CHAPTER 27
Sensor-Enabled Climate Financing for Clean Cooking

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Traditional mud stove (left) and improved cookstove with sensor (right). *Source*: Nexleaf Analytics

Summary Household indoor air pollution kills approximately four million people every year. **Affordable** access to **usable** clean energy technologies is essential for the poorest three billion, who rely on solid fuels for cooking, heating, and lighting, to protect themselves from air pollution and to adapt to devastating climate changes. Project Surya has developed an innovative, collaborative approach, called Sensor-enabled Climate Financing (SCF) (Ramanathan et al., 2017), that aligns the objectives of clean energy implementers, stove manufacturers, governments, and multinationals with the needs of the individual women and families they strive to impact. SCF is a verified solution to the sector-wide problems of clean cookstove *affordability* and *adoption*.

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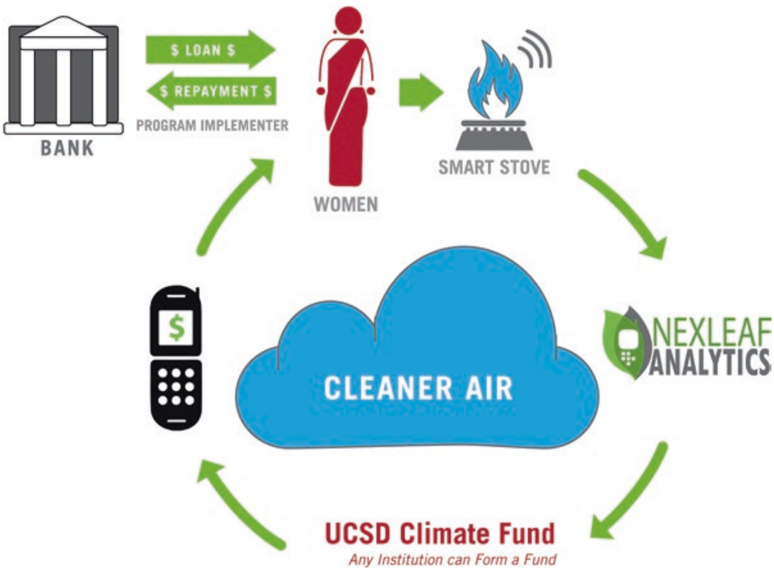

Fig. 27.1 SCF model. *Source*: Nexleaf Analytics

In the SCF implementation model (Fig. 27.1), a woman secures a microloan from a local bank to purchase an improved biomass cookstove equipped with a sensor that transmits objective cooking data in near real time to a Nexleaf server. Small payments to women are made through a donor-based climate fund established at the University of California at San Diego.

Women receive payments through a mobile money app, and clean cooking payments are deposited electronically. This approach funnels results-based financing directly to the individual women who cook, financing the purchase of the cleaner-burning cookstove.

Sustained adoption of clean cooking technologies is required to bring about any of the promised health- or climate-related impacts of these innovations. With SCF, we are seeing sustained improved cookstove adoption in multiple villages (over 89% for over 18 months).

Background

Reducing harmful emissions from traditional solid biofuel (firewood, dung, and crop residues) cookstoves is at the forefront of global efforts to improve the lives of the approximately three billion people worldwide who depend on biofuels for their basic needs. Close to four million people die every year from health complications attributable to household smoke (World Health Organization, 2018). Women and children are particularly impacted by polluting stoves inside the home.

What's More, Traditional Cooking Is a Major Contributor to Global Climate Change

Burning biomass in inefficient handmade stoves, a common practice in more than 600 million households worldwide, contributes to the carbon crisis through carbon dioxide emissions and deforestation. Even more damaging are the short-lived climate pollutants (SLCPs), including soot, also known as black carbon (BC), emitted by traditional cooking. These pollutants have a warming impact many thousands of times greater per unit than carbon dioxide (Ramanathan & Carmichael, 2008).

Since the 1970s, scientists have been working to study the scope of the household smoke crisis, and stove designers have been designing cleaner-burning biomass cookstoves for scale.

Project Surya researchers, through our field work deploying advanced stoves and advanced wireless cookstove usage and soot monitoring systems (Graham et al., 2014; Ramanathan et al., 2011), have published several peer-reviewed papers that document the extent of pollution from stoves (Kar et al., 2012), their impacts on indoor human exposure and ambient levels of BC (Patange et al., 2015; Praveen, Ahmed, Kar, Rehman, & Ramanathan, 2012; Rehman, Ahmed, Praveen, Kar, & Ramanathan, 2011), and the cooking technology that can drastically reduce BC emissions. Our data indicate that among available clean cookstoves, forced-draft stoves, also known as forced-air or fan stoves, burn most efficiently and reduce climate-warming particulates the most. We found that forced-draft stoves, which burn locally available biomass, can reduce cooking-related emissions of BC by approximately 90% (Kar et al., 2012) and, when completely displacing traditional cooking, can reduce the overall concentration of BC in the kitchen by approximately 40% (Patange et al., 2015) (with kerosene lamps and outdoor emissions continuing to contribute to overall kitchen BC concentrations).

Alternatives to forced-draft stoves include gas (or LPG) stoves and electric induction cookstoves, which are among the cleanest technologies. However, the associated fuel costs are prohibitive, and there is no reliable fuel supply or supply chain to deliver the required energy to all. For the many off-grid communities and villages around the world, waiting for grid power or an LPG distribution channel is simply not possible. Forced-draft stoves are relatively cheaper, at a cost of approximately US$80 (which includes the cost of delivery), but still unaffordable for a majority of the underserved, many of whom earn less than US$2 a day. However, these stoves will likely remain the best option until a more cost-effective and feasible solution becomes available for large-scale adoption.

A Data-Driven Approach to Adoption and Impact

Project Surya, launched in 2009, is an international collaboration between NGOs, academic institutions, and the private sector. Given the potential impact of forced-draft stoves, Project Surya set out to understand women's adoption of these stoves and to develop a methodology to tie adoption to impact. Project Surya was also convinced that getting climate financing directly into the hands of low-income women was a moral imperative. Because the world's poorest three billion will bear the brunt of dislocation and disruption caused by global climate change, it is especially important to ensure that the financial benefits of their climate stewardship reach them directly.

Clean-energy implementers often use surveys to verify the adoption of newly introduced clean technologies in remote places. Project Surya's early research included an investigation into the accuracy of using self-reported stove usage data. StoveTrace sensors—wireless thermal sensors attached to stoves in household kitchens that transmit, using local cellular networks, in near real time information about stove use —were deployed in households with traditional cookstoves. Women in those same households were then asked to report how much time they spent cooking each day (Ramanathan et al., 2017). The data (reproduced in the plot in Fig. 27.2) show the lack of correlation between individual stove users' self-reported

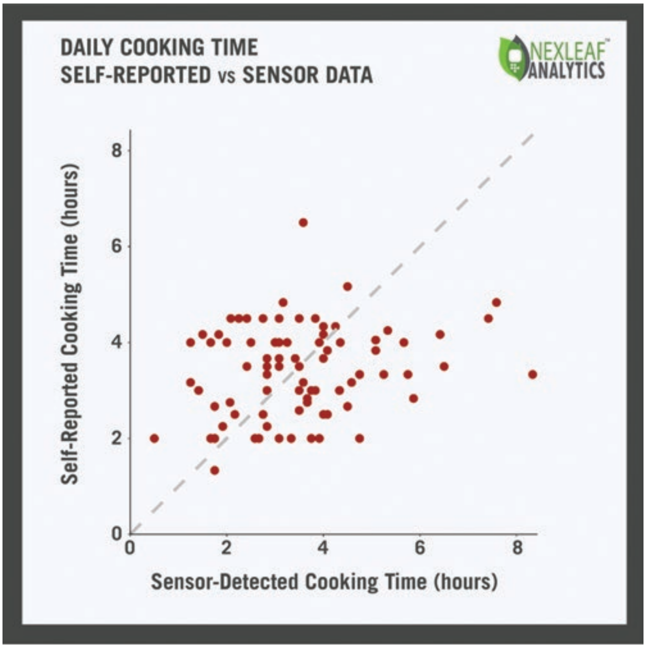

Fig. 27.2 Self-reported cooking data vs. sensor data. *Source*: Nexleaf Analytics

cooking (y-axis) and sensor-verified measurements of actual cooking (x-axis) in households.

These early data demonstrated the importance of employing objective sensors for measuring usage of the improved cookstoves. The objective sensor data on cookstove usage are crucial not only to verify the use of improved cookstove interventions, but also to validate feedback from women to better understand what is working in terms of cookstove technologies and last-mile service and to address barriers to adoption.

Surya researchers developed the SCF methodology to use objective sensor data from both improved and traditional stoves to more accurately quantify the reductions in emissions generated when women switch from a traditional mud stove to an improved biomass stove. Surya researchers published the SCF methodology, which translated emissions reductions into tons of carbon dioxide equivalents, or CO_2e (Ramanathan et al., 2017), based on objective data on the usage of the stove. CO_2e includes reductions of SLCPs, including BC, which contribute to global climate change, and cooling agents such as organic carbon. The methodology integrates available knowledge from peer-reviewed publications with data collected by the Surya team on air pollution levels in the field, compliance on the use of clean technologies, and types and amount of fuel consumed to quantify the emissions reductions achieved. Because clean energy implementers seek to measure impact and hit emissions reduction targets, quantifying baseline emissions for existing traditional cookstove technologies is crucial.

Climate Credit Pilot Project: Findings from a Woman-Centered Approach

Using the SCF implementation model, real-time sensor technologies, and methodology described earlier, Project Surya launched the Climate Credit Pilot Project, or C2P2, in 2014 in Odisha, India.

Project Surya implementers distributed over 4000 forced-draft cookstoves—the cleanest available biomass-burning cookstoves—to households in Odisha, India. Implementers equipped over 450 of the forced-draft cookstoves with Nexleaf's StoveTrace remote wireless sensors. These sensors uploaded cooking event data automatically to Nexleaf's servers in real time, and the data were immediately available on display on the web-based StoveTrace data dashboard.

In 2016–2017, we published findings from the C2P2 stove distribution pilot in India in *Nature Climate Change* (Ramanathan et al., 2017). Analysis of pilot data verified that our financing mechanism works. However, the sensor measurements of cookstove usage by women (y-axis) showed low usage of the forced-draft cookstove over time (Fig. 27.3).

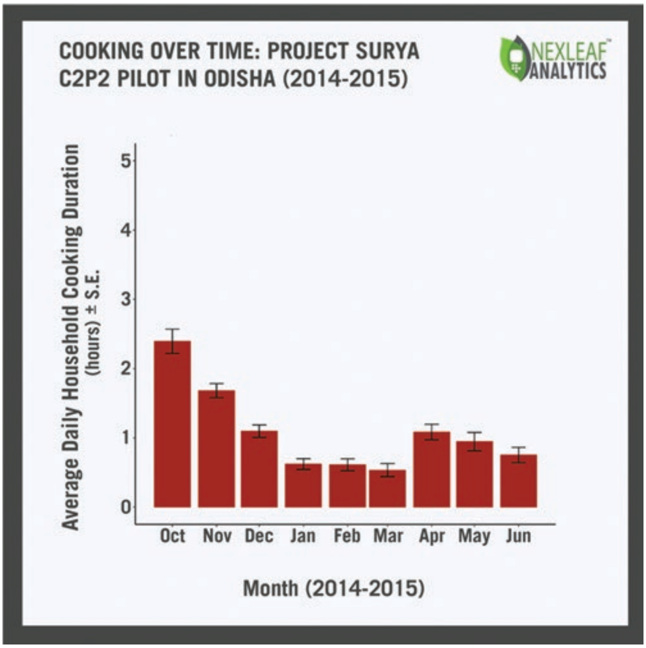

Fig. 27.3 Cooking over time, C2P2 pilot in Odisha. *Source*: Nexleaf Analytics

Quantitative and qualitative follow-up with stove users identified key challenges that likely plague most clean cooking interventions.

First, there is a need for last-mile distribution and service. Like any household appliance, clean cookstoves sometimes break. Technicians need to be trained, resourced with tools and spare parts, and paid to ensure that stoves are repaired and continue to operate.

Second, distributing results-based financing through rural banks alone is ineffective. The individual women enrolled in C2P2 rarely if ever visited their banks to check their balance or verify their receipt of the micropayments they were receiving for their clean cooking.

Third, stoves must be usable, and stove users want consumer choice. Too many of the clean cookstoves available on the market do not adequately reduce emissions, and those that do are often difficult or inconvenient for women to use. Stove users want the opportunity to select a stove among multiple options that best fits their lifestyle. Therefore, a variety of clean, usable stove models must be available to women if they are to switch away from traditional cooking.

Fortunately, an analysis of these data revealed the path to sustained adoption.

Improved Sensor-Enabled Climate Financing Model: 2016–2017 Implementations

Project Surya improved the SCF model to address the gaps identified. Implementations in Odisha beginning in 2016 demonstrated the effectiveness of SCF in India in promoting sustained usage of improved cookstoves. Initial data on adoption (Fig. 27.4) suggest that the improved model leads to sustained usage of the clean cookstoves at levels commensurate with scientific data on cooking behavior.

The aforementioned data set is small, but success has continued beyond these initial pilot homes. By the time of the Vatican meeting in November 2017, program households were using their improved cookstoves consistently, achieving 93% adoption. A full report can be found at nexleaf.org/impact/iot-for-development-stovetrace/. The following modifications made this quantifiable improvement possible.

Introducing Mobile Money Instead of obliging women to visit distant banks to see the rewards of their clean cooking, we worked with Vodafone M-Pesa to register the women on the M-Pesa mobile money application. The women then received payments via their cell phones. For women without a cell phone, a local M-Pesa cash-out agent provides payments in cash.

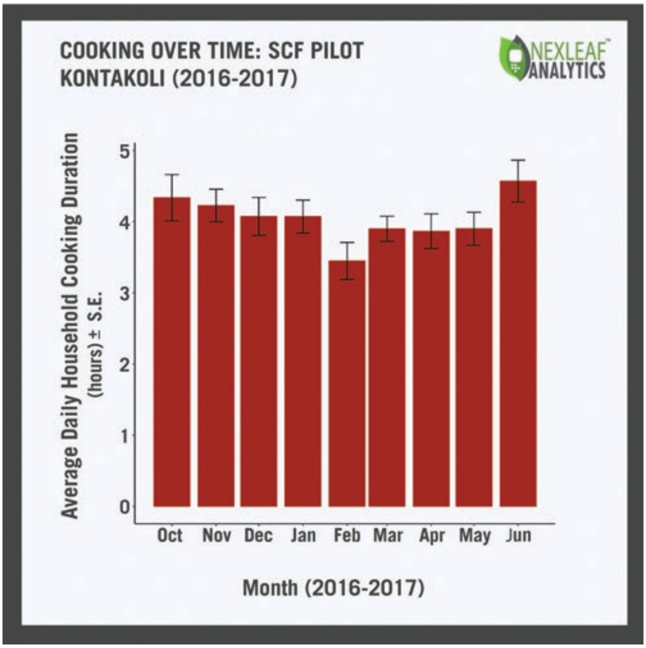

Fig. 27.4 Cooking over time, SCF pilot in Kontakoli. *Source*: Nexleaf Analytics

Strengthening Supply Chains by Mobilizing Clean Energy Entrepreneurs Drawing upon existing networks of rural women entrepreneurs, we developed a distribution and after-sales service model for cookstoves that employs women entrepreneurs. Women energy entrepreneurs want the chance to work with their community to increase access to great products.

Independent Stove Testing We designed a laboratory testing protocol to evaluate improved cookstoves for BC reductions and emissions.

Achieving adoption of new technologies such as improved cookstoves requires multidimensional interventions. However, the dearth of clean, usable biomass stoves in the marketplace continues to pose a critical and persistent challenge.

In recent months, Nexleaf has developed a mechanism for in-home usability testing using StoveTrace sensors and detailed, data-enabled user feedback to continue to identify promising technologies for potential scale. This new standard for clean cooking evaluation helps ensure that manufactured stoves meet women's needs before deployment at scale:

1. Rigorous independent lab testing of stove emissions, including BC;
2. In-home usability testing conducted by women in their homes for at least 3 months to identify the most user-friendly stoves;
3. Due diligence with stove manufacturers to determine whether they can meet last-mile distribution demands, including fulfilling warrantees and providing training and capacity building to last-mile technicians;
4. Long-term cost of ownership, including purchase, financing, maintenance and fuel, to evaluate true affordability.

These four measures inform our evaluation process for clean cooking implementations, which focuses on an incremental scale-up of cooking technologies. We begin with pilots of ten households and deliberately increase the program size only after evaluating the performance of the cookstove and proving 80% adoption.

Recent data confirm sustained adoption (above 89%) of improved cookstoves in SCF households for more than 18 months. A 2018 report including data from SCF households and explaining Nexleaf's adoption metric can be found at nexleaf.org/reports/joint-learning-series/beyond-monitoring-and-evaluation.pdf.

The Future of SCF

Moving forward, Project Surya aims to preserve the environment, empower women, improve health, and bolster the market for clean and usable cooking solutions, organizing our actions around operationalizing objective data. In the future, we will test the SCF model's resilience at greater scale and continue using data and analytics to reveal and help us resolve any challenges that arise. We will expand SCF by scaling the best stove models we have identified, and we will continue lab and usability testing to identify more SCF-eligible stoves to address the broader market failure and increase women's choice.

Our SCF method has sparked interest across multiple sectors because it addresses 10 of the 20 United Nations Sustainable Development Goals.

Conclusion: Transparency in Clean Energy Interventions Is Key to Climate Justice

One key to our success has been an unflinching dedication to the power of data. Even—and perhaps especially—when the data contradict our assumptions, we must continue to adjust and iterate based on objective and transparent measures of impact. In the clean energy sector as in other sectors Nexleaf works in, we have seen how introducing sensor data can bring about anxiety. Too many development initiatives have faced punitive measures or encountered censure for falling short of their objectives. Changing the world for the better is difficult, complicated work, and we assume good will on the part of all global stakeholders, from multinationals to governments to stove manufacturers. That's why, for example, Nexleaf provides feedback to stove manufacturers whose stoves do not pass our evaluation standards.

Clean energy stakeholders can embrace the power of data to reveal both unforeseen problems and their potential solutions. Additionally, small and well-measured pilots must be scaled at a pace that aligns with the capacity of the data and the implementation team to reveal and react to the objective truth. Every village, district, province, state, and country has its own context, and data-driven implementations provide the flexibility necessary to serve cookstove users with many different preference and behavior profiles.

Data not only help steer clean cooking implementations in the right direction; they also enable all stakeholders to tap into new and exciting avenues of financing. From corporate social responsibility campaigns to individual buyers who wish to offset their carbon expenditures, an objective feedback portal will serve eager donors and climate credit buyers.

SCF has the power to accomplish three primary objectives critical to successful climate change interventions, climate justice, global emissions reductions, and economic inclusion for the world's poorest:

1. Align incentives and provide feedback loops necessary to bring about sustained adoption of clean cooking technologies.
2. Provide verification of climate impact of interventions against agreed-upon emissions reductions targets (i.e., Paris Accords).
3. Revolutionize access to results-based financing driven by objective data. This funding can be used to reward individual rural women and women entrepreneurs with results-based financing for their roles as climate stewards.

Ultimately, we believe in unlocking this financing for the world's poorest and using cutting-edge technology both to verify and to disburse these funding streams.

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