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Effects of USB port access on advanced cookstove adoption

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ABSTRACT

Three billion people cook using traditional fires, and exposure to smoke from cooking remains a persistent and significant environmental health risk factor: household air pollution is estimated to cause 3–4 million premature deaths per year. "Improved cookstoves" could reduce the health risks associated with cooking, but the performance of most improved cookstoves is insufficient to result in meaningful health benefits, and global adoption of low-emission cookstoves remains low. However, a new class of advanced cookstoves equipped with thermoelectric generators could improve both emissions performance and adoption leading to better health outcomes. These cookstoves use electrical power provided by a thermoelectric generator to power combustion-improving fans while powering outboard USB charging ports. In communities lacking electricity access, USB levels of power could provide much-needed off-grid charging for mobile phones, small lights, and other loads. However, there is a risk that instead of being used primarily as a cooking tool, these cookstoves could be used solely as fire-powered USB chargers. Without displacing traditional cookstoves, "charging-only" adoption would result in a net increase in emissions exposure. In this study, we used custom Advanced Stove Use Monitor (ASUM) sensors to measure adoption of TEG-equipped cookstoves in 72 rural homes without electricity access in Odisha, India. To measure the impacts of the USB charging port, we randomized whether recipients received a cookstove with USB ports enabled or disabled. We found that access to USB charging ports significant increased adoption of cookstoves in "cooking" use modes; USB-enabled cookstoves were used for cooking 3.5X more than identical cookstoves with disabled USB ports. This substantial increase in cooking came with a relatively small marginal use of the cookstove in a "charging-only" mode; just 11% of total cookstove use was in this mode. As with past work, data showed that surveys of user behavior do not correlate well with sensor-measured behavior. The trial cookstove was much smaller and more cumbersome than traditional cookstoves, but still, we found that users were willing to prepare fuel and found the cookstove useful for light cooking tasks. Access to USB charging served as a catalyst for adoption of advanced cookstoves as cooking tools and did not increase undesirable "charging only" adoption modes. This work suggests that these kinds of USB-enabled cookstoves could be an important tool to improve biomass combustion, increase adoption, and realize meaningful health benefits.

1. Introduction

Two fifths of the global population cooks on smoky traditional fires fueled by wood, dung, charcoal, crop residues, and other forms of biomass (The World Bank, 2011), and although the proportion of the planet using the fuels has decreased since 1980, population growth has maintained the total number of users relatively constant at 2.8 billion (Bonjour et al., 2013). Globally, exposure to biomass cooking smoke is one of today's greatest environmental health risk factors; it's estimated that cooking smoke causes some 3–4 million premature deaths annually (Forouzanfar et al., 2015; Lim et al., 2013; Smith et al., 2014). Additionally, biomass cooking contributes meaningfully to the total anthropogenic burden of atmospheric aerosols, especially black carbon (Bonjour et al., 2013; Bond et al., 2004). To combat this crisis of cooking, "clean cookstoves," which emit less harmful emissions per meal, have been suggested as a tool to reduce the dangers of cooking.

Presently, a new class of clean cookstoves are entering the market. These new cookstoves rely on forced air provided by electric fans. When

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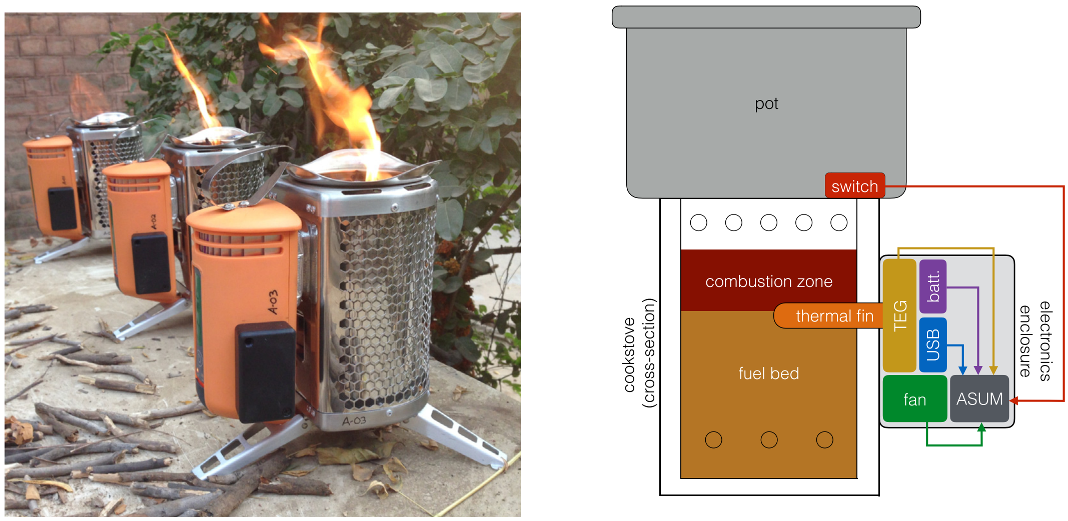

Fig. 1. Left: three Shakti Chulhis undergo quality control testing before distribution. Right: a schematic of the Shakti Chulhi and ASUM. The ASUM is integrated within Shakti Chulhi's electronics enclosure. The ASUM collects voltage information from the cookstove's TEG, fan, USB port, battery, and a pot proximity switch.

designed well, forced air cookstoves can improve combustion of biomass and greatly reduce harmful emissions (Jetter et al., 2012; Just et al., 2013; MacCarty et al., 2010; Rapp et al., 2016). Some forced air cookstoves use traditional wall plugs to power their fans, but an increasingly large number utilize thermoelectric generators (TEG) to generate electrical power (Horman et al., 2013; Champier et al., 2010; Gao et al., 2016; O'Hanley, 2009; Mal et al., 2014, 2015). Thermoelectric generators operate on the Seebeck Effect: a thermal gradient applied across a junction of dissimilar conductors will create a voltage difference, and this voltage difference can be employed to perform useful work (Priya and Inman, 2009). While the primary purpose of TEGs on cookstoves is to improve combustion (typically by powering a fan), most TEG cookstoves can generate surplus electrical power beyond what is necessary to improve combustion. Increasingly, manufacturers have installed outboard Universal Serial Bus (USB) ports. These stoves with USB ports are marketed to customers without access to grid power so that customers can charge small electronics such as mobile phones or lights.

Off-grid charging is a disruptive technology and an important benefit for many customers. In India, 700 million people (54%) rely primarily on open biomass-fired “chulhas” for their daily cooking (Smith and Sagar, 2014). However, at the same time, mobile phone ownership and penetration of low-energy appliances such as LED lights and radios is booming (Rai, 2016; Chaurey and Kandpal, 2009; Lam et al., 2012). In fact, mobile phones have become so ubiquitous that our research team could not find a household in this study (which took place in one of the most rural and poor parts of India) that did not own a mobile phone. By contrast, 20% of all Indians and 30% of rural Indians do not have access to grid electricity (Access to Electricity, 2017).

The disparity between the ubiquity of small battery-operated devices and access to electricity has created a cottage industry of charging services. Many Indians who own mobile phones and other devices will

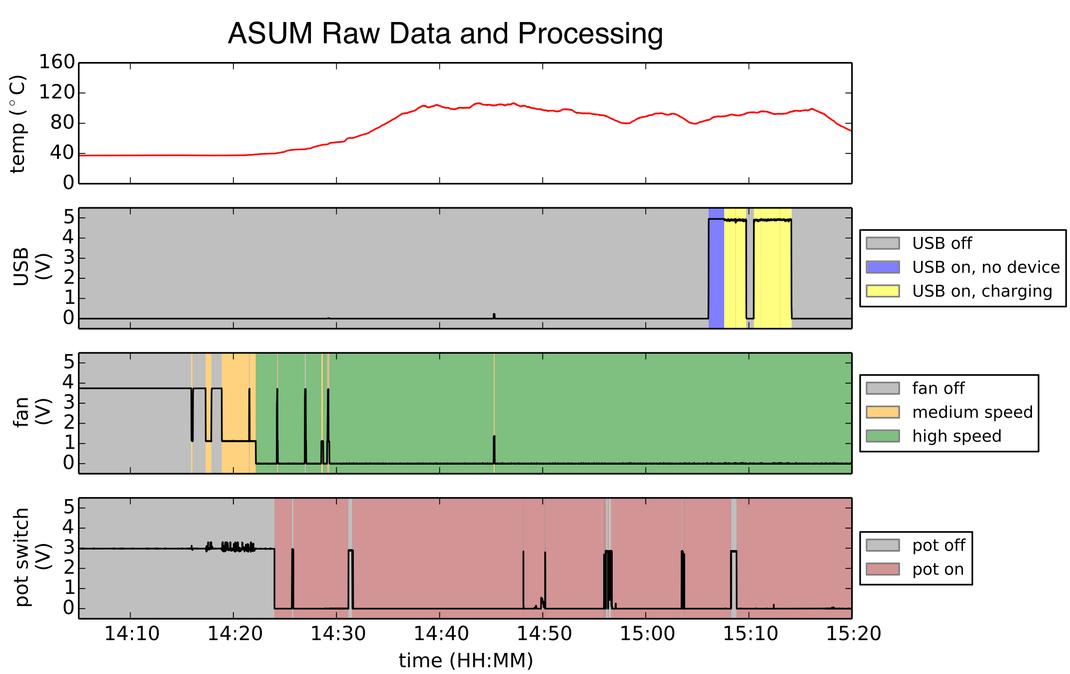

Fig. 2. ASUM raw data is shown as line plots. Results of processing are shown as colored regions representing different states. Combinations of states are used to create use modes. For example, if the pot is off while the USB is charging a phone, this would be the “pot off and changing” use mode.