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Prevalent degradation and patterns of use, maintenance, repair, and access to post-acquisition services for biomass stoves in Peru☆

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ABSTRACT

This paper presents an assessment of post-acquisition service for "improved" cookstoves (e.g., user maintenance training, replacement parts, and repair services) in four regions of Peru. Household surveys assessed current stove use behavior, maintenance practices, stove damage, access to after-sales services, and user preferences towards after-sales intervention strategies (n = 699). Stove use and performance was evaluated in a subsample of households through kitchen performance tests (n = 122) and direct stove use monitoring (n = 58). Participants reported having had their improved cookstove for an average of 5 years. Measured and reported improved stove use was high across all households, including widespread displacement of traditional stoves. Nearly all interviewees recognized that stove performance and stove lifetimes were enhanced through regular stove maintenance. Although more than half of participants reported that no post-acquisition services were offered, two-thirds of those that were offered services utilized them and nearly all found the services either somewhat or very useful. The majority of participants with an improved stove reported damage, primarily to the combustion chamber and chimney. However, results from kitchen performance tests showed no difference in stove performance between stoves with and without damage to the combustion chamber or chimney. Overall, survey results suggest high demand for improved access to post-acquisition services.

Introduction

There remains an urgent need for long-term reductions in exposure to household air pollution (HAP) from solid fuel combustion in inefficient traditional stoves. HAP exposure is now estimated to be a leading global environmental health risk factor for morbidity and mortality (Lim et al., 2012). Nearly three billion people around the world (Bonjour et al., 2013) and one-third of households in Peru depend on solid fuels like wood, charcoal, and crop residues to fulfill their daily cooking and energy requirements (INEI, 2012). Poor and rural households are most reliant on biomass in Peru—57% of the 1.8 million rural households and 62% of the 813 million poor households in the country use biomass for cooking (INEI, 2014)—and thus face the highest burden of associated negative health and socioeconomic consequences (WHO, 2014).

After several decades of effort, interventions have still not achieved extensive reduction in exposure to HAP. Widespread uptake and sustained correct use of "improved" cookstoves[1] has potentially large health impacts in target populations, but realizing this benefit in real world scenarios is often not straightforward (Kowsari & Zerriffi, 2011; Pine et al., 2011; Shankar et al., 2014; Simon, Bailis, Baumgartner, Hyman, & Laurent, 2014). There remains a gap between intent and long-term impacts (Thomas, 2017). The adoption of improved cookstoves is dynamic, dependent on the relationship between user and technology (Ruiz-Mercado, Masera, Zamora, & Smith, 2011; Troncoso, Castillo, Masera, & Merino, 2007) and the interrelated influences of sociocultural factors. Since even minor use of traditional cookstoves can increase health risks, emphasis on sustained, nearly exclusive

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[1] "Improved" or "advanced" cookstoves aim to provide benefits of increased energy efficiency, combustion, and/or venting emissions outdoors, thereby reducing exposure to harmful biomass smoke. They may also provide benefits associated with climate change, time/money savings, ease of use, among others. The term "improved" is used throughout this article to differentiate the stoves from their traditional baseline counterparts. Use of this term does not indicate evidence of improved efficiency or reduced emissions.

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use of clean cooking technologies and fuels is needed (Johnson & Chiang, 2015).

Among other factors, improved cookstove adoption and sustained use depends on supplying an appropriate technology that meets users' needs, addressing liquidity constraints, and offering user training and support (Lewis & Pattanayak, 2012; Rehfuess, Puzzolo, Stanistreet, Pope, & Bruce, 2013). The first two aspects—stove design and financial concerns—have received more attention in cookstove adoption and use literature and research (Bailis, Cowan, Berrueta, & Masera, 2009; Beltramo, Levine, & Blalock, 2014; Granderson, Sandhu, Vasquez, Ramirez, & Smith, 2009; Namagembe et al., 2015; Shankar et al., 2014); however, post-acquisition services have not been studied as thoroughly yet are equally as critical in improving long-term use of improved cookstoves by prolonging stove functionality (Granderson, Sandhu, Vasquez, Ramirez, & Smith, 2009; Simon, Bailis, Baumgartner, Hyman, & Laurent, 2014).

Systematic review and quantitative investigation of the impacts of such post-acquisition services related to improved cookstove adoption is scant. Proyecto Mirador in Honduras has detailed use and maintenance training for all adopters, and in limited settings provides repair services, but installation rate far exceeds repair capacity. A health study on plancha stoves to rural Guatemalan pregnant mothers, The Randomized Exposure Study of Pollution Indoors and Respiratory Effects (RESIRE) provided specific maintenance instructions to all adopters, but little in the way of practical lessons for programmatic scaling (Granderson, Sandhu, Vasquez, Ramirez, & Smith, 2009). We can also learn from other environmental health interventions employing post-acquisition services to improve sustained use and benefits over time. In particular, water, sanitation, and hygiene (WASH) interventions face a crucial obstacle the same as clean cooking interventions: exclusive and proper use of the intervention is required to realize benefits (Thomas, 2017). Furthermore, in both environmental health interventions there is evidence for behavioral reactivity during studies, implying that long-term behavior does not match what is observed during monitoring periods (Thomas et al., 2016).

After limited success because of short intervention lifetimes due to limited time or money dedicated to maintenance or repairs (Dutton, Nguyen, & Peschiera, 2011; Njuguna et al., 2008; Saboori et al., 2011) or poor use training (McLaughlin et al., 2009; O'Reilly et al., 2008), WASH researchers have studied, implemented, and evaluated services to improve maintenance and repair to reduce downtime and abandonment of interventions (Alexander, Dreibelbis, Freeman, Ojeny, & Rheingans, 2013; Chatterley, Linden, & Javernick-Will, 2013; Prokopy, Thorsten, Bakalian, & Wakeman, 2008; Thomas, 2017). For example, a 2005 study in Peru carried out in 99 communities and 2365 households testing the impacts of post-construction support (PCS) for rural water supply systems showed that communities receiving management-oriented PCS visits from external agencies had better performing systems than those not receiving such support (Davis et al., 2008). In another example, a 2013 study showed that hand pumps monitored by cellular-network-enabled sensors to signal repair need decreased pump downtime by nearly 90% during a trial and willingness to pay for pump services increased by three times (Koehler, Thomson, & Hope, 2015). While the evidence remains somewhat mixed, there is support for the influence of both social (like maintenance practices) and engineering factors on benefits gained from environmental health interventions (Chatterley, Linden, & Javernick-Will, 2013; Davis et al., 2008).

Here we explore access to, and demand for post-acquisition services like use training, maintenance, and repair options for improved cookstoves in four regions of rural Peru. First, we characterize cookstove and fuel use as well as current maintenance and repair practices and offer an indication of the acceptability of post-acquisition maintenance and repair training. Then, we discuss willingness-to-pay for such services. Finally, we report the results of kitchen performance tests (KPTs) where we test the efficiency and performance of households' improved cookstoves. We aim to inform future decisions about post-acquisition maintenance and repair services and respond to the lack of quantitative study on how after-sales services have and can be incorporated into programmatic efforts to improve sustained adoption of improved cookstoves.

Potential effects of post-acquisition services for environmental health interventions

Environmental health projects, like WASH and clean cooking interventions, have great potential health and socio-economic benefits. Services that enable long-term high-performance use can be crucial to obtaining the benefits posited by such interventions. In addition, there is potential for increased local economic benefit from the development of markets for repair parts and services. Here, we discuss the case of improved wood-burning stoves with holes to insert pots in rural Peru. Chimney stoves in particular, popular in Central and South America, require more maintenance than other models because of the added complexity of the stove's internal draft (Kshirsagar & Kalamkar, 2014).

Methods

Peruvian improved stove dissemination programs

Since 2007, approximately 350,000 improved cookstoves have been installed in Peruvian households, including 90,000 stoves in this study's regions of focus: Ancash, Cuzco, Ayacucho, and Arequipa (Fig. 1). These study regions were chosen for two principal reasons: 1) there have been dissemination programs developed in all study regions, with a majority of cookstoves in use for more than four years and 2) they have similar socio-demographic characteristics. The main projects provide cookstoves in the study regions are described in Table 1.

In Peru, improved cookstove dissemination programs usually provide stove parts while local partnering organizations provide additional materials and labor to complete the installation process. Although there are slight design differences between improved stove models used in different dissemination programs, the stoves are all built from bricks or adobe, with two burners, a combustion chamber and a chimney (see Fig. A.1 for images of improved cookstove types and Table A.1 for laboratory-based performance specifications). After several years of use, many of the stoves have degraded. A 2014 study revealed that of the approximately 136,500 improved wood-burning stoves installed with technical assistance from EnDev GIZ-Peru (by early 2016 there were a total of 210,000 improved cookstoves), an estimated 37% had fully degraded grates and 17% had cracked combustion chambers (Bernilla, Moreno, & Cabezudo, 2014). The study suggests that all improved wood-burning stoves will be fully degraded and largely unusable by the end of 2019 (Bernilla, Moreno, & Cabezudo, 2014).

Study design

We employed a nested approach with targeted subsampling to accommodate the need for a large survey sample size in addition to direct measurements of stove and fuel use. Based on a target study population of 70,000 households, household surveys were administered to at least 150 households in each of the four study regions. Within in each region, surveys were conducted in at least three communities, selected from a list of communities with a minimum of 30 homes with an improved stove. Study communities were selected based on the logistical constraints of transporting and housing the field team and study households were then randomly selected from a list of households with an improved stove. Data were collected between October and December 2015.