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THE BOTTOM LINE

Meeting the goal of universal access to clean cooking by 2030 remains a formidable challenge, as the current growth rate in clean-cooking coverage lags far behind the rate required to meet the goal (0.5 percent per year vs. 3 percent). An estimated $4 billion in investment is needed to achieve universal access in 20 high-impact countries—125 times current spending of $32 million a year (SE4All 2018). Most of the 20 high-impact countries are in Africa and Asia.

Have Improved Cookstoves Benefitted Rural Kenyans? Findings from the EnDev Initiative

Why promote improved cookstoves?

Millions continue to use biomass for cooking. More efficient stoves will protect their health and the environment

Biomass is the main source of energy for cooking in most developing countries. An estimated 3 billion people—40 percent of the world's population—use inefficient biomass cookstoves, exposing them to indoor air pollution, drudgery, inconvenience, and physical endangerment (World Bank 2018). Within households, women and children are the most affected. Harvesting of biomass also causes deforestation, loss of ecosystem services, and emission of greenhouse gases.

Clean cooking is a priority theme of the United Nation's Sustainable Development Goals. Clean cooking solutions are defined as those that are efficient, have low emissions of carbon monoxide and fine particulate matter ($PM_{2.5}$), and are safe to use.[1] The Clean Cooking Alliance (formerly the Global Alliance for Clean Cookstoves) has set a goal of having 100 million households adopt clean cookstoves by 2020 (GACC 2012). Clean cookstoves include liquefied petroleum gas, electric, and ethanol stoves. Fan gasifier stoves that use biomass pellets can also be considered clean stoves, as they meet the emission criteria.

Initiatives like these have reduced biomass consumption. But the results have been marginal, with the global share of biomass consumption in total energy consumption dropping slowly—from about 10 percent in 1990 to less than 8 percent in 2015 (World Bank 2018). Sub-Saharan Africa, where population growth outpaces the growth of clean cooking adoption by a margin of 4:1, fares worst.

Most of the rural population in developing countries, particularly in Sub-Saharan Africa, will continue to use biomass for cooking for the foreseeable future. In the meantime, use of improved cookstoves (ICS) is a good transitional solution. The idea is, until the dependence on biomass can be completely eliminated, improved cookstoves will relieve pressure on biomass resources and slow down deforestation and greenhouse gas emissions.

This Live Wire summarizes the socioeconomic benefits of ICS from a study of a cookstove program in rural Kenya administered by the EnDev program of GIZ, the German development agency. The study is a product of the Status of Energy Access Report (SEAR), an initiative of the Energy Sector Management Assistance Program at the World Bank. By documenting the effects of energy access programs on beneficiaries' welfare (for example, income, health, and education), SEAR enables policy makers and other stakeholders to assess energy-access benefits and make informed decisions about future projects.

[1] The Clean Cooking Alliance developed a tiered framework of cookstoves (Tier 0 indicating the worst performance and Tier 4 the best) based on the 2012 ISO International Workshop Agreement. According to the agreement, stoves meeting at least the Tier 3 standard for indoor emissions are considered clean for health impacts; stoves meeting the Tier 3 standard for overall emissions are considered clean for environmental impacts. For details, see GACC (2012).

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Until the dependence on biomass can be completely eliminated, improved cookstoves will relieve pressure on biomass resources and slow down deforestation and greenhouse gas emissions.

What are the benefits of improved cookstoves?

Fuel savings, better health, less pollution, and new jobs head the list

Because improved cookstoves are more efficient than traditional or open-fire stoves, they can yield substantial fuel savings.[2] According to a recent study, in Burkina Faso, improved stoves reduce fuelwood consumption by 28 percent (Bensch, Grimm, and Peters 2015) and shorten cooking time.[3] Using less fuel also means spending less time gathering it. Fuel is often collected by women and children, who often must walk long distances from the home and return carrying loads of firewood. The time women save in cooking and fuel collection can be used to generate income, care for children, read, or socialize. Children can use the time they save to study. The substantial savings in fuel can also increase disposable income, which can be spent on productive activities.[4]

Improved cookstoves also improve health. Household air pollution from solid fuel consumption is the leading risk factor in the global burden of disease. Indoor air pollution, caused mainly by smoke from traditional biomass cookstoves, accounts for an estimated 3.7 million premature deaths each year, making it the second leading cause of disease, after smoking (Smith and others 2014). Because of its higher efficiency and more complete combustion, ICS can substantially reduce smoke and indoor pollution.

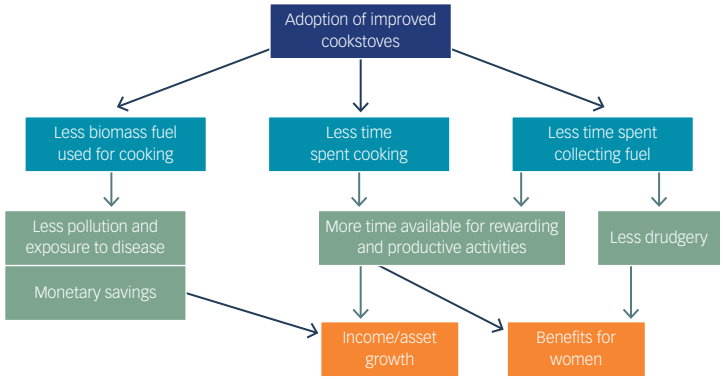
Finally, improved cookstoves reduce greenhouse gas emissions. Cooking accounts for an estimated 2 percent of all greenhouse gas emissions worldwide, and cooking with three-stone stoves using firewood produces 45 percent of the CO_2 emissions attributed to cooking (Grupp 2004). A 2015 study finds that emissions from wood fuel account for 1.9–2.3 percent of global CO_2 emissions (Bailis and others 2015).

[2] For example, the Tier 3 ICS developed by the Infrastructure Development Company Limited in Bangladesh is claimed to increase thermal efficiency by at least 35 percent over traditional stoves (http://idcol.org/home/ics).

[3] There is, however, some evidence to the contrary. A study in Bangladesh finds that cooking time was slower with improved stoves than with traditional ones (USAID 2014).

[4] Because firewood is collected more than purchased, money saved from reduced fuel consumption is largely imputed rather than actual.

Figure 1. Benefits of improved cookstoves



Source: Barnes and Samad (2018).

Note: The benefits shown do not include other related benefits, such as employment generation and training and skill development.

Thus the accumulated benefits from using ICS for a long period can be high. The benefits are shown in figure 1.

EnDev Kenya, a division of GIZ (the German development agency), has been promoting improved cookstoves since 2006, in collaboration with the government of Kenya, nongovernmental organizations, and private firms. It has also helped develop the cookstove market in Kenya. Its activities span the ICS supply chain, including production, marketing, installation, and end-use. EnDev is also involved in results-based financing programs that encourage firms to promote modern cookstoves by raising awareness of their benefits and lowering barriers to distribution.

The ICS market has created jobs in rural Kenya in the production, marketing, and installation of stoves. Some 4,200 previously unemployed people (mostly women and youth) have become self-employed in the ICS market. EnDev was instrumental in the formation of the Improved Stoves Association of Kenya (ISAK).

EnDev Kenya promotes two types of energy-efficient and improved cookstoves, the Jiko Kisasa and the Rocket Stove, the benefits of which are reported here. The Jiko Kisasa stove uses a ceramic-lined chamber for combustion. It can be adapted for either

Adoption of improved cookstoves is a transitional solution that yields many benefits, for both households and the environment.

stationary or mobile use, is up to 40 percent more efficient than a three-stone stove, and has a lifespan of three years. The Rocket Stove has a stationary brick structure. It is 20 percent more efficient than the Jiko Kisasa stove and has a lifespan of five years.[5] Both types are produced locally, use firewood, and have no chimneys but provide good combustion.

EnDev's program covers three geographical clusters: Western, Central, and Trans Mara. As of December 2017, about 9.6 million people had benefited from it. According to EnDev, ICS lowered firewood consumption by 638,000 tons (corresponding to 38,000 hectares of forest) and cut CO_2 emission by more than 738,000 tons between 2016 and 2017.

How were the benefits of the EnDev Kenya program measured?

Two evaluation techniques were used on the cross-sectional data collected for this study

At the heart of any evaluation lies a comparison of outcomes (such as fuel consumption) between a treatment group (those who have an ICS but no traditional stoves) and a control group (those have traditional stoves but no ICS), called the counterfactual.[6] Determining the counterfactual is the most critical task in any impact evaluation, and evaluation techniques must make various assumptions to do so. With a valid counterfactual, the difference in outcomes between the treatment group and control group yields the impact of the intervention. Here, two evaluation techniques were used to compare the treatment and control groups—inverse probability weighting (IPW) and naive estimation.

- *Inverse probability weighting* is a two-step process. In the first step, the probability of ICS adoption by each household (called the propensity score) is calculated, based on a range of control variables at the household and community level.[7] The control variables chosen are those that are expected to influence ICS adoption. In the second stage, the propensity score is used to create a weight, which is then used in a regression-based estimation to assess impacts.[8]
- *Naive estimation* is also based on regression estimation. In this method, the treatment group are households that use only an improved stove; the control group includes households from control villages that use only traditional stoves but have shown willingness to adopt an improved stove if offered. The idea behind this method is that people adopting ICS and people from control villages showing interest in doing so are statistically comparable.

Of the two methods, inverse probability weighting is more rigorous; it is thus preferred.

The study controlled for a number of factors—including "stove stacking" (use of multiple stoves in combination), fuel type, stove condition, stove maintenance, and kitchen characteristics—that may affect the estimated benefits of ICS.[9] Depending on whether stacking involves cleaner or traditional stoves, the measured benefits of ICS may over- or underestimate actual benefits. If not controlled for, the use of fuel for improved and traditional stoves may bias the estimated benefits. Kitchen characteristics also affect the measured benefits, especially for health. Time spent in the kitchen was controlled for in estimating health benefits. The study also took into account dealer characteristics, such as experience, training, and membership in ISAK. Community characteristics, such as community infrastructure and the prices of alternate cooking fuels, were also accounted for.

Because the study was based on recalled data, information collected may be subject to response bias, leading to under- or

[5] A 2013 study finds that the Rocket Stove is 33 percent more efficient than three-stone stoves (Ochieng, Tonne, and Vardoulakis 2013).

[6] "Counterfactual" represents a hypothetical situation of what would have happened to the treatment group had they not received the intervention. Obviously, it is an imagined scenario, since the treatment group, by definition, always receives the intervention. In reality, a subset of the control group is selected to mimic the counterfactual.

[7] Control variables considered included the age, gender, and education of the household head; the amount of agricultural land; the condition of housing structure; village characteristics (mostly infrastructure variables); and prices of alternate fuels.

[8] The weight is the inverse of probability of ICS adoption. That is, it is given by $w = \frac{1}{p}$ for owners of an ICS, and $w = \frac{1}{(1-p)}$ for nonowners.

[9] Enumerators were asked to check stove conditions and to rate them as poor, average, or good, based on specific criteria.

Cooking accounts for an estimated 2 percent of all greenhouse gas emissions worldwide, and cooking with three-stone stoves using firewood produces 45 percent of the CO_2 emissions attributed to cooking.

Table 1. Distribution of villages and households in the sample

Cluster	Villages			Households		
	Treatment	Control	Total	ICS	Non-ICS	Total
Central	27	15	42	399	472	871
Trans Mara	32	15	47	499	446	945
Western	40	20	60	600	586	1,186
Total	99	50	149	1,498	1,504	3,002

Source: ESMAP household survey, 2015.:

overestimation. Especially for information about cooking (such as cooking time and fuel consumption), survey data are less accurate than information collected in a controlled field test. Moreover, particulate emissions or exposure to indoor air pollution from cooking can be measured only using specialized instruments. This study, on the other hand, depended solely on survey data, and collected information on various symptoms of household members (such as respiratory problems) that can be linked to exposure to indoor air pollution.[10]

Data for this study came from a household survey conducted in August–October 2015 with funding from the World Bank's Energy Sector Management Assistance Program. The survey sample included two types of villages: villages in which the EnDev ICS program operated (treatment villages) and villages in which the program did not operate but that had similar socioeconomic characteristics (comparison villages). In most of the treatment villages, the EnDev program had been operating for at least four years (enough time for benefits to have materialized).

One hundred treatment and 50 comparison villages were selected; about 20 households were selected in each. Households selected from the treatment villages included both owners and nonowners of an ICS. A total of 3,197 households were interviewed, split evenly between users and nonusers of an ICS. After data cleaning, 3,002 households were left for analysis. As the ICS households are purposely sampled to constitute about 50 percent of all sample households, which may not necessarily be the distribution in the underlying population, household sampling weights were used in the analysis to make the findings representative within the survey areas.

The survey collected information on basic demographic characteristics of the household members, such as age, gender, education, and employment, as well as information on household assets, income, expenditure, housing, sanitation, incidence of illness, and women's use of time. Detailed data were collected on households' biomass collection and consumption, kitchen characteristics, cooking patterns, and stove characteristics. ICS owners were asked about the adoption and maintenance of their units. Opinion questions were also asked about various aspects of the stove.

In addition to the household survey, a community survey was conducted in every survey village. This survey collected information on village infrastructure, development activities, prices of different fuels, and consumer goods.

Finally, a dealer questionnaire was administered to the dealers who supplied or built improved stoves for the sample households. This questionnaire covered demographic characteristics of the dealers, as well as their experience, training, and various other aspects of the ICS business (time in business, revenue and profit, number of units sold or produced per month, training, and so on).

The sample consisted of 1,498 ICS and 1,504 non-ICS households from 149 villages in three clusters.[11] Table 1 shows the distribution of wards, villages, and households in the sample.

[10] Notwithstanding the limitations, recall-based surveys have certain advantages. They are useful for collecting a wide range of socioeconomic information on the household and its members, for example, and are feasible when the sample size is as large as in this study (about 3,000 households).

[11] Because of administrative changes in Kenya, former clusters were divided into smaller administrative units called counties.

Households saved an average of 34–47 minutes a day in cooking and about 38–52 minutes a day in overall stove use. Adopting an improved stove reduced the time women spent collecting biomass fuels by 92–105 minutes a week.

Table 2. Distribution of sample households by cookstove use (percent)

Cluster	ICS	Traditional stoves	Other cookstoves
Central	25.5	53.8	20.7
Trans Mara	48.6	44.7	5.7
Western	75.5	20.4	4.1
Total	52.1	39.0	8.9

Source: ESMAP household survey, 2015.

Table 2 shows the distribution of households by cookstove type. Households are categorized into three groups by cookstove ownership:

- All ICS-owners, who may or may not have traditional (three- or five-stone) or other stoves
- Owners of traditional stoves only
- Owners of other stove types, who may or may not have traditional stoves but did not have an ICS.[12]

More than 50 percent of households had an ICS, 39 percent had traditional stoves only, and less than 10 percent had other types of stoves. The ICS penetration was highest in the Western cluster (about 75 percent) and lowest in the Central cluster (about 25 percent).

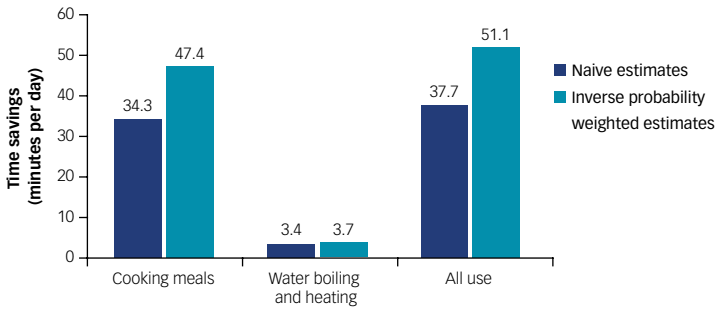
What did the survey reveal?

Adoption of an improved stove had positive effects on the outcomes

Fuel consumption declined; households saved time (which they used for income-generating activities, child care, and leisure activities); and some of the symptoms associated with exposure to household air pollution abated. Findings that are statistically significant at the 10 percent level or better are reported below.

Improved cookstoves reduced fuel consumption. ICS adoption reduced firewood consumption by about 20–32 kilograms a month (about 18–29 percent of consumption). Use of other biomass fuels, including dung (animal waste), maize cobs, sorghum stalks, sawdust, and others, declined by about 35–40 percent.[13]

Figure 2. Reductions in stove-use time from adoption of improved cookstoves



Source: ESMAP household survey, 2015.

Improved cookstoves saved time. Households save time using an ICS in two ways—by cooking faster and reducing the time spent collecting fuel. Stove use time is the daily use in minutes averaged over a seven-day period. Households were asked about the time they spent using stoves to cook meals vs. other uses (boiling water and heating). Households saved an average of 34–47 minutes a day on cooking and about 38–52 minutes a day in overall stove use after adopting the ICS (figure 2).

ICS adoption reduced the time women spent collecting biomass fuels by 92–105 minutes a week. It saved other household members 43–57 minutes a week (figure 3).[14]

Improved cookstoves increased the time women spent on income-generating activities, child care, and leisure. ICS adoption, by saving time and money, enables women to use the freed-up time

[12] Most of these households own ceramic Jiko or metal charcoal stoves. Charcoal stoves have been in use in rural Kenya for more than 20 years.

[13] The monetary value of the consumed biomass is not necessarily what households actually spent, because a large share of the biomass consumed is collected from nature. The value of the collected biomass is estimated using community prices of the fuels in question. Monetary savings in the fuel are therefore imputed rather than actual.

[14] The estimated time saved in collecting fuel may be overestimated because the reported time may include time spent on other activities. For example, children may collect fuel on their way back from school but report the entire time as spent on collecting fuel. However, if we assume that such overlapping of activities is random and does not depend on the type of stoves (ICS or traditional), the time savings still can be attributed to the ICS, though the magnitude of the saving may be overestimated.

The benefits of improved stoves depend on sustained use, but not all households continued using theirs.

Table 3. Impacts of improved cookstoves on fuel consumption

Item	Inverse probability weighted estimates	Naive estimates
Change in firewood consumption (kg/month)	–31.5	–19.5
Change in monetary value of all consumed biomass (percent)	–40.3	–35.1

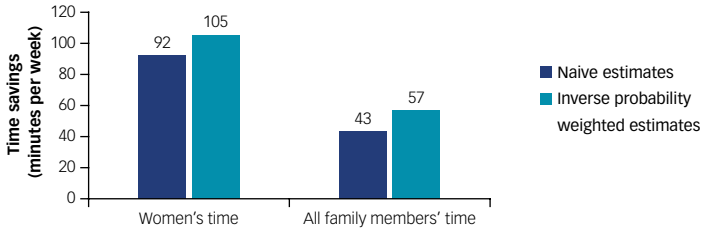
Source: ESMAP household survey, 2015.

Table 4. Changes in women's use of time as a result of use of improved cookstoves (minutes per day, except as otherwise indicated)

Outcome	Inverse probability weighted estimates	Naive estimates
Engagement in income-generating activities (percent)	4.4	5.7
Time spent taking care of children	19	6
Time spent resting	23	16
Time spent listening to radio or watching TV	15	7

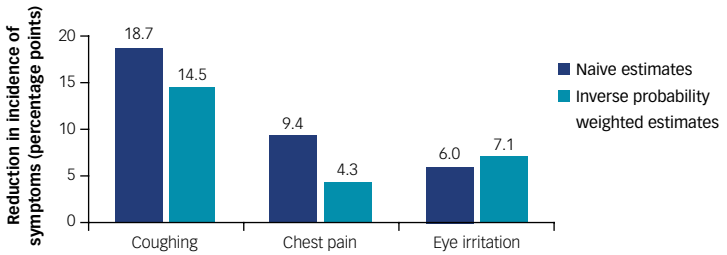
Source: ESMAP household survey, 2015.

Figure 3. Savings in fuel-collection time from adoption of improved cookstoves



Source: ESMAP household survey, 2015.

Figure 4. Reduction in emissions-related symptoms among women associated with adoption of improved cookstoves



Source: ESMAP household survey, 2015.

in more rewarding activities, including those that generate income. ICS adoption increased the probability of women's engagement in self-employment by 4.4–5.7 percentage points. It also increased the amount of time they spent taking care of their children, resting, and listening to radio or watching TV (table 4).

Improved cookstoves reduced some of the symptoms associated with exposure to household air pollution. This study did not measure the level of pollution (for example, concentrations of $PM_{2.5}$ and CO). Instead, it investigated symptoms of ailments associated with household air pollution and smoke.[15] The survey collected information on the incidence of coughing, chest pain, and eye irritation among women (over 15) and children (15 and younger) during the six months preceding the survey, which it considered as proxies for exposure to indoor air pollution or smoke.[16]

The self-reported incidence of coughing decreased by about 15–19 percentage points among women as a result of ICS use. The incidence of chest pain and eye irritation fell by about 4–9 percentage points (figure 4). The study found little impact on children's symptoms—among the three ailments, only coughing was found to have decreased among children as a result of ICS adoption, by 10–14 percentage points.

[15] These questions were asked only of women (female heads of household and wives of male heads).

[16] Most women were heads of household or the wives of the household head; they were also the main cook in the household. For a small number of households, unmarried daughters over the age 15 were included in this group. Other symptoms, such as shortness of breath, irritation of nose and throats, and asthma, were also investigated. However, ICS use had no statistically significant impact on these symptoms.

What can be done to improve outcomes?

The EnDev Kenya initiative achieved positive results, but not all households reaped full benefits. Several further steps could help…

ICS is a transitional solution toward cleaner cooking; the ultimate goal is for households to adopt cookstoves that use clean, modern fuels

Ensure that households continue to use their stoves. The benefits of improved stoves depend on sustained use, but not all households continued using theirs. About 12 percent of nonusers had used an ICS in the past; the most common reason for stopping was the inconvenience of not being able to use large pots or large pieces of firewood. Thus, user concerns should be taken into account in stove design. To ensure sustained use, stakeholders and promoters should also include more sensitization activities in their dissemination plans.

Ensure that households use and maintain their stoves properly. More than 40 percent of ICS users did not keep their stoves in good condition, and only 60 percent reported having received any training on stove use and maintenance. ICS promoters must put training programs in place to ensure that stoves are kept in good shape and regularly maintained. Customer training should be made mandatory and training programs monitored.

Before customers can be trained, dealers must have proper training, affiliation, and experience. On average, ICS dealers have been in business for almost six years. Only 45 percent of dealers are members of ISAK, the premier organization for dealers, producers, and marketers of cookstoves in Kenya. About 70 percent of dealers seem to have received formal training from EnDev, ISAK, or another organization. Improvements in these areas would enhance the benefits of ICS.

Discourage stove stacking. About 10 percent of ICS owners stack their improved stoves with traditional stoves, a practice that can reduce the benefits of the improved stove. More awareness raising and sensitization are needed to encourage households to gradually replace their traditional stoves with an improved one.

Encourage the adoption of clean cookstoves. ICS is a transitional solution toward cleaner cooking; the ultimate goal is for households to adopt cookstoves that use clean, modern fuels. An initiative by Netherlands-based SNV disseminates clean and efficient (gasifier) stoves and fuel pellets in urban and rural areas of Kenya. Kenya is also one of the focus countries of the Clean Cooking Alliance, which has been working with international and local partners to help the government prioritize clean cooking by reducing taxes and import duties on clean cookstoves.

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