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Impacts on household fuel consumption from biomass stove programs in India, Nepal, and Peru

Michael A. Johnson [a,*], Verónica Pilco [b], Rafael Torres [c], Sandeep Joshi [d,j], Rajeev M. Shrestha [e], Mahesh Yagnaraman [f], Nicholas L. Lam [a,g], Brenda Doroski [h], John Mitchell [h], Eduardo Canuz [i], David Pennise [a]

[a] Berkeley Air Monitoring Group, 2124 Kittredge St. #57, Berkeley, CA 94704, USA
[b] German Agency for International Cooperation, Program for Energizing Development, Prolongación Arenales 801-Miraflores, Lima, Peru
[c] Servicio Nacional de Capacitación para la Industria de la Construcción, Av. Canada 1574, San Borja, Lima, Peru
[d] Center for Rural Technology, Nepal, Kumaripati, Lalitpur, Nepal
[e] Energy Sector Assistance Program, Alternative Energy Promotion Center, Khumaltar Height, Lalitpur, Nepal
[f] First Energy, Office No. B-101 to B-105, First Floor, B-Wing, Signet Corner, S.No-134, Baner, Pune, 411 045, India
[g] Environmental Health Sciences, University of California, Berkeley, 725 University Hall, Berkeley, CA 94720, USA
[h] United States Environmental Protection Agency, Partnership for Clean Indoor Air, USA
[i] Universidad del Valle de Guatemala, Guatemala City, Guatemala
[j] Winrock International, Nepal

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ABSTRACT

Published data from quantitative assessments of in-home fuel use in developing countries are sparse, yet this information is important for understanding the basic daily energy consumption of half the world's population as well as the effectiveness of programs seeking to reduce the health, environmental, and socioeconomic impacts of using inefficient cooking technologies and fuels. This paper presents results from a coordinated training and field study program sponsored by the U.S. Environmental Projections Agency, with the goal of increasing our understanding of household energy use by building capacity of stove implementing organizations. The programs were conducted with stove organizations in India, Nepal, and Peru, with results from Nepal and Peru indicating the respective stove interventions resulted in significant fuel savings (~27–66%), and in India the energy consumption from combined usage of a pellet stove and liquefied petroleum gas was 59% lower than use of traditional biomass stoves. The fuel savings in Peru were highly dependent on the level of stove maintenance and user training with the largest savings (66% per capita) achieved in homes where the stoves were maintained and users were provided additional training, indicating that these are critical factors for realizing maximum stove performance in homes. Combining these results with previously published KPT results showed patterns of higher baseline fuelwood consumption in Latin America (2.1–3.4 kg per capita per day) in comparison to Nepal and India (1.0–1.4 kg per capita per day). The fuel savings estimates from the KPT studies were generally similar to savings estimates for controlled testing (Water Boiling Tests and Controlled Cooking Tests) of the respective program stoves, showing promise for better linking stove performance in the laboratory with field performance. Finally, variability of fuel consumption and fuel savings estimates are examined to inform on study design and monitoring for carbon offset methodologies.

Introduction

The majority of households in developing countries depend on solid fuels for their primary energy use, such as cooking and heating (Rehfuess et al., 2006). Cooking with solid fuels in inefficient stoves often results in high levels of indoor air pollution (Saksena et al., 2003), which is associated with several health impacts and estimated to be responsible for 3.5 million deaths annually (Lim et al., 2012). Solid fuel use can be costly in terms of money and time for fuel gathering/purchasing (García-Frapolli et al., 2010), and there are also considerable climate implications as inefficient cooking technologies and charcoal production produce relatively large quantities of warming species such as methane and black carbon (Johnson et al., 2008; Pennise et al., 2001; Roden et al., 2006).

Efficient stoves and fuels have been primary interventions to address these impacts, with recent interest in addressing the impacts bringing more attention and resources (Smith, 2010). The Partnership for Clean Indoor Air, for example, included over 480 Partner organizations in 2011, which sold or disseminated more than 2.5 million stoves the previous year (Colvin and Vergnano, 2011). International

* Corresponding author at: 2124 Kittredge St #57, Berkeley, CA 94704, USA. Tel.: +1 510 649 9355; fax: +1 510 295 2664.
E-mail address: mjohnson@berkeleyair.com (M.A. Johnson).

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efforts such as the Global Alliance for Clean Cookstoves, as well as national stove programs in India, Peru, and Mexico, amongst others, are seeking to develop and implement more efficient cooking technologies. International carbon markets are also including more cookstove projects. Overall, this growing interest and investment in cookstoves will likely result in more scrutiny, and evaluations to verify that potential impacts are meaningful and real will be critical for justifying continued global investment in stove technologies.

Given the scope of the problem and growing global interest, there are surprisingly few current peer-reviewed estimates of fuel savings from in-home assessments (Bailis et al., 2007; Berrueta et al., 2008; Granderson et al., 2009; Wallmo and Jacobson, 1998). In turn, there is limited knowledge of how much fuel is actually being used across different regions and the overall impact stoves are producing. At a program level, organizations often rely on controlled stove testing to evaluate stove performance and lack estimates for the in-home performance of their stove(s), as in-home assessments require considerably more time and money, and can be more technically complex in terms of study design and data analysis. Using results from controlled testing to predict real stove performance, however, can be difficult as stove and fuel use practices in homes are typically much different (Bailis et al., 2007; Berrueta et al., 2008; Chen et al., 2012; Johnson et al., 2009).

In response to the need for more field-testing of stove performance, the U.S. Environmental Protection Agency (EPA) sponsored a program to assist PCIA Partner Programs in undertaking the Kitchen Performance Test (KPT), which estimates fuels consumption from daily household visits. Here we present the results from these KPTs, with fuel consumption and savings estimates from India, Nepal, and Peru.

Methods

Stove performance testing

Stove performance testing can assess a variety of metrics such as fuel efficiency, thermal efficiency, cooking time, ease of use, and emissions. Stove performance on these metrics can be applied to improve stove design and performance, inform stakeholders and potential funders, guide implementation decisions, and support the carbon credit process. The three main stove performance tests that are commonly used are the Water Boiling Test (WBT), Controlled Cooking Test (CCT), and KPT, originally developed by Volunteers in Technical Assistance (Baldwin, 1986), and later updated by the University of California, Berkeley and Aprovecho Research Center for the Shell Foundation's Household Energy and Health Program (www.pciaonline.org/testing).

- The WBT assesses stove performance using standardized cycles of boiling and simmering water under highly controlled conditions. It is generally used for stove design purposes and comparing different stoves using a common protocol.
- The CCT assesses stove performance based on preparation of common foods cooked by local people in a semi-controlled setting. CCTs are designed to compare a new or intervention stove to the stove it is primarily meant to replace while performing the same cooking task.
- The focus of this paper is the KPT, which is the least controlled and most real-world of the three tests. The KPT assesses stove performance in homes during normal daily stove use and evaluates actual impacts on household fuel consumption. It is most commonly used for program level impact evaluation.

KPT program overview

The PCIA Partners selected for this program were from a pool applications seeking to receive KPT training and assistance in carrying out the field campaign. The training and assistance was provided by Berkeley Air Monitoring Group (Berkeley, USA). The first phase of the program consisted of a training workshop at the host organization to cover the theoretical aspects of the KPT, including study design, an overview of stove performance testing, data analysis, report writing, and KPT protocols. The second phase was the field campaign, during which KPTs were conducted at the chosen study sites.

India

The Partner program in India was First Energy, who manufactures and sells the Oorja stove and the biomass pellets used in the stove. The KPT was conducted to evaluate the Oorja stove (see Fig. 1) in peri-urban neighborhoods of Kolhapur, Maharashtra. The Oorja stove is a mass-manufactured, portable, forced-air gasifier stove, optimized to use pellets made from compressed sugar cane residues.

The stove/fuel combinations in Kolhapur are varied and dynamic, with many families using a mix of fuels and stoves depending on the cooking tasks and fuel availability. The most common fuels are LPG, wood, and dung, with kerosene and pellets also used in some homes. In Kolhapur the Oorja was observed to be used in conjunction with LPG or kerosene stoves. As a transition from traditional biomass chulhas to the Oorja was not common in this area, we designed the KPT study to provide a survey of homes primarily using sugarcane pellet Oorja stoves, traditional wood-burning chulhas, and LPG stoves. This provided a cross-sectional evaluation of household energy use. Fuel consumption data were collected at the end of the rainy season (October, 2010) in 20 homes primarily using traditional wood-burning chulhas, 7 primarily using LPG, and 25 homes using both Oorjas and LPG. Oorja users were identified from a list of customers supplied by the distributors, and non-Oorja users were recruited by visiting households in the same neighborhoods.

Nepal

The Partner Programs in Nepal were the Center for Rural Technology, Nepal (CRT/N) and the Energy Sector Assistance Program (ESAP), a program executed by the Alternative Energy Promotion Center (AEPC), which hosted the KPT program. The Nepal stove assessed for this project came in two models: one-pot or two-pot, either of which could be raised or installed with the base on the ground. The stoves are built in-place, designed for wood use, constructed of mud bricks, a mixture of clay, cow dung, sugar/molasses, salt, and rice husks, reinforced with iron support rods, and with chimneys to vent smoke outside (see Fig. 1).

The study site selected for the KPT study was a series of peri-urban communities approximately 5 km east of Dhulikhel, just outside the Kathmandu Valley. Multiple cooking fuels were used in nearly all households, although wood is the dominant fuel source. Most households had small traditional charcoal stoves and an additional traditional open fire for cooking food for domestic animals. Corn cobs and bamboo were used as supplements to wood in most households. Electricity and biogas were used in some clusters, and LPG was present, but rarely used. Kerosene was used for lighting but not for cooking. The KPT was cross-sectional, performed at the end of the rainy season (late August, 2010) in 50 baseline households using traditional wood stoves and 50 households with the Improved Cooking Stove. The participants with Improved Cooking Stove had been using them for at least one year.

Peru

The Partner programs in Peru were the Servicio Nacional de Capacitación para la Industria de la Construcción (SENCICO) and the German Agency for International Cooperation's Energizing Development Program (GIZ-EnDev). The intervention stoves were two chimney stoves, the Inkawasi-UK, and the Inkawasi-Sujta. Both stoves are built in-place, have an adobe base and reinforced concrete top plate with two hot-rings for submersing pots into the combustion zone (see Fig. 1). The main difference between the stoves is that the UK