Impacts From Best Practices Applied in a Solar Cooking Initiative at Kakuma Refugee Camp, Kenya

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Abstract

Best practices applied to a multi-year solar cooking initiative at Kakuma Refugee Camp, Kenya are demonstrating beneficial impacts. This initiative's best practices have included collaborating with a trusted local implementing organization, local manufacturing of solar cookers using locally available material, testing solar cookers according to methods developed by the International Organization for Standardization (ISO), selecting participants according to a needs assessment, involving women solar cooking champions that speak local languages during training and follow-up activities, and acquiring evidence-based results. Through this initiative, locally constructed solar ovens empower refugees to lead healthier, safer lives. During the 2025 cycle, participant families reported saving USD $162.91 a year on average due to reduced usage of polluting cooking fuels because they were solar cooking about one third of their meals. Their reduced use of polluting fuels per year per cooker correlates to an estimated average reduction of at least 1,500 kg CO_2 emissions from the cooking-related combustion process alone.

Keywords: Best practices, solar cooking, solar cookers, adoption and impact, emission reduction

1. Introduction

Currently, about 1 out of 4 people in the world cook using polluting fuels such as wood, charcoal, and dung. Cooking this way causes myriad health and safety issues, primarily affecting women and girls responsible for cooking and collecting cooking fuel. Household air pollution was responsible for an estimated 3.2 million deaths per year in 2020, including over 237,000 deaths of children under the age of 5 (World Health Organization, 2024). Household air pollution exposure leads to noncommunicable diseases including stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and lung cancer (World Health Organization, 2024). Exposure of pregnant mothers to indoor air pollution specifically by cooking on cook stoves has been shown to result in fetal thrombosis, which leads to an increased incidence of stillbirths and infant mortality (Apte & Salvi, 2016). When families cannot access firewood or other cooking fuel, they may be forced to barter food for fuel, consume raw meals or go hungry, leading to the risk of serious illness and malnutrition. Collecting cooking fuel leaves women and girls vulnerable to rape, assault, and death (UN Women, 2010). Women and children can spend considerable time collecting firewood, which leaves little time for other activities like education or income generation.

Solar box ovens work by collecting sunlight, absorbing sunlight (transforming the energy of light to thermal energy - heat), and retaining heat for cooking. In 2023, UN-Energy – the United Nations' mechanism for inter-agency collaboration in the field of energy – published A Global Roadmap for Just and Inclusive Clean Cooking Transition (UN-Energy, 2023), which stressed the need to expand the use of clean fuels and technologies like solar cooking to transition to net-zero emissions in the cooking sector by 2050. In addition to improving the lives of women and girls who are at risk from their roles in cooking with polluting fuels, this transition will improve the environment, reduce household air pollution, and protect health worldwide. Considering this transition at the country level, in 2022, the proportion of the rural population in Kenya with primary reliance on polluting fuels and technologies for cooking was 89.6%, according to the World Health Organization. Furthermore, Kenya has a substantial solar resource available for solar cooking: a cross-cutting

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solution that makes a positive impact on all 17 of the United Nations Sustainable Development Goals (SDGs).

Figure 1: Picture of a refugee participant with her Standard-size ULOG solar box oven at Kakuma Refugee Camp, Kenya. Photo credit: Eco-Impact Hub CBO.

Kakuma Refugee Camp is in a barren area in Northern Kenya. According to the United Nations High Commissioner for Refugees (UNHCR), as of February 28, 2025, there were 300,106 registered refugees and asylum-seekers at Kakuma Refugee Camp and at Kalobeyei Settlement for refugees, which is adjacent to Kakuma (UNHCR The UN Refugee Agency, 2025). Administrators at Kakuma Refugee Camp cannot meet the cooking-fuel needs of an average family within the camp because of the scarcity of firewood. While humanitarian agencies previously distributed firewood for a portion of a family's cooking-fuel needs, they switched to a cash-based distribution model in 2022 but then discontinued that in 2023 in favor of a market-based approach. Refugees are now left to fend for themselves to acquire charcoal and firewood at pop-up cooking-fuel markets established by members of the host community through spending precious cash or

through bartering a portion of their limited food rations, which are both challenging decisions refugee families make daily. The cooking-fuel situation at Kakuma Refugee Camp demonstrates the critical need and opportunity for access to clean, sustainable solar cooking solutions, as shown in Figure 1.

2. Methodology

This initiative has applied best practices to empower refugees with solar cookers in Kakuma Refugee Camp through annual implementation cycles of solar cookers with the capacity to cook for 7-10 people, depending on the specific type / size of solar cooker distributed per cycle. This initiative's best practices have included collaborating with a trusted local implementing organization, local manufacturing of solar cookers using locally available material, testing solar cookers according to methods developed by the International Organization for Standardization (ISO), selecting participants according to a needs assessment, involving women solar cooking champions that speak local languages during training and follow-up activities, and acquiring evidence-based results.

2.1 Collaborating organizations

This solar cooking initiative at Kakuma Refugee Camp, Kenya is a collaboration between Solar Cookers International (SCI), Eco-Impact Hub CBO, and participants from the refugee population. SCI is a non-profit organization, with over 35 years of experience as a leader in the solar cooking sector. The mission of SCI is to improve human health, economic well-being, women's empowerment, and the environment by promoting climate-friendly solar cooking for vulnerable populations worldwide. SCI accomplishes its mission through advocacy, research, and capacity building by providing resources and locally based solar cooker implementation programs.

Eco-Impact Hub CBO is a Community Based Organization (CBO) registered in Kenya to promote solar cooking and sustainable energy development in Eastern and Central Africa to address challenges of safe fuel and energy access. Eco-Impact Hub CBO is especially valuable in incorporating a local perspective in solar cooker manufacturing, training, sensitization, distribution, data collection, and maintenance for local populations and refugees. For this initiative, Eco-Impact Hub CBO oversees the manufacturing of solar cookers in Kenya using local materials and implements solar cookers in the environmentally sensitive region at Kakuma Refugee Camp.

This collaboration developed shared goals in an inclusive and participatory manner. For instance, refugee recruits at Kakuma are included on the implementation team and assist interactions with recipients during training, distribution, and follow-up. Furthermore, this initiative considers recipients as participants and collaborators for the project's inclusive design aspect and mutually beneficial learning.

2.2 Solar cooker selection, production and testing

SCI recommendations and inclusive best practices relating to the selection of solar cookers for implementation are that they are appropriate for the community, that they can be manufactured using locally available materials and that they have been tested according to methods published by the International Organization for Standardization (ISO).

The solar cookers for this initiative are expected to last at least 15 years each and the types of solar cookers distributed thus far, including the Standard-size and the Family-size ULOG solar box ovens (Solar Cookers International, 2025), have the capacity to feed households numbering 7 to 10 people. From participant feedback, SCI learned that refugees have a limited number of food types they can prepare during one meal, and a refugee family may use only one or two cooking pots during one cooking session. Such feedback aligned with this initiative's use of the Standard-size ULOG box oven, which is suitable for the number of pots used to prepare one meal. 98.5 % of new participants responding to initial Adoption and Impact surveys during the 2024 and 2025 annual cycles indicated that the Standard-size ULOG solar cooker is perfectly sized, while 1.5% indicated it was too big, and no participant indicated it was too small.

Pictured in Figure 2, solar box ovens are manufactured at the Kiini Institute for Advanced Technology in Chuka, Kenya, by Kenyan workers, from materials available in Kenya, for use in Kenya, and using an open-

source design intended for developing areas. Locally available materials used during production included: wood for the boxes, stainless steel for the reflectors, toughened glass for the windows, and sisal for insulation. In collaboration with SCI, staff at the Kiini Institute workshop included design improvements for enhanced durability and to accommodate the harsh environmental conditions at Kakuma Refugee Camp. These box ovens are well-matched for the typical household size of selected participants (~7.3 members/household) at Kakuma Refugee Camp.

Figure 2: Picture from the production phase of Standard-size ULOG solar ovens manufactured at Kiini Institute, Chuka, Kenya for the 2025 annual implementation cycle of this initiative. Photo credit: Eco-Impact Hub CBO.

Fulfilling SCI recommendation that solar cookers for any initiative be tested according to ISO methods, staff at SCI's collaborating Stove Testing Center at the University of Nairobi, Nairobi, Kenya have tested representative units of all the types of solar cookers used in this ongoing initiative – see Figure 3. The tests measured standard cooking power specifications using SCI's Performance Evaluation Process (PEP) (Bigelow, Tabatchnick, & Hughes, Development and Implementation of a Performance Evaluation Process (PEP) for Solar Thermal Cooking Devices, 2021) (Bigelow, Tabatchnick, & Hughes, Testing solar cookers for cooking efficiency, 2024), which automates ISO methods for measuring solar cooker performance. PEP results reports are posted on the SCI website (Solar Cookers International, 2024) as a resource for consumers and stakeholders to make informed decisions when comparing solar cookers.

Figure 3: Picture of a Family-size ULOG solar box oven being tested using the SCI Performance Evaluation Process (PEP) solar cooker testing instrumentation at the Stove Testing Center, University of Nairobi, Nairobi, Kenya. Photo credit: Justus Muoki.

2.3 Implementation

Eco-Impact Hub CBO applied SCI best practices for implementation while distributing solar ovens to families in Kakuma Refugee Camp and the adjacent Kalobeyei Settlement. Each annual project cycle included a series of activities to select and train enumerators, to select the participating refugee families, to provide training for participants, and to distribute solar box ovens.

Eco-Impact Hub CBO team members recruited enumerators from the refugee population that have experience using hand-held devices running the Kobo Toolbox (https://www.kobotoolbox.org/) to collect data in the field. For each annual work cycle, Eco-Impact Hub CBO conducted training sessions with their enumerators to discuss solar cooking essentials and the questions in SCI's Quick Needs Assessment, which was used for gathering data to assess community and individual needs and expressed desire for solar cooking. This survey was based on a survey by the Food and Agriculture Organization (FAO) of the United Nations and was conducted as an initial step for each annual cycle to help identify and select communities and households for solar cooking. The enumerators gained thorough knowledge of the project through their training sessions to reinforce how to acquire high-quality and reliable data from their interviews with potential participants. During the needs assessment, Eco-Impact Hub CBO's enumerator team used hand-held devices running Kobo Toolbox while interviewing a group of potential participants (that was approximately twice the number of selected participants) and took pictures of their current cooking solutions – see Figure 4.

Figure 4: Samples of pictures of the pre-solar cooking approaches of selected participants, taken during the Quick Needs Assessment and prior to the selection process for the 2024 work cycle. Photo credit: Eco-Impact Hub CBO.

Criteria for selecting participants followed best practices for ensuring diversity, equity, and inclusion (DEI). The subsequent selection process aimed for an equitable distribution of the cookers across the camp and named participants based on gender, location in the camp, persons living with disabilities, nationality, access to sunlight, willingness and enthusiasm in the usage of a solar cooker, and willingness to abide by the terms of the initiative. The pie chart in Figure 5 shows the country of origin by percentage of participants selected in 2025 for the program. The country-of-origin distribution of selected participants reflects the diverse and dynamic population demographics at Kakuma. For instance, the high percentage of participants from South Sudan (64%) in the 2025 cycle is on the order of the percentage of registered refugees and asylum-seekers from South Sudan (61%) at Kakuma Refugee Camp and at Kalobeyei Settlement for refugees as of February 28, 2025 (UNHCR The UN Refugee Agency, 2025), coinciding with the month when participants were selected for the 2025 cycle.

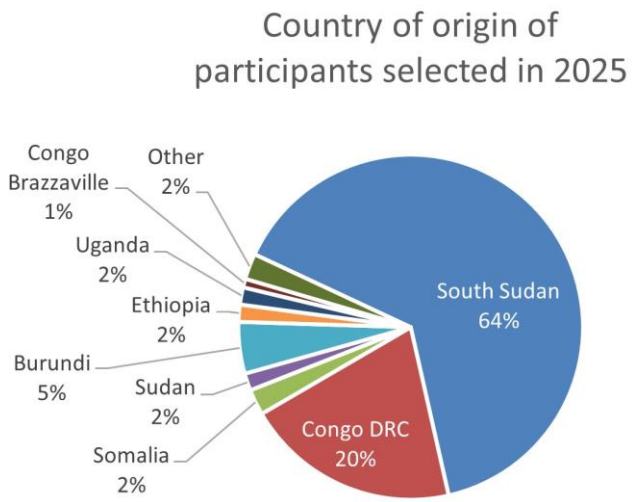

Figure 5: Pie chart displaying the distribution of 2025 participants by country of origin. This distribution is representative of the diverse population distribution within Kakuma Refugee Camp

With cooking practices so deeply ingrained in cultural traditions and personal activities, trainers should be sensitive to the intimate aspect of cooking, understand the subtleties of the cooking customs, and take care to build trust with new participants. The training program in this initiative includes innovative, peer-based methods involving refugee women solar cooking champions that speak the language(s) of the participants while explaining how to use solar ovens to cook food and pasteurize water and how to seek customer support. This culturally sensitive approach was critical with introducing new technology such as a solar oven to those who have typically cooked over an open fire.

The training program took place in two settings: in a classroom and during an outdoors workshop. The classroom setting allowed for a comfortable discussion, for instance about how solar cooking is a cross-cutting solution with many benefits, including how it is useful during a global health crisis. The outdoors workshop as shown in Figure 6 gave new solar cooks the experience of how a solar oven works and provided an opportunity for tasting solar-cooked food prepared on site. The women solar cooking champions also take charge of follow-up visits to participants to monitor solar cooking usage and provide additional tips and training, as needed.

Figure 6: Picture of Eco-Impact Hub CBO's outdoors training session. Rebecca, a woman refugee solar cooking champion trained during a previous work cycle and now a part of the Eco-Impact Hub CBO team, contributed to both the lecture and demonstration components of the training sessions. Peer-based instruction by trusted refugee women solar cooks is an effective pathway to demonstrate how a solar cooker is a viable, clean, sustainable, and economic cooking solution. Photo credit: Eco-Impact Hub CBO.

Participants were given the opportunity to sign photo-permission forms and contributed to the initiative by giving their permission to welcome follow-up visits by surveyors and answer questions in SCI's Adoption and Impact survey; this survey was developed by a working group of solar cooking experts, led by SCI, and was designed for gathering baseline and post-distribution data. Participants also contributed through their willingness to use their own cookware and their willingness to have the outsides of their cookware painted matte black, during the distribution phase, to improve efficiency during solar cooking – see Figure 7.

Figure 7: Left-Right: Pictures of solar ovens ready for distribution at Kakuma Refugee Camp in 2024 and the outsides of cookware belonging to participants being painted matte black in 2025 to improve efficiency during solar cooking. Photo credit: Eco-Impact Hub CBO.

3. Results

Evidence-based results are valuable for informing and shaping the future of the solar cooking sector. During each annual work cycle, the Eco-Impact Hub CBO team, including refugee recruits, used hand-held devices running the Kobo Toolbox to conduct the baseline and post-distribution parts of SCI's Adoption and Impact survey. The post-distribution survey was conducted ~six months after new solar cooks had been using their solar ovens, which produced qualitative and quantitative before-and-after comparative results. Project results are presented below in a series of sections to cover: 1) baseline results, 2) post-distribution results, 3) emission reduction, 4) tracking participants from previous cycles, and 5) financial savings.

3.1 Baseline survey

During the baseline part of the Adoption and Impact survey, cooking-related information was collected about each participant. Baseline information included monthly expense and consumption of charcoal and firewood, number of people cooked for, and cooking frequency. The baseline information of fuel expense and consumption will factor in calculating the reduction in expense for and usage of polluting cooking fuels and associated CO_2 emissions, respectively, after the post-distribution part of the Adoption and Impact survey is completed.

3.2 Post-distribution results

Adoption and impact results are largely derived by comparing responses to parallel questions in both the baseline and the post-distribution components of the Adoption and Impact survey. Additional questions pertain to the integration of a solar cooker at the household level and reveal additional quantitative and qualitative information. Photographs of solar cooked food taken during follow-up visits (Figure 8) offer additional evidence of adoption and impact of solar cookers.

Figure 8: Pictures of solar cooked local food at Kakuma Refugee Camp during the 2024 cycle (Left-Right): stew, ades, cowpeas, greens, rice, and githeri (maize and beans)

For each annual distribution cycle, the number of solar cookers produced and distributed is linked to available funding and manufacturing expenses. The table below lists the percentage of female cooks per distribution year. These evidence-based gender statistics align with recommendations for a gender-responsive approach to identifying and advancing synergies across the United Nations Rio Conventions and their implementation (UN Women, 2024).

Table 1: Post-distribution data showing the percentage of female cooks per distribution year.

Distribution year	Percentage of female cooks
2020	84%
2021	84%
2022	91%
2023	98%
2024	93%
2025	90%
Total	91%

During each annual cycle, comparisons are made between the baseline and post-distribution amounts of cooking fuel consumption to assess the reduction of polluting fuel usage after a solar cooker is integrated into individual households. The fuel use comparison for the 2025 cycle is shown in Figure 9, which suggests fuel savings of both charcoal and wood, and which is consistent with results from previous implementation cycles.

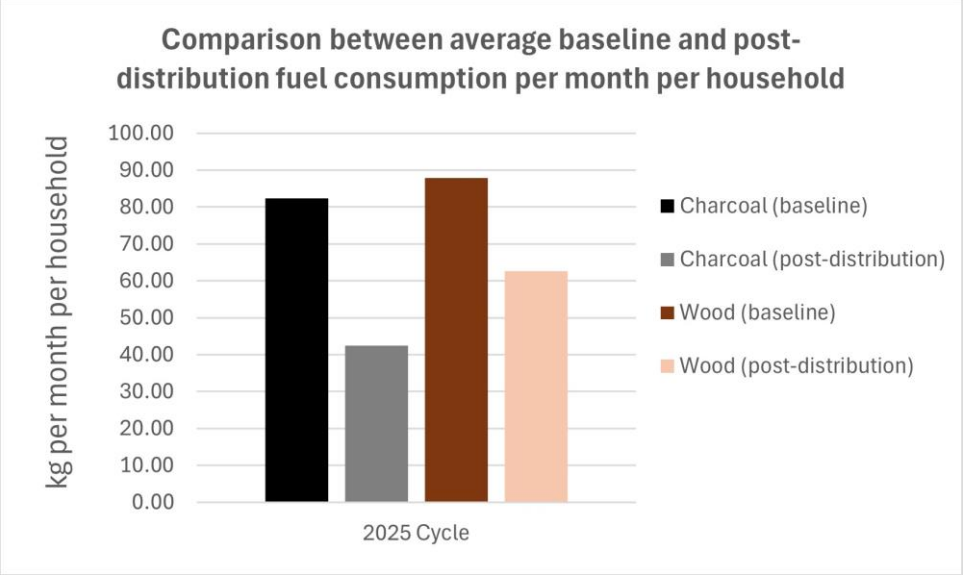

Figure 9: Bar chart showing the fuel use comparison between the baseline and post-distribution time points for the Adoption and Impact survey for the 2025 implementation cycle.

3.3 Emission reduction

There are multiple methods to calculate CO_2 emissions from polluting fuels like charcoal and wood. The assessment presented here will focus only on emissions from burning the fuel and not include other upstream carbon footprint aspects like production and transportation.

Calculating CO_2 emissions from the burning of firewood is complex and evolving. Many variables are involved, including wood type, moisture content, stove type, combustion level, cooking phase (starting, full flame, smoldering, extinguishing), and test type: International Organization for Standardization (ISO), Water Boiling Test, etc. There is a range of emission factors used in various sources (Bhattacharya, 2002) (Champion, 2021). To simplify the presentation of estimates of impacts from cooking, the authors chose to use a single figure, an emission factor of 1.49 metric ton of CO_2/metric ton of wood as a conservative estimate between the range of sources. Similarly, the authors considered emission factors from burning charcoal in the literature

(Champion, 2021), and to simplify the presentation, an average across cooking power values (high, medium, and low) was taken to give a single figure, an emission factor of 2.89 metric ton of CO_2/metric ton of charcoal. Incorporating those emission factors, the reduced use of polluting fuels per year per solar cooker for participants in the 2025 cycle correlates to an average emission reduction of 1,835 kg CO_2 (see Figure 10), which is comparable with emission reduction estimates from previous annual cycles of at least 1,500 kg CO_2.

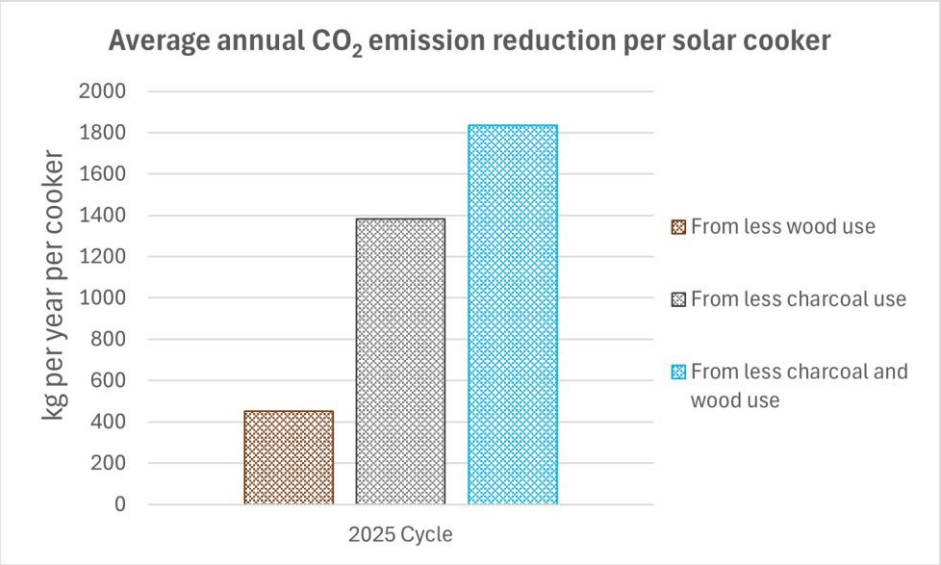

Figure 10: Bar chart showing the average annual CO_2 emission reduction per solar cooker due to the reduction in usage of polluting fuels like wood and charcoal. This assessment only accounts for the burning of the fuels.

3.4 Tracking participants from previous cycles

In addition to acquiring evidence-based results from new participants, this initiative tracked experienced solar cooks that joined this program during previous annual implementation cycles. The results for the average percentage of meals solar cooked (Figure 11) and reduced post-distribution fuel use (Figure 12) show consistency, suggesting that participants that joined the program across annual implementation cycles 2020-2025 have consistent adoption and use of solar cookers, and are experiencing similar positive impacts from using solar cookers.

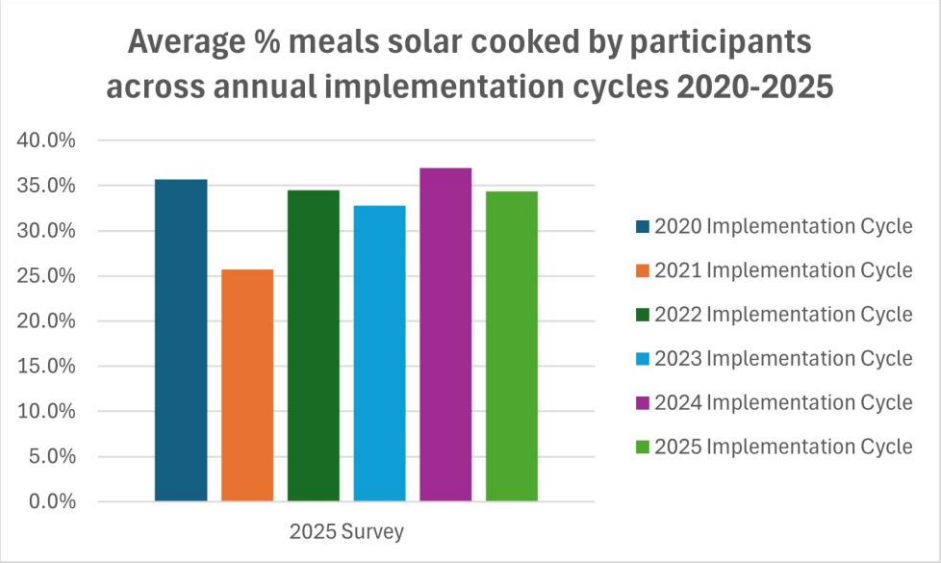

Figure 11: Bar chart showing the average percentage of meals that were solar cooked by participants that joined the program during implementation cycles spanning 2020-2025. The values result from comparing survey responses regarding the number of times per week participants cook meals using their solar cooker to the number of times per week participants cook meals using any cooking method.

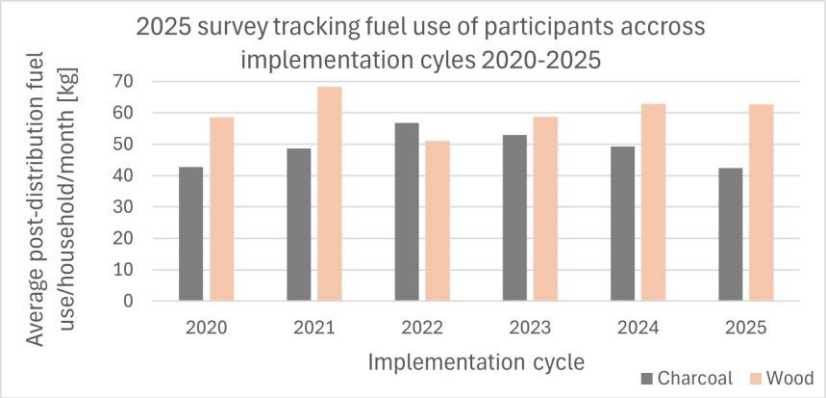

Figure 12: Bar chart showing 2025 survey results of the average post-distribution fuel use per household per month by participants that joined the program during implementation cycles spanning 2020-2025. Presuming all the participants represented in this bar chart would have had similar baseline fuel use in 2025 as participants joining the program in 2025 (Figure 9), these results show consistent post-distribution fuel use for participants that joined the program during 2020-2025.

3.5 Financial savings

Evidence-based results from the adoption and impact survey indicate participants have financial savings from decreased purchasing of polluting fuels after they started solar cooking. Participant families that received solar ovens during the 2025 cycle reported their cooking fuel expenses during the baseline and the post-distribution parts of the Adoption and Impact survey. During the six months between those survey times, inflation increased fuel costs by approximately 40%. Contacts at Kakuma Refugee Camp shared that in January and February 2025, a basin of charcoal (~9 kg) sold for 400 Kenyan Shillings (KES) and in August 2025 (during the post-distribution survey), a basin of charcoal sold for 550 KES, which is an increase of 37.5%. Similarly, a sack of charcoal (3 basins) sold 1300 KES in February 2025 and in August 2025 a basin of charcoal sold for 1850 KES, which is an increase of about 42.3%. Adjusting for inflation, participants reported saving USD $162.91 a year on average by solar cooking about one third of their meals.

That is a significant financial saving for a family that typically live on less than the international poverty line of USD $2.15 per day. Refugees also report that with a solar cooker they no longer must trade their food for cooking fuel. This means families can make their food go further, improving access to adequate nutrition. While the cost of cooking fuel relates to several factors, such as family size, type of fuel, market price, and ratio of fuel purchased to fuel accessed from bartering, gathering, work/service, etc., there is a significant measurable financial benefit from solar cooking.

4. Conclusion

As of October 2025, recent funding cuts in humanitarian assistance are negatively impacting conditions for refugees and asylum seekers at Kakuma Refugee Camp and at Kalobeyei Settlement for refugees in Kenya. Along with added challenges to accessing food at Kakuma and Kalobeyei, rising costs for traditional (polluting) cooking fuel like charcoal and wood are straining the cost of living for the refugee families. Meanwhile, the extraordinary solar resource at Kakuma and Kalobeyei and the expanding traction of solar cooking there underscore the vast potential for integrated solar cooking solutions. Through applying best practices during solar cooking initiatives such as, collaborating with a local implementing partner, local manufacturing, product testing, involving women solar cooking champions from the community during training and follow up, and acquiring evidence-based results through monitoring and evaluation (M&E), SCI and Eco-Impact Hub CBO measured consistent and positive solar cooker adoption and impact among participants that joined the program during annual implementation cycles spanning 2020-2025.

While best practices applied to a solar cooking initiative have demonstrated positive economic and environmental impacts at Kakuma and Kalobeyei, this case study can inform pathways to scaling solar cooking, such as through microloans and carbon credit opportunities. This study can also inform assessments for nationwide economic impacts. Alignment with national plans and policies can further accelerate access to affordable solar cookers by unlocking funding opportunities and capitalizing on enabling environments to

boost local production, awareness and marketing.

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