Why Have Improved Cook-stove Initiatives in India Failed?

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Introduction: The Cook-stove Conundrum

Cooking with firewood and other biomass fuels is by many accounts among the most urgent problems in the developing world today. An estimated 2.7 billion people cook meals over brick, stone and clay stoves fueled by wood, leaves, dung, etc. (International Energy Agency 2015). The resulting indoor smoke pollution causes serious health problems, especially for women and children who have the most frequent exposure. The World Health Organization estimates that more than four million people die annually from exposure to indoor or household smoke, and one quarter of these deaths occur in India and South Asia (Yadama 2013:44; World Health Organization 2014, 2016). Also at issue is the increasing scarcity of firewood in many parts of the world due to both deforestation and the enclosure or privatization of common lands. Longer and longer treks in search of wood-fuel, combined with illness and death caused by smoke inhalation, exemplify the 'slow violence' (Nixon 2011) that causes profound morbidity and mortality but is not dramatic enough to grab the headlines. Nevertheless, government agencies and development organizations have been researching, designing, and rolling out "improved" cook-stoves (ICs)—also identified as "smokeless," "clean," "efficient," "labor-saving" and "modern"—in many developing countries for nearly a century to address these issues (Muniandi 1993, Barnes et al. 1993, Gifford 2011, Sarin 1986).

In India, efforts to design and diffuse improved cook-stoves began with nationalist organizations in the 1930s; after independence, these efforts were folded into sporadic state-level efforts and then became part of the NGO patchwork of development projects. Very low public

demand discouraged the private manufacture and marketing of ICs, but since 2010 official interest has intensified. New designs, new distribution channels and a new sense of urgency have reached a crescendo with the formation of ministerial-level departments and programs that aim to make biomass combustion in ICs as safe and satisfactory as compressed natural gas (CNG).[1] UN agencies, NGOs and other international organizations have offered technical and material support, and India is under significant pressure to find solutions that will work (Barnes et al. 2012; Putti et al. 2015).[2] And yet, success has remained elusive. This extended trajectory demonstrates what Sivaramakrishnan and Agrawal call 'stories of development' that recognize modernization as a set of stubborn, incomplete projects that draw in a wide cast of authors, activists and critics (2003:47-49). This notion of 'stories' draws attention not only to the multiple voices joining the fray and the search for heroes (i.e., people or things that solve the problem), but also to the practice of development as an 'intimate and unpredictable process' (Sivaramakrishnan and Agrawal 2003:47-49).

[1] The National Biomass Cook-stoves Initiative (NCI) has proclaimed that "Our aim is to achieve the quality of energy services from cook-stoves comparable to that from other clean energy sources such as LPG" (Venkataraman et al. 2010: 63). This initiative represents a retreat from earlier ambitions to move all Indian households onto electricity, CNG or other smoke-free energy sources (Subramanian 2015).

[2] International pressure to change fuel use and cooking practices comes from both global/private sector initiatives like Sustainable Energy For All (SE4ALL) and international agreements like the 2015 UN Resolution, Transforming our world: the 2030 Agenda for Sustainable Development.

Our aim in this essay is not to provide new data from field testing of a particular stove, as such case studies exist in abundance, but rather to take a step back and offer a broader view. We synthesize an expansive body of research on cook-stoves in India, which tends to be technical and applied, and bring it into conversation with social science analyses of the power dynamics that shape development and narratives that animate it. Our multi-disciplinary view chips away at disciplinary silos and brings together insights from anthropology, history, gender studies, global health, geography, development and environmental studies. We summarize medical and technical aspects of this most ordinary kitchen tool, but highlight lesser known historical, social, cultural, and gendered aspects of India's IC story. Rather than assuming axiomatically that all hand-built cook-stoves require immediate improvement if not outright replacement, we begin with a different set of big questions: Why have cook-stoves been the focus of so much attention for so long? Why has IC adoption proved so elusive, and what might this delay tell us about the perspectives of those women expected to change their ways and about development more broadly? Our purpose is to demystify the most likely reasons for the long deferment of this development goal. We explore these questions critically and reflexively, even as we ourselves are involved in an effort and ongoing research project to diffuse technology meant to improve cook-stoves in southern Rajasthan. For all its drawbacks the traditional Indian cook-stove, or *chulha,* is a remarkably robust device that has existed in South Asia for millennia.[3] Evidence

[3] The adjective "traditional" is frequently used in ahistorical ways. But it is difficult to avoid it entirely, however vague and imprecise. Rather than repeatedly using the phrase "traditional cook-stove," we henceforth employ the Hindi term *chulha* (English plural *chulhas*), which unambiguously refers to hand-made, usually of clay, and locally resourced cook-stoves.

from religious texts, women's songs, and ethnographic studies shows that, for rural women across India, the hearth is primarily associated with home, love, family and female competence. To target this particular object for change has profound implications that cannot be reduced to either wood consumption or emission of greenhouse gases and particulate matter.

In this review we first demonstrate that the chulha has been a target of modernization for almost a century, for some good reasons to be sure, but these efforts are simultaneously part of a larger development logic that frames social, economic and environmental improvement with familiar narratives. In the first section, we also identify five goals—all worthy and particularly urgent in South Asia—that have motivated various actors in the chulha story (improving health, solving the fuelwood crisis, slowing deforestation, addressing climate change, securing women's empowerment), argue that the Indian chulha is an artifact deeply embedded in history and culture, and note its persistence. Second, we summarize current knowledge about the successes and failures of improved cook-stove models and programs in India and identify multiple reasons for the striking lack of their diffusion. If the chulha can be described as stubbornly persistent, the same can be said for development efforts to improve on the chulha that continue with relentless optimism even with little evidence of success. Third, we suggest that complex gender issues converge around food preparation and the cook-stove conundrum and help to explain the low adoption rates. Finally, we argue that stepping back from the dogma of cook-stove improvement (without abandoning concerns we share about cooking with biomass) not only offers insight into the obsessive nature of modernist development and its undesirable effects (such as the wasteful

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Contrasted throughout with *chulha* are all varieties of workshop-designed, usually metal and mass-produced improved cook-stoves or ICs.

reproduction of failure), but may help us to imagine a broader range of potential solutions. Historicizing and demystifying the cook-stove conundrum in India offers some useful lessons.

The Long History and Striking Persistence of the Indian Chulha

Hand-crafted chulhas made from stone and clay and fueled with biomass are standard fixtures in 150-200 million rural Indian households.[4] It is common for a family to have two chulhas, one inside and one outside, and to shift between them seasonally. These chulhas found in rural India today have surprisingly deep roots. Excavations in southeast Rajasthan (precisely in the zone of our current research) have unearthed 3800-year-old U-shaped cook-stoves that were used domestically by the Ahar (or Banas) people circa 1800 BCE (Hooja 1988;Misra 1997).

The ubiquitous Indian chulha has long drawn the notice of outsiders. A medieval language scholar observes that "many Persian, Turkish and Central Asian historians were very interested in the Indian kitchen, their cooking practices and cuisines" (e.g. Leyden and Erskine

[4] The Indian Census counted 247 million rural households in 2011 (average household size 5 persons) of which 64 percent or 158 million used firewood as their primary cooking fuel (India Registrar, Census 2011). A larger number is suggested by other authors who include dung, agricultural wastes, charcoal and other biomass sources as fuel, but the true number lies between 150 and 200 million households (Legros et al. 2009; Energy and Resources Institute 2010; India, Registrar General 2011). Indoor and outdoor chulhas may be built entirely of clay or with clay applied over stone or brick armatures. There is no standard size or shape, and customization to fit available spaces and women's preferences is the norm. In many rural households a clay wash is applied regularly to purify the cook-stove (see Sarin 1981).

1921).[5] In the later colonial era, when foreign administrators kept troops in reserve and strove to rule by survey and census—the so-called "ethnographic state" (Dirks 2001)—the chulha made several unusual appearances. For example, in 1902 British census commissioners stipulated that persons sharing meals prepared on a single chulha constituted a household (India 1902:18). In another example a highly placed Victorian official worried about the poor state of India's farming practices and recommended much greater use of manure to increase grain output (Hume 1879). Where should this manure come from? He pointed to the only practical source: dung produced in vast quantities by cattle and buffalo. But Indian women, especially in arid districts, regularly scavenged dung to burn in their chulhas. Reasoning that "very few natives will cook with cow-dung cakes if they can procure sticks," he proposed to wean women away from manure by planting wood-fuel groves in every village, thus releasing manure for cultivation (Hume 1879: 52). Nothing came of this proposal, but it shows that asking Indian women to alter their cooking practices for grand state causes has a long lineage leading up to the present.

Two distinct narratives about this common household fixture circulate in different disciplines. In the first, chulhas are not simply a tool for heating and cooking but are a perennial focus for women's cultural work. This benign narrative focuses on food-preparation and consumption rituals that hold Indian families together. Indeed, ethnographic literature underlines the centrality of the chulha for the worship of deities and the transmission of gendered skills (Khare 1976; Herman 2000; Mohanty 2004:581). A second narrative articulates the views of outsiders from foreign countries or India's urban centers that understand (often for good reason) the chulha to be an unhealthy, dangerous or wasteful means of combustion, one that needs urgent

[5] Pranav Prakash, personal communication.

correction for the sake of familial, national or even global goals (Kammen 1995; Hager and Morawicki 2013). This narrative assumes that chulhas and cooking over open flames will eventually be replaced by safer, more efficient and industrial sources of energy. These two narratives, one emphasizing continuity and the other striving to accelerate change, are often interwoven. However, only the first acknowledges the views and cooking-related competencies of women, which are essential not only for implementation of IC programs, but also for defining the problem in the first place.

Despite the hearth's positive cultural associations, it is clear that from the colonial era to the present chulhas have been marked as 'traditional' in the negative sense of the term—as backward, inefficient, unhealthy, and destined for obsolescence. Experts share a rational desire to replace the literally dirt cheap and hand-crafted chulhas with newer, costlier designs, technologies and materials that women will no longer be able to fabricate locally. Yet despite a plenitude of programs (Table 1), there is little evidence that efforts to popularize ICs in India have met stated goals. Indeed, of the roughly 35 million improved (biomass) cookstoves distributed by the National Programme on Improved Chulha in India from the early 1980s onwards, by the late 2000s, virtually none were in use. In contrast of the over 148 million distributed by the National Improved Stove Program in China over the same time-period, over 100 million were still in use in 2010 (Sesan 2014). By and large, rural Indian women do not seek ICs on their own initiative; where they are adopted it is largely through the earnest efforts of outside people and organizations. As a result, home-made chulhas persist everywhere, even in towns and cities where CNG and electric ovens are common. While rural women may be reluctant to adopt ICs, their reluctance is not a simple matter of aversion to new technology. On

the contrary, even when residing in villages without electricity, they have enthusiastically welcomed other new technologies, such as solar lights and cell phones.

We suggest that the chulha's persistence can also be read as resistance and that this is itself a puzzle. In other parts of the world a transition away from burning biomass is underway (Bonjour et al. 2013), yet the slow adoption of safe, efficient and well-engineered cook-stoves to replace the inefficient and unhealthy Indian chulha has been a nagging source of concern for years among researchers and practitioners (Barnes et al. 2012; Yadama 2013). If foresters, environmentalists, engineers, feminists, advocates for poor and indigenous communities have all coalesced around efforts to diffuse ICs in India, only to fail to convince the ultimate users, then perhaps it is the assumption itself—that rural women should and will abandon their long-established cooking technologies for "modern" manufactured biomass cook-stoves—that must be queried.

Why is it that Indian women overwhelmingly opt to stay with their inefficient, smoking, "unimproved" chulhas? To be sure, past IC programs rolled out by government and NGO agencies were plagued by problems of faulty installation, poor performance, non-durability and lack of repair services (Sarin 1986, Gill 1987, Kishore and Ramana 2002). But social, cultural, pragmatic and gender-political reluctances have also played a role. In essence, the rural women targeted by development experts have different priorities and seem not to share the same vision of a better life as those promoting the ICs. We believe that technological problems are only part of the answer to this question.

As noted above, the Indian chulha has had many critics. Calls to improve this most ubiquitous technology represent many different groups with distinct goals. The motivations to improve chulhas have varied and have shifted over time; they include such disparate aims as

improving health, addressing a fuelwood crisis and deforestation, releasing women from domestic labor, educating girls and stemming climate change (Rehfuess 2006; Gifford 2011). Table 1 below outlines the five most salient motives that galvanized these efforts over the course of the twentieth century.

Table 1. Multiple Goals of Improved Cook-stove Programs in India.

Salient Goals of IC Programs	**Proposed Solution(s)**
Improving health with focus on indoor air pollution	Promoting chimneys to remove smoke from household and improving chulhas to reduce polluting emissions.
Solving the fuelwood crisis with focus on resource availability	Promoting conservation efforts to increase supply of local biomass via reforestation, agro-forestry, and joint forest management. Promoting improved cook-stoves (ICs) to reduce fuelwood use.
Stemming deforestation with focus on ecological impacts of chulha use	Promoting ICs to reduce fuelwood use. Studying relative impacts of agriculture, urbanization and fuelwood use on forests.
Securing women's empowerment with focus on household dynamics	Promoting ICs as a way to improve health, reduce women's unpaid subsistence labor, and free them for other productive work (for payment or profit).
Addressing climate change with focus on greenhouse gases and black carbon	Promoting ICs to reduce fuelwood use and emissions. Studying relative climate impacts of biofuel and petroleum-based fuels for cooking.

These goals and proposed solutions, each detailed below, are intertwined, global in scope, and particularly urgent in India.

Improving Health

In the early twentieth century (Wiser 1937), medical and environmental scientists cataloged the hazards of indoor air pollution, largely due to incomplete combustion of wood and coal, which included respiratory infections, chronic bronchitis, asthma, obstructive pulmonary disease, lung cancer and tuberculosis. Because, in developing countries like India, concentration of air pollution indoors is often much greater than that outdoors (particulates and gases can be

ten times more abundant), incomplete solid-fuel combustion is especially dangerous to those regularly closest to cook-stoves: women and children (Godish 1989:4; Kankaria et al. 2014: 203; Upadhyay et al. 2015). This realization disturbed Indian physicians in the 1920s and soon led to a key recommendation: add chimney-pipes to expel smoke. But this was easier said than done; chimneys were exotic to India and imposed their own costs and mechanical difficulties. Nonetheless a public health concern for women and children before Independence provided new grounds for government workers to enter domestic spaces, where they tried to convince villagers to adopt "smokeless chulhas" and keep flies away from food (Wiser 1937: 203-04).[6] Nationalist leaders M.K. Gandhi and Vinobha Bhave advocated smokeless chulhas along with vegetarianism and temperance, and an ashram was set up in 1940 at Kallupatti (Tamilnadu) where potters were trained to make clay chimney-pipes (Muniandi 1993; Dupkar 2009:78). At least 50,000 "Kallupatti chulhas" were distributed in the 1940s and 1950s in Tamilnadu villages (Muniandi 1993). The guiding hand in this work was Dr. J.C. Kumarappa, a prominent Indian nationalist known as "Mahatma Gandhi's economist." Kumarappa aimed not only to improve village health but also to demonstrate the commercial viability of Indian-made (*swadeshi*) technologies based on accessible materials and local knowledge (Lindley 2007). Like hand-woven cloth (*khadi*) and the spinning wheel, the smokeless chulha was drafted into the nationalist repertory.

After independence, from the 1950s through the early 1980s, a number of "improved" cook stoves were designed (e.g., the Magan, the Nada and the Astra chulhas), mainly by state and central government employees of India's science, technology and engineering laboratories—but none were favored by village women (Barnes et al. 2012:18-20). Epidemiological studies

[6] As Ferguson (1994:180) has argued, 'development' is a machine for expanding the reach of bureaucratic state power; it is not a machine for eliminating poverty, though it takes 'poverty' as its point of entry and its justification.

since the 1980s have repeatedly correlated household air pollution with acute lower respiratory tract illness, chronic obstructive pulmonary disease, lung cancer, heart ailments, and asthma (Haines et al. 2009; Rehfuess 2006). Subsequently, external agencies like WHO, UNICEF and CARE began to take a keen interest in the impact of indoor smoke in India, because the country contributed the lion's share of global morbidity and mortality from air pollution (Bruce et al. 2000). These impacts have been ever more meticulously documented in burden of disease (BOD) studies (Smith 2000; Venkataraman et al. 2010: 67-69). While indoor air pollution has been recognized as a significant source of health problems in India for decades, the concern it aroused in national planning circles was always less than that for medical services, family planning and communicable disease control. Even when air pollution was recognized, greater attention was paid to ambient emissions from vehicles and factories in the largest cities (Kandlikar and Ramachandran 2000). Only recently has the unitary nature of India's air pollution problems—whether indoor or ambient, whether rural or urban—begun to be recognized, which should elevate its prominence in public health planning (Balakrishnan, Cohen and Smith 2014). At present, the most sustained promotion and distribution of ICs comes not from India's Ministry of Health and Family Welfare but from the Ministry of New and Renewable Energy, because the government's reasons for promoting ICs, as discussed below, have broadened beyond improving health to address global concerns over deforestation, sustainable energy use and the crisis of atmospheric warming.

Solving a Rural Fuelwood Crisis

The market shocks and increases in oil prices during the 1970s led to a focus on global energy supplies and local to national energy availability. A key focus of many stove programs during this period was to address the perceived rural fuel shortage problems resulting from

widespread deforestation (Eckholm 1975). Regional and national-level assessments of available biomass estimated a higher demand for fuelwood than the long-term supply. This perceived 'fuelwood gap' spurred interest in both reducing demand for fuelwood and increasing its supply. Thus, in addition to a wave of high efficiency stove (HEC) projects, India and many other nations implemented community-based programs focused on reforestation, agroforestry, and joint management of forest resources (Schreckenberg et al. 2006; Ravindranath et al. 2011). These HEC projects were aimed primarily at reducing fuelwood use, although there was secondary interest in reducing particulate emissions (Kshirsagar and Kalamkar 2014).

Outcomes from these efforts varied. HEC performance and adoption largely lagged published potential. For example, early tests focused primarily on lab-based metrics such as thermal efficiency and specific fuel consumption (Hager and Morawicki 2013, Arora, Das et al. 2014, Arora, Jain et al. 2014). However, critiques suggested the need to examine real-world conditions and practical measures of consumption through field tests in households. Estimates of biomass availability and use also have been limited. Typical accounting estimates and remotely estimated forest biomass are typically generated through the classification of the type and location of larger forest stands and statistical modeling of commercially available timber (Menon and Bawa 1998, Ito and Penner 2004, Kajisa et al. 2009). The scale mismatch between household-level activities and regional assessments may underestimate ecosystem responses (Bearer et al. 2008). Finally, local to regional differences point to a need for studies across scales. Bailis et al. (2015), for example, examined the proportion of fuelwood use relative to annual productivity; they found extensive differences in the sustainability of fuelwood use across India, and in particular, between nations. Thus, over time concerns have shifted from resource availability to ecological impacts such as deforestation, and methodological preferences have

shifted a well, with mixed methods approaches to understanding household dynamics becoming more popular.

Stemming Deforestation

Scholars have pinpointed the use of biomass cook-stoves like chulhas, and the ever growing demand for biofuels they require, as a major cause of deforestation, land degradation, and desertification. Forest degradation results when the quantity of annual biomass removed from a forest exceeds the amount produced. When people remove fuelwood from a forest, they may also extirpate woody species; if the plants do not grow back, the habitat they provide to other species disappears (Bearer et al. 2008). Forest degradation has further indirect impacts as it changes the micro-climate within forests (Linderman et al. 2005). For example, forest canopy decline often leads to increased solar penetration, higher soil temperatures, enhanced evaporation, and changes in nutrient cycling. Skole and Tucker (1993) have shown that micro-climate changes may further reduce biomass production, species composition, and ecological suitability, all impacts that are much more significant than the direct impacts of the original species loss. Studies have shown clear linkages between fuelwood collection and localized over-exploitation and other impacts on forest systems (An et al. 2011; Bearer et al. 2008).

However, there are few studies of long-term impact of fuelwood collection on forest ecosystems; we need studies at regional and national scales that can differentiate between the impacts of agriculture and fuelwood collection on forests. Evidence suggests that commercial forestry, clearing of land for agriculture, urbanization, and other broad changes in land cover have far greater impacts than fuelwood harvesting (Barnes et al. 1994, Foley et al. 2005). In addition, the lack of alternative economic activities available for women and the commodification of wood through charcoal production and rural-to-urban trade mean that

women collect woody biomass for sale as well as for household use. Because alternative economic opportunities for women are limited in rural India, the added labor and time costs of having to trek further for wood does not lead them to modify fuel use except in cases of extreme scarcity (Heltberg et al. 2000; Kanagawa and Nakata 2007).

Increasing recognition of the complexity of household decision-making processes, local economies and gender relations leads us to acknowledge that the sought-after outcomes of chulha programs are not a foregone conclusion. For example, if women required less fuelwood due to improved cooking technologies, there are many possible outcomes. Would they cut less wood or just sell more of it? Would their work lives improve or worsen? These questions have no singular answer.

Empowering Women

As earlier efforts to improve chulhas were frustrated, it became increasingly evident that experts needed a better understanding of household and gender dynamics. In general, development programs to improve health, environment and climate around the world pointed to the need for better understanding of gender and household dynamics. Similarly, attempts to solve the fuelwood crisis and address deforestation also led to consideration of the household. While early IC programs in India focused on macro-level goals that linked deforestation, fuelwood scarcity and rural poverty, starting in the mid-1980s these projects identified women as primary collectors and users of fuel and explicitly linked IC programs to 'women in development' (WID) framework (Ghertner 2006). Although women were already integrated into development in unequal ways, the WID aim was to explicitly target women for development in order to mobilize their participation in economic growth (Ghertner 2006:288).

Simultaneously, with growing recognition of the complexity of household decision-making processes, gender emerged as a central concern in IC efforts by the 1990s. From these concerns, a linkage between IC programs and women's 'empowerment' was born.[7] So from the 1990s onwards, a number of IC projects were launched in India with the hope that replacing the traditional chulha could empower disenfranchised women and enhance the livelihood of poor families (Barnes et al. 1993; Rehfuess 2006). This focus is in fact a major emphasis of the recent efforts by the United Nation's Global Alliance for Clean Cook-stoves that hopes to distribute clean and efficient stoves to 100 million homes globally by 2020 (Global Alliance for Clean Cook-stoves 2015; Subramanian 2014).

Before detailing the importance of gender analysis for understanding the chulha story, we address concerns related to climate change. If fuelwood use were to decline, there are many possible impacts not only for women but also for forests. Would the forests grow back or would their reduced usage for cooking have no impact in the face of over-exploitation for large-scale commercial interests? In the 1980s and 1990s the worldwide imperative to respond to declining biodiversity and climate change grew louder. In this context, localized deforestation in India and elsewhere was discussed in terms of its impacts on biodiversity, ecosystem function and climate change.

Addressing Climate Change

Until recently, the daily residential burning of upwards of 2 million tons of biomass as fuel has not been recognized as an important source of greenhouse gases or pollution, likely

[7] As feminist scholars have shown, by the time 'empowerment' had become a buzzword of neoliberal discourse in the 1990s and one of the most loosely-used terms in development, it had been evacuated of its political power (Leve 2007, Batliwala 2007).

because solid biomass fuels (excluding coal) were considered renewable in the sense that the combusted carbon is eventually sequestered by the regrowth of vegetation (Bond et al. 2004). However, research since the 1990s has shown that cooking with biofuels can be a major source of greenhouse gases (e.g., CO_2, CH_4, N_2O) and black carbon (Smith 1994; Smith, Khalil et al. 1993, Smith et al. 2000; Venkartaraman et al. 2005; Bond et al. 2004; Grieshop et al. 2011; Ruiz-Mercado et al. 2011), usually surpassing fossil fuel impacts on a per meal basis. Moreover, modification or change of the aboveground vegetation has a significant impact on soil processes and the ability to sequester carbon below ground (Bondeau et al. 2007).

With worries about global biodiversity and climate change mounting by the 1990s, various actors, including researchers like Kirk Smith (see Smith 1994, Smith, Shuhua et al. 1993), think tanks like the Stockholm Energy Institute, and organizations like the United Nations Development Program (UNDP), began to promote ICs explicitly as a key technological solution to these problems. Although fuelwood collection is rarely conducted sustainably (Bailis et al. 2015), many researchers saw improving chulhas as the logical solution for rural villagers rather than the gas stoves widely used in Indian cities. One key argument for this choice was economic: replacing biomass with finite resources such as petroleum products would make households vulnerable to price fluctuations due to global market dynamics. A second reason was environmental: due to more complete combustion, biomass-fueled ICs tend to reduce emissions of both particulate matter that harms health and those gases that most exacerbate global warming (Smith et al. 2000). In a departure from the widely accepted view, Kirk Smith (2002) has argued that LPG is not only more sustainable than use of biomass fuel in terms of impacts on local ecosystems and methane and particulate emissions, but the health benefits of cooking with fossil fuel are undeniable. Below we return to the suggestion that efforts to improve cook-stoves

should be redirected to making fossil fuels available to meet the cooking needs of the world's poor.

What emerges from this overview of IC efforts is that while each goal arose separately in different contexts of expert and professional alarm, the newer goals have not replaced earlier ones. Rather, these aims have accumulated over time so as to involve ever more complex concerns, a proliferation of engineered technological solutions, and an increasing number of insistent and sometimes jostling proponents. By the beginning of the 21st century, national and international governments, aid agencies, and non-governmental organizations were implementing over 160 programs that distributed more than 150 million ICs in rural areas across the globe, including India (Barnes et al. 1993; Gifford 2011). We now turn our attention to summarizing outcomes of these programs.

Success and Failure, but Mostly Failure, of IC Programs in India

The traditional clay chulha used across India has low thermal efficiency (5-15%), which is its ability to convert energy in the fuel-wood into heat, and emits a lot of pollutants. This low efficiency means that much energy is lost during cooking; as a result more biomass must be burned, requiring additional hours of fuel collection. The chulha also produces high concentrations of particulate matter such as black carbon, greenhouse gases such as carbon dioxide, and toxic gases such as carbon monoxide (Gill 1987; Mukhopadhyay et al. 2012). These emissions present real problems for household air quality (and human health), the environment and climate. We agree with Barnes et al. (2012:115) that 'the problems associated with using biomass energy in traditional stoves are too important to ignore' (2012:115).

These problems have driven research laboratories, governments, international organizations (such as WHO, USAID etc.), and NGOs to push for improved cook-stoves of various kinds. "Smokeless chulhas" vent harmful combustion effluents away from living spaces, thus addressing health but not environmental concerns. "High efficiency cook-stoves" (HECs) with efficiency of 20-25% aim to cut fuelwood consumption significantly. Generally, ICs improve on traditional chulhas because of one or more of the following innovations: more complete combustion of wood through improved air supply; air flow unobstructed by ash and embers; redirection of the flame towards the cooking vessel; reduction in size of fuel insertion opening to prevent fuel over-feeding and heat loss. These improvements derive from well-established air flow and combustion principles, and the performance of many ICs on the market today has been replicated in research laboratories around the world. In short, from a purely technological perspective, under controlled conditions the best ICs do meet engineers' desired levels of thermal efficiency and emission reductions. Thus, it would seem to logically follow that if ICs could replace clay cook-stoves widely, then dramatic environmental, health, social and economic (e.g. money, time) improvements would accrue around the world (Barnes et al. 1993).

The design or adoption of new technologies tends to be conceptualized as a means for humans to fix some 'real' or practical problems seen to be standing in the path of progress (Pfaffenberger 1992). Research on the diffusion of new technologies shows that the invention and adoption of technology is not simply a function of necessity forcing unidirectional change; rather, adoption of new technologies is a complex social process that requires critical shifts in culture and behavior. This need for significant behavioral and cultural change explains at least

partially why so few IC programs are successful.[8] Indeed, most improved biomass stove programs in India have failed to achieve the desired levels of adoption or goals of stemming deforestation rates, addressing fuel shortages, or curbing respiratory disease (Hana et al. 2012).[9] The most salient problems are low rates of initial household adoption and subsequent low usage rates. Even when initial adoption rates are adequate, there is usually a marked decline in use over time due in part to rapid deterioration of these products (Sarin 1986). In other cases, users modify the IC in ways that compromise the stove's performance (Barnes et al. 2012; Palit and Bhattacharyya 2014). IC programs led by governments or other agencies are highly bureaucratic in nature and do not prioritize receiving feedback from users (Gifford 2011). Most stove programs focus on designing, manufacturing, and/or marketing ICs, rather than trying to understand how and why stoves are adopted (Ruiz-Mercado et al. 2011; Palit and Bhattacharyya 2014). In general, more successful programs offer stoves with the following features: they save

[8] While some centralized IC programs have been successful, such as the Chinese National Improved Stove Program, which distributed more than 200 million stoves between 1993 and the end of the decade, the majority of which were still in use ten years after initial adoption (Barnes et al. 1993; Smith, Shuhua, et al. 1993; Smith and Keyun 2010), many other national programs had much less success for socio-economic, behavioral and cultural reasons (Malla and Timilsina 2014).

[9] For Smith (2011), hearing the suggestions of village women in India led to an epiphany: In measuring performance of improved biomass cook-stoves, researchers should compare them not to traditional chulhas but rather to cooking with gas—since gas stoves are the aspirational appliance that all women want.

fuel in settings where fuel is scarce or costly to purchase; they significantly decrease cooking time; they are easy to use and compatible with existing cooking practices; they are appropriate for a family of a certain size (Bielecki and Wingenbach 2014; Ruiz-Mercado et al. 2011; Thacker et al. 2014). Below we identify the five key reasons cited by researchers to explain the failure of many IC programs.

1) T**he goals and needs of rural people and those of IC promoters are often mismatched.**

IC advocates commonly emphasize fuel economy and/or decrease in emissions as the key goals of the stove (Palit and Bhattacharyya 2014; Mobarak et al. 2012). However, users of biofuel stoves often say that they have other priorities, including cooking speed, ability to burn fuels other than firewood (e.g., coal, crop residue, and dung), capacity to cook with different sized utensils, and cost (Gill 1987; Mobarak et al. 2012; Thacker et al. 2014). While many participants in IC programs clearly understand the health benefits of reducing household smoke, they repeatedly state that improving other aspects of family health is more important to them (Mobarak et al. 2012).

2) **The performance of ICs has not always lived up to their claims.**

This may be because, when used in the home, the stove is not actually more efficient or smokeless compared to the traditional clay stove. Gill (1987) and Barnes et al. (1993) have noted that many early "improved" cook-stoves were simply assumed to be more efficient than traditional systems; these judgements were often based on anecdotal accounts or unspecified data. A frequently cited problem with IC programs is that stove performance demonstrated in a laboratory setting could not be replicated in the field (Smith 1989; Johnson et al. 2008; Roden et al. 2009, Aung et al 2016).

3**) Many ICs were poorly designed and require burdensome lifestyle changes.**

Improved Cook-stoves must meet the needs of users. They must be compatible with local preferences for food types, fuel sources, cooking practices and vessels and should not increase the labor of cooking. Some ICs with low adoption rates cannot handle various sizes of wood and require women to cut wood into smaller pieces. By contrast, the ubiquitous clay chulha is useful and effective from users' perspectives. It can be constructed for little or no cost and with minimal technical skill. Its shape ensures that the heat from the flame is steady and temperature can be easily controlled by the addition or removal of fuel. The chulha's box-like shape means that its open front is a convenient portal for the fuel and air intake, while its three sides can support cooking utensils of various sizes. Numerous scholars have pointed out that "improved stoves" of lack the basic design attributes that would meet the needs of users (Gill 1987, Barnes et al. 1993, Kammen 1995, Bielecki and Wingenbach 2014, Thacker et al 2014, Palit and Bhattacharyya 2014). Stoves may tip over easily, resulting in waste of both time and precious food. They may present risk of burn. They may be difficult to light, or have openings too narrow for the intended fuel source. They may produce food that is either over- or undercooked. They may break after repeated use and be difficult or costly to repair. Our own observations and conversations in Karech village confirm that users experience these problems.

New stoves are often designed in ways that make it difficult for women to prepare their standard meals using preferred cooking utensils or to use biofuel of the usual size and type (Palit and Bhattacharyya 2014; Pandey and Yadama 1992). These changes may require abandoning valued recipes or dishes, learning new cooking techniques, performing an annoying or laborious task (such as cutting firewood into small pieces) or adjusting to the altered taste of common foods, prompting women to abandon the new stoves. Even in cases where ICs are successfully

adopted rarely does the new device entirely replace existing technologies. More commonly, new stoves, if adopted, are used alongside the old stove (Ruiz-Mercado et al. 2011). The coexistence of an IC and traditional chulha is likely due to the fact that the IC works well under certain conditions, such as whether cooking is being done indoors or outside, whether cooking is for a large group or small family, whether it is for cooking bread or making tea, whether cooking involves frying or boiling water (Ruiz-Mercado et al. 2011; Bielecki and Wingenbach 2014). We return below to this phenomenon of using multiple technologies.

The overall IC challenge is that new stoves and fuel sources enter an existing socioeconomic and enviro-technological context (Ruiz-Mercado et al. 2011). The user's primary goal is to cook food with a particular and familiar taste, texture, and appearance; they likely also have concerns related to cooking time, time spent acquiring or preparing the fuel, and the amount of smoke and heat in the cooking area. The problem is that most new stoves or fuels require significant changes to the existing conditions and tasks of food preparation. Moreover, IC users have a learning curve and may need to change or adapt their cooking practices simply to use the new device. Users are more likely to make the necessary changes if they perceive that the IC offers real advantages relative to existing technology, is generally compatible with existing cooking practices and goals, and is easy to understand and use (Pandey and Yadama 1992). Some new technologies in rural India meet these criteria. For example, solar lamps, like ICs, are intended to displace a familiar domestic appliance, namely, the kerosene lantern. Solar lamps are popular in non-electrified villages, where users purchase them despite the government's substantial kerosene subsidy (Cross 2012; Kumar 2015). A more extreme contrast can be drawn between ICs and cell phones (mobiles). Cell phones entered rural India without precedent and widely and quickly diffused to meet a vast demand. To be sure, cell phones are as disruptive in

India as anywhere else, but villagers of all ages and both gendersrely on them even though they impose significant monetary and cultural costs (Matanhelia 2010; Jeffrey and Doron 2011; Doron and Jeffrey 2013). We mention the ready adoption of cell phones and solar lamps to dispel any suspicion that rural Indians are simply opposed to technological or social change.

4) IC programs have underestimated the value of traditional chulhas.

Many IC programs have been inattentive to cultural and practical functions served by traditional modes of cooking (Bielecki and Wingenbach 2014; Muneer and Mohamed 2003; Thacker et al. 2014). For example, chulhas sometimes also serve as a primary source of heat or light or as a means for boiling water for bathing. Likewise, despite health concerns, users may find the smoke to be useful to cure food, dry hand-made ceramics, or deter insects and other pests (Gill 1987). Not only do traditional stoves have symbolic cultural or spiritual value (Bielecki and Wingenbach 2014; Gill 1987; Subramanian 2015:117), but they also, as noted above, are easily built and repaired by women users or a local craftsperson—making them a source of autonomy.

5) Problems occur with IC implementation and organization.

Since the 1970s, governments, international aid organizations, and NGOs have implemented numerous programs that have distributed millions of purported efficient and/or cleaner cook-stoves to rural areas across the globe (Barnes et al. 1993; Gifford 2011). One of the largest projects, as discussed above, was the Indian National Programme on Improved Chulhas, which continued through the early 2000s (Barnes et al. 2012; Sarin 1986). It developed more than 60 IC models and distributed over 35 million of them. In 1982, a Department of Non-conventional Energy Sources, was founded and later became the Ministry of New and

Renewable Energy or MNRE (Sarin 1986). Although massive in scale, the Indian National Programme on Improved Chulhas was unable to bring about the hoped for change.

In India today many efforts to improve chulhas, cooking technologies and poor villagers' health are managed by NGOs. Two critiques of NGO-led development offer insight into IC efforts, namely, the lack of coordination among NGOs and the uneven distribution of investments from region to region or even village to village. In India today, universities, NGOs, philanthro-capitalists, international development agencies, government researchers and corporations work on different stove technologies, deploy these on different scales and rely on disparate models of social change, resulting in a fractured maze of IC projects. There is little data to suggest that their efforts have resulted in significant rates of adoption or the promised improvements in health, household economies or local environments (Agarwal 1983; Bhojvaid et al. 2014; Maniates 1990, 1992; Puzzolo et al. 2011).

There is a robust debate among IC researchers and promoters in India about the relative effectiveness of designing and distributing ICs through NGO and government subsidies or through market mechanisms (see Bailis et al, 2009, Smith 2010). Meera Subramanian (2015) describes her interview with Harish Anchan, the head of Envirofit in India; Envirofit is a for-profit company launched in 2003 from activities begun at the University of Colorado which collaborates with corporate social responsibility programs and microfinance banks to sell ICs. Reflecting on the lack of sales for this simple technology, Anchan explains that convincing people to use it is more a matter of human emotions and politics than the technology itself. He refers to ICs as "push products" or something that consumers must be convinced that they want rather than something they seek out (Subramanian 2015:138-139). Neither non-profits nor for-profit companies have succeeded in diffusing ICs.

Gender Convergence: Hearth, Food, and Women's Work in Rural India

IC advocates frequently describe cooking with biomass-fueled stoves as 'drudgery'. Easing women's workload, they presume, would result in a cascade of positive social and health consequences, including reducing rural poverty, enhancing quality of life for women, putting girls in school, and improving health. Economic metrics define the labor of wood collection as 'unproductive' because it is usually done for neither payment nor profit (Krishnaraj 2008). Thus one aim of IC programs has been to improve rural economies and environments by releasing women from fuelwood collection so that they may become more economically productive. This neoliberal economic discourse posits that making women more productive will address gender inequality because it assumes that gender inequality is caused by poverty. ICs are seen as labor-saving technology that, by increasing fuel efficiency, 'releases' women's time from domestic chores for income-generating activities. Women's increased productivity is assumed to result in improved family welfare, rising income and gender equality (Ghertner 2006:288-89).

Feminist research has shown that there are many possible outcomes when women are incorporated into market relations and wage labor. Details, such as what kind of paid work is available to them, matter. If families no longer depend on women and girls for fuel collection, they may gain access to beneficial educational and employment opportunities. Alternatively, their value may decline and daughters may be married off earlier. Women 'freed' from subsistence labor generally have several options available them: difficult and poorly-paid agricultural labor; heavy labor on construction sites (carrying headloads of bricks, etc.); piecework done in the home (embroidery, beedi-rolling, etc.) with most of the profits going to middlemen. The degree to which women feel 'empowered' by the work has less to do with the physical work itself and more with the respect, financial reward, autonomy, flexibility and

security it offers them. This may explain why women in rural India may or may not clamor for freedom from subsistence activities such as fuel collection. All interventions have unintended consequences that might be positive or negative. Negative consequences, such as girls being married off at younger age if not needed at home for fuel collection, could diminish the overall benefits of improved chulhas.

Looking at gender and micro-level household dynamics highlights issues of culture in relation to both chulhas and fuelwood. Wood is biofuel. It is also carbon that, when burned, releases greenhouse gasses. However, wood is neither simply biofuel nor carbon. Wood burning in the chulha is needed for purposes other than fuel; its warmth locates the hearth as the center of home life and its smoke infuses food with distinctive flavor. Moreover, its collection brings women together for work that is certainly arduous, but also offers opportunities for pleasure and sociality (Gururani 2002, Natarajan 2000). Along with collecting wood and hauling their heavy loads across treacherous terrain, women we observed might also be laughing, singing, and complaining about their husbands. The activities of collecting, chopping, and hauling wood (and other fuels or water) may cause physical pain while at the same time building physical strength and creating a space of sociality in which women may share information, act in their own interests, and enjoy the company of others (Gururani 2002). Feminist scholars have shown that gender segregation resulting from division of labor, stereotypically associated with pre-modern patriarchy, creates female social spaces of pleasure and solidarity that benefit women in surprising ways (Arora-Jonsson 2009; Gururani 2002; Jassal 2012; Maggi 2001; Natarajan 2000). Furthermore, in addition to collecting wood for their own household needs, women may barter and sell it to meet the needs of their families (Patrick 2006, Babar 2001). Its exchange

value makes wood a commodity, and it may be one of the few forms of currency that women control.[10]

Similarly, the chulha is more than simply a tool to turn grain into bread. In rural India, the 'hearth' is simultaneously the center and the boundary of a household. Those who are fed from the same hearth are members of a household, and moral order is maintained by preparing, serving and eating food (Khare 1976, Kolenda 1989). Given that women are generally in charge of cooking, the hearth—the chulha—is a site for the enactment of femininity. It is well documented that love is not simply expressed (symbolically) with food in South Asia, but food is understood to transmit love and other emotions from giver to taker (Toomey 1990, Trawick 1990:94). And yet it is also a site of power struggles in an extended family; these struggles can be about quantity and quality of food prepared, about who is doing the cooking, and who is judging the taste. It is an object of deep affect. The fire of a chulha offers light and warmth on a winter night, but, given women's loose and flammable clothing, can also be the cause of tragic accidents or a weapon of domestic violence; it is communities or courts that draw the line between accident and murder. And yet the chulha is a relatively egalitarian technology, given that it is produced by women themselves or local craftsmen out of materials collected from the immediate environment. Similarly, to the extent that biomass resources are available, it can be operated at no monetary cost. What gets lost in the dogma of improving cook-stoves is the

[10] A report produced from an Asian Institute of Technology workshop found that women's involvement in the wood fuel business across Asia tends to be small-scale, scattered, and informal, while men control large commercial enterprises (Babar 2001).

recognition that to target the chulha for replacement has profound implications and that these may be positive, negative or even contradictory.

Rural Indian women are defined, implicitly, in opposition to urban middle-class 'modern' women in India and the Global North. Those of us who cook with electricity or fossil fuels, imagine these women's lives as filled with relentless suffering. But the 'modern woman' is a trope with shifting content, having been used to promote multiple and contradictory agendas not only by colonial and nationalist discourses, but also by feminist and anti-feminist discourses (Khandelwal and Freeman, in press). This has not always served the interests of rural women in India. During the colonial period and post-independence, their songs (women sing while collecting wood, grinding grain, celebrating life-cycle rituals, etc.) were suppressed and sanitized in the name of modernization; while such songs were hailed as backward and vulgar (particularly those relating to sexuality), reformers felt that women's songs encouraged them to be confrontational and to challenge hierarchies related to marriage, family and work (Jassal 2012, Chowdhry 2001). That the call for 'modernizing' rural women motivated efforts to stamp out cultural practices that were empowering should serve as a cautionary tale for IC advocates.[11]

[11] During the colonial period, nationalists responded to British critiques of the status of Indian women with reform efforts. The educated and respectable—'modern'—woman was defined in opposition not only to British women, but also against her own mother and rural women, who were now seen as uneducated and uncouth (Chatterjee 1989). The emergence of this new ideal required active suppression of women's singing traditions that were now criticized as backward and vulgar, though women's songs not only had didactic content but also allowed women to critique the social order and to share strategies for dealing with hierarchies related to marriage,

Rhetoric of modernity aside, the lives of rural women in India do not reflect some unchanging past. If modernization is the process by which kin and community networks are subordinated to relations with the nation-state and capitalist world economy (Bernal 1994:39-43), then rural Indian women have been modern for a very long time. For example, the colonial policy of reserving forest to 'protect' it from 'tribal' people so that it could be maintained as a resource for timber and other commodities reconfigured village life as the colonial and later independent state tried to get rural people to lead a life of settled agriculturalists (Gadgil and Guha 1992). Also, Gururani (2002) suggests that collection of fuelwood and fodder is not 'naturally' women's work but became women's work when environmental degradation led to out-migration of men. Thus it is a matter of rhetoric rather than fact when agents of change recode women—or rural women—as "ignorant, traditional and unchanging fixtures of the local" (Pessar and Mahler 2003:828). Rural women are already modern, their current lives shaped by history of contact with a range of outsiders: precolonial elites, colonial officers, state agents, moneylenders, businessmen and agents of development.

Even if we (and rural women themselves) think that ICs may bring benefits, the obstacles to adoption are many and no simple fix exists. Complex household dynamics mean that IC programs must consider not only the technology itself, but also the politics of implementing them. Ghertner shows that different strategies of delivering the same technology to a household can have drastically different implications for women's ability to negotiate; 'technology' refers

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family and work (Jassal 2012, Chowdhry 2001). Male reformers felt that songs encouraged women to be confrontational, to transgress boundaries and to challenge familial hierarchies and so they suppressed some and sanitized others in the name of modernization (Jassal 2012: 3-11).

to both chulhas and a social process of implementing them (2006:283-284). Implementing technology is a source of contestation and negotiation, and IC programs have perpetuated a rural power system in which women are regulated by development professionals who monitor fuel and stove use (Ghertner 2006:289). Inevitably, diffusion of stoves involves not only technical issues, but also complex household and community dynamics, unequal relations between rural women and IC advocates who are urban professionals, and competition with existing technologies and cooking practices.[12]

It is not our intent here to romanticize poverty; the frame of 'drudgery' is not wrong so much as it is reductive. Hard labor done for one's family is often a source of pain at the same time that it brings pleasure as well as cultural and economic value. It may be any of these things or, more likely, a complicated mix that depends on factors other than the activity itself; it depends on context. Who is to say whether a day spent collecting fuel for one's own use, hauling bricks at a construction site for a pittance, or sitting for hours doing needlework in one's home for even less pay is more desirable, except the women doing it? When IC programs consult rural women, it is to secure their compliance or to ensure success of the intervention rather than to with engage them as agents who can speak on equal terms with elites—whether academics such as ourselves, corporate elites, government officials or IC advocates—and be heard by them (see Jackson 2012). If donors are convinced that ICs are the solution, then

[12] O'Reilly (2006) argues that with rise of gendered participatory approaches to development, women fieldworkers have been recruited into projects to facilitate participation of village women, but, once hired, often find themselves on the margins of their organizations; they are assumed to have 'modern' beliefs but also a natural affinity with village women.

organizations they fund to implement them will not ask whether women want them at all; nor will they build women's abilities to demand, as citizens, improved health care or protection of environment (see Cornwall 2003:1327).

Lessons from India's Chulha Story

What can we learn from the decades-long history of chulha replacement efforts in India? If there has been no widespread adoption of ICs across the Indian countryside, why not? At a micro-level researchers have identified many reasons, summarized above, that success has been spotty at best. While many good studies chart success and failure with detailed case studies, our interest is in the larger narrative of the chulha story and the perspectives of multiple protagonists.

It is easy to think that cooking practices are so deeply enmeshed in the traditions of rural life that that new chulhas have represented a cultural shift so profound that it could not be effected in a short time without concomitant broad-based shifts in cultural norms and economic incentives. It is true that worldwide cooking practices seem to be especially resistant to change, but this does not mean that clay chulhas are impossible to dislodge. We reject modernist tales, including the narrative that rural Indian women are naturally (and irrationally) resistant to new technologies, for rural women have quickly and enthusiastically embraced some new technologies. Indeed, Sarin (1986) found that in some contexts women wanted new chulhas but could not get them for a variety of reasons, including cost and resistance from husbands. Again, we find the contrast with rapid adoption of cell phones to be obvious but instructive. In many parts of rural India, cell phones are a leap-frog technology embraced by people who have never had landlines, who may not have electricity and who may not be literate (and thus able to write letters); in such contexts, the cell phone does not displace other forms of communication. ICs, in

contrast, are explicitly intended to replace clay chulhas that we believe, in women's own experience, seem to function pretty well.

If inherent resistance to new technologies cannot explain the chulha conundrum, what other factors have emerged from this inquiry? We first became interested in chulhas after learning about deforestation in the Aravalli Hills in Rajasthan and perceptions that fuel collection by women for cooking purposes is the primary cause of deforestation. But is this perception true? As Gadgil and Guha have shown, the causes of deforestation in India include timber extraction during the colonial period to build British war ships and the railways of India (which enabled further intensification of other extractive industries). Since independence, forests have been cleared in order to expand agriculture, intensify livestock production, make way for urban sprawl, build dams for hydropower, and enable mining and other commercial industries. Such forest-depleting projects serve the interests of elites, whether they are urban consumers, foreign companies, the Indian state, or private companies in India (Gadgil and Guha 1992).

One unanswered question we raise is an ethical one about scholars and activists in the Global North and high consumption urban core who focus so much attention on changing the behavior of poor women in rural India. Expanding on earlier work in political ecology, Latour (2014) notes that term 'Anthropocene' puts human agency at the center, but it is an undifferentiated human agency, defined broadly to include ecosystems, land use patterns, migration of plants, etc. However, as Latour notes, human agency raises the issue of 'responsibility' that requires action. Thus, the 'anthro' in Anthropocene suggests that US leaders and a woman in Karech village whom we persuaded to test an IC for us, share equal responsibility, but women in rural Rajasthan use energy primarily to cook food—and very little of it—to feed their families, and it is for this reason that they cut wood. Latour, along with

critics of development and feminist scholars before him, ask who defines the problem of climate change, who is responsible for causing it, and who bears responsibility for solving it?

Rethinking of the pre-occupation with improved biomass stoves is increasingly evident. In a 2002 editorial, leading IC researcher Kirk Smith (2002) suggests that IC efforts should be abandoned in favor of providing LPG cooking to the world's rural poor and instead targeting those who produce the most greenhouse gases (wealthier folk) to use new, experimental technologies for environmental reasons. Recently, Smith and Sagar (2014) have advocated both 'stacking' of cooking appliances and a massive shift to gas and electricity as solutions to what they call the Chulha Trap. Indeed, Subramanian's (2014, 2015) research suggests that what rural people really want for cooking is LPG, not manufactured ICs that offer slight improvements in emissions and fuel use but continue to rely on biomass.

Defining wood collection as drudgery and cooking with fire as dirty and inefficient led many (governments, NGO, advocates) to push for change; however, those pushing for change often simplistically presume that new forms of labor will inevitably replace these activities and those will be more pleasant, more efficient, more remunerative, and thus enable better quality of life. It thus becomes possible for agents of change who might otherwise disagree with each other (environmentalists, foresters, advocates for the rural poor, feminists, engineers) to galvanize around a shared goal: replacing the chulha with ICs. It becomes easy for us to think that we know what is in the interests of non-literate rural women and that it is their responsibility to change their behavior, not our responsibility to change our behavior.

Published research and our own preliminary field work in Rajasthan suggest that rural women do not highly rank acquiring (biomass) ICs on a list of things they urgently need to better their lives. It is hardly a surprising or profound realization that these women are much more

vocal about their desire for improved drinking water, irrigation systems, electrification, and access to pasture land. These demands, however, require either capital-intensive investment or taking on the powerful interests responsible for over-exploitation of resources. And while most development experts agree in principle that we should turn our attention to concerns that women voice themselves, responding to them is difficult by definition. Meanwhile designing, manufacturing and distributing ICs appears to be a straightforward, inexpensive and seemingly apolitical intervention; persuading poor and relatively powerless rural women to change their cooking practices has been imagined to be relatively easy. Our argument is that this seductive simplicity, when compared to other, more challenging interventions, is one reason why IC programs have been a development story with great appeal. Another reason is that an industry has developed around the cook-stove conundrum with the institutionalization of IC efforts.. Some working within the field recognize that, despite an abundance of good intentions, the IC industry has also become an industrial interest group in that "everybody makes money, but the problem does not get solved" (Subramanian 2015:149). The decades-long effort to improve chulhas exemplifies what Ferguson (1994) has so famously called the 'anti-politics machine', a phrase coined to describe the practice of defining development problems as technical. However, this consistent erasure of power, politics and historical specificity by the development industry cannot be reason enough to halt efforts to improve cooking practices, given the nagging concern we share aoub the health impacts of indoor air pollution.

Quarles van Ufford, Giri and Mosse (2003:8) argue that one striking characteristic of development projects over time is the developers' unfailing optimism about their ability to effect change. They point out also that this optimism is almost matched by the antagonistic pessimism of the critics of development (particularly anthropologists), who focus on the hegemonic

destructiveness of externally-initiated projects. This antipathy constitutes, they argue, "one of the main problems we are facing in development" (Quarles van Ufford et al. 2003:11). Because of our multidisciplinary approach, we want to claim a middle ground and reject the optimism of the applied approach as well as the relentless pessimism of anthropological and postcolonial critique. Even if ICs are unlikely to solve the major water, land and income problems facing rural populations in India, this does not mean that all efforts to improve cook-stoves should be abandoned. Rather, we suggest that a humbler, less radical approach might be more successful. Specifically, we reject the common goal of all IC programs which has been to persuade women to get abandon their traditional hand-made mud chulhas, demonized as wasteful, unhealthy, dirty and obsolete, in favor of highly engineered, steel replacements.

This singular focus may be the problem. What if we were to change track and work with rather than against rural women's clear preferences and were to make LPG affordable and available, or, alternatively, seek a more gradual shift rather than outright replacement of existing technology? What if cook-stove improvements were seen as additions to rather than replacements of existing chulhas, a situation often called "stove stacking" (Subramanian 2015:155). Gradual and additive technological transitions may be more common than outright substitutions. For example, newer medicines based on bioscience have added to the repertory of existing Ayurvedic, naturopathic and homeopathic remedies in India. Medical anthropologists have said for decades that rural Indians, like others around the world, take recourse when ill to "a hierarchy of resort" among the various available systems and options in the marketplace, moving from one to another as their needs and satisfactions shift and change (Sobo 2004). We suggest that rural Indian women have rejected a form of techno-modernity that requires them to completely give up the clay cook-stove to use an IC that does not function very well.

In recent research in Rajasthan, working under the viewpoint that additive technologies may bear a higher chance of success than replacement technologies, we looked into possible improvements to the mud and brick chulha itself. Out of this effort came a simple, inexpensive metal device that can be inserted into the chulha with minimal change of geometry of the chulha/wood placement or to traditional cooking practices. This insert, called Mewar Angithi (MA), serves as a flange that opens up a secondary channel for air-flow that supplies additional oxygen for combustion (Udaykumar et al. 2015). The MA is a seamless add-on to the chulha and does not require any dramatic change in cooking practices. A preliminary set of lab and field tests showing reduction in fuelwood usage and particulate emissions are encouraging and suggest that the MA may provide an intermediate solution because it is very inexpensive, does not demand change in cooking patterns, and has so far been positively received by women in four villages in southern Rajasthan where it has been distributed. In field tests in Rajasthan (Udaykumar et al. 2015) women who used the MA remarked on the noticeable reduction of smoke, while also noting the reduction in wood required. This device has the potential for greater adoption by women who use chulhas in their quotidian cooking activities, perhaps more because of its immediate reduction of smoke than as a means to save wood. Therefore, due to its low cost, ease of adoption and noticeable benefits in terms of energy efficiency and emissions reduction, the additive strategy of the MA may present a wiser intervention strategy than the en masse introduction of manufactured cook-stoves.

Thus, we agree with the argument that--rather than improved biofuel stoves—a better solution is to make LPG or electric stoves both available and affordable. However, even after decades of awareness about problems associated with biofuel use for cooking, this transition away from biofuel has not occurred in India. The reasons have to do with politics and

infrastructure, not technology. It is hard to imagine that women would reject readily available and affordable LPG the way they have rejected ICs. It is in this context that we feel benefits can accrue from incremental shifts such as stove stacking or stove inserts to the extent that they are rapidly adopted. Transitional technologies, like simple and cheap stove inserts, can have potentially high impact if they reduce fuel use and emissions produced by biofuel.

While in this paper we have highlighted weakness of past chulha replacement efforts we recognize that these projects involved well-meaning experts who are responding to strong empirical evidence for the problems associated with the use of traditional chulhas, such as serious negative health consequences (Ezzati et al. 2004; Rehfuess 2006; WHO 2014) or that burning of biofuels is a major source of greenhouse gases and black carbon (e.g., Smith et al. 2000; Venkartaraman et al. 2005; Bond et al. 2004; Grieshop et al. 2011; Ruiz-Mercado et al. 2011). For decades, researchers and development experts have been quite successful in defining the problems associated with the use of traditional chulhas. It is experts' ability to identify solutions or create interventions that actually solve these problems that have been less apparent. In this paper we argue that the failures of chulha replacement efforts are in part a result of the experts' belief that the benefits of a better chulha would surely be evident and quickly manifest, and that the success of their initial interventions would snowball into a wider nationwide movement for replacement of traditional chulhas. Development planning literature is replete with examples of failures from such top-down, expert-driven efforts to develop people. As a result both the theory and practice of development interventions have shifted significantly since the 1980s. There is widespread recognition that the intended beneficiaries of any intervention must be involved in the problem-scoping stage, and in the generation of context-specific alternatives to solve high-priority problems. More specifically, the problems identified are those

of the beneficiaries, and not those deemed most important by the experts, the non-profits or the state agencies that promote them. Likewise, the solutions to those problems become their solutions, not something that has been foisted upon them or that they have been incentivized (perhaps monetarily) to adopt. Indeed, as Sarin (1986) notes, in some contexts, women did not want improved chulhas but felt either forced or pressured by the government or NGOs to accept them. Beneficiary ownership of problems and solutions has well-documented positive effects on adoption rates, and more importantly, on the long-term sustainability of those solutions. However, long term change requires structural transformation that may threaten vested interests and thus becomes political rather than technical (see Ferguson 1994).

If improved chulhas, whether manufactured high efficiency cook-stoves or even our recently conceived additive insert (MA), were to become widely diffused, it may very well have positive impact on forests, the fuelwood crisis, respiratory health, and even women's empowerment. Over the decades, ICs have come to be invested with many distinct goals including the rescue of women from poverty, drudgery and patriarchy. It seems to us that many of the academic researchers, development practitioners, activists and officials who have hitherto taken on the chulha have tried to change too much and have hoped that ICs would be a silver bullet that would solve a host of problems. Perhaps these unrealistic expectations are the problem. We must accept the possibility that some IC technologies will be largely rejected (e.g. solar cookers in rural India) while others will have contradictory impacts. For example, Cornwall (2003) has shown that ICs may improve respiratory health but further entrench social hierarchies. The appeal of ICs to developers is that they offer a technical, cheap, easy and non-controversial fix to what in fact are serious, complex, deeply structural and thus highly political

problems. The IC approach, we argue, is by its very nature reductive and thus doomed to fail to achieve the lofty goals set out. Thus, the chulha story remains a story without a hero.

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