SEI STOCKHOLM ENVIRONMENT INSTITUTE

ESMAP Energy Sector Management Assistance Program

DISCUSSION BRIEF

# Improved cookstoves in Central America: health impacts and uptake

## About this brief

This discussion brief summarizes a desk study carried out by SEI and commissioned by the World Bank. The study distils recent research linking cleaner cookstoves to health gains at the household level and offers insights into what type of technical solutions can have an impact in Central America. It also provides a snapshot of the sector in terms of technologies being adopted and their potential for improving household health. The desk study can be found at this link: bit.ly/1LW0Xfs

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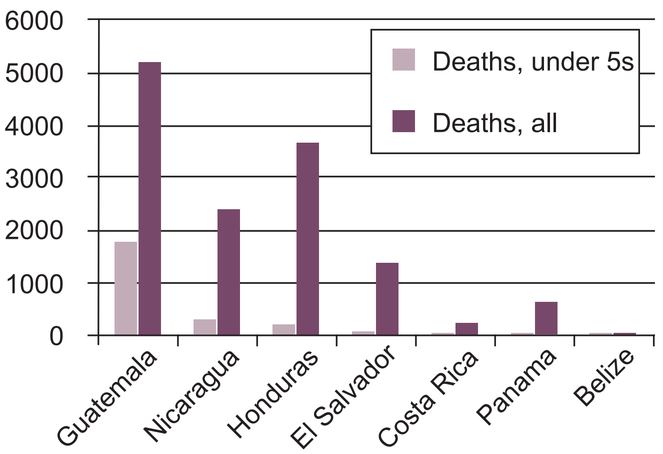
**Figure 2: Fuelling and baking tortilla on an improved cookstove (Proyecto Mirador's Justa 2x3), Honduras.**

## 1. Introduction

Globally, more than three billion people continue to rely on traditional biomass to meet their household energy needs. In Central America approximately 20 million people cook in this way (more than half of the region's population) and 86% of these are located in Guatemala, Honduras, Nicaragua and El Salvador. Strong associations have been found between indoor air pollution and acute lower respiratory infection and chronic obstructive pulmonary disease.

Every year in Central America, 37,000 people die prematurely – most of them women and children – because of exposure to household air pollution (see Figure 1). In Guatemala, the top cause of premature mortality and disability in 2010 was lower respiratory infections. As in other parts of the world there is a long history of improved cookstove programmes in the region. However, many of these initiatives have not been adopted in a sustained way, mainly because of poor performance of cookstoves in the field, the availability of free wood, the absence of quality standards in improved cookstoves, and the lack of attention to the needs of the end user and specific socio-cultural contexts.

In Central America, few cookstoves have been evaluated for their performance on reducing emissions (with much of the analyses done in the lab) or on air pollution exposure. And even fewer have been evaluated for their performance in realizing the many potential health benefits, which still remains the primary motivator for cookstove programmes. Most evidence on health benefits is drawn from the RESPIRE (Randomized Exposure Study of Pollution Indoors and Respiratory Effects) trial carried out with the Plancha stove in Guatemala. Its results have been confirmed by studies in several other regions, and have led to strong recommendations to make clean fuel an available option as a means to tackle health problems resulting from household air pollution.




Source: www.healthdata.org/about/ghdx

**Figure 1. Annual deaths attributable to household air pollution across Central America**

However, because the transition from biomass to clean fuels, such as liquefied petroleum gas and electricity, takes time, clean cookstoves are still needed in the interim. For benefits to be realised, stoves should meet performance standards and be used correctly and consistently. The World Health Organization (WHO) guidelines for indoor air quality, published in 2010, outline the levels of indoor air pollution that should not be exceeded. The WHO's updated 2014 guidelines focus on household fuel combustion, and also provide concrete recommendations both on the technical requirements for cookstoves to meet the WHO recommendations, but also policy advice for effective and sustained uptake of these technologies.

Even where technologies are available that can meet the guidelines, households often do not adopt them since this entails a shift in behaviour which can be difficult to bring about, because cooking is deeply embedded in socio-cultural contexts. Also, low-income households tend to be highly risk averse and therefore less prone to change behaviour patterns.

The most commonly used improved cookstove in Central America is the Plancha. Advanced biomass cookstoves (using secondary combustion) have not been widely disseminated in the region, chiefly because the technology is not yet easily available and fuel supply chains have not been developed.

Compared to other parts of the world, improved cookstove technologies in Central America are often very expensive for low-income households relative to what is currently in use. This is because stoves need to accommodate a "plancha" (griddle) so that households can bake tortilla (a regional staple) which adds significantly to the cost. There are also

**Table 1: Emission rates for vented and unvented stoves required to meet WHO (annual average) air quality guidelines and interim target-1 for particulate matter (PM) and carbon monoxide (CO).**

| Recommendation | Emission rate targets | | Strength of recommendation |
|---|---|---|---|
| Emission rates from household fuel combustion should not exceed the following emission rate targets (ERTs) for $PM_{2.5}$ and CO. | $PM_{2.5}$ (unvented)<br>$PM_{2.5}$ (vented) | 0.23 (mg/min)<br>0.80 (mg/min) | Strong |
| | CO (unvented)<br>CO (vented) | 0.16 (g/min)<br>0.59 (g/min) | |

Source: World Health Organization

**Table 2: WHO guidelines on values for particulate matter (PM) and carbon monoxide (CO).**

| Pollutant (unit for guideline) | Mean concentration over averaging time | | | | | | | Unit risk | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | 10min | 15min | 30min | 1hr | 8hr | 24hrs | 1year | | |
| $PM_{2.5}$ (µg/m$^3$) | - | - | - | - | - | 25[a] | 10 | - | 24 hour guideline max 3 days/year |
| $PM_{2.5}$ (µg/m$^3$) | - | - | - | - | - | 50[b] | 20 | - | 24 hour guideline max 3 days/year |
| Benzene (risk of leukaemia per 1 µg/m$^3$) | - | - | - | - | - | - | - | $6.0 \times 10^{-6}$ | No safe level |
| CO (mg/m$^3$) | - | 100 | | 35 | 10 | 7 | - | - | - |

Source: World Health Organization

market barriers to the availability, delivery and service of such products. In short, while there are many hurdles to increasing the use of cleaner cookstoves, doing so could achieve benefits for health in terms of respiratory illnesses, eye problems and burns, as well as benefits for livelihoods and the local environment.

## 3. Methods, scope and approach

We reviewed the cookstove options in terms of the potential emission reductions and health benefits they can offer, in light of the 2014 WHO indoor air quality guidelines. We also identified the improved cookstoves that households are actually taking up, and analysed the factors that appear to support uptake. The results are summarized in the following sections. We conclude with a discussion of the challenges involved in introducing improved cookstoves, both in terms of the behavioural shifts needed at the household level and in establishing sustainable local markets for them.

## 4. Results

### Stove performance on emission reduction

We identified 34 stove models in use in Central America. In a 2014 Global Alliance for Clean Cookstoves report, efficiency is defined as "gain over open fires" (i.e. the amount of energy produced per emissions of carbon monoxide (CO) and particulate matter (PM). The various stove programmes reported very mixed results on efficiency levels, making it difficult to compare the performance of different stove types. For instance, one programme reported stove performance as 53%, while another reported it as 45%/100%. It is clear that the metric for the efficiency measure was not understood in some instances. And because the efficiencies are reported as percentage values, it is also not possible to compare them to WHO guidelines, which insteas use concentration values to quantify emissions that should not be exceeded in specific time periods.

All but four stove models use firewood, with three using liquid petroleum gas and one using biogas. Interestingly, even though only five of the 34 stoves were certified by a third party, nearly all provide values of efficiency performance.

On average, the stoves reduce CO emissions by 59% (SD 11.7) relative to the open fire, and PM by 95% (SD 8.0). A repeat of the analysis with only the five certified stoves suggests a reduction in CO of 64% and PM of 94%. Although the sample is too small to draw solid conclusions, it does suggest that stoves tested by a third party are making substantial efficiency gains. None of the programmes reported stove performance below a level of 50% more efficient than a three-stone fire. This means that all the stoves would meet the WHO guidelines for household fuel combustion (see Table 1).

The Zamorano University test centre is currently the only cookstove testing and certification body serving the Latin America region (see Box 1). Like regional test centres in other parts of the global south, it has limited funds and human resources. Furthermore, the costs of testing are often prohibitively high for many potential users (e.g. artisanal and semi-industrial manufacturers), and reliable in-field testing programmes, involving cookstove remote usage sensors and field emission monitors, often require the involvement of costly international experts.

Overall, the results on stove efficiency should be taken with caution because they are based on only a few stoves (34), the majority of which are uncertified. Stove performance in the lab has also been shown to vary significantly from field performance. It should be noted that the results we reviewed are based on self-reporting, and it is clear that many of the programmes had different interpretations of the performance metric. Self-reporting could also have caused a bias towards reporting a higher stove performance.

**Stove performance in relation to health and indoor air-quality standards**

The WHO has set guidelines for indoor air quality based on evidence on the links between exposure to pollutants such as CO and PM and various health outcomes. Table 2 summarizes these guidelines.

Our literature review suggests that the installation of improved stoves significantly reduces household air pollution, and also brings health gains in terms of respiratory conditions and other conditions such as low birthweight. This is in line with the findings of the WHO systematic reviews, which show significant post-intervention reductions in both CO and PM concentration (for cookstoves with chimneys, the average reduction in PM concentrations was 63.3% and CO concentrations was 62.8%).

However, as is the case with our review of emission values (see Table 1), it is difficult to do a comparative analysis of these studies because they differ in design, lack standardized measurements (e.g. instruments, duration, pollutants), include different stove types (i.e. vented and unvented) and do not take account of cultural differences across geographical settings. Looking at the specific values for CO and PM extracted from the literature review and comparing them with the guideline values in Table 2 above, we can see that even stoves with "high" performance (e.g. the plancha stove tested in the RESPIRE study) are not achieving reductions in PM to levels that meet the guidelines.

In those studies that do not report health outcomes, a critical question is whether the reported emission reductions are representative of reductions in personal exposure, which is of more interest when assessing the health impacts of improved woodstoves. For instance, in the RESPIRE study, use of improved stoves with chimneys was associated with a 90% reduction in indoor CO concentrations. However, reductions in personal exposure were more modest (50%) because of other determinants of exposure in households. These include stove-tending practices, the extent to which stoves are maintained, and continued use of traditional stoves alongside improved ones (known as "stove stacking").

Studies from other settings outside Guatemala confirm that reported reductions in emissions do not translate into reductions in exposure. In Mexico for instance, one study reported a 74% reduction in median 48-h $PM_{2.5}$ concentrations in kitchens, but only a 35% reduction in median 24-hour $PM_{2.5}$ personal exposure. This raises an important question when it comes to interpretation of the guidelines: although stoves might meet the emission targets as set out in the WHO guidelines (see Table 2) they might not yield significant health benefits because of other determinants of exposure.

It is also important to note that the RESPIRE trial may overestimate the performance of the plancha stove, because the trial was randomized. While such trials do give accurate information on the performance of an intervention or technology (e.g. a cookstove) in a controlled setting, this does not necessarily tell you how it works in the real world, where resources are lacking for thorough follow-up with households on correct use of improved stoves or to carry out regular stove maintenance.

### Box 1. How are cookstoves tested?

Cookstoves can either be tested in laboratory conditions or under realistic conditions in homes where parameters may be harder to control. While laboratory and field test results do not always correlate well, both are necessary to evaluate whether technologies align with WHO indoor air quality guidelines. Currently, however, it is possible only to certify improved cookstoves based on lab testing. The five certified cookstoves we reviewed underwent lab tests in at least one of the following centres: Aprovecho Research Centre; the Improved Stoves Certification Center (ISCC) at Zamorano University; or the University of Colorado Denver. The methodology of lab tests typically involves the Water Boiling Test (WBT) version 4.2.2; a controlled cooking test (CCT) conducted under a portable emissions-collection hood to record real-time emissions of $CO_2$, CO and PM; and a cookstove safety test.

## 5. Which improved stoves are being adopted?

Of the 34 programmes reviewed, we identified six that are being successfully adopted.

The number of stoves installed by the six programmes varied between several hundred to 100,000, but in all cases there was evidence of sustained use by households.

All six technologies meet the WHO cookstove performance guidelines for emission reduction (see Table 1). In terms of health impacts, the Onil stove in Guatemala and the Dos Por Tres in Honduras are the only ones that have been rigorously tested in the field and independently certified.

## 6. Factors that affect cookstove adoption

The most commonly adopted stove model is the plancha cookstove, with chimney. Only one "fully mobile" rocket stove, the Ecocina, was achieving some level of adoption in the region. The key factors that determined adoption across all six programmes include:

- training of users prior to installation
- involvement of households and the wider community in installation and user training
- cost sharing with households, and
- the availability of after-sale service and spare parts.

Crucially, almost all of the programmes reported that taking a user-centred approach to designing the cookstove was essential for ensuring household uptake. Overall, adoption rates reported in the six programmes that are achieving uptake were between 69% and 100%. However, most of the six were not monitoring sustained use over time, and where they were, implementers tended to rely on reported use, rather than more objective data generated by remote sensors.

Some of the plancha programmes reported regional variation in adoption rates. For example, adoption rates were reported as higher where fuelwood is scarce, and lower where households are closer to the sea, because the damp salty air rusts plancha chimneys causing the stoves to malfunction.

Our findings reflect those in the wider literature on cookstove adoption. For example, two systematic reviews of enablers of and barriers to uptake point to a set of critical factors. These are that improved cookstove programmes should:

- meet users' needs (e.g. enable people to cook local dishes and burn locally available fuels)
- save fuel
- offer user training and support, and
- offer effective financing for households.

As in other parts of the world, households in Central America "stack" their stoves, typically using different stoves for different dishes, so introducing an improved cookstove doesn't necessarily mean abandoning a traditional one. One study in Guatemala that monitored use of improved cookstoves over time using remote sensors found that it is reasonable to expect 90% "stove days" – that is, stoves being used for some cooking tasks on 90% of monitored days. Another recent study of the drivers of behaviour change related to cookstove uptake found the three most effective drivers to be:

- reward (e.g. savings in fuel cost)
- social support (community involvement and influence of peers), and
- shaping knowledge (marketing and information).

In the six initiatives that we identified as having achieved adoption, at least two – and often all three – of these behavioural drivers are being applied.

## 7. Data gaps and study limitations

A key finding of this review is that there is no comprehensive study in Central America of household adoption of improved cookstoves over time. In this respect evaluation lags behind that which is occurring in East Africa. Data on adoption is scattered and largely comprised of self-reported evaluations by project implementers, or third-party academic research focusing on specific drivers of adoption (e.g. social perceptions or dissemination of information). Without comprehensive studies on adoption, it is impossible to understand what works in bringing about sustained uptake of cleaner cookstoves, which could severely limit the success of future interventions.

The fact that those field studies that have been done are geographically limited (mainly to Guatemala) means that the findings can't be generalized with any confidence. Only five of the 32 stoves had been evaluated by a third party, which means that the data is largely self-reported and therefore not fully reliable. Finally, a lack of resources meant that we could not carry out a full systematic review, so therefore it is possible that some field studies reported in the grey literature were overlooked.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## 8. Recommendations

- *Introduce standardized measures for assessing and reporting stove performance, including, where possible, the use of remote sensors for measuring use.*
  Stove promoters should be trained further in use of remote sensors and in interpreting efficiency values. Not only is this important to enable promoters to understand the figures they report, but also for promotion purposes (e.g. based on the values, one can tell if a stove can bring health benefits or save fuel, or both, and inform the users appropriately when marketing the stoves to them).

- *Develop standardized measures to assess the field performance of stoves.*
  The studies we reviewed used mixed approaches in monitoring durations (e.g. 8 hours, 24 hours, 48 hours) and assessed different pollutants (i.e. different types of particulate matter) making it difficult to compare findings. The WHO, The World Bank, and others should champion ongoing efforts to develop standardized measures through the ISO stove standardization process. This would enable countries to monitor their performance in meeting the WHO guidelines.

- *Set up a national standardization body for stoves, and require all stoves to undergo certification before introduction into the market.*
  Only 5% of stoves in our study were certified by an independent third party. There is an ongoing effort to set up such a body in Kenya.

- *Build more longitudinal evidence on the field performance of cookstoves in Central America.*
  Except in the case of the Plancha stove, which has undergone many field tests as part of the RESPIRE trial, there is limited information on field performance of the other stoves.

- *Carry out more academic research on cookstove adoption.*
  This would help develop understanding of decision making around purchases of improved cookstoves, as well as of the factors that underpin their sustained uptake and correct use.


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