity, philanthropic funders and investors should:

- **Design investments by segments; women are not one market.** Conduct market research to understand and define the archetype of the women investments aim to reach. The same assets perform differently depending on women's initial conditions, roles, and context. Upfront investment in understanding local context and shaping complementary investments is what separates successful interventions from underperforming solutions.
- **Intentionally bundle clean energy and non-energy solutions** to deliver transformative impact. Two-thirds of the solutions identified in this research included bundled solutions. Invest or partner with other funders to deliver holistic solutions that address women's diverse roles and needs. Include solutions such as agency-building training, market access, digital access, and financing with terms that work for women, as well as valued health interventions like family planning, to ensure uptake and multiply impact for women.
- **Understand the payback model from women's perspective** before designing new investments. Financing terms alone can turn a viable return into a loss. Upfront assessment of whether proposed financing terms are affordable relative to household cash flows distinguishes interventions that deliver from those that underperform.
- **Design with ARISE in mind.** Ensure the right conditions are in place for solutions to work by using these factors as a minimum checklist during design.
- **Measure a range of outcomes — not just income** — aligned to the relevant impact pathways identified in this research. Frameworks should track both monetary outcomes (income, productivity, yields) and non-monetary ones (time savings, health, agency). Programmes that measure holistically will generate insights that narrow monetary-oriented metrics miss.
- **Invest in women's employment in the clean energy sector.** Low-barrier entry points offer strong returns for women's income, agency and household decision-making. Opening more technical, leadership roles and shifting social norms will build a more inclusive clean energy sector, but requires a longer-term investment.
- **Continue funding research** that links intermediate outcomes to long-term WEE, so that future investment rests on up-to-date and broader evidence.

This report provides early insights into the opportunity that clean energy solutions offer for women. The field of the gender–energy nexus is still nascent, and the evidence base is strongest for cookstoves and lighting. For productive use technologies and agricultural energy, the impact pathways are clear, and emerging evidence is compelling. However, more rigorous, longitudinal research is needed. This report is a strong start. It is not the final word.

Clean energy and WEE are mutually reinforcing. Funders who invest across both with intentionality, rigour, and patience are positioned to deliver outsized returns for women, for climate, and for the broader systems of which both are part.

Where clean energy meets women's economic empowerment

Climate change is not gender neutral. Women are disproportionately affected by energy poverty and climate impacts, making gender inclusion an essential pillar for building resilient communities.

Climate shocks are becoming more severe, with women in rural areas disproportionately impacted. In Africa, effects of climate change will potentially push 158 million more women and girls into poverty by 2050.[7] Women and girls, particularly those living in rural areas and lower-income households, bear a disproportionate burden of this impact because of existing gender inequalities that influence how women can respond to climate change.[8] They spend more hours collecting fuel and water.[9] When resources become scarce due to climate change, they adapt by working harder and travelling further.[10]

7 UN Women, "As Climate Change Pushes Millions of Women into Poverty, UN Women Calls for a New Feminist Climate Justice Approach."

8 UN Women, "How Gender Inequality and Climate Change Are Interconnected."

9 Kafayat and Audu, "A Review on Women, Climate Change and Clean Development Mechanism."

10 Jagoe et al., "Sharing the Burden: Shifts in Family Time Use, Agency and Gender Dynamics after Introduction of New Cookstoves in Rural Kenya."

Energy poverty restricts health potential and reduces safety for women

An estimated 2.2 billion people rely on biomass for cooking, heating, and lighting.[11] Two-thirds of women in rural communities across Africa, Asia, and Latin America spend one to three hours each day collecting fuelwood and managing household energy needs.[12]

The health consequences of energy poverty are severe. Household air pollution from traditional cookstoves and kerosene lighting causes over 3.2 million deaths annually, including more than 237,000 children under five.[13] Millions more suffer from respiratory illness, heart disease, and cancer. Kerosene lighting exposes households to double the particulate matter levels of solar alternatives[14] and is linked to a 9.4 times higher probability of active tuberculosis.[15] Burns kill an estimated 180,000 people each year; the vast majority come from traditional cooking fires,[16] with women accounting for around 65% of severe kitchen burn injuries.[17]

The risks extend beyond the home. In displaced and refugee settings, 75% to 90% of rapes occur when women and girls leave camp to gather cooking fuel.[18] The search for energy exposes women to violence in ways that cleaner, closer alternatives could prevent.

11 WHO, "WHO Publishes New Global Data on the Use of Clean and Polluting Fuels for Cooking by Fuel Type."
12 Kojima, "Here's How Households Can Abandon Polluting Fuels Used for Cooking."
13 WHO, "Household Air Pollution."
14 Muyanja et al., "Kerosene Lighting Contributes to Household Air Pollution in Rural Uganda."
15 Blount et al., "Indoor Air Pollution and Susceptibility to Tuberculosis Infection in Urban Vietnamese Children."
16 WHO, "Burns."
17 Mehta, "Epidemiology and Outcomes of Cooking- and Cookstove-Related Burn Injuries: A World Health Organization Global Burn Registry Report."
18 Global Alliance for Clean Cookstoves, "Statistical Snapshot: Access to Improved Cookstoves and Fuels and Its Impact on Women's Safety in Crises."

Energy access shapes women's economic participation

Across Africa and Asia, women play a pivotal role in agriculture, shouldering most manual tasks, from planting and harvesting to food processing and water carrying.[19] Yet they are less likely than men to own land, secure credit, receive training, or benefit from government energy programs.[20] Yields in Africa are 13% to 25% lower for women than men, partly attributed to lack of access to productive resources, including modern energy and mechanisation.[21] Closing this gap could raise agricultural output by 2.5% to 4% and lift 100 to 150 million people out of hunger.[22]

Women-led businesses are concentrated in heat- and light-intensive trades but typically rely on only one or two energy sources such as diesel, biomass, or Liquefied Petroleum Gas (LPG). As a result, women-owned businesses in Africa often spend over US$100/kg of output on energy, compared to US$10/kg for men.[23] The difference is not ability but access. When women and men have access to the same appliances, financing, and infrastructure, measures of productivity are similar.[24]

Within clean energy, women remain underrepresented relative to their share of overall employment. Globally, women hold 32% of clean energy jobs — below the roughly 40% share they account for in the broader labour force — with participation as low as 11% in South Asia.[25] Cultural norms, limited access to technical education, workplace bias, financing gaps, and a lack of inclusive workplace policies restrict entry and advancement across both formal employment and informal roles in the sector.[26]

At the same time, women's participation in clean energy value chains, as customers, employees, micro-entrepreneurs, and leaders, can accelerate the adoption of solutions and maximise climate impacts. Strategies and solutions that invest in women's economic participation can unlock dual benefits for women's economic empowerment (WEE) and climate outcomes. However, estimates suggest that as of 2021, only 2% of global climate financing is gender-responsive,[27] indicating a significant disconnect between climate ambition and gender-responsive action.

19 SOFA Team and Doss, "The Role of Women in Agriculture."
20 World Bank, *Levelling the Field: Improving Opportunities for Women Farmers in Africa*.
21 World Bank, *Levelling the Field: Improving Opportunities for Women Farmers in Africa*.
22 World Bank, *Levelling the Field: Improving Opportunities for Women Farmers in Africa*.
23 Gad and Leone, "Productive Use of Energy of Women-Owned Micro-, Small-, and Medium-Sized Enterprises."
24 ENERGIA, *The ENERGIA Gender and Energy Research Programme: A Short Overview of the Results*; Pueyo and Maestre, "Linking Energy Access, Gender and Poverty: A Review of the literature on Productive Uses of Energy."
25 IRENA, *Renewable Energy: A Gender Perspective*.
26 Bergamo et al., "Women's Leadership: The Multiplier Effect in the Energy Transition."
27 Climate Policy Initiative, *Global Landscape of Climate Finance 2021*.

Realising this potential requires addressing persistent barriers faced by investors. Limited gender-disaggregated impact data makes it difficult to design targeted interventions or to justify gender-focused climate funding. Investors often lack a clear assessment of how clean energy solutions contribute to WEE and effective proxies for measuring impacts. Gender and climate investing operate in silos, with less than 2% of global climate financing being gender-responsive.[28] Bridging this divide could simultaneously advance climate goals and transform women's economic lives.

About the research

This report draws on research and evidence synthesis conducted by Caribou and Value for Women for the Shell Foundation. Our objective was to curate, code, and synthesise the available impact evidence on clean energy solutions and WEE. We mapped 130 relevant studies and coded 115 in-depth, extracting findings on how different clean energy interventions affect women's income, time use, health, and agency. The literature skews towards academic journals (57%) over practitioner literature (43%). However, only 17% of studies use rigorous experimental approaches, and nearly half are qualitative, narrative assessments. The remaining 40% of studies use quasi-experimental approaches to assess impact.

The literature clusters around five key archetypes that showcase how women interact with clean energy. Individual studies often cover multiple archetypes and/or geographies.

Coupled with this work, Caribou and Value for Women conducted 18 key expert interviews to generate additional insights on how commercial and concessional capital unlock gender and climate outcomes, and to validate findings emerging from the evidence review.

Building on the research base, Caribou developed interactive financial models for 15 clean energy products across 5 technology categories: solar irrigation, milk chilling, cold storage, solar refrigeration for small enterprises, and clean cooking. Each model allows users to adjust parameters, including household income, financing terms, technology costs, and local market conditions, to test how returns change under different assumptions. The models focus solely on financial metrics: ROI, payback periods, net annual benefit, and affordability relative to income. They do not capture gains in health, reduced drudgery, time for rest or family, or other dimensions of well-being that may justify investment even when financial returns are marginal or negative. The models also do not

28 UNDP, "Gender and Climate Finance."

capture climate and environmental benefits of adopting clean energy assets. For more information on the models, please visit caribou.global.

This evidence synthesis provides the foundation for the findings, impact pathways, and recommendations that follow. Where the evidence is strong, we say so. Where gaps remain, we identify them. We aim to give investors and programme designers a clear-eyed view of what the research supports and where further learning is needed.

FIGURE 1

Sub-Saharan Africa dominates the evidence base, while solutions for women in agriculture are noticeably thin

Note: Counts exceed 115 because studies covering multiple archetypes or regions are counted in each category.

Clean energy assets can lead to women's economic empowerment when paired with agency, skills, and opportunity

Clean energy solutions reach women's economic lives through three distinct pathways.

- **Direct:** Productive-use technologies increase yields, reduce waste, and generate new revenue streams, connecting energy access to economic returns more immediately.
- **Indirect:** Assets that save time or reduce costs create the preconditions for economic participation. Indirect solutions require women to have agency, market access, and complementary support in place to convert that potential into income.
- **Employment:** Working within the clean energy value chain delivers income, agency, and skills gains through the most legible and measurable route of all.

The evidence synthesis identified five archetypes of women as users of clean energy (micro-entrepreneurs, farmers, cooks, non-cooking household users, and workers in the clean energy value chain), each experiencing benefits through unique pathways.

ARCHETYPE	INCOME PATHWAY	PRIMARY IMPACT MECHANISM	ECONOMIC CASE*	DEPENDENCY ON ENABLING CONDITIONS**
Value chain workers	Direct	Employment Earnings	Very strong	Medium
Micro- entrepreneurs	Direct	Increased throughput Increased efficiency New revenue lines	Strong	Medium–high
Farmers	Direct	Increased output Reduced waste	Strong	Medium–high
Cookstove users	Indirect	Time savings Cost savings	Contextual	Very high
Household energy users	Indirect	Time savings Cost savings	Contextual	Very high

* Assessment of the strength and directness of the income uplift argument for each archetype, ranging from clear, measurable, and relatively fast to theoretically possible but not inherent and highly dependent on context.

** Assessment of how much each archetype's income outcomes are linked to specific enabling conditions being met alongside clean energy intervention. High ratings indicate that outcomes are unlikely without deliberate investment addressing enabling conditions. Medium ratings suggest that returns are achievable under a broad range of conditions, though enabling factors still matter for depth and equity of outcomes.

TABLE 1

The income uplift of clean energy varies by archetype, asset, and use

The way women benefit depends on their baseline socioeconomic status, the assets they use, the purposes for which they use them, and the surrounding context.

Measurement frameworks should reflect complexity

Effective measurement requires a mixed-methods approach tailored to the sector and use case. Frameworks should track both monetary outcomes, such as income, employment, and productivity, and non-monetary outcomes, such as time savings, health, and agency. Without this breadth, investors risk undervaluing interventions that deliver significant welfare gains, or overestimating the income impact of assets that save time but do not translate into economic participation. Only by capturing the whole picture can funders identify what works, for whom, and under what conditions. → Appendix 2 includes an overview of key metrics identified.

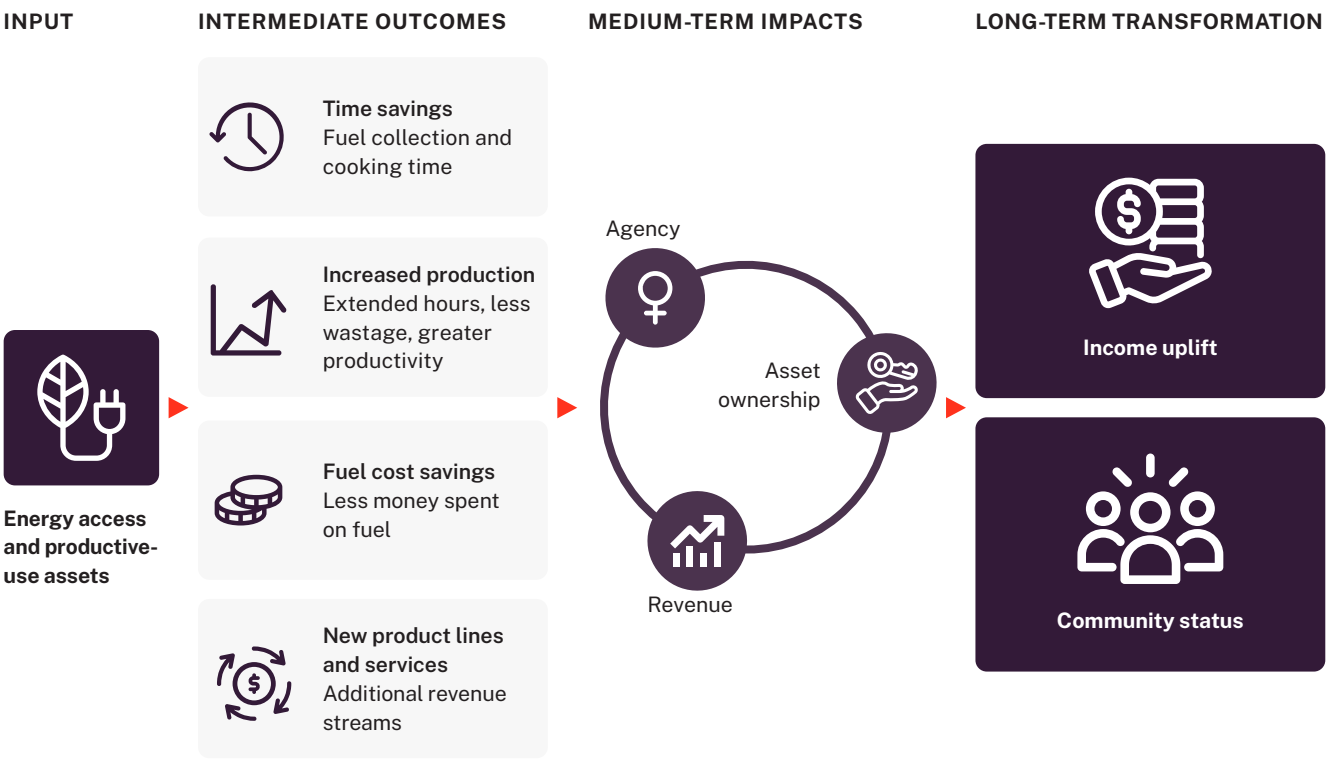
Investors do not need to design measurement frameworks from scratch; several robust tools already exist and are well documented in the EMERGE Gender Empowerment Measures Repository, CGAP's framework for financial inclusion, and the Global Multi-Dimensional Poverty Index. These resources and others offer a practical starting point that programmes can adapt to the clean energy sector rather than building from zero.

Productive-use assets directly connect energy access to economic returns

For women running small businesses (micro-entrepreneurs), access to energy determines whether they can extend their working hours, preserve perishable goods, process raw materials efficiently, and reach new customers. As micro-entrepreneurs, these women more typically operate above the threshold where time savings is the primary mechanism driving income. They are more likely to have market access, business infrastructure, and opportunities to monetise reclaimed hours, especially in urban and peri-urban contexts, where enterprises cluster.

FIGURE 2

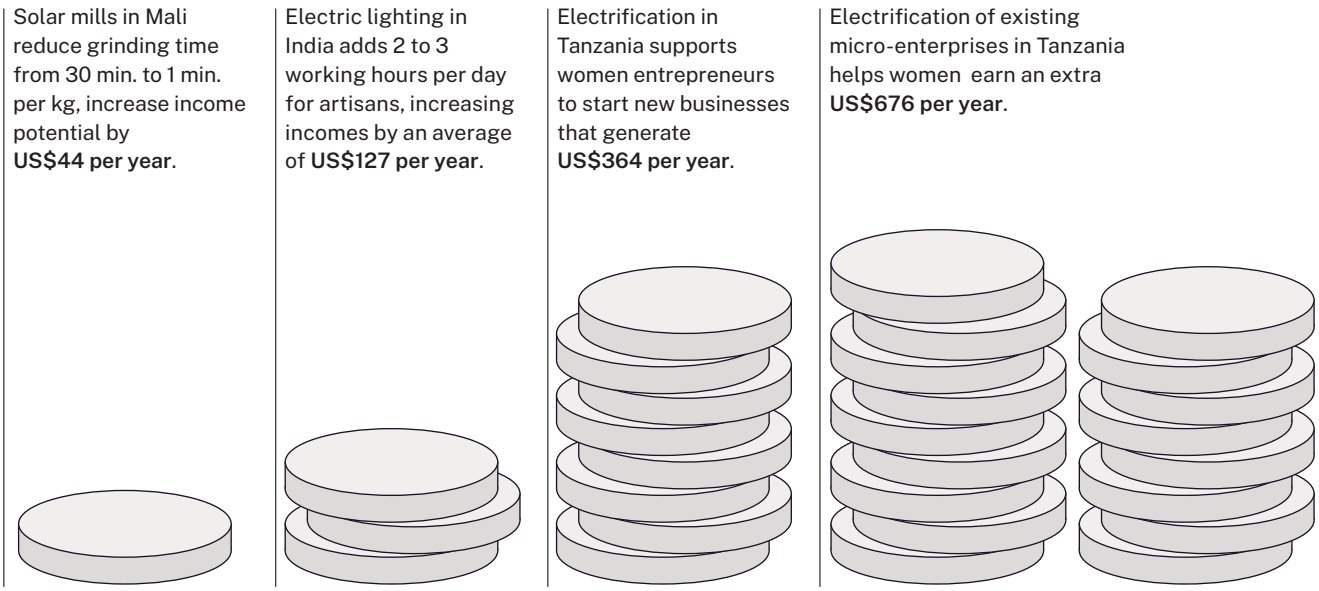
Impact pathway of clean energy assets for micro-entrepreneurs



Clean energy solutions allow women to work faster across a diverse range of micro-enterprises. For example, electrified sewing machines and irons increase throughput for tailors.[29] Off-grid solar extends working hours, increasing production that was previously limited to daylight hours; 87% of artisans in Tanzania improved their business after the introduction of solar lighting.[30] Cooling technologies help micro-entrepreneurs manage inventory better; reduce the frequency of trips to the market, saving an estimated 2 hours per week; and offer perishable goods and chilled products that command higher prices.[31] As a result of efficiency improvements, women realise tangible revenue gains in their businesses.

FIGURE 3

Electrification significantly increases business revenue



Sources: Sovacool et al., "The Energy-Enterprise-Gender Nexus: Lessons from the Multifunctional Platform (MFP) in Mali"; Bera et al., "Renewable Energy for Women Empowerment: Experiences from Rural West Bengal"; Gray et al., "The Power of Small-Scale Solar: Gender, Energy Poverty, and Entrepreneurship in Tanzania."

Access to affordable, reliable energy, combined with appropriate financing and training, can shift women's enterprises from marginal survival to meaningful income generation.[32]

In turn, successful women micro-entrepreneurs gain status and recognition in their communities, becoming role models who shift perceptions of what women can achieve,[33] contributing to less overall gender discrimination.[34]

29 ENERGIA, *Women's Empowerment and Electricity Access: How Do Grid and Off-Grid Systems Enhance or Restrict Gender Equality?*

30 Gray et al., "The Power of Small-Scale Solar: Gender, Energy Poverty, and Entrepreneurship in Tanzania."

31 GOGLA, *Powering Progress for Productive Use of Renewable Energy (PURE)*.

32 Duke University and Shell Foundation, forthcoming.

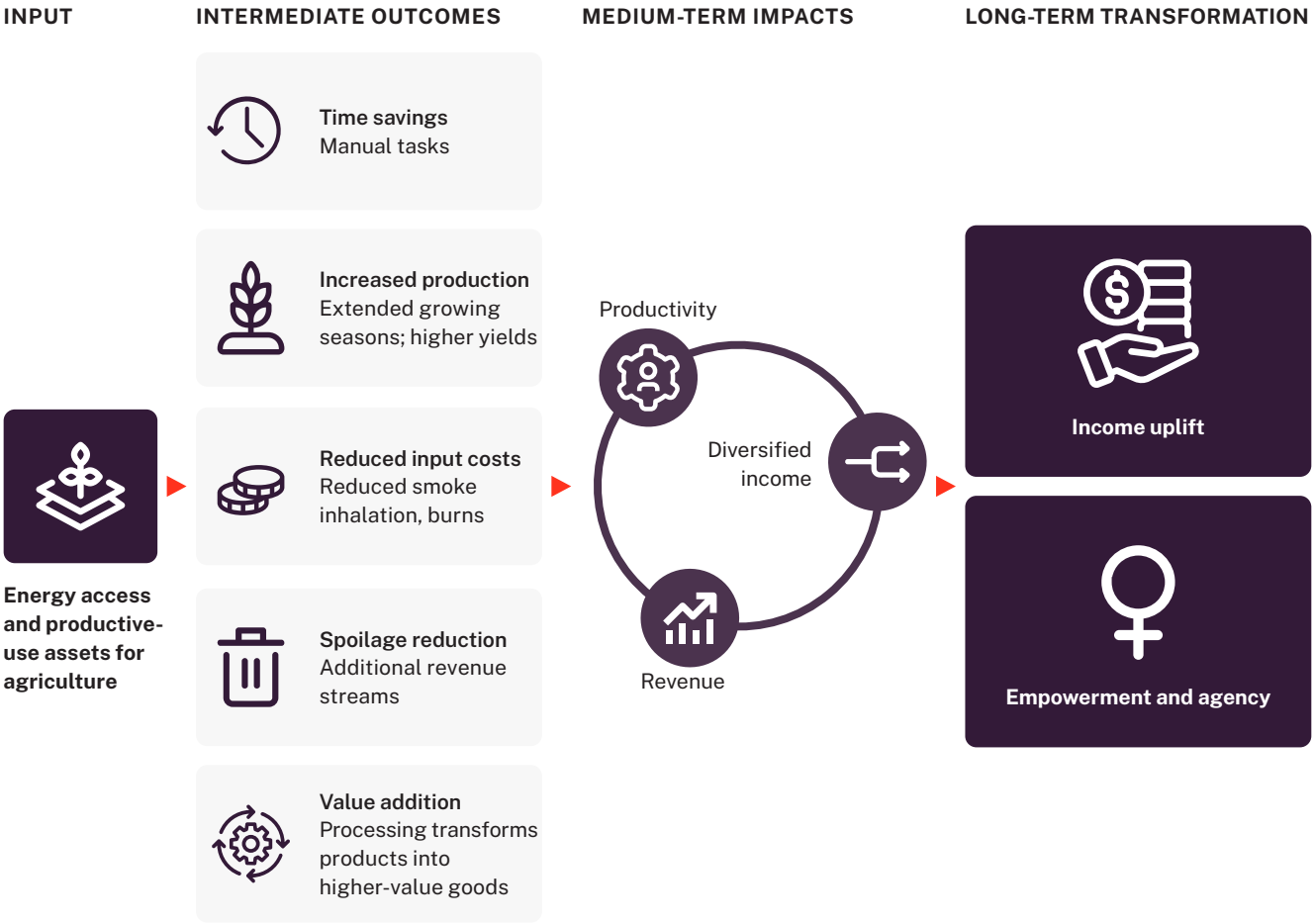
33 Osunmuyiwa and Ahlborg, "Stimulating Competition, Diversification, or Re-Enforcing Entrepreneurial Barriers? Exploring Small-Scale Electricity Systems and Gender-Inclusive Entrepreneurship."

34 Barron et al., "Gender and Entrepreneurship in the Renewable Energy Sector of Rwanda."

For women farmers, clean energy technologies, including solar irrigation, efficient milling, and cold storage, can transform women's agricultural productivity while shifting their role from unpaid labourers to being economic actors with control over assets and income.

FIGURE 4

Impact pathway of clean energy assets for agriculture



Productive-use assets reduce on-farm drudgery for women and save costs. Milling, grinding, irrigation, and other machinery significantly reduce the time spent on physically demanding and time-consuming tasks. While drudgery is rarely quantified, time savings are significant and measurable: between 2 and 6 hours per day in Mali after the introduction of clean energy-powered grain mills.[35] Solar irrigation in Benin reduces the time women spend watering crops by 50%, freeing large blocks of time for other activities, including on-farm labour,[36] especially in households where women have greater participation in agricultural decision-making.[37] Solar-powered pumps can reduce irrigation expenses by up to 91% across five sub-Saharan African countries.[38] The savings flow directly to household income or reinvestment in the farm.

35 Sovacool et al., "The Energy-Enterprise-Gender Nexus: Lessons from the Multifunctional Platform (MFP) in Mali."
36 Sehgal, "Case Study of a Solar Powered Drip Irrigation System for Women Farmers in Northern Benin, West Africa."
37 Duke University and Shell Foundation, forthcoming.
38 Efficiency for Access and 60 decibels, *Uses and Impacts of Solar Water Pumps*.

With time and money freed, women can increase and diversify production. Solar-powered irrigation enables year-round horticulture, overcoming the constraints of rain-fed agriculture. In East Africa, 75% of women using solar irrigation reported increased productivity, and 70% of women farmers in Benin raised their income by US$250 per year.[39] Cold storage protects these gains: Zero-Energy Cool Chambers (ZECCs)[40] reduced post-harvest losses in India by 30% to 35%, ensuring that increased production reaches the market rather than spoiling in the field.[41] In Kenya, solar milk chillers more than doubled the incomes of predominantly female smallholder dairy farmers by significantly reducing waste and losses.[42]

These economic gains shift power within households. In Benin, women with access to agricultural clean energy assets were 2.7 times more likely than similar women without such assets to score above average on empowerment measures. In Mali, 1,800 small generators supporting irrigation, processing, and refrigeration reached 2.4 million rural clients and created new economic opportunities for an estimated 200 women per village through activities such as mechanised rice hulling, shea nut grinding, and small-scale farming.[43]

39 Efficiency for Access and 60 decibels, *Uses and Impacts of Solar Water Pumps*.

40 Zero Energy Cold Chambers (ZECCs) are large clay or sand coolers, capable of storing and cooling vegetables post-harvest through evaporation, thus eliminating the need for electricity completely.

41 Ghosal and Mohanty, "Studies on Use of Renewable Energy Gadgets for Enhancing Livelihood of Farm Women."

42 Usagi et al., "Assessment of the Effect of Solar Powered Milk Cooling Technology on Small Holder Dairy Farmer Earnings, Siaya County, Kenya."

43 Sovacool et al., "The Energy-Enterprise-Gender Nexus: Lessons from the Multifunctional Platform (MFP) in Mali"; UNDP, *Reducing Rural Poverty through Increased Access to Energy Services*.

Productive-use technologies that are successful create displacement risk

When clean energy assets prove economically valuable, male capture is a systematic risk, not an exception. In many agricultural value chains, men control technology adoption decisions even where women perform the majority of the labour. The same solar irrigation system that expands a woman's productivity can shift into male hands as its value becomes visible — particularly where assets are registered in men's names or governed through male-dominated cooperatives.

Gains are most likely to reach women in contexts where they retain decision-making authority over productive assets. In many agricultural value chains, men control technology adoption and use decisions. This means that the same assets that expand women's productivity can bypass women's economic benefit entirely if asset ownership and governance are not designed with gender intentionality in mind.

The position of assets in the value chain offers a partial but important mitigation. Evidence from agricultural value chains across India, Kenya, and Nigeria shows that technologies introduced at post-harvest and processing stages (e.g., drying, milling, storage, sorting) are more likely to retain gains for women because women already control those stages. In contrast, assets introduced at production stages, such as irrigation, pruning, or mechanised land preparation, occur where men are more likely to control decisions and asset use.[44]

This dynamic is not a reason to avoid productive-use investment. It is a reason to treat asset placement registration, governance design, and women's formal ownership as core investment conditions rather than complementary add-ons. Interventions that do not specify how women will retain control of assets and income should be assessed as higher-risk.

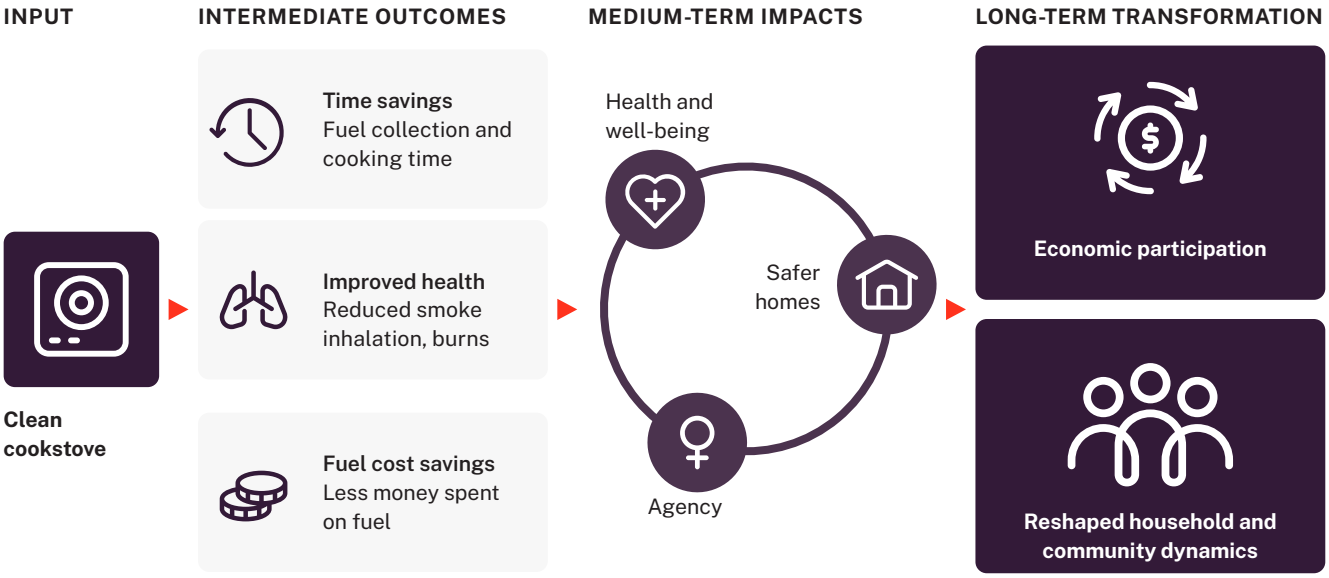
44 Sattva Consulting, forthcoming.

Clean energy assets in the household require complementary support to turn benefits into income gains

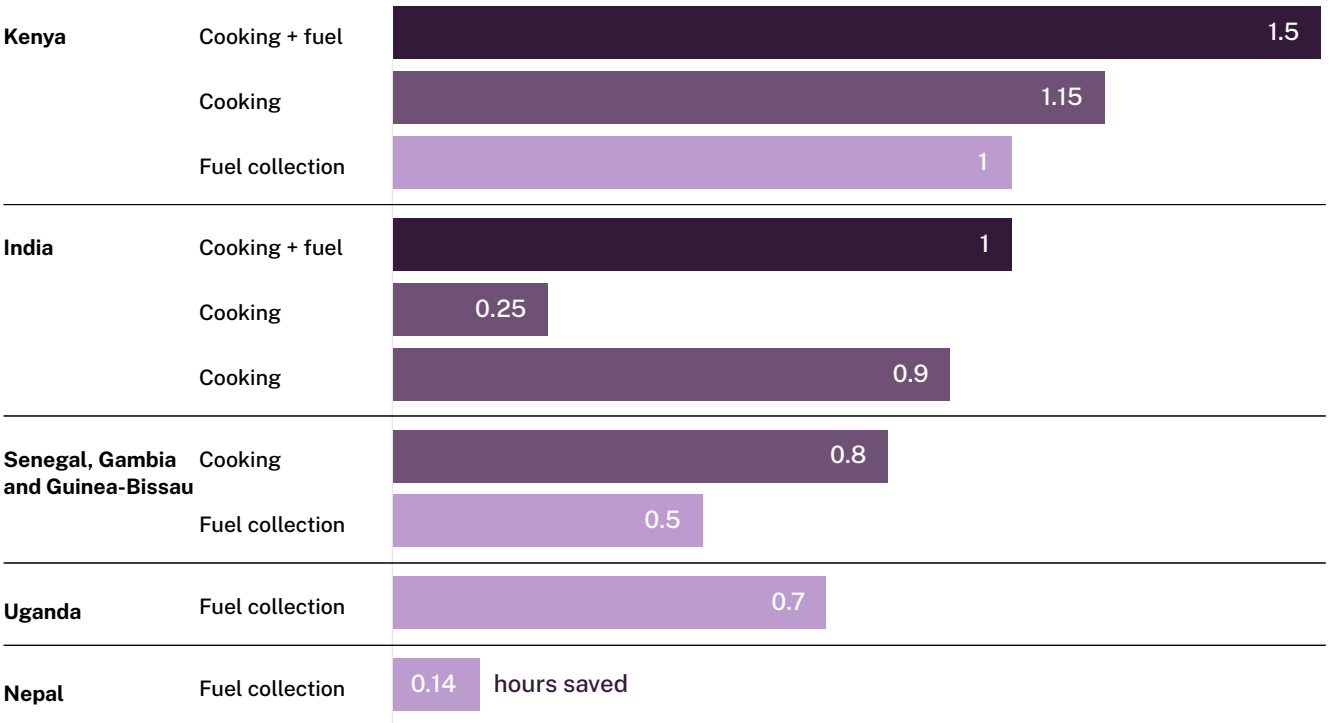
Women as users of clean cookstoves gain access to efficient and improved cookstoves powered by LPG, biogas, or electricity. When bundled with reliable fuel supply, appropriate training, and access to financing to pay for more expensive cookstoves, women save time, improve respiratory health, and save costs.

FIGURE 5

Impact pathway of clean cookstoves



The time savings are substantial. Evidence from across Africa and Asia indicates gains ranging from 15 minutes to over 1.5 hours per day, depending on the type of fuel previously used, the solution introduced, and the time women previously spent on fuel collection and cooking.



Sources: IFC, *Clean Impact Bond*; Jagoe et al., "Sharing the Burden"; Poushali et al., "Incomplete Transitions to Clean Household Energy Reinforce Gender Inequality by Lowering Women's Respiratory Health and Household Labour Productivity"; Imelda and Verma,"Clean Energy Access: Gender Disparity, Health, and Labour Supply"; Climate and Health Evidence Bank, "Improved Cookstoves in Senegal, The Gambia and Guinea-Bissau"; Guzmán et al., "Improved Cookstoves as a Pathway between Food Preparation and Reduced Domestic Violence in Uganda"; Akter and Pratap, "Impact of Clean Cooking Fuel Adoption on Women's Welfare in India"; Mahat, "Gender and Rural Energy Technologies."

FIGURE 6

Clean cookstoves save women up to 1.5 hours per day

Household electrification and non-cooking appliances work through similar mechanisms. Reducing the use of kerosene lighting and introducing energy efficient appliances improves women's health, saves time, and enables women to engage in income earning and household labour after dark.[45]

Whether these time savings translate into economic participation depends on the amount of time saved and on the context of women's livelihoods. In urban settings, small but reliable and well-timed savings, particularly during evenings or peak business hours, can generate returns as women have access to market infrastructure. Other factors that influence women's ability to convert time savings into paid work include time agency (the extent to which women have control over how their time is allocated and reallocated), and training and knowledge of business skills that facilitate entry to paid work. In contrast, in rural settings, gains of three to four hours are generally necessary before women engage in income-generating activities; less is usually allocated to rest or absorbed by other unpaid work.[46]

45 Gray et al., "The Power of Small-Scale Solar: Gender, Energy Poverty, and Entrepreneurship in Tanzania."

46 Duke University and Shell Foundation, forthcoming.

When conditions align and gains translate into economic participation, women increase their time spent in income-generating work by as much as 20% for every hour saved.[47] Financial savings compound the effect: reduced fuel costs can save households up to US$480 annually.[48] When women control these savings, their agency expands. In one study, 91% of women reported using energy-related savings to purchase clothes and personal items, a marker of increased decision-making power.[49]

Beyond income and financial benefits, women also experience immediate benefits from reduced drudgery and improved health. Studies have measured significant increases in women's lung capacity and a 19.5% reduction in lung cancer risk, as exposure to harmful smoke and pollutants decrease.[50] Burns and respiratory illness decline. One study linked use of clean cookstoves to a 16-percentage-point reduction in domestic violence, suggesting that reduced household stress and improved living conditions may reshape family dynamics.[51]

Over time, individual gains can reshape household and community dynamics. Women may transition from being unpaid labourers to being economic actors with greater control over their time, income, and choices, with investment in children's education and health noticeably increasing.

47 Imelda and Verma, "Clean Energy Access: Gender Disparity, Health, and Labour Supply."

48 Shell Foundation, *Landscape Analysis & Market Sizing Report: Results Based Financing for Productive Use Appliances to Promote Gender Outcomes*.

49 Ding et al., "Impacts of Renewable Energy on Gender in Rural Communities of North-West China."

50 Imelda and Verma, "Clean Energy Access: Gender Disparity, Health, and Labour Supply."

51 Guzmán et al., "Improved Cookstoves as a Pathway between Food Preparation and Reduced Domestic Violence in Uganda."

Clean energy reduced exposure to gender-based violence

Our review identified eleven studies that link the use of clean energy technologies in the household (mainly solar lamps and cookstoves) with reductions in gender-based violence (GBV). While many studies referenced the qualitative (and often unmeasured) benefits of cookstoves and electrification for women's safety, very few provided quantified measurements of changes. The main pathways identified for how clean energy reduces GBV are:

- **Exposure to violence while collecting fuel:** Qualitative reports indicate women and girls face high rates of sexual harassment and assault while collecting fuelwood, and in some cases, men and boys who take over this task face physical assaults.[52] There are also reports of men coercing women into exchanging sexual favors to facilitate access to forests in refugee and displaced person camps, but these lack robust quantitative measurement.[53]
- **Exposure to intimate partner violence:** Randomised control trial data from Uganda found statistically significant differences between treatment and control villages in pre- and post-intervention measures of domestic violence, with an average treatment reduction of 16 percentage points.[54] Researchers attributed this drop to more efficient fuel collection, more efficient food preparation, and tastier food from clean cookstoves.
- **Reduction in household disagreements:** There is some evidence that suggests that electrification can reduce household conflicts over kerosene purchases, potentially reducing the risk of violence against women.[55] However, some accounts indicate that violence remained prevalent or even increased, suggesting a more nuanced picture.[56]

52 ENERGIA, *Women's Empowerment and Electricity Access: How Do Grid and Off-Grid Systems Enhance or Restrict Gender Equality?*

53 Matinga, "We Grow Up with It: An Ethnographic Study of the Experiences, Perceptions and Responses to the Health Impacts of Energy Acquisition and Use in Rural South Africa."

54 Guzmán et al., "Improved Cookstoves as a Pathway between Food Preparation and Reduced Domestic Violence in Uganda."

55 Winther et al., "Solar Powered Electricity Access: Implications for Women's Empowerment in Rural Kenya."

56 Das et al., "Frameworks, Methods and Evidence Connecting Modern Domestic Energy Services and Gender Empowerment."

PERSONA

Selam's story
How clean cooking creates safety

Selam is a 32-year-old mother of four living in rural Ethiopia. Her day revolves around her three-stone stove. She spends more than two hours each day gathering firewood, often walking long distances at dawn or dusk. These trips are not just exhausting; they are dangerous. Selam has experienced harassment on the route to the forest, and she constantly worries about her eldest daughter, who has started collecting fuel alongside her.

At home, tensions rise when resources are scarce. Selam's husband controls financial decisions and sees the upfront cost of a clean stove as a luxury they cannot afford. When meals are late, or the fire smokes too much, arguments escalate, and the stress affects her sleep, her health, and her ability to work her small farm.

A clean cookstove would change more than how Selam cooks. It would reduce or eliminate the fuel collection trips that put her and her daughter at risk. Shorter cooking times and less smoke would ease daily tensions in the household.

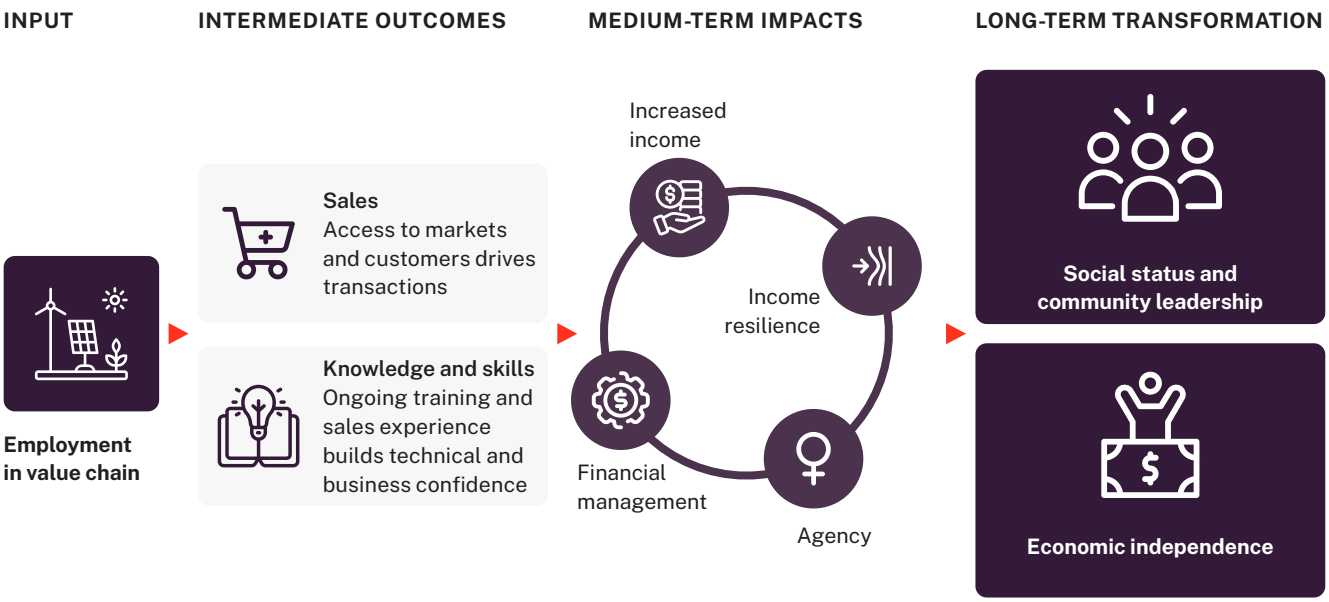
With greater safety, Selam can move more freely. Rather than gathering fuel, she can spend her time as she chooses, for leisure, working on her farm, care responsibilities, or attending market days without rushing home. A clean cookstove is not just a household asset. It is a pathway to safety, and safety is the foundation of her own economic future.

Women working in the clean energy value chain have the most direct path to income uplift

Working in the clean energy value chain offers direct pathways to WEE. According to the International Renewable Energy Agency (IRENA), women make up an estimated 40% of the global solar photovoltaic workforce,[57] compared to 22% in the oil and gas sector.[58] This growth reflects both expanding opportunity and a strengthening business case for hiring more women in clean energy value chains.

FIGURE 7

Working in clean energy has the most direct, measurable impact on women's incomes



Working in the clean energy sector delivers strong outcomes for women across sales, finances, and personal agency.

57 IRENA, *Decentralised Solar: A Gender Perspective*.

58 Boston Consulting Group, *Untapped Reserves 2.0 Driving Gender Balance in Oil and Gas*.

Sales performance

▲ +60%
higher sales after training

3:1
women outsell men after training
KENYA

▲ +36%
women outsold men working solo
RWANDA

Financial outcomes

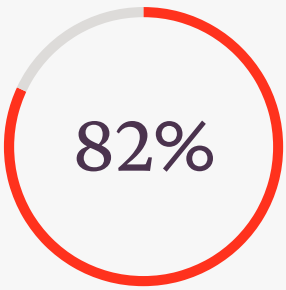
loan repayment rate

$49 *to* $195
stable monthly income
KENYA

of women-led enterprises are profitable

Agency and empowerment

of women exercise control over own earnings



participate in household decisions

▲ +68%
income increase
ETHIOPIA

Sources: Shankar et al., "Agency-Based Empowerment Training Enhances Sales Capacity of Female Energy Entrepreneurs in Kenya"; Barron et al., "Gender and Entrepreneurship in the Renewable Energy Sector of Rwanda"; ENERGIA, "Supporting Last-Mile Women Energy Entrepreneurs"; Dutta, "Promoting Women's Entrepreneurship in Distribution of Energy Technologies"; Gray et al., Turning on the Lights; Shiradkar et al., "Can Community Based Solar Energy Initiatives Deliver on Women's Empowerment in India?"; ENERGIA, *Building the Business Case for Women's Inclusive Financing in Last-Mile Renewable Energy Markets in Sub-Saharan Africa*; International Energy Agency, *Women Working in the Rooftop Solar Sector*.

FIGURE 8
Working in clean energy has the most direct, measurable impact on women's incomes

These results reflect several reinforcing mechanisms. Women agents typically sell to women, and direct experience as users of household energy products builds credibility that male agents cannot replicate. Existing community trust networks reduce acquisition costs and improve conversion. Agency-based training amplifies these advantages: when women develop confidence and self-efficacy alongside product knowledge, performance gains compound.

PERSONA

Siti's story
Building a career in clean energy

Siti is a 36-year-old trained nurse and mother of two in rural Indonesia. After the birth of her second child, she was unable to manage the long shifts alongside care responsibilities and supporting the family farm, leaving her with very little financial independence.

When Siti bought her first solar lantern from a neighbour, she immediately saved money on kerosene and her children were able to study after dark. When the same neighbour mentioned that the distributor was recruiting new sales agents, Siti was interested. The role required minimal upfront investment and flexible hours she could fit around her family responsibilities.

Siti's nursing background proved an unexpected asset. She already knew and was trusted by women across the village from her time as a nurse. Within months, she was earning up to US$75 per month. She reported feeling more confident, more respected at home, and more in control of how she spent her time and money.

A year later, Siti entered a training programme covering product repair and maintenance. She faced scepticism from some family members and customers, who saw repair work as a man's domain. Peer mentoring from other women technicians helped her persist, and the company's commitment to building an inclusive pipeline gave her room to grow.

Today, Siti keeps solar products working in her community. She is saving to buy a motorbike to expand her business to nearby villages. For Siti, clean energy created more than income; it empowered her livelihood.

Working as sales and repair agents, in particular, is a good, low-risk option for women, as it requires low capital overhead (after training).[59] Creating pathways for women to enter agent roles has significant rewards, but it requires longer-term investment.

Despite differences in archetypes, all women need assets, agency, and market access to maximise the potential of clean energy

While all pathways show potential for income gains, they take different routes depending on the type of clean energy user, asset, and location.

Agency over time allocation, market access, complementary assets, and safe mobility are central to transforming saved time into income-generating work. For women's income-generating activities, assets that reduce waste, increase yields, and improve efficiency offer an alternative path to economic empowerment. Understanding which route applies shapes how investment design and what outcomes investors should expect.

Fundamental differences in baseline conditions determine how the same technology performs differently across contexts. Investors and programme designers cannot assume that technology alone will deliver results. Complementary investments in bundled solutions to build time agency, including in skills, create market access and infrastructure, and provide childcare support are needed to translate the gains enabled by clean energy technology into economic empowerment.

59 ENERGIA, *Women's Energy Entrepreneurship: A Guiding Framework and Systematic Literature Review*.

Positive financial returns for women are achievable, under the right conditions

The financial case for gender-focused clean energy investment is frequently underestimated. A persistent assumption in development finance holds that designing for women carries financial penalties of lower returns, thinner margins, or longer payback periods. Under financial modelling led by Caribou, it is clear that positive returns are achievable, but whether they materialise depends less on the technology than on the conditions surrounding it.

The most consistent barrier our modelling surfaces is not the underlying economics of the asset, but the financing layer: standard consumer finance and pay-as-you-go (PAYGo) terms frequently eliminate returns that would otherwise be viable. This is a market design problem, not an inherent feature of investing in women. Better-structured financing products, blended finance mechanisms, and first-loss arrangements can address without requiring permanent subsidy.

Underlying conditions determine returns

All clean energy technologies depend on underlying conditions and enabling infrastructure that should be verified, rather than assumed. Knowing the existing infrastructure and its reliability is central to calculating potential returns.

- Milk chillers are most effective when evening milk collection services are unavailable. Where evening collection is available, the primary benefit disappears, leaving only incremental potential gains from premium milk prices and lower transportation costs.
- Solar irrigation requires access to water sources and conditions that enable multiple growing seasons. A solar pump cannot irrigate from a dry borehole; an additional growing season doesn't materialise if water, seeds, or labour are not available.
- Solar refrigeration in micro-enterprises requires sufficient customer demand for cold beverages and other products. A fridge in a location without traffic or in a community that cannot afford a premium price will not generate revenue increases.
- Clean cookstoves are most often used alongside traditional stoves (a practice known as "stove stacking").[60] Stove stacking can reduce fuel savings, time savings, and health benefits proportionally. The availability of fuel (LPG canisters) and intra-household decision-making around fuel purchases significantly affect the extent of stove stacking.

60 Gould and Urpelainen, "The Gendered Nature of Liquefied Petroleum Gas Stove Adoption and Use in Rural India"; World Bank, *The State of Access to Modern Energy Cooking Services*; Puzzolo et al., "Clean Fuels for Resource-Poor Settings."

Productive-use assets deliver stronger economic returns than well-being

Technologies that directly support income generation (by increasing production or reducing waste) offer more direct and measurable paths to positive economic returns than those that primarily save time or reduce costs. For investors, this may mean that there should be different expectations for how "success" is defined and measured in terms of return on investment for productive versus non-productive assets.

Solar milk chillers and irrigation systems can nearly double the volume of products reaching the market. Milk chillers enable farmers to monetise evening milk production that would otherwise spoil or be sold at significant discounts, nearly doubling total milk volume. Similarly, where solar irrigation can enable an additional growing season, it can nearly double yields. In contrast, when evening milk collection is available, or irrigation increases production by only 13% to 20% through yield improvements, the capital costs often outweigh the asset benefits. Milk chillers and cold storage can be particularly beneficial for women because they sit at post-harvest stages, where women retain control and decision-making power.

Food businesses are a slightly different case. Women running food enterprises typically purchase fuel rather than gather it. Where LPG or electric cooking comes at a lower cost than charcoal, women realise an immediate savings.

In contrast, household users rely on reallocating time savings from clean energy assets to income-generating activities, which rarely happens without complementary programming and time savings above two hours per day.[61] In these cases, the net financial returns are modest for household users.

61 Duke University and Shell Foundation, forthcoming.

Financing improves access, but terms can eliminate positive returns

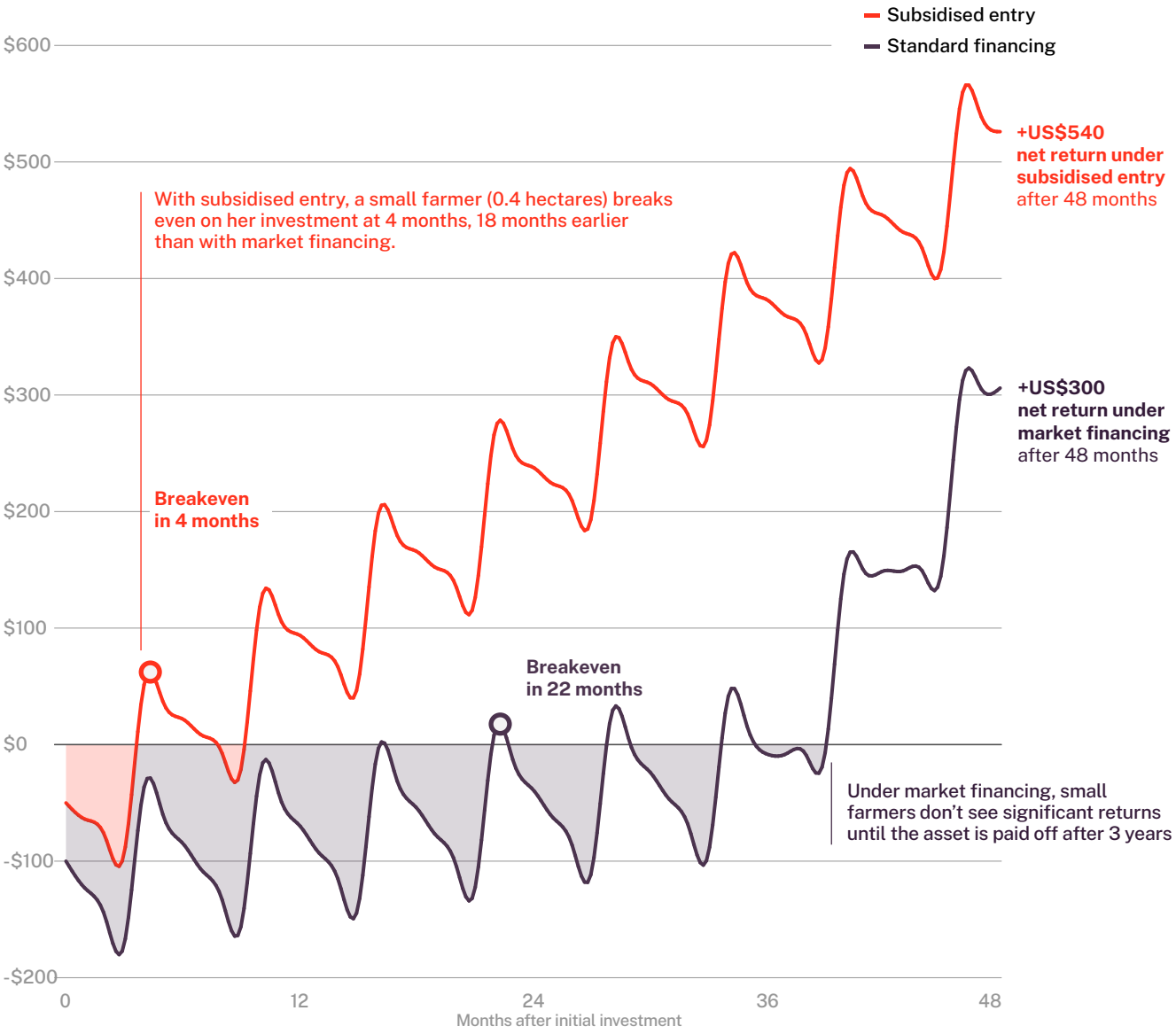
Across all but the cheapest of the fifteen assets modelled (improved cookstoves), realistic financing terms often flip positive returns into negative ones. A solar irrigation system that generates a +30% annual return when purchased up front can incur losses when financed through a PAYGo arrangement or a consumer loan that carries an annual percentage rate of 25% to 35%, which may add a 50% to 80% premium to the retail price. As a result, users may pay more in financing costs than they earn in additional revenue.

These conditions reflect the real costs of absorbing maintenance and default risks when serving households with volatile incomes. However, financing conditions can mean that low-income households, who could benefit most from clean energy assets, are the least likely to access them.

The financing gap can be narrowed through several mechanisms. Deposit subsidies are one option: a 200W solar irrigation system for a 0.4-hectare plot can take nearly 2 years to break even under standard market financing. However, with subsidised entry, the breakeven point can be pulled forward by 18 months, significantly increasing the solution's viability.

Extending the loan tenor, introducing a harvest-aligned moratorium, or reducing interest rates can achieve comparable effects within a commercial framework. For service-based models like pay-per-use mechanisation, cross-subsidisation or volume-based discounts may be more appropriate than direct subsidy. For financiers to reduce premiums and subsidise access, they must absorb risk elsewhere. This can be achieved through guarantees or first-loss capital, or by reducing underlying default rates through effective targeting.[62]

62 Guarantees are commitments from a third party (e.g., development finance institution, donor) to cover a portion of losses if borrowers default, reducing the lender's risk exposure. First-loss capital is funding, typically from philanthropic or public sources, that absorbs initial losses before other investors are affected, making it safer for commercial capital to participate.



At the same time, financial products need realistic affordability checks built in. While models can predict a positive return for women, the financial burden of fixed monthly repayments or upfront capital costs may still be unrealistic. For this reason, affordability checks are essential to ensure that upfront costs or monthly payments are sustainable relative to household income. While our models explicitly flag this risk, women may still become over-indebted.

FIGURE 9

Subsidised solar irrigation kits reach breakeven 18 months faster than conventional terms

PERSONA

Neema's story
Financing terms shape whether an asset builds wealth or creates risk

Neema is a 32-year-old maize farmer in Southern Kenya. A simple 200W solar pump would cost more than US$500 — significantly more than she earns in three months — putting it firmly out of reach under any conventional financing arrangement. Through her local women's savings group, she accessed a PAYGo arrangement requiring only a 10% deposit and daily micro-payments via mobile money.

The terms made access possible, but they made returns fragile. Over three years, the total cost runs nearly 60% above the upfront retail price — the premium the group absorbs for bearing her default risk. In the early months, Neema's net benefit is close to zero. She services payments from existing income while waiting for the asset to prove itself. A bad harvest, an illness, or an unexpected expense during that time could trigger the remote lockout and end the arrangement before it delivers.

What saves the calculation is the asset itself. Solar irrigation enables a second growing season on her 0.5-hectare plot, nearly doubling her on-farm revenue. That additional output converts a precarious financing arrangement into a viable one. By month eighteen, Neema is repaying faster than scheduled, building a small buffer, and beginning to plan her next investment. The pump that once seemed out of reach is now an asset she owns outright.

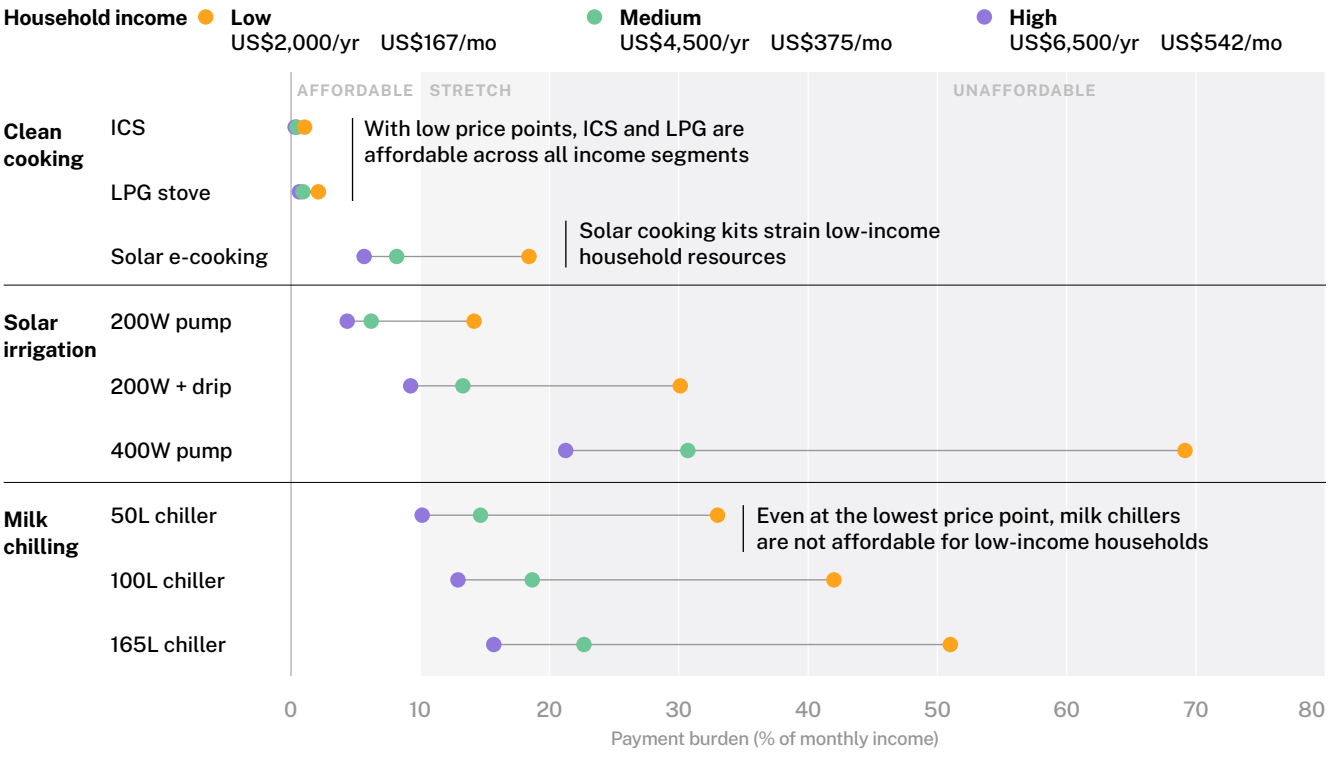
For example, households with lower income (e.g., ~US$2,000/year, or roughly US$1/day per person) might be illustrative of rural populations in countries such as Burundi or Malawi, where cash incomes are limited and livelihoods are largely subsistence-based. Even households in "medium" income brackets (~US$4,500/year, or ~US$2.5/day per person), representative of better-off rural households in Kenya or Tanzania, reflect constrained and irregular cash flows. In these contexts, even modest repayment burdens can quickly become unaffordable.

Additionally, there may be timing gaps between when new income from an asset materialises and when payments are due. Harvests are seasonal, fuel savings accumulate gradually, and new revenue streams take time to establish. Women must be able to service payments during this gap. In this stretched zone, women face higher default risks, especially in the case of disruptions. A bad harvest, a family emergency, school expenses, illness, or an unexpected expense may trigger missed payments and lost assets. The longer it takes for assets to pay themselves off, the greater the risk of default and of the asset never reaching the breakeven point.

Where payments fall into the stretched zone, financiers may require greater payment flexibility or subsidised loan terms to be viable for more risk-averse financial institutions. A positive rate of return does not mean cash flow risks have ceased to exist. Affordability analysis based on what households can actually pay before realising a solution's benefits should be part of any return projections. For finance to be affordable, repayments should fall below 10% of monthly income. But for households earning less than US$60 per month, even modest payments can be out of reach.

FIGURE 10

Payment burdens keep productive technologies out of reach for lower-income households



For capital-intensive assets, like milk chillers, cold storage facilities, and larger irrigation systems, individual ownership is often structurally unaffordable, and the ownership model itself usually needs to change. This is true even for relatively better-off rural households with higher incomes (e.g., ~US$6,500/year, or ~US$3.5/day per person), which might correspond to more commercially oriented farmers in Kenya or Ghana. For these cases, where monthly repayments consistently exceed what individual households can sustain, shared ownership through Savings and Credit Cooperative Organisations (SACCOs) or farmer cooperatives, fee-for-service models, or community-scale facilities spread both capital costs and utilisation risk across a larger group. A milk chiller that creates unsustainable debt for a single farmer earning US$130 per month from dairy can generate viable returns split across three or four farmers using 80% of its capacity. For assets at this price point, collective models are often the only route to affordability.

Business scale determines whether investments pay off

For technologies where returns scale with existing business size (e.g., a micro-retailer adding solar fridges for chilled products), existing business size and baseline income are the primary determinants of financial viability. Financing terms, however well designed, cannot compensate for an insufficient revenue base of the existing business model.

Assets like milk chillers and solar pumps deliver strong financial returns when they allow for evening milk collection or unlock an additional growing season, potentially doubling yields. However, solar refrigeration typically delivers a percentage uplift on existing revenue, by adding premium products to a micro-retailer's shop, rather than doubling customers or revenue outright. As a result, the absolute value of the return depends entirely on what the business is already generating. The same asset with the same financing terms and the same percentage improvement produce fundamentally different outcomes at different income levels.

For the smallest micro-retailers, the monthly payment for these assets cannot be recovered from the income they generate — not because the technology fails, but because the base it is working from is too small.

The tension in the scale of returns leads to a dilemma. Vendors who most need income support may operate at scales where productive-use assets cannot pay for themselves. Programmes may face a choice: target operators above viability thresholds where impacts are incremental, or subsidise solutions for smaller operators, where the case depends on grant funding rather than returns.

PERSONA

Amina and Grace's stories
Two vendors, two different trajectories

Amina runs a small kiosk in a rural village, selling snacks and warm beverages. She earns around US$150 per month. A solar refrigerator would allow her to stock cold drinks and perishable items, increasing revenue by ~30%, or US$45 per month. The refrigerator costs US$800 with interest-free financing over 3 years (US$22 monthly payments).

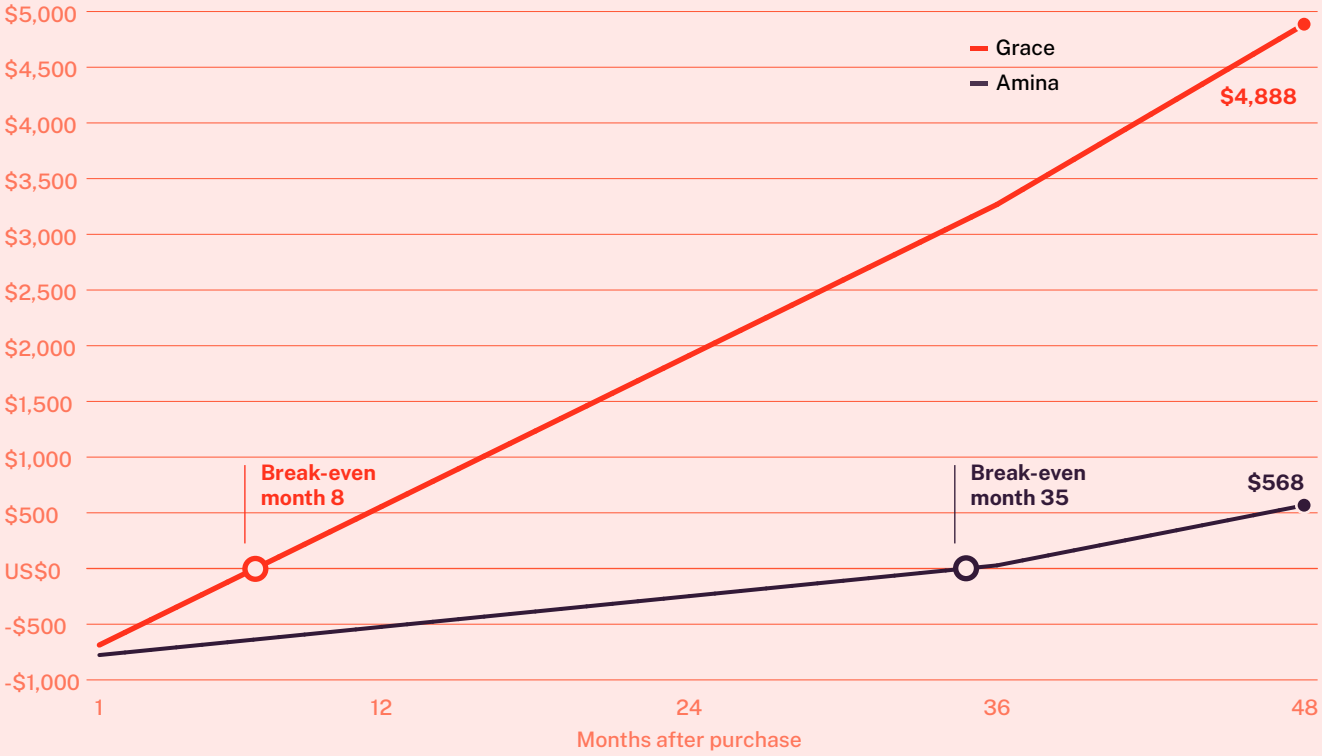
Amina's monthly gain after payments is US$23, but she must first recover the US$800 equipment cost. She does not break even until month 35. By month 48, she has accumulated US$570 in net returns. During those first 3 years of negative returns, a single disruption could trigger default.

Grace operates a shop near a transport hub, earning US$450 per month. The same 30% revenue increase generates an additional US$135 in monthly income. With the same US$22 payment, she nets US$113 monthly and breaks even at month 8. By month 48, she has accumulated over US$4,800 in net returns.

The technology, financing terms, and percentage uplift are identical. Baseline revenue is the only difference, and it determines whether the investment builds wealth or creates financial risk. Programmes targeting vendors at Amina's income level require grant subsidies, shared ownership models, or lower-cost technologies to achieve viable returns.

FIGURE 11

Baseline revenue determines investment viability



Note: Both vendors receive 30% revenue uplift. Same equipment and 36-month financing.

Shared ownership improves affordability for capital-intensive technologies, but coordination costs may be high

For higher-cost productive-use assets, shared ownership offers a pathway to viability. Our milk-chiller model shows that splitting capital costs across 2 to 4 farmers can move monthly payments from unaffordable to sustainable. A US$1,400 chiller requiring US$39 monthly payments may strain a single farmer earning US$150 from dairy. Split across three farmers, the US$13 payment falls within sustainable thresholds while each farmer captures meaningful returns. This approach requires coordination that programmes can build into their designs.

Solar-powered cold storage facilities scale this logic further. Community-scale cold storage rooms serving 20 to 50 smallholders can achieve utilisation rates that individual units cannot, spreading capital costs while providing access to reliable storage.

The trade-off is coordination cost and infrastructure that programme designers should plan for from the outset.

Clean energy assets can fuel WEE under the right conditions

Clean energy investments that address women's need for holistic solutions for both income-earning and household needs, financing with terms that work for women, and training that enables women's agency deliver stronger outcomes for WEE.

The conditions for viable returns are demanding but achievable. What is most important is to understand context and design, and how a given intervention is expected to increase incomes. Productive-use assets often offer clearer and more direct pathways to income uplift than household-oriented assets.

Bundled solutions outperform single-asset interventions as they address women's holistic needs and multiple roles in households and the economy. Financing terms can make or break viability. An existing business's scale can determine the viability of investment, and shared ownership may be a viable route to affordability. Finally, training can significantly broaden and deepen the impact on WEE. Investing in training that builds women's agency, self-efficacy, confidence, and self-control not only improves qualitative measures for women but also directly impacts measurable business outcomes.

PERSONA

Lilian's story
One milk chiller, shared viability

Lilian keeps three dairy cows on her small farm in Meru County, Kenya, and earns around US$132 per month from morning milk sales to the local cooperative. There is no evening collection in her area, so her 8 litres of evening milk each day is either sold to neighbours at a steep discount or lost to spoilage.

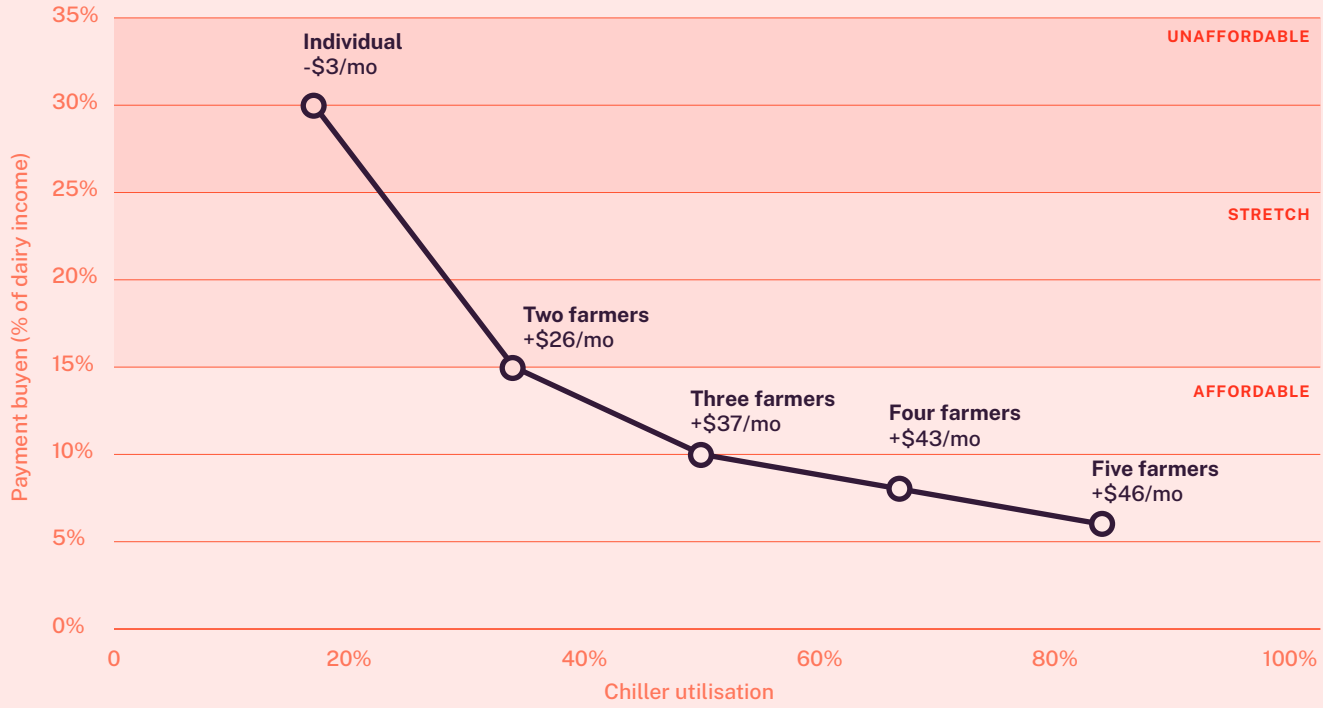
A 50-litre solar milk chiller would allow her to store evening milk for morning collection. But the numbers do not work. Her 8 litres would fill only 17% of the chiller's capacity, generating roughly US$40 in additional income per month. The chiller costs US$1,000 with 36-month financing, requiring US$40 in monthly payments. After maintenance costs, she loses US$3 per month. The payments consume 30% of her dairy income, well above the threshold for sustainable debt, and she quickly becomes overwhelmed by debts.

Instead, if Lilian joined a small dairy group in her village with 3 other farmers, they could purchase a shared milk chiller. Each household keeps 3 or 4 cows, and together, their herds produce 42 litres of evening milk daily. The same 50-litre milk chiller that would have put Lilian into debt can now be shared, as the 4 dairy farmers would use 80% to 90% of its capacity. At this level, the chiller generates roughly US$275 in total benefits across the group per month. Each farmer saves approximately US$55 per month while paying only US$8, netting US$46 per month, or roughly US$550 per year. The payment burden drops to 6% of dairy income.

This shared ownership changes the economics by increasing the utilisation rates that a single farmer cannot capture and spreading payments across four households, making the investment affordable.

FIGURE 12

Shared ownership improves utilisation and affordability



Context drives impact for women: Five enabling conditions for impact

Knowing that clean energy works is not sufficient for investment design. The same asset can double a woman's income or push her into debt depending on context, financing terms, and whether the right enabling conditions are in place. ARISE (Agency, Relevance, Infrastructure, Skills, and Engagement) is a practical framework for assessing those conditions before committing resources. Each factor represents a design decision, not a background assumption. They align with established models of technology diffusion, which emphasise that adoption depends on fit, accessibility, and sustained support, not technology alone.

The framework emerged from a review of 115 studies, where over 90% cited agency or infrastructure as crucial factors for positive outcomes. But the five conditions are not independent: weakness in any one can limit or reverse gains from the others. Interventions that cannot demonstrate how they address each factor should expect weaker outcomes for WEE.

FIGURE 13

The ARISE framework

A	R	I	S	E
Agency	**Relevance**	**Infrastructure**	**Skills**	**Engagement**
Decision-making, control	Fit to needs, culture	Access, reliability	Experience, understanding	Repeated use, service
Who decides energy purchases? Does the main user have a real say?	Does it meet current preferences and habits? Is it designed with women's needs in mind?	Can women connect / refill easily and safely? Do women have access to financing? Is it affordable?	Do users know how to use / maintain it safely, and what to do if it fails?	Do women keep using it most of the time? Is service / after-sales responsive?

Agency

Self-efficacy and bargaining power enable women to redirect time savings toward income-earning work, to retain earnings, and to influence household spending.

When men remain the default decision-makers over what solutions are adopted and how they are used, gains stall because women cannot control the benefits. Women's lack of decision-making power and control over household expenditure often undermined the adoption and sustained use of modern energy technologies, leading to limited or failed outcomes for interventions.[63]

- Men are rarely the primary users of household energy technologies, despite being the primary decision-makers for purchases.[64] This disconnect leads to low uptake of modern energy solutions by women.[65] In contrast, prioritising women's decision-making in community solar projects led to greater empowerment and challenged gender norms.[66]
- In Senegal, women with higher intra-household bargaining power were 10% to 15% more likely to adopt clean fuels.[67] Conversely, when women lacked bargaining power, adoption rates were lower, and women did not experience the intended health and economic benefits of clean energy interventions.
- As assets prove economically valuable, men frequently assume control over assets women previously managed. Technologies placed at post-harvest and processing stages, where women already have operational authority, are more likely to retain gains for women than those introduced at production stages where men dominate from the start.[68]

Agency plays a key role in ensuring women claim, and retain control of clean energy assets, so that the benefits of investments are not captured by men. Agency and empowerment training featured in 20% of studies, typically through peer-to-peer and group learning, highlighting the importance of training for building agency.

63 Pachauri and Rao, "Gender Impacts and Determinants of Energy Poverty"
64 Winther et al., "In the Light of What We Cannot See: Exploring the Interconnections Between Gender and Electricity Access."
65 Fingleton-Smith, "The Lights Are on but No (Men) Are Home. The Effect of Traditional Gender Roles on Perceptions of Energy in Kenya."
66 Winther et al., "Solar Powered Electricity Access: Implications for Women's Empowerment in Rural Kenya."
67 Sonne and Elise, "'Stop the Killer in the Kitchen': Do Women's Intrahousehold Bargaining Power Trigger Clean Fuel Adoption? Evidence from Senegal."
68 Sattva Consulting, forthcoming.

Relevance

Bundled solutions address women's interconnected needs.

Assets and the supporting infrastructure around them must be designed with women's needs in mind. Solutions designed without understanding women's realities often fail, regardless of their technical efficiency. Women's needs are interconnected: they manage households, care for families, farm, and run enterprises, often simultaneously. They face multiple barriers, including limited access to finance and assets, limited digital and financial literacy, and social and cultural norms that constrain their ability to adopt new clean energy solutions.

Cookstove adoption, for example, is complex, with stacking common in over 80% of households.[69] Many factors affect stove adoption and use, including compatibility of new stoves with current practices, perceptions of stove benefits, durability of stoves, ease of stove use, and affordability.[70]

Irrigation equipment is often designed without understanding women's typical landholding sizes, water source proximity, and the physical demands of use. As the impact modelling in this research illustrates, a solar pump sized for a larger plot can quickly produce net losses for smallholders with less than 0.5 hectares.

These examples highlight the importance of designing products and interventions that are responsive to women's actual needs, preferences, and cultural contexts.

69 Ochieng et al., "Household Perspectives on Cookstove and Fuel Stacking: A Qualitative Study in Urban and Rural Kenya."

70 Burwen and Levine, "A Rapid Assessment Randomized-Controlled Trial of Improved Cookstoves in Rural Ghana."

Multiple asset packages address the diversity of women's needs in a holistic package

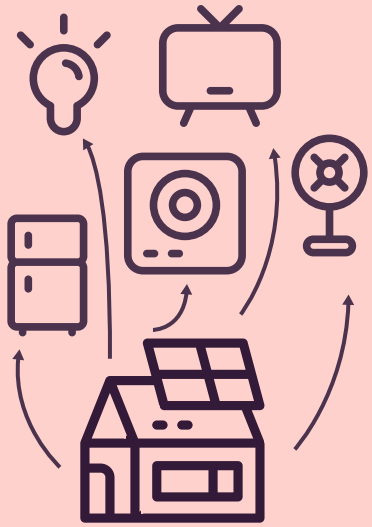
Two-thirds of the solutions assessed in the literature base were packages of multiple assets, typically comprising four or more physical assets. While no single combination dominates, three patterns emerge.

FIGURE 14

Three packages of multiple assets illustrate the most common combinations

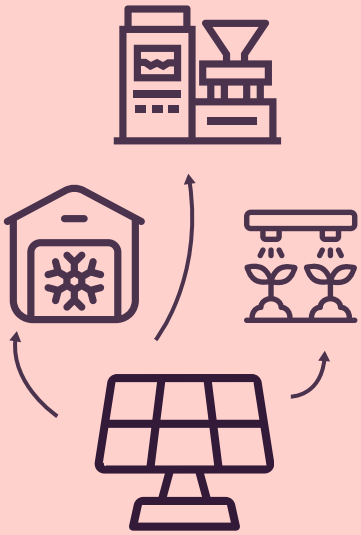
1

Solar home systems form the foundation for electrification, which energy-efficient assets can be layered on top.



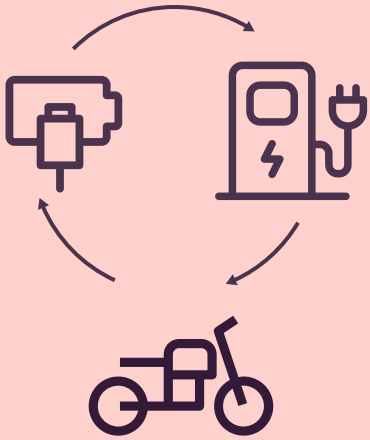
2

Agricultural bundles centre on solar-powered cold storage, food processing, and irrigation assets.



3

Electric mobility forms a distinct, closed bundle of vehicles, batteries, and charging infrastructure.



These solutions address multiple constraints by clearing successive barriers; each one addressed makes the next easier to overcome.

In some cases, single-asset solutions can also address the diversity of women's needs by performing multiple functions. Biodigesters, for example, produce both fertiliser and cooking fuel; solar pumps provide water for domestic and agricultural use. Whether standalone or bundled, these assets offer multifaceted benefits for women.

PERSONA

Adama's story
Addressing multiple constraints unlocks compounding benefits

Adama is a 45-year-old smallholder rice farmer in rural West Africa. She cultivates one hectare of land, manages a household of five, and spends five to six hours each day on irrigation, weeding, and processing. Energy costs consume nearly a quarter of her seasonal income. She relies on a community diesel pump controlled by men in her village for irrigation, pays for diesel-powered milling services, and lights her home with kerosene and firewood collected by her daughters. Her days are long, her margins thin, and her options limited. Without a land title or formal identification, she cannot access credit.

A biodigester could change the equation. Fed by agricultural waste and animal manure already available on Adama's farm, it would produce both cooking fuel and organic fertiliser from a single system. Her daughters would spend less time collecting firewood, reducing their daily burden by two hours. Cleaner air in her kitchen would ease the respiratory symptoms she has learned to live with. The fertiliser would improve her soil and yields without incurring chemical input costs. If she produces more than her household needs, she can sell surplus fuel or fertiliser to neighbours, creating a new income stream from a domestic asset.

Healthier days mean more time spent on her farm. Lower input costs improve Adama's margins. Improved yields increase her total revenue. She can use the biodigester as collateral to secure a loan for additional assets, such as a solar pump or post-harvest storage. The additional income from her farm provides the required deposit for these assets.

Access to an electric vehicle, even a simple e-bike, could further expand her reach: enabling faster trips to market, access to better prices, and the possibility of providing transport services to other farmers and rural women.

For Adama, a single well-designed intervention does not solve one problem in isolation. It removes a constraint that was blocking progress on others, unlocking a sequence of gains across time, health, productivity, and agency.

Infrastructure

Access to physical, market, and financial infrastructure enables women to adopt and benefit from clean energy assets.

Roads, storage facilities, and distribution networks determine whether technologies reach women and whether their gains reach markets. Of these enabling conditions, financing terms present the most consistent and documented barrier, and financing with terms that work for women is essential.[71]

Across contexts, high upfront costs, lack of collateral, high interest rates, and financial service provider reluctance to serve women are reasons why women are unable to access or adopt new technologies and assets.[72] In sub-Saharan Africa, women-owned micro-, small, and medium enterprises face an estimated financing gap of US$42 billion.[73] They have limited access to appropriate, gender-responsive financial products, and collateral requirements are significant barriers to women's uptake of renewable energy assets and business growth. The lack of scalable, gender-inclusive financing models and insufficient capital flows to the sector have disproportionately impacted women, especially during crises like COVID-19. Gender-responsive financing is beginning to address this gap in the clean energy sector, supporting women's uptake of modern technologies.

Microcredit, typically at market rates, is the default financing mechanism for most assets. However, women have often faced gender-based barriers in accessing financing, including a lack of assets to act as collateral, lack of formal credit history, restrictive social norms, mobility constraints, and financial products mismatched with women's needs.[74]

Alternative finance mechanisms, such as PAYGo and asset financing, are designed to lower traditional barriers to collateral and account requirements and to provide more flexible repayment options. PAYGo assets typically have remote lock/unlock technology, so if payments

71 This includes flexible repayment terms, minimal documentation requirements, and no reliance on assets women do not control.

72 ENERGIA, "Building the Business Case for Women's Inclusive Financing in Last-Mile Renewable Energy Markets in Sub-Saharan Africa."

73 ENERGIA, "Building the Business Case for Women's Inclusive Financing in Last-Mile Renewable Energy Markets in Sub-Saharan Africa."

74 African Development Bank, *Increasing Business Opportunities and Access to Credit for Women in Renewable Energy in Uganda, Kenya, and Rwanda*.

stop, the asset switches off. After the final payment, customers often own the asset outright. Asset financing allows women to use the asset itself as collateral, eliminating the need for separate collateral. Payments can be fixed or flexible, and after the final payment, customers own the asset. Community financing, often channeled through groups or SACCOs, enables shared ownership of assets, reducing collateral requirements and repayments, thereby bringing more assets within reach.

While still not mainstream, these mechanisms are gaining commercial traction, particularly for more costly productive-use assets and infrastructure. They pose a lower risk for women and expand access for many who were previously "unbankable" under traditional microcredit.

However, these mechanisms still need intentional design to overcome old barriers and avoid creating new ones.

- **Upfront demands:** Women may still need IDs to sign contracts and collateral or a down payment on assets.[75] Women micro-entrepreneurs are still often "unable to take advantage of lease-to-own programmes because they did not have full initial deposits of 20–30 percent."[76]
- **Asset registration:** PAYGo schemes do not inherently address asset registration norms or household decision-making dynamics. Initiatives that encouraged registration of assets in women's names have enhanced legal asset ownership and decision-making power, supporting WEE.[77]
- **Affordable repayments:** Innovative financing models risk passing high costs on to consumers.[78]
- **Payment dependencies:** PAYGo often shifts the onus from bank accounts to mobile money/digital payments. Data from the GSMA shows that women are 4% to 18% less likely than men to use online banking/mobile money, and 400 million women globally do not have access to a mobile phone.[79] New dependencies on phone ownership, digital literacy, and mobile money access can continue to exclude some women.

Promising approaches are emerging to women-centric financing that addresses these barriers by dropping requirements for collateral, guarantors, or formal credit scores, allowing flexible repayments and employing gender inclusive workforces. However, these approaches may be most effective for women in peri-urban areas, who have stable incomes, mobile money access, and supportive household dynamics.

A meta-review by the World Bank confirms that microfinance, community finance, and asset financing have been crucial for women in acquiring

75 Kumaraswamy, "Does PAYGo Solar Improve Women's Lives? A Look at the Evidence."
76 ENERGIA, "Building the Business Case for Women's Inclusive Financing in Last-Mile Renewable Energy Markets in Sub-Saharan Africa."
77 Singh, "Financial Services Are the Key to Gender-Inclusive Carbon Markets."
78 Energy Growth Hub, "Off-Grid Solar's Poverty Premium: PAYGo Solar Models Leave the Poorest Behind."
79 GSMA, *The Mobile Gender Gap Report 2025*.

productive assets such as solar pumps, improved cookstoves, and electric vehicles.[80] Where these financing mechanisms are not gender-responsive, women's uptake is significantly lower.

For larger, typically income-generating, productive-use assets, financing determines access to assets and income-generation opportunities. As a result, financing is a defining feature of the sector, with bundled financing appearing in two-thirds of the studies reviewed, most often in the form of credit and microcredit. Innovative models (including PAYGo and battery-as-a-service) appear in a third of studies, indicating a growing alternative.

TABLE 2

Financing patterns by asset category

ASSET TYPE	DOMINANT FINANCING (% OF STUDIES PER ASSET TYPE)		EMERGING / INNOVATIVE FINANCING
Household energy	Microcredit	29%	N/A
	Subsidies	11%	
	Community financing	10%	
Productive-use assets	Microcredit	36%	PAYGo
	Community financing	14%	Community financing
	Asset financing	14%	
Infrastructure (mini-grids)	Microcredit	24%	PAYGo
	Subsidies	12%	Results-based financing
	PAYGo	9%	Equity financing
Electric mobility	Microcredit	33%	Asset financing
	Development finance	13%	

Access to credit increased the probability of clean cookstove adoption by 23% for female-headed households in Kenya, primarily delivered through women's social groups.[81] Further flexible mechanisms, like PAYGo, have increased access to solar energy systems. While high connection costs and financial dependency on men are significant barriers, flexible repayment solutions, often integrated with mobile money, are found to reach more women.[82]

Results-based finance instruments, like the Clean Impact Bond, launched in 2022 by the International Finance Corporation, and partners (BIX Capital, the Osprey Foundation, and Sistema.bio), are expected to unlock over US$800,000 in upfront financing for clean energy solutions for women-serving enterprises.[83]

Without accessible, affordable, and gender-responsive financing, women are often unable to benefit from energy assets and technologies, limiting both their economic empowerment and the overall success of interventions.

80 ESMAP, *Gender Equality in the Off-Grid Solar Sector*.
81 Karanja and Gasparatos, "Adoption of Improved Biomass Stoves in Kenya."
82 Winther et al., "Solar Powered Electricity Access: Implications for Women's Empowerment in Rural Kenya."
83 IFC, *Clean Impact Bond: Mobilizing Finance for Clean Cooking*.

Skills

Capabilities determine whether women can benefit from assets or just own them.

The evidence points to four types of skill-building that matter: technical and vocational training (repair, maintenance, installation), business development (management, cash flow, planning), agency-building (confidence, self-efficacy, decision-making), and basic operational training for end users. More than half of the included studies reported training components, most often vocational training in business and entrepreneurship, and technical skills.

Technical and business skills are critical for women seeking roles within the clean energy value chain as technicians, distributors, and micro-entrepreneurs.

- In Nepal, limited technical training meant women remained dependent on male family members for repairs of rural energy technologies, restricting their autonomy and the sustainability of interventions.[84]
- In Mali, women's associations received training in management, business skills, and maintenance to operate community-owned solar assets. Where training was sufficient, women significantly increased their economic empowerment; where it was not, breakdown and repair costs offset income generated.[85]
- In Senegal, ElleSolaire's Academy trained women from village savings associations as solar sales agents, covering business strategy, financial literacy, marketing, and technical skills. The programme raised the company's customer closing rate from 60% to 80% and drove 286% sales growth in one region.[86]

Hands-on training, reinforced with peer demonstrations and follow-up support, is the most effective.

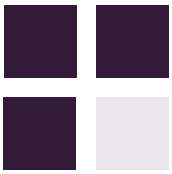
Beyond these technical and business skills, agency-building lays the foundation for broader empowerment among women as users of and workers in the clean energy sector. Beyond business returns, training leads to improvements in self-efficacy, business commitment, and psychological empowerment. When bundled with cookstoves,

84 Mahat, "Gender and Rural Energy Technologies: Empowerment Perspective — A Case Study of Nepal."
85 Sovacool et al., "The Energy-Enterprise-Gender Nexus: Lessons from the Multifunctional Platform (MFP) in Mali."
86 Value for Women and Acumen, *Pathways to Growth: Gender-Smart Business Actions that Work*.

empowerment training led to meaningful increases in "self-knowledge, intentionality, self-reflection, and a sense of control over one's own life,"[87] with a 21% increase in grit (perseverance), and 32% increase in personal growth for women involved.[88]

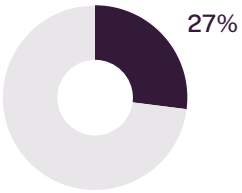
FIGURE 15

Training leads to measurable impacts for women in sales and profits



Women **out-sold men by three to one** after completing agency-based training as last-mile-sales agents.

Women who completed psychology-based entrepreneurship training **increased profits by 40% overall**, and by 5% more than women who completed traditional business training.



Women who undertook personal initiative training saw a **27% increase in profits**, 30% increase in sales, and 35% increase in hiring.

Source: Clean Cooking Alliance, *Understanding Impacts of Women's Engagement in the Improved Cookstove Value Chain in Kenya*; ESMAP, *Gender Equality in the Off-Grid Solar Sector*; Shankar et al., "Strengthening the Women's Entrepreneurship Ecosystem Within the Energy Sector."

Evidence from adjacent sectors reinforces this finding. A large-scale randomised trial of socioemotional skills training for agribusiness entrepreneurs in Nigeria found that interpersonal skills training covering negotiation, empathy, and collaboration raised women's business profits by over 50%, with profits at existing businesses rising around 32%.[89]

87 Shin and Fu, "Looking Back, Moving Forward: A Systematic Review of Entrepreneurship Studies in Communication Research."

88 Clean Cooking Alliance, *Understanding Impacts of Women's Engagement in the Improved Cookstove Value Chain in Kenya.*

89 Das et al., "Turning Inward and/or Outward: Which Socioemotional Skills Pay for Agribusiness Entrepreneurs in Nigeria?"

Engagement

Frictionless after-sales support sustains adoption.

Without the backbone of refueling, fast repairs, warranties, hotlines, and reliable PAYGo or LPG delivery, even successful early adoption can decay into abandonment. The technology only works if it keeps working.

A solar pump without spare parts or a PAYGo system without mobile money access will not deliver lasting impact. After-sales and maintenance services, ideally provided explicitly by women, are a cornerstone of trust-building for clean energy assets.[90] When examining the customer journey from a gender perspective, the World Bank has highlighted the importance of offering a package that includes post-sales service to help women feel more comfortable buying new assets. While studies highlight how the lack of after-sales services (e.g., repair and parts purchasing) can decrease asset adoption, this is rarely formally measured and is instead indicated as a barrier contributing to the disuse or abandonment of clean energy assets.[91]

Five questions funders should ask

ARISE can function as a minimum design checklist for clean energy investments targeting WEE. Programmes that cannot demonstrate how they address each factor should expect weaker WEE outcomes. Agency is perhaps the most important of these factors. Investments that build agency alongside deploying assets consistently outperform those that treat technology access as sufficient on its own.

Funders and programme teams can use these five criteria during due diligence to assess whether proposed interventions have the enabling conditions in place to deliver sustained impact. Where gaps exist, complementary investments in agency-building, financing design, training, or after-sales infrastructure may be needed to unlock the full potential of the clean energy asset.

1. **Do women have the necessary agency to decide how they will use an asset?**
2. **Does it match needs and cultural requirements?**
3. **Is access to and continued use of it reliable, legal, and affordable for women?**
4. **Do users know how to use/maintain it safely and what to do when it fails?**
5. **Is there reliable after-sales support to support sustained use?**

90 ENERGIA, *Women's Energy Entrepreneurship: A Guiding Framework and Systematic literature Review*.

91 Karanja and Gasparatos, "Adoption of Improved Biomass Stoves in Kenya: A Transect-Based Approach in Kiambu and Muranga Counties."

The investment case for the gender–clean energy nexus is clear

This report set out to answer a practical question: under what conditions do clean energy investments improve women's economic lives, and how can funders design for those conditions? The evidence across 115 studies and five archetypes gives a clear answer.

The conditions and pathways to impact are real, and the returns for women are meaningful when the design is right. Productive-use assets and employment in the value chain offer the most direct, measurable, and immediate benefits to WEE. Household assets play a meaningful role in welfare-related outcomes and can have an indirect impact on incomes when the surrounding context is supportive. Financial modelling confirms that positive returns are achievable across a range of technologies, but whether they materialise depends less on the asset than on the conditions surrounding it: financing terms, baseline business scale, and the enabling factors that the ARISE framework captures. Realising the potential of clean energy assets means deliberately designing against all five ARISE conditions.

However, the evidence also shows, with equal clarity, that the gender–clean energy nexus is still nascent in important respects. The evidence base for cookstoves and lighting is deep, built on decades of programming and increasingly rigorous measurement. For productive-use technologies, agricultural energy, and women's participation in clean energy value chains, the picture is compelling but thinner.

Our modelling suggests that the archetypes where evidence is weakest are often those where economic returns are strongest and most direct. Productive-use technologies and employment in the clean energy value chain offer clearer, faster, and more measurable paths to income uplift than household assets, yet these are the areas where rigorous, longitudinal evidence is thinnest. That gap is itself an investment signal: the case for funding both programming and measurement in these archetypes is stronger, not weaker, for the relative lack of data.

The practical implications follow directly from the evidence.

1. Funders and investors should invest in market research upfront to match impact pathways to investment design. The same asset performs very differently depending on women's initial conditions, and a context-driven theory of change using the archetype and ARISE frameworks improves outcomes significantly.
2. Assess all five ARISE conditions before committing resources, building enabling conditions into programme design rather than assuming them.
3. Investments should bundle deliberately, prioritising interventions that pair productive-use assets with agency training, market access, and gender-responsive financing — these offer the clearest path to return on investment.

4 Funders and investors should verify financial viability using realistic financing terms, not optimistic ones. Stress-testing the proposed terms against real-world baseline conditions and can flip a positive return on paper to a negative one under market-rate financing.

5 Impact measurement and social return on investment should measure across both monetary and well-being dimensions (e.g., income, productivity, and yields alongside health, safety, agency, and time savings), because single-proxy metrics undervalue the investment and miss what is actually changing.

6 Invest in women's employment across the clean energy value chain, where low-barrier entry points in sales and repair offer quick, measurable returns while longer-term investment opens technical and leadership roles and shifts the norms that shape the sector.

Clean energy and WEE are connected and can be mutually reinforcing. Funders who invest across both with intentionality, rigour, and patience are positioned to deliver outsized returns for women, for climate, and for the broader systems of which both are part.

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APPENDIX 1

Interviewees

Aditi Kothari, Climate Policy Initiative

Amanda A. Satterly, Asian Development Bank

Beatriz Velho, J-PAL Global

Gerbrich Salverda, FMO

Jael Amati, Africa Enterprise Challenge Fund

Jimena Serrano Pardo, IDB Invest

Leesa Shrader, Gates Foundation

Leonor Gutiérrez, Root Capital

Petra Mikkolainen, Nefco

Pranita Achyut and **Depannita Misra**, International Center for Research on Women

Rebecca Rhodes, GOGLA

Richard Midikira, Aceli Africa

Sam Jewett, Acumen

Sara Litke-Farzaneh, Mathematica

Sinead Maharrey, Solar Sisters

Sitara Merchant Carter, Swiss Capacity Building Facility

Venu Aggarwal, 60 Decibels

Xavier Collet and **Noreen Oloya**, Mirova

APPENDIX 2

Measuring multidimensional impacts requires impact frameworks that reflect complexity

WEE is not a single outcome but a multidimensional process spanning economic advancement, agency, and well-being. To measure the impact of clean energy assets on WEE, investors need frameworks that reflect this complexity. A cookstove may improve health, save time, and enable opportunities for entrepreneurial activities. However, a narrow assessment focused only on income uplift would miss most of the story.

Multi-outcome frameworks capture the interactions between different dimensions of empowerment. They can reveal, for instance, when income gains come at the cost of increased time poverty, or when asset ownership translates into meaningful use only where women also have decision-making agency. They show whether productivity gains are linked with them reaching markets and generating profitability. Most importantly, multi-outcome approaches tell us not only what changed but also how and for whom.

Metrics for non-income-earning use cases

For household-use assets, such as improved cookstoves, welfare-focused metrics on health, safety, and agency may more accurately capture impact than income proxies. The most commonly used metrics for these interventions include cost and time savings (related to fuel and cooking time), changes in household agency and financial decision-making, and health and safety.

TABLE A1

Metrics for non-income-earning use assets (improved and efficient cookstove example)

METRIC	IMPACT NARRATIVE	MINIMUM CONDITIONS NEEDED FOR WOMEN TO BENEFIT
Time savings	Faster cooking and fewer fuel trips each week. Women can apply the time saved to income-earning work, where conditions align.	Translating savings into income-generating work depends on the magnitude of savings, women's control over time allocation, and access to market opportunities. Below certain thresholds, women typically reallocate time to rest, free time, childcare, or other domestic responsibilities. In rural settings, women are less likely to reallocate time saved into income-generating activities as compared to those in urban areas.[92]
Cost savings	Switching from costly, inefficient fuels (firewood/ charcoal/kerosene) to LPG/electric/efficient stoves reduces recurring fuel and health-related expenditures. These monthly savings become disposable income that a woman can deploy toward food, healthcare, school fees, small assets, or working capital, improving household resilience and her financial control.	Whether women retain control over these savings depends on household decision-making dynamics; in households where men dominate financial decisions, cost savings may not translate into increased financial agency for women.
Agency	Control over time, health, and cash strengthens a woman's say in purchases, savings, and livelihood choices. Critically, this includes control over when and how women use time savings, not just how many hours are saved. Greater agency improves investment quality (education, assets) and risk management, enabling persistent income mobility.	The relationship between agency and the use of cookstoves can be circular, where agency may be critical for obtaining a cookstove in the first place.
Health and safety	Includes moving away from dangerous energy sources. It reduces exposure to indoor air pollution from kerosene lamps and traditional stoves, minimises the risk of fires and burns, and provides outdoor lighting that increases a woman's sense of security and mobility around the home after dark. Also reflects reduced outcomes from higher levels of drudgery work.	Improved health translates into more healthy days that women can apply to income-earning work. However, if women lack time-use agency, this additional "healthy time" can be absorbed by household labour and care responsibilities.
Physical safety and gender-based violence (GBV)	Reducing fuel-collection trips, especially at dusk/ night, lowers exposure to harassment/assault and related trauma. Safer domestic energy routines also reduce conflict triggers at home (e.g., fuel scarcity), enabling women to maintain work/school continuity and well-being.	In some contexts, GBV and WEE can become cyclical. Where the root causes persist (power imbalances, social norms), increased economic participation can increase GBV (backlash to changing gender dynamics).

92 Duke University and Shell Foundation, forthcoming.

Metrics for income-earning use cases

For women already engaged in income-generating work, using clean energy assets within their businesses or enterprises increases efficiency, reduces costs, and increases revenues. Productive-use assets offer more direct measurement pathways. Solar irrigation systems, for example, save time,[93] reduce costs,[94] and increase yields[95] — indicators that together can proxy for revenue growth. Milk chillers improve quality and reduce spoilage,[96] enabling women to sell more at better prices.[97] Yet even here, profit and revenue remain notoriously difficult to measure accurately across diverse contexts.

TABLE A2

Metrics for productive-use assets

METRIC	IMPACT NARRATIVE	MINIMUM CONDITIONS NEEDED FOR WOMEN TO BENEFIT
Time savings	Mechanised pumping/processing replaces manual hauling and hand processing, reducing hours and physical strain. Women can use free time to tend additional plots, improve agronomic practices, or reach markets on time, thereby increasing realised output and prices.	Women need agency, access to markets, and opportunities to apply time savings to income-generating work.
Cost savings	Switching from diesel or inefficient power to grid/solar power, or to efficient appliances, reduces energy bills per unit of output, freeing cash for inputs, labour, inventory, and marketing.	Women need control over business-related cash flows to retain and reinvest savings.
Asset ownership	Ownership of or co-titled assets and control over energy expenditure increase women's bargaining power over input use, crop choice, and marketing, thereby improving investment decisions and income retention.	Legal ownership or co-titling doesn't guarantee control. Social norms may override formal property rights; women need knowledge, confidence, and supportive household dynamics to exercise ownership authority.
Agency	Control over purchasing, pricing, and reinvestment decisions converts energy-driven gains into durable business growth and personal economic mobility.	Having control over decision-making doesn't guarantee women have the confidence, business knowledge, or social networks to exercise that control effectively. Agency gains remain theoretical without complementary access to business training, market information, and viable economic opportunities where decisions matter.
Profits/ revenues	Consistent revenue and growing profits demonstrate a viable business model. It allows her to pay herself a salary, reinvest in the business, and build personal financial security, moving her beyond subsistence.	Women must retain control over business income rather than having earnings extracted by household members; sustainable profitability requires business management skills, financial literacy, and stable market demand.

93 Seghal, "Case Study of a Solar Powered Drip Irrigation System for Women Farmers in Northern Benin, West Africa."

94 Efficiency for Access and 60 decibels, *Uses and Impacts of Solar Water Pumps*.

95 Burney et al., "Impact of a Rural Solar Electrification Project on the Level and Structure of Women's Empowerment."

96 USAID, *Clean Energy for Productive Use in Post-harvest Value Chains*.

97 Usagi et al., "Assessment of the Effect of Solar Powered Milk Cooling Technology on Small Holder Dairy Farmer Earnings, Siaya County, Kenya."

METRIC	IMPACT NARRATIVE	MINIMUM CONDITIONS NEEDED FOR WOMEN TO BENEFIT
Reduced spoilage	Refrigeration, cold storage, and quality lighting reduce defects/spoilage and enable premium presentation, improving unit prices and repeat demand.	Quality improvements only translate into higher prices if buyers are willing to pay premiums and women have market information/negotiation skills to maximise benefits. Women must continue to retain operational control of post-harvest operations where quality improvements happen.
Production quantity	Reliable irrigation and energy for critical operations (e.g., threshing, milling) improve effective water application and task quality, thereby increasing yields per acre and crop uniformity.	Increased yields require market access to sell additional output without local oversupply depressing prices.

Caribou

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