Are Inexpensive Solutions Affordable?

Bio-Sand Water Filters and Improved Wood Stoves in San Miguel Totonicapán

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ABSTRACT: This article explores the efforts of an indigenous non-governmental organisation (NGO) to solve two related problems in San Miguel Totonicapán: the lack of clean drinking water and deforestation. Drawing on participant observation conducted during field stays over 10 years and survey data collected over 18 months, the article examines the affordability of bio-sand drinking water filters and high-efficiency wood cooking stoves. It considers whether savings over typical current practices for the procurement of drinking water and cooking fuel offset the purchase price of new sustainable technologies. The article also outlines data-driven recommendations offered to the NGO. While there are significant obstacles to market distribution, the acquisition of a bio-sand water filter or an improved wood stove makes good economic sense for households that presently purchase drinking water or firewood.

KEYWORDS: air quality, bio-sand water filter, deforestation, indigenous NGO, sustainable development, potable water, San Miguel Totonicapán

Rosa Alvarado is at the *pila* with Emilia Yax.¹ The large, cast concrete reservoir of water is flanked by two drained washing stations. Situated just outside the centre of San Miguel Totonicapán, Guatemala, the household is in a compound of five dwellings, all belonging to members of the same patrilineage. Rosa is Mexican American and a fluent speaker of Spanish, as it is the language of her home and family. Emilia is K'iche' Maya; she speaks Spanish as a second language by virtue of a colonial history that has clear vestiges in the present. Rosa is a college student from Chicago and a guest of Emilia, whose family provides homestay hospitality through a community tourism project.

They work together to wash the breakfast dishes. In the process and over the course of her stay, Rosa learnt that the two spigots that feed the *pila* represent two sources of water. She had noticed that the lines

supplying the faucets leave the house in different directions. Emilia informed her that one set of pipes connects the household to the municipal water supply. It is somewhat reliable and generally not potable, even though municipal authorities occasionally chlorinate the water. Emilia comments that chlorination may make the water free of contamination, but that the smell and taste are unpleasant. She and her neighbours wonder whether the amount of chlorine used by the municipal authorities might make the water harmful to drink. The other faucet is sourced by the water committee (*comité de agua*) that the Yax family and several neighbouring households formed. The *comité* acquired land with a spring, built a collection cistern, and laid pipe to deliver water to member households. In rotation, each household contributes labour to maintenance. When repairs are needed, money is collected to pay for materials and all are

expected to work to return function to the system. Water from the *comité* is generally more reliable and cleaner than municipal water, but is not entirely safe to drink, especially for international guests. As she rinses the dishes that Emilia passes to her, Rosa is reminded that her host family does not treat the cold rinse water with bleach, despite what she had learnt earlier about best practices for dishwashing in rural Guatemala.

Richard G. Fox (2004) encourages ethnographers to recognise continuity as vital to understanding the Maya of the present. Their cultures and communities are neither static reiterations of the past nor constructions from unanchored contingencies of the present moment. Examining Highland Maya environmental and social activism in the context of recent archaeology and ethnohistory on natural resource management reveals contemporary work that reflects both present realities and cultural heritage. In this light, contemporary Highland Maya water and forest management reflect both colonial history and neo-colonial realities. They also manifest a spiritual and political relationship with water that has deep and wide Mesoamerican roots.

Indeed, there is a growing body of work exploring Ancient Maya natural resource management. Arlen Chase and colleagues (2014), in their examination of Maya tropical landscapes, reveal sophisticated land and resource management strategies that carefully combined agriculture, agroforestry, and urban spaces in the Maya lowlands. Research more specific to water management reveals sophisticated engineering employed to collect, direct, and store rainwater (Scarborough et al. 2012). Although these sorts of projects were typically directed by states, ancient Maya water management was not limited to projects organised by government authorities. Indeed, Andrew Wyatt (2014) describes evidence of widespread household- and community-level water management across the Maya Lowlands beginning in the Middle Preclassic (400 BCE). Despite centuries of colonial impositions, household- and community-level water management by indigenous Mesoamericans continued to be a feature of the ecological landscape through the colonial period and into the present. Wyatt (2014) identifies 'numerous examples' of such organisations. In particular, he describes 'waterhole groups' in the Guatemalan Highlands and in the well-studied Tzotzil Maya community of Zinacantan, Chiapas, Mexico.

How state-orchestrated and smaller-scale water management combine can reveal how societies respond to ecological challenges. Chase and colleagues (2014) uncovered a great deal of regional diversity in

how communities and polities responded to resource pressures in the final centuries of the first millennium CE. Interestingly, and relevant to the present discussion, household-level innovations in water management allowed certain regions to withstand drought, while others, lacking such practices, experienced population decline in the same period. Not only does this scholarship enhance our understanding of Maya and Mesoamerican technology, it also reveals interesting tensions between political centralisation and local political autonomy. As Wyatt (2014) points out, a village that manages its own water has little use for the engineers and tax authorities of the city-state. The sorts of public works projects that sustain bureaucracies and legitimise central authorities have little purchase amongst resource-autonomous villages.

In a sense, exploring how resource management in the past is reflected in environmental activism of the present is applied anthropology. If something revealed or reinforced by ethnohistory or archaeology gives greater meaning to efforts towards sustainable improvements in daily living, then anthropology has been appropriately applied.

As it is more directly practised, applied anthropology involves the active listening characteristic of good ethnography and the use of other anthropological approaches to assist groups in efforts to improve their lives in culturally meaningful ways. Accordingly, the work described in this article is applied anthropology because it employs ethnographic field methods to collect data of use to Ajpu Association, an indigenous K'iche' Maya non-governmental organisation (NGO). Ajpu Association seeks to address human and environmental health challenges connected to watershed conditions, and it is involved in the promotion of household solutions as well as in the management of community forest resources. Its work realises a continuation of the Maya political ecology described above. Their efforts reflect the 'quest for autonomy' identified by June Nash (2001) across Maya time and space by working to localise resource management.

The environmental and human health issues that Ajpu Association works to address are unfortunately all too common. Lack of clean drinking water (Vanderzwaag et al. 2009), poor indoor air quality (Ludwinski et al. 2011), and deforestation (United Nations 2015) are widely acknowledged and grave problems. While all three tend to affect most directly the global poor, they are not generally connected in other respects. However, Ajpu Association applies two relatively inexpensive technologies, a household potable water filter and a high-efficiency wood cook-

ing stove, to link these problems in their solution. A rural family that uses a household filtration system to produce drinking water no longer burns firewood to purify contaminated source water. A household that further reduces its firewood use by employing a high-efficiency stove contributes less to deforestation while improving indoor and local outdoor air quality. Healthier forests, in turn, mean healthier watersheds that produce cleaner drinking water.

Based in San Miguel Totonicapán, Guatemala, Ajpu Association produces and distributes bio-sand water filters and improved wood stoves. Reflecting a deliberate expression of K'iche' culture, *Ajpu* refers to one of the spiritual energy essences (*nawal*) identified with days in the Highland Maya ceremonial calendar, *Cholq'ij*. Ajpu is associated with leadership, the ancestors, and the sun. One member once remarked to me that the name is meant to emphasise the light of the sun that illuminates and helps solve problems.

Beyond its intentional cultural identification, Ajpu Association also has the human capital necessary to partly realise its vision. Indeed, with contributions from international NGOs, the group has already installed hundreds of donated filters and stoves in households of some of the neediest families in the region. Association leadership, nonetheless, recognises that, in order to have the greatest impact, market distribution must become a *part* of its strategy. It recently succeeded in founding a financial cooperative that will allow community members to buy water filters and improved stoves on credit (as well as to finance other community development and small business projects). Having reached this goal, Ajpu is developing a strategy to significantly expand its sales of filters and stoves on the open market.

Despite the real need for such filters, the unsubsidised sales of filters and stoves directly to households involve significant challenges. Families that most lack access to clean water are also the ones who are most likely to use wood as their exclusive cooking and water purification fuel. Unfortunately, they are also often the families without the cash to make significant investments in their homes. This is not the case, however, for all households in rural Guatemala. San Miguel Totonicapán, in particular, features a relatively wealthy urban centre of mixed ethnicity surrounded by rural indigenous communities where material poverty is common. In this economic landscape, families in and near the centre often enjoy relatively predictable cash income. Similar to their poorer neighbours, these families often acquire potable water and cook in ways that are expensive and that create negative environmental externalities. However, they

are also more able to purchase Ajpu Association's products. The purpose of this article is to ascertain the viability of this market segment and to generate data-inspired recommendations for the sales of filters and stoves. Before examining the potential market for water filters and improved stoves, I will delineate my methodology and place Ajpu in context and describe the specific technologies in question.

Methodology

For the past 13 years, I have been an advisor to an alternative trade project dedicated to empowering people in need through markets. This work involves twice annual two- to three-week field visits to the Maya Highlands. Our partnership with Ajpu Association began in 2007 with work to market textiles produced by its members. This collaboration eventually shifted to community-engaged research dedicated to the sale of bio-sand drinking water filters and improved wood stoves.

This article began with and draws on participant observation conducted during repeated field stays beginning in 2007 and on video-recorded interviews with stove and filter recipients used for a documentary film and promotional shorts featuring Ajpu Association. Research specifically dedicated to the marketability of the bio-sand filter and improved stove was conducted during three field stays: one in July of 2015, one in December of 2015, and one in July of 2016. Three primary methods were employed: survey, unstructured interview, and participant observation.

The survey was administered to heads of households. We enquired about the procurement, use, and cost of water and firewood. Additionally, investigators asked about awareness of alternatives to the household's current method of obtaining potable water and of generating heat for cooking. Unstructured interviews were conducted with leaders and participants in community-based projects revolving around the protection of water sources, delivery of water to households, and regulation of firewood extraction from community forests. Participant observation examined water and firewood usage in seven households. Researchers lived with K'iche' Maya families over the course of approximately a week and volunteered to help with chores involving any use of water and firewood, from procurement, to cooking, to washing dishes. The intention of the participant observation was to verify data collected in the survey and to uncover patterns in use and practice not revealed or considered in the survey and interviews.

Surveys were administered in the centre of Totonicapán and in nearby *cantones* (satellite villages) with good infrastructure and with relatively abundant cash-earning opportunities. Our intent was to discover whether such areas would be receptive to the purchase of the filters and stoves. Here people are more likely to have cash and to purchase bottled water (typically delivered to the home in reusable five-gallon jugs known as *garrafrones*). As such, we theorised that more families would be interested in technologies as they would have the means to acquire them and would also be able to experience savings directly and immediately.

Six heritage² Spanish speakers administered the surveys with the assistance of the Aventura Maya K'iche' community tourism organisation. The six survey administrators, the author, and five students with limited but formal instruction in Spanish conducted participant observation. Given the zones targeted for research, we expected (and indeed encountered) monolingual Spanish and bilingual (Spanish and K'iche') speakers. Community tourism field assistants were able to provide K'iche'–Spanish translation when (only occasionally) needed.

Additionally, we conducted unstructured interviews with members of organisations dedicated to providing access to potable water and to the protection of communal forests. These interviews took the form of informal group conversations. When leaders were present, conversation was more oriented around a presentation followed by questions. More often, we simply talked with people about their work and experiences. Topics included regulation of firewood extraction, forestry practices, threats to communal forests, maintenance of water delivery systems, watershed and spring protection, landholding and title protection, communal labour requirements, costs of membership, decision-making processes, and so forth.

Ajpu Association and Quiacquix

As specified above, Ajpu Association is based in the *municipio* San Miguel Totonicapán, which has a total estimated population of 125,000 people, roughly 90 per cent of whom identify as K'iche' Maya. It is the largest *municipio* in the department of Totonicapán and is further divided into 48 village (*aldea* or *cantón*) governments. The populations of Totonicapán's rural *cantones* approach 100 per cent indigenous K'iche' Maya. It is one of the remote rural *cantones*, Quiacquix, that Ajpu Association calls home.

At an elevation of 2,650 metres, the *cantón* of Quiacquix is home to about 1,400 people (FCEE 2016). Subsistence agriculture and artisanal weaving are the most common economic pursuits, and a large majority of the households responding (67/86) to our survey report less than Q1,500 (~US\$200) in monthly income (FCEE 2016). Not surprisingly, given these income figures, unemployment is the problem that community members most frequently identify (FCEE 2016). At the same time, people in Quiacquix generally have active spiritual lives, participate in local government, and enjoy strong and wide family and friendship networks. In short, the community is rich in social and cultural life, but poor in cash.

Consistent with scholarly description of local K'iche' attitudes (Conz 2014; Ekern 2008; Veblen 1978), members of Ajpu Association see forest care as a part of their culture and identity. They are K'iche' Maya, a name typically translated as 'People of Many Trees'. Their home community, Quiacquix, is named for a red-thorn bushy tree (*kiäq* 'red', *k'ix* 'thorn') that is prominent in the local landscape. Not surprisingly, Ajpu Association builds solutions to community challenges that emphasise the integration of the social and ecological. In the present case, the construction of water filters and improved wood stoves provides employment opportunities and addresses human health problems while reducing human impact on the environment. Reduced demand for firewood means improved forest and watershed health. People protect the forest, and the forest protects the groundwater. A family and its adjacent forest see substantial and immediate improvements in their health.

Members of Ajpu Association also participate in other local indigenous institutions with ecological functions, something that, no doubt, has influenced their work to reduce firewood consumption. They are active in the management and maintenance of the Quiacquix communal forest. This involves regular tree plantings, the removal of rubbish, fire prevention and suppression, pest management, and so forth. Accordingly, in addition to a world-view that emphasises mutuality amongst the social, natural, and spiritual, Ajpu members (and the community as a whole) have ongoing and direct experience with the state of the forest. They are responsible for the forest's health and understand that there are unhappy and immediate consequences that result from neglect. This combination of culture, agency, and direct familiarity with the impact of mismanagement best explains the cohesive agenda and activity of Ajpu Association.

Not all of Ajpu Association's activities are local and self-developed. Like many other indigenous institutions, Ajpu has relied on transnational NGOs for training, technical support, and funding. The most important of these NGOs is Help for the Highlands of Guatemala Society (HHGS). An independent non-profit organisation based in Calgary, HHGS recently completed a seven-year relationship with Ajpu Association. During this period, HHGS provided technical support and training in addition to support for training through the Centre for Affordable Water and Sanitation Technology (CAWST).³ In addition to support from HHGS, Ajpu has collaborated with US-based churches and inter-denominational groups. This has meant an uneven pattern of employment for workers in the project. For example, a large donation to instal water filters in all of the households of a specified community means steady employment for a small workforce for several months. In periods between such projects, however, fewer people are employed and the workshop is quiet. Ajpu Association leadership hopes that the sales of their products on the market can bridge these gaps and make the organisation less dependent on donations. The purpose of the survey described below is to provide the group with information that will help in the design of a strategy to reach households with sufficient resources to buy bio-sand filters and improved stoves.

Technologies and Application

Before discussing the results of our study, a brief description of the technologies is warranted. The bio-sand filter is a slow sand filter with a layer of standing water above a filtration medium of sand (CAWST 2009). As constructed by Ajpu Association, it consists of a square 30-by-30-centimetre concrete housing that is 94 centimetres tall. A flexible plastic tube runs from the bottom to a spout outlet near the top of the housing. The bottom of the housing is lined with approximately 10 centimetres of gravel, which is topped with about 55 centimetres of carefully selected sand. As the rate of flow is critical to water purification, the filter is calibrated by adjusting the size distribution of the sand according to the time taken for a pre-determined volume of water to pass from introduction into the standing layer through to the receptacle bucket.

A space between the top of the sand and gravel and the spout outlet allows for a stratum of approximately 5 centimetres of standing water. A biologically active layer develops in the sand immediately below this standing water. Before initial use and after

flow-rate calibration, the filter must be charged with water each day for a month. Daily charging feeds and promotes the development of beneficial microbes.

According to the CAWST (2009), four processes allow the bio-sand filter to produce potable water. When new source water is introduced, the first stage of purification occurs in the biologically active layer. Here pathogens are eliminated, as they are predated by beneficial micro-organisms. As water passes through the sand below the bio-cap, '[s]uspended solids and pathogens are physically trapped in the spaces between the . . . grains' (CAWST 2009). Further pathogen elimination and clarification occurs subsequently, as the water passes through the rest of the sand and pathogens are absorbed, becoming 'attached to each other, suspended solids in the water, and the sand grains' (CAWST 2009). Finally, as water makes its way to the deepest layer of sand, natural death occurs as '[p]athogens finish their life cycle or die because there is not enough food or oxygen for them to survive' (CAWST 2009).

In 'Review of Biosand Water Filters' (2017), Bethesda O'Connell and colleagues summarise and evaluate 19 theses, dissertations, and peer-reviewed studies on bio-sand filters, which were published between 2006 and 2013. The field studies evaluated were based on research conducted in Central America, the Caribbean, Southeast Asia, East Africa, West Africa, and Southern Africa. The authors identify a number of limitations in terms of study design, and specify areas for further study. For example, the studies reviewed report filters that remove between 48 per cent and 100 per cent of *Escherichia coli* (*E. coli*), a range that needs further explanation. However, O'Connell and colleagues (2017) conclude that overall 'there is evidence of reduction of diarrhoeal disease and increase in water quality' as a result of the use of bio-sand water filters. One study on the implementation of bio-sand filters in Central America suggests a basis for some of the variability in outcomes. According to Jason Vanderzwaag and colleagues (2009), bio-sand filters in use in Posoltega, Nicaragua, removed 96 per cent of *E. coli*, 98 per cent of total coliforms, and 88 per cent of turbidity. Moreover, filters in use for eight years were shown to be highly effective regardless of maintenance practice. Vanderzwaag and colleagues (2009) do caution that the bio-sand filters that they tested did not completely eliminate *E. coli* from the source water. Accordingly, the filters were not compliant with World Health Organisation standards. However, the study was conducted in a coastal region with poor drainage and sanitation. In highland regions, drain-

age and source water are generally better. Moreover, the common development of human tolerance to low levels of microbes in local water sources further suggests the efficacy of the filter. Indeed, according to a Landivar University study of Quiacquix (FCEE 2016), where bio-sand filter use is common, only 16 of 278 households indicated stomach difficulties and gastritis (combined) as the most frequent health problem encountered within the family. 'Tap water gives us stomach aches and headaches', reported one recipient in the community, relating how the bio-sand filter improved the health of her family. In comparison, 215 households cited influenza (*gripe*) and cold (*resfriados*) as their most common health problems (FCEE 2016). The bio-sand filter, therefore, is an appropriate technology for the environment where Ajpu Association is currently working to implement it. It is very effective in purifying source water that is generally good but not quite fit for consumption.

The environmental impact of the bio-sand filter is indirect. If a household boils to purify drinking water, the fuel spent is reduced by the bio-sand filter. However, participant observation reveals that women often keep water on the cooking surface as they build the fire and cook meals. As such, their use of firewood to boil water is already relatively efficient. On the other hand, families that use propane gas reduce their consumption with the adoption of the bio-sand filter, as one burner is no longer ignited to purify water. However, such fuel savings are also difficult to calculate, and real environmental benefit will be paid through the widespread adoption of bio-sand filters. Ajpu Association works to instal filters and stoves together, and it makes sense. A small long-term savings is added to the dramatic immediate one described next.

Since 1970, a variety of governmental organisations and NGOs have been promoting improved cooking stoves with the goal of addressing dire human and environmental health problems in developing countries (Urmee and Gyamfi 2014). In their review of such programmes and technologies, Tania Urmee and Samuel Gyamfi note a great diversity in the design, construction, distribution, and long-term success of improved cookstoves worldwide. Amongst the technologies reviewed is the Onil stove of similar design to the stove utilised by Ajpu Association. Also, consistent with Ajpu Association's approach, Urmee and Gyamfi (2014) stress the need for a 'bottom-up' approach that emphasises local ecology, economy, and culture.

Similar to other improved cookstoves, the Onil stove achieves reduced firewood consumption and

diminished indoor pollution through high-temperature combustion (Urmee and Gyamfi 2014). A very hot burn is achieved by combining the firebox size, firebox shape, firebox material, and flue design. As a result, oils that contribute to soot and dirty smoke are fully consumed and far less wood is needed to achieve heat for cooking (Ludwinski et al. 2011). However, the original Onil stove did not achieve much adoption in Quiacquix or in Totonicapán. Its no-nonsense design does little to suggest a point of gathering. Although bulkier and less efficient, the commonplace *pollo* brick-and-iron stove provides a place for a family to eat the late evening dinner together. The thick wall of a typical *pollo* provides a place to rest food while eating supper, and the stove becomes an expedient kitchen table. At 8,000 feet above sea level or higher, the warmth of the stove and cooking area is no small consideration. Recognising this flaw in the original Onil stove, Ajpu Association designers added a small, ceramic tile surface around three sides of their *ecoplancha*. This modification has improved the acceptance of the stove, as it does not require a family to alter its dining routine (reflecting one of Urmee and Gyamfi's [2014] findings regarding patterns of adoption or rejection).

According to Daniel Ludwinski and colleagues (2011), Onil-type stoves result in considerable firewood savings over conventional wood stoves and open fires. The data collected in Panyebar, Guatemala, indicates that adoption of an improved stove meant the conservation of one full-grown white pine tree per household annually. Moreover, subjects reported a significant decrease in coughing and other symptoms related to poor, smoky indoor air (Ludwinski et al. 2011). Recipients of the Ajpu Association *ecoplancha* report similar firewood savings and improvements in indoor air quality (although not in response to a systematic study as in the case of Ludwinski et al.). One recipient noted that cooking over an open fire 'gave us sore throat, pain in the eyes, headaches'. Additionally, constructed of reinforced concrete, firebrick, and steel, the *ecoplancha* is extremely durable. Replacement of its galvanised steel chimney (about Q150 or US\$20) every five to ten years is the most significant upkeep cost. A family can expect the stove to last indefinitely.

Water Procurement and Usage

We surveyed 57 households regarding water usage. The average household reported consuming 7.9 litres of drinking water per day. Families that buy water

(37) reported an average weekly cost of Q13.4 (about US\$1.80). In addition to queries about consumption and cost, we asked respondents about their purification and procurement practices and their awareness and consideration of alternative methods of obtaining safe drinking water. We found interest in alternative potable water systems, but a lack of awareness of bio-sand filters. About 60 per cent (34/57) of survey respondents reported that they were unaware of home-based potable water filtration systems. Bio-sand filters were even less well known, with about three quarters (42/57) of respondents professing no knowledge of the system.

At the same time, respondents generally expressed interest in learning more about bio-sand filters. They also indicated that they had considered alternatives already. Of the 48 households that reported boiling as their method of water purification, 20 (about 40 per cent) had considered alternatives to the tried-and-true method. Eight considered purchasing water, six considered treatment with bleach, five considered filtration, two considered participation in a community project, and two considered construction of a well. Of the 37 families that purchase water, seven had considered alternative methods. Three explored community projects, three considered boiling, two considered filtration, one considered treatment with bleach, and one considered construction of a well. Additionally, consultants in participant observation households and community water activists also indicated interest in the bio-sand system. Accordingly, we concluded that there was widespread concern amongst indigenous Totonicapenses about how potable water was procured and that there was receptiveness to alternative methods of obtaining it.

However, our findings regarding price expectation suggest that there are significant obstacles to a market-based distribution of the bio-sand filter. Most respondents were not willing to hazard a guess as to a price that they would pay (often citing lack of information). The few (9) who did suggest a specific price that they would pay for such a system indicated an average of Q250, which was significantly lower than the actual production cost of Q675. Moreover, cost was the leading reason cited for not changing water procurement practice. Even in relatively wealthy sections of the community, families are frequently cash-strapped and stable cash-earning opportunities are scarce. Moreover, a general distrust of credit systems means that families are reticent to take loans. Generally high interest rates and uncertainty about future income combine to represent a threat to the existence of future cash resources.

While these are significant obstacles, our data also indicates that, despite the high initial cost, there is good reason for certain families to invest scarce resources in a bio-sand filter. For households that purchase bottled water, the average cost of Q13.4 (about US\$1.80) per week is a significant expense. Accordingly, the payback period for the investment in a bio-sand filter is under 60 weeks (at a purchase price of Q800). Given the filter's longevity and its low maintenance cost (Vanderzwaag et al. 2009), a family will experience significant and long-lasting weekly savings beginning approximately 14 months after purchase.

The savings for families that boil water are less immediate and more difficult to calculate. Costs for water delivery via the municipal government or through a water committee are minimal. They are even less if family members fetch water from a spring or community faucet. Moreover, if a family uses firewood obtained by its own labour from a community forest, as Ludwinski and colleagues (2011) indicate, the cost is not monetised. It is either paid in uncompensated labour or potential deforestation. I will address firewood consumption in more detail below in my discussion of firewood survey results.

Additionally, in wealthier areas that have suitable infrastructure, propane gas is a common cooking fuel. While we did not query respondents regarding gas expenditures, respondents who boil their water seemed not to take fuel costs into account when they considered their water expense. As such, the bio-sand filter does offer potential savings for families that cook with gas, but they are difficult to estimate. Accordingly, another advantage of the filter, superior flavour, may make the minor savings more attractive.

In addition to high cost, scepticism about credit, and uncertainty regarding savings for some families, another potential obstacle to sales of the bio-sand water filter was municipal water supply practice. Field consultants reported that the water supply in the city centre of Totonicapán was *occasionally* chlorinated. As discussed above, the bio-sand filter relies partly on microbial action in the top layer of the filtration medium. Chlorinated water poses a threat to the bio-cap, and the efficacy of the filter would thereby potentially be compromised. Accordingly, for the bio-sand water filter to be optimally effective, a family living in the centre would have to know beforehand whether the supply water was to be treated with chlorine in order to protect the biologically active layer of the system. Alternatively, the family would have to allow the bio-cap to regenerate following the introduction of chlorinated water. For significant period of time, members of the household

would have to charge the filter daily but not use the water produced. Because the chlorination schedule is not regular, both of these procedures would carry a degree of risk and uncertainty. A family could potentially consume water that it believes to be safer than it actually is. As discussed above, households in the urban centre are generally wealthier and more likely to be paying cash for the delivery of bottled water. Accordingly, the bio-sand filter was rendered inappropriate for a large concentration of potential clients because of current municipal water management practice.

Despite these obstacles, our data is clear that a bio-sand filter would pay for itself relatively quickly if it were to be adopted in place of purchasing bottled water. Accordingly, in addition to targeting households that buy water we made two recommendations.

First, the non-governmental water committees (*comités de agua*) are a critical audience for education regarding bio-sand filters. As described in the opening fieldwork narrative, these groups provide water for groups of families by acquiring land with springs and developing infrastructure to deliver water to their homes. By necessity, most families reside in zones without chlorinated municipal water. Most importantly, they meet regularly and there are existing relationships among member families. Given these ties, neighbouring households within the committee may be receptive to divide the purchase of a bio-sand filter. Its capacity of 48–60 litres per day⁴ is more than adequate for two to four families at the potable water consumption levels reported in our survey. As such, each family would have a significantly smaller cash outlay.

Participant observation data reveals another potential advantage of the bio-sand filter. Its high capacity (Vanderzwaag et al. 2009) means that users have a ready supply of safe water for washing produce in food preparation. We also observed that people generally wash dishes with cold water without adding bleach. A possible source of water-borne illness could be eliminated with the use of bio-sand filtered water for dishwashing, especially in the final rinse stage of washing. This is particularly true for the rainy season, when high humidity and limited sunlight make air-drying less effective.

Firewood Procurement and Use

Standing in a clean bright kitchen, Ana seems both nervous and proud to have foreign guests in her household. She is very pleased with her *ecoplancha*

and testifies extensively about its benefits. ‘For this reason’, she said, ‘we asked them the favour of giving us one [an improved stove] to make things faster because with an open fire, one tires more, one gets sooty more than anything’. Pointing to the small firebox, she goes on: ‘Not with this one, you see, I just put in two sticks of firewood’.

Ana shows us a large pot of nixtamalising maize as it approaches a boil. She lifts the cover from one of the unused rear burners, revealing a veritable jet of flame drawn to the back of the stove by the carefully placed chimney. ‘Before we used more firewood, and moreover, as one is poor, the money doesn’t [always] reach.’

After explaining how the household has cut its firewood expenditures by half, Ana describes other benefits. ‘[With an open fire], one’s eyes are really bothered because how the smoke burns, so one begins to cry. . . . Sometimes, just because of smoke one has to buy glasses, how the smoke burns. . . . Now it is better as the smoke no longer gathers. Before, there was a lot of smoke. Now, thank God, the smoke goes outside. The metal roofing panels and clay tiles are no longer ruined’.

The most compelling evidence for improvement, however, comes as we move into the room that she uses to store firewood and various implements. Its walls are black, and, although there is no sign of a fire, it smells of smoke and soot. One of the visitors gasps as Ana recounts that this was the space where she cooked before she received her *ecoplancha*. The soot mutely supports Ana’s testimony regarding improvement in her quality of life. While forest health is important, for Ana *human* health is most immediately benefitted by her new stove.

We surveyed 57 households regarding cooking method and firewood use. We asked respondents to identify which of four types of stoves they had in the home. These were: (1) the *ixku’p*, an open fire surrounded by three stones; (2) the *pollo*, a large brick or concrete stove with an iron cooking surface; (3) the propane-gas-fuelled mass-produced stove; and (4) the improved wood stove or *ecoplancha*. We also enquired about firewood consumption and expenditure as well as awareness and consideration of alternatives to the present method of cooking.

Forty-seven households had either an *ixku’p* or a *pollo*, indicating use of firewood as a cooking fuel by a large majority of respondents. That is, a significant number of households could realise savings by adopting a more efficient wood stove. Forty-six households cook with gas. This is not a surprise, given that we deliberately conducted the surveys in

zones and villages close to primary roads and with good cash-earning opportunities. They can afford a gas stove, and there is sufficient infrastructure for cheap delivery of propane tanks. Accordingly, quite a few of the families (37) with a gas stove also had a wood-burning *pollo* or, less frequently, an *ixku'p*.

Participant observation revealed that a wood-burning stove was employed on special occasions, while the gas stove was the more common tool for everyday cooking. However, a wood-fired iron is said to produce a better tasting tortilla or toasted tamale and is frequently used simultaneously with a gas stove. A new stove is not always acquired as a total replacement for an old stove, and presentation of the *ecoplancha* to potential customers should consider simultaneous or complementary use.

Households that relied at least partly on a wood-fired stove reported Q134 in average weekly firewood expenses. This is significantly more than the Q71 reported by Ludwinski and colleagues (2011). Our results feature a mode of responses at Q300 to Q350 per week, and we suspect that some of our respondents may be using firewood in the commercial production of ceramics. If we remove these responses, the average reported weekly firewood expense declines to Q113 (about US\$15) per week, which is still higher than that reported by Ludwinski and colleagues (2011). The higher cost of living in Totonicapán may have been partly driving this difference. In any event, both studies reveal that relative to income, indigenous Guatemalan families were (and are) expending considerable resources in procuring firewood.

Our findings about awareness of the improved wood stove are similar to our results regarding the bio-sand filter. Fifty-six per cent (32/57) of respondents reported no knowledge of the improved wood stove. About one quarter (14/57) indicated some familiarity with the Onil-type stove. Only about one fifth (11/57) had extensive knowledge of the reduced consumption and the higher efficiency of the improved stove.

There seems to have been similar interest in the new stove to what we found regarding the bio-sand filter. A large majority of respondents (41/57) were not willing to indicate how much they would pay. Those who did respond stated a willingness to pay Q675 on average.⁵ The *ecoplancha* to be offered by Ajpu Association costs about Q900 to produce.

Despite reticence about the price, as with the bio-sand filter there is good reason for families to acquire the improved wood stove. If we assume approximately 50 per cent reduction in firewood consump-

tion (consistent with what recipients reported and below the 60 per cent calculated in Ludwinski and colleagues' study of 2011), the average payback period for respondents in our study would be less than 22 weeks. Given the wide range of reported weekly firewood costs (from Q18.75 to Q350), we recommended the creation of a reference sheet that would allow household decision-makers to know their specific payback period. For example, a family that pays only Q80 per week would still have significant savings and could expect payback in about 30 weeks. These figures are impressive and may sound too good to be true to a potential client. This is not an unreasonable response, given the tendency of well-intentioned outsiders to promote technologies that prove more expensive and less practical than promised. Under the system that we recommended, a family would record its spending for a specified period before and after installation of the *ecoplancha*. The real difference in cost would become the basis for a periodic payment plan whereby the family is guaranteed no additional expense. A similar system would serve bio-sand filter sales as well. Of course, these payment plans would need to be developed in consultation with the financial cooperative. Given the short payback time, however, there should be plenty of room for the cooperative to cover its expenses and generate a profit for its membership while keeping payments in line with existing household expenditures.

Households with very little cash faced additional obstacles to adopting the improved stove. Because such families typically gathered their own firewood from community forests, they tended not to perceive fuel procurement as a cash expense. To address this problem, Ludwinski and colleagues (2011) suggest a firewood bank system whereby a family continues to gather firewood but sells the excess fuel to the stove provider. The provider then resells the firewood to recoup its costs. Although the environmental benefit is delayed, the family's firewood use and labour would decline significantly once the stove is paid off. We discussed this system and other in-kind payment arrangements with Ajpu Association leadership. Nevertheless, remote and cash-strapped families may be better suited for sliding-scale pricing or outright donation schemes. In addition to aiding the people most in need, reduced-price or free stoves in such communities will be an environmental benefit for the entire *municipio* and provide a rationale for local government subsidisation.

Towards the other end of the wealth spectrum are families with gas stoves. At first examination, these households seemed to be the least likely to be inter-

ested in acquiring a stove that promises drastically reduced firewood costs. However, participant observation suggested that families with gas stoves may be interested in replacing an auxiliary *pollo* with an *ecoplancha* to achieve improved air quality and overall cleanliness. The improved wood stove produces cleaner smoke, less soot, and fine, clean ash (which can serve as a soil additive or mild abrasive for cleaning). Reduced smoke and ease of cleaning are the features to stress to households with a gas stove and an auxiliary *pollo* or *ixku'p*.

Before proceeding to our conclusions, I will address a recommendation that applies to both the stove and the filter. As with the suggestions made above, these were offered first to Ajpu Association, but they are also intended to inform any organisation or partner group that is currently working towards market-based solutions to human health and environmental health issues.

First, as awareness of both technologies is lacking, we recommended a media campaign utilising departmental and regional radio and cable television outlets. An extended-family weaving cooperative based in Totonicapán had success in drawing clients from remote parts of the department by airing a television commercial on a local cable television channel. The commercial emphasised the indigenous identity of the weavers and their art. We produced a similar advertisement for Ajpu Association. With Spanish and K'iche' versions, the spot is intended to raise awareness of the technologies, but also to promote the notion that native Maya people could purchase useful products from an indigenous enterprise. Ajpu Association has not been able to obtain the funds needed to air the commercial. However, the newly established cooperative may provide financing for investment in an advertising campaign.

In summary, our main recommendations for open market sales are:

- Focus direct outreach on *cantones* close to the centre not yet served by municipal water service.
- Target water committees within these *cantones*.
- Create payment plans based on the purchaser's current firewood/water expenditures.
- Air commercials on local cable outlets viewed commonly in the Highlands.

Conclusion

Much as Ajpu Association connects the bio-sand filter and *ecoplancha* in installation, the marketability of the

two technologies is connected by common characteristics. Both present potential savings that are most apparent for households with particular practices. Families that purchase firewood or bottled water will find that an improved wood stove or bio-sand water filter will pay for itself in a period typically less than a year and a half. As such, there is great potential household financial gain as well as human and environmental health benefits.

Both also confront significant obstacles to marketability. First, there is a lack of awareness regarding the technologies and their cost effectiveness. There are proven methods to address this issue, but so far a lack of capital to finance an advertising campaign has been a barrier. Ajpu Association hopes to overcome this barrier soon.

Moreover, the people most able to purchase the improved wood stove are also likely already using gas stoves. Analogously, the zones with a high density of households that purchase bottled water are also served by a municipal water system whose practices make the bio-sand filter less effective. Families in the urban centre are provided tap water that is occasionally safe to drink. Unfortunately, using a bio-sand filter would make this water occasionally questionable to drink. This is not a real improvement, and boiling or purchasing bottled water will continue to be the best options for urban Totonicapenses until municipal water chlorination practices are altered.

Not surprisingly, households that do not purchase bottled water or that gather firewood tend not to have disposable cash. They also hold justifiable suspicion of credit and payment schemes. Their margin for error is very small, and they are understandably risk-averse in decisions regarding their scarce cash. Moreover, the time and effort needed to gather firewood and to boil water do not represent a cash outlay. These non-monetised costs are difficult to perceive as savings when they are to be eliminated at some future moment.

Similarly, while there is awareness that smoky indoor wood stoves and improperly treated water can cause illness, the onset of such maladies is unpredictable and subject to a variety of known and unknown factors. The cash spent or loan taken to acquire a bio-sand filter or an *ecoplancha* is real. The fees for the doctor or lost productivities due to illness are potential, and there is no guarantee that the new stove or filter will eliminate possible episodes of ill health. The lack of cash amongst the poorest households is thus an entrenched and self-reinforcing obstacle. These are, unfortunately, the families that would benefit most from the technologies, illustrat-

ing how poverty and poor health can form a vicious cycle. In this respect, the present study confirms a raft of scholarship debunking the notion that such problems are primarily technical. Two proven, low-cost technologies that address pressing health and environmental challenges are only slowly being adopted. Resistance to change is not the issue. An array of related structural, economic, and political factors are keeping viable solutions out of the hands of those who most need them. As such, Ajpu Association's plan to use profits from sales to subsidise or donate filters and stoves to the neediest families is a critical and necessary part of the solution. Moreover, the work of transnational groups to pay the association to instal filters and stoves in poor households remains critical (even if subsidies to consumers are less than ideal [Urmee and Gyamfi 2014]).

As complex and interlinked as environmental problems and poverty are, it should be clear that solutions must take into account an array of factors both particular to the local and rooted in macro-social forces. Yet, these problems are too often framed simplistically and attributed to the poor and marginalised themselves. In parallel, solutions to complex problems are still often presented as largely technical. The present case suggests that multiple approaches are necessary to address the related problems of cash poverty, lack of access to clean drinking water, and deforestation. Furthermore, no one means of distribution should be given priority across cases without careful consideration of circumstances on the ground. Accordingly, solutions will necessarily involve varied combinations of NGOs, private enterprises, and government initiatives.

That said, state action has been left largely out of the discussion. This reflects a weak state justified by a strong and enduring global current of neoliberal governance. The state neglects what is commonly seen as a basic government function: the provision of decent water. It also is a product of an insistence on political and cultural autonomy. Mayas, as they have for centuries, keep the state at arm's length by solving their own water and forest resource management challenges. Although well established in the Maya region, government inaction in the domain of water is not typical, and it inspires some parting questions. Does Ajpu Association (and similar efforts by other groups) relieve the state of a primary responsibility? What are the implications if the state does not achieve legitimacy by this tried-and-true method? Can a nation-state function when other (and occasionally unofficial) levels of government are viewed as more legitimate and are experienced as more effective?

Given the recent history of the state's recourse to violence to compel rural Maya populations to 'progress', these are not insignificant questions.

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Notes

1. All persons described in this article are identified by pseudonyms.
2. Students born in the US but raised in Spanish-speaking homes.
3. Beyond water and sanitation projects, HHGS also provided funding for training and various education and community development initiatives, including a village savings and loan programme, a women's self-esteem development programme, and sponsorship of an extensive community study (FCEE, 2016). HHGS's goal was to build capacity in the community for economic self-sufficiency so that the people of Quiacquix could realise their own development and life project agendas.
4. Personal correspondence with Bill Skinner of HHGS.
5. An outlier, at more than twice the next lowest response, was removed from the calculation of the average.

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