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EVALUATING USER INTENTION FOR UPTAKE OF CLEAN TECHNOLOGIES USING THE THEORY OF PLANNED BEHAVIOR

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ABSTRACT

Understanding and integrating a user's decision-making process into design and implementation strategies for clean energy technologies may lead to higher product adoption rates and ultimately increased impacts, particularly for those products that require a change in habit or behavior. To evaluate the key attributes that formulate a user's decision-making behavior to adopt a new clean technology, this study presents the application of the Theory of Planned Behavior, a method to quantify the main psychological attributes that make up a user's intention for health and environmental behaviors. This theory was applied to the study of biomass cookstoves. Surveys in two rural communities in Honduras and Uganda were conducted to evaluate households' intentions regarding adoption of improved biomass cookstoves. Multiple ordered logistic regressions method presented the most statistically significant results for the collected data of the case studies. Baseline results showed users had a significant positive mindset to replace their traditional practices. In Honduras, users valued smoke reduction more than other attributes and in average the odds for a household with slightly higher attitude toward reducing smoke emissions were 2.1 times greater to use a clean technology than someone who did not value smoke reduction as much. In Uganda, less firewood consumption was the most important attribute and on average the odds for households were 1.9 times more to adopt a clean technology to save fuel than someone who did not value fuelwood saving as much. After two months of using a cookstove, in Honduras, households' perception of the feasibility of replacing traditional stoves, or perceived behavioral control, slightly decreased suggesting that as users became more familiar with the clean technology they perceived less hindrances to change their traditional habits. Information such as this could be utilized for design of the technologies that require user behavior changes to be effective.

INTRODUCTION

Understanding how consumers make decisions about engaging with products can help designers to develop more desirable technologies and targeted marketing materials to generate increased market share. For energy-efficiency and other clean technologies, this can also result in increased uptake and sustained adoption, ultimately leading to greater environmental impact [1]. One way to describe this decision-making process is through modeling the attributes that influence a person's intention to use a technology. Intention is the central factor that determines whether an action is performed, and indicates an individual's openness and the level of effort they are willing to exert to conduct an action [2]. This study investigates and applies the Theory of Planned Behavior, a quantitative theory from psychology to evaluate household's intentions related to adopting clean technologies.

One example of an energy-efficient technology where user adoption is critical is that of improved cookstoves (ICS). Currently, traditional open fire cooking has a multitude of negative consequences on livelihoods for people in rural developing communities. For 2.7 billion of the world's population, firewood is the primary source of energy and can meet more than 90% of a households' energy needs for cooking and heating [3]-[4]. Household air pollution from incomplete combustion contributes to 3.5-4 million premature deaths every year, representing the second leading cause of death for women globally [5]-[6]. Contributions to global climate change are also significant, as recent estimates show 34 – 45% of the warming due to black carbon is generated by traditional biomass combustion, and up to 8% of warming overall [7]-[8]. To address these challenges, many types of ICS have been developed and widely disseminated with the goal of increasing the heat transfer and combustion efficiency of biomass combustion, thereby reducing the emission of toxic chemicals, and consuming less firewood to complete the cooking tasks. However, despite the potentially significant benefits to livelihoods and climate, low adoption rates are observed in many projects [9]-[10]-[11]. Some studies suggest that systematic integration of users in design and implementation can lead to increased uptake [5]-[8]-[9], and there is significant need for research in this area.

There are a variety of methods to predict human behavior through quantitative approaches. These are often applied in research into health and environmental behaviors. One of the more prominent of these methods, The Theory of Planned Behavior (TPB), intends to predict individuals' behaviors based on the attributes that form their intentions. In this method, intentions are considered the main determinant of behavior, and are based on three categories of beliefs: behavioral, normative, and control. Behavioral beliefs describe the attitude toward behavior that captures an individual's personal beliefs and evaluations regarding an action. Normative beliefs are the outcomes of society's norms and an individual's evaluation regarding social norms related to their behavior. Control beliefs determine the level of control an individual perceives that they have for conducting or avoiding a particular behavior. TPB is one of the well-established user behavioral intention analysis methodologies that proposes a systematic and efficient evaluation of the attributes that lead to reasoned behavior.

The goal of this study is to better understand the motivation for consumers to adopt clean technologies such as ICS through application of TPB. Household surveys were developed to describe the three categories of TPB through Likert-scale survey questions to evaluate the influential attributes of the intention for stove adoption. The surveys were implemented in 380 rural households in Copan Ruinas, Honduras and 110 rural households in Apac, Uganda both before and after provisioning ICS. The survey results were analyzed using multiple regression analysis to determine the factors most significant to the household decision-making process. Results of this study introduce a new approach for design and implementation of the clean technologies that demand user behavior modifications to be effective.

BACKGROUND

By nature, consumers are faced with a number of competing preferences and objectives. It is therefore necessary to formulate the product design and dissemination strategy based on an understanding of their priorities. Despite the potential positive impacts of using clean energy technologies such as solar panels, electric vehicles, or cookstoves, successful user adoption of such products can be a challenge because the technology must be in well enough aligned with the user's needs and motivations that they choose to change their traditional behavior. For example, a study in Malaysia ranked multiple attributes associated with small scale household renewable energy adoption such as awareness, ease of use, cost, perceived behavioral control, and relative advantage [14]. Results of their study suggest that manufacturers should provide technologies that are easy to use in order to increase the likelihood of users' uptake. In addition, a study in 1994 reviewed a survey of 137 stove dissemination programs to evaluate main reasons for success and failure of such projects [15]. This study suggested that widespread adoption requires both engineering advancements and effective involvement of both users and local manufacturers. They argue that considering the needs of main consumers, in this case the female cooks, when designing the stoves is crucial for increasing the likelihood of bringing benefits of ICSs to more people. Therefore, incorporating the users into the design process by understanding their motivations and decision-making process is known to be essential to successful dissemination but still remains a challenge over 20 years from the time of that study.

Aspects of Technology Adoption

A clean energy technology should align with users' attitudes and beliefs to benefit both the user and environment. Addressing consumer preferences is not limited to only the design of a user-centered technology, but also the development of strategies that convert the *need* into *demand* for the technology [16]. Understanding how women, as the main cooks, prioritize cleaner cooking practices over other household goals highlights the importance of user-centered technology design and distribution. If the households do not perceive the importance of changing their cooking behavior, it is less likely for them to adopt a new cooking technology. A user-centered study in urban settings in India monitored user behavior in early stages of improved cookstove adoption for six weeks [17]. Results revealed that although the single user studied expressed interest in cooking with the ICS, her experience with the stove led her not to. Based on her habits she did not regularly remove the ashes from the stove, and she only used one of the two burners provided, reducing the ICS efficiency significantly. Finally, she perceived less smoke emission of ICS as a drawback since smoke keeps mosquitos away during cooking. In this case, lack of user-centered design and attention to the user's attitude toward behavior and habits resulted in a less efficient and more burdensome experience for the user. Thus, a user's attitude toward cooking and her evaluation of the cooking experience plays an important role in her adoption decision and reflects her motivation to change her behavior.

Cooking is an activity that occurs multiple times each day and traditional cooking practices are deeply entrenched in a culture. As a result, rapid technology dissemination along with a brief informational campaign without any support or follow up in later stages is not likely to impact household's behavior over time. A long-term study in rural India followed stove adoption behavior in a community for four years [18]. Their results indicated that even though the performance of the introduced technology was effective in laboratory tests, low stove valuation by users prevented improvements in health or firewood consumption because the stoves were not used frequently enough to displace traditional cooking methods. Their study concluded that if users decide not to use the stove regularly and properly, avoid regular maintenance, or do not update their beliefs about how to use it, the desired health and fuel savings may not be achieved. Therefore, it is important to update users' attitude and knowledge about the importance of changing traditional cooking methods. A similar study in rural Bangladesh traced low ICS adoption rates to lack of user valuation regarding importance of the cleaner cooking practices, despite that 94% of respondents believed that smoke emissions of traditional cooking practices are unhealthy [13]. That study determined that cleaner cooking practices had a lower priority in the household than several other demands such as sanitary latrines, electricity access, school attendance, and doctor consultations. As a result, information campaigns to inform households regarding negative consequences of traditional practices combined with more user-oriented technologies were recommended to achieve higher adoption rates.

Information campaigns can effectively increase public awareness regarding the issues associated with inefficient practices and present technological alternatives as a solution, helping to not only inform users about issues but also to increase social influence to adopt clean energy technologies in a community. Recent works in discrete choice analysis suggest that choices are social, meaning that society plays an important role in influencing users for making decisions [19]. This social pressure is a function of community scale social relationships, where bonding social capital, or the intra-communal links, can significantly contribute to the likelihood of individual technology usage [20]. This means that households are more likely to adopt a technology if their social ties are satisfied with it and less likely to keep using a technology if their trusted peers discourage them because of failed performance or other negative experiences. Although the role of information campaigns can be significant, they are not enough for households to keep using technologies if social pressure dictates otherwise. A study in rural north India showed only a 25% chance for a household who is aware of the negative effects of traditional stoves to own an ICS [12]. A willingness-to-pay analysis in these households suggested that user preferences must be better understood and incorporated to develop more effective policies to address low adoption rates.

One of the most practiced methods to update users' preferences for changing their behavior, for positive actions such as handwashing or recycling, is through behavior change communications (BCC) [21]. There are multiple methods that inform individuals regarding their behaviors with the aim to reduce the negative health or environmental impacts of current behaviors such as nutrition sensitive agriculture [22], water treatment interventions [23], and sanitation and hygiene improvement [24]. Regarding traditional cooking practices, a study in four lower-middle income countries indicated affordability as the main barrier for them to adopt an ICS. However, many of the respondents who expressed this also had discretionary consumer items such as TVs and mobile phones at the time of the survey [25]. The authors suggest that effective BCC techniques should be applied for increasing awareness to encourage users to prioritize the ICS usage over other goals.

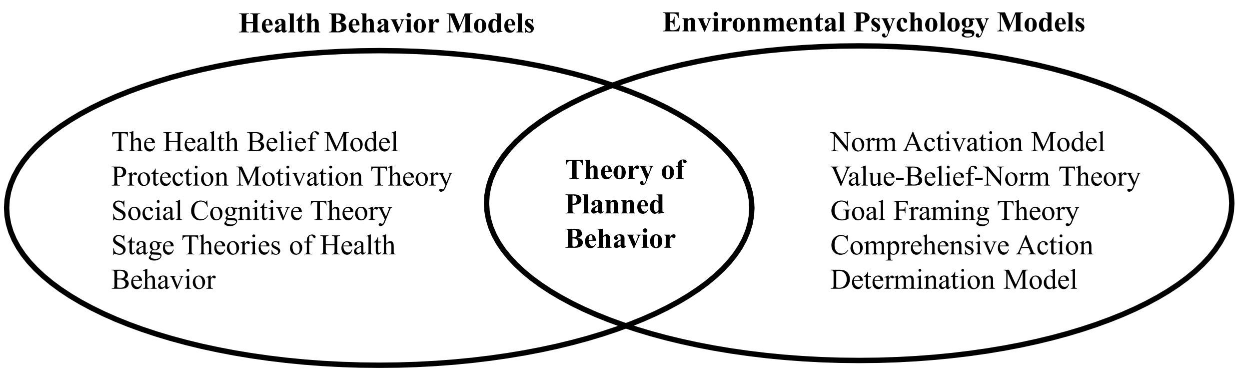
Although the BCC is important in increasing the awareness regarding improvements in health associated with adopting a clean technology, increasing awareness may lead to technology acquisition but not necessarily technology usage. Some of the works in the field of technology adoption that investigate the role of BCC assume the technology ownership translates to the technology adoption [25]. However in the case of ICS adoption, there are different attributes that must be addressed along with effective supply side policies to lead to gradual transition of households from traditional practices to ICS [26]. These include financing options for buying ICS, cultural considerations, and effective user engagement. Such a transition driven by consistent and correct use of ICS will eventually maximize the benefits of ICS adoption.

Consistent usage is the ultimate goal of clean technology diffusion projects and can occur when three conditions are met: (1) the individual has the opportunity to adopt the technology, (2) the individual is able to work with it, and (3) the individual is motivated to change their behavior [27]. These conditions can be achieved via user-oriented recommendations to improve impacts of technology projects including developing user manuals and trainings that are accessible to the audience, design for usability, and customer service after a sale [28].

Models of Behavior

Although various studies have identified attributes that influence individuals' decision-making regarding technology adoption, there is a need for improved systematic and comprehensive analysis of these significant attributes. Because user preferences and values are reflected through their intentions, a better understanding of users' behavioral intention could potentially inform the designers and project implementers about best approaches for technology design and dissemination to improve adoption. Borrowing methods from other sectors may enable researchers to better characterize these intentions in terms of adoption of energy efficient technologies. In order to develop a method that incorporates these aspects of the decision-making process, theories from disciplines beyond typical engineering design are needed.

There have been several methods developed to predict health and environmental behaviors from a psychological perspective. Beyond financial aspects, adopting a clean technology encompasses the health and environmental beliefs of decision-makers. Clean technologies may perform the same tasks as conventional technologies, but with less negative consequences to environment and/or health. Since such environmental or health impacts may be intangible or long-term, the benefit of using clean technologies may not be instant and perceivable by users. Therefore, it is important to predict environmental and health based on the literature of available methodologies that are proven to successfully predict such behaviors. Using systematic models of these beliefs and behaviors, clean technologies and diffusion strategies could be more user-oriented, ultimately leading to higher usage. Therefore, the intention should be described in terms of the behaviors related to both health and environment contexts. Figure 1 shows the methods developed in the behavioral health and environmental psychology fields for predicting behavior [29]. The left circle describes existing methodologies that are prominent in predicting health related behaviors based on social cognition models reviewed by Conner and Norman [30]. Beyond



medium-to-large intention change is likely to lead to a small-to-medium behavior change [37].

TPB is based upon the assumption that human behavior is a direct function of individual's intention. According to this theory, the intention is composed of three categories of attributes that form the decision:

1. Attitude toward behavior
2. Social and subjective norms regarding a specific behavior
3. Perception of the control an individual has regarding the behavior

Belief and evaluation are two determinants of an individual's opinion regarding a specific behavior [38]. Therefore, an individual's attitude toward behavior is the outcome of her personal beliefs and her evaluation regarding validity of such beliefs. Similarly, an individual's related value for subjective norms is the outcome of her normative beliefs, beliefs about whether people important to the person approve or disapprove the behavior, and her evaluation of the social pressure for conforming to such normative beliefs. And, the person's perception for the control she has over the behavior is a function of her control beliefs and the power she feels in such control beliefs.

Health and environmental behaviors are among the most frequent applications of TPB. Food consumption decisions [39],

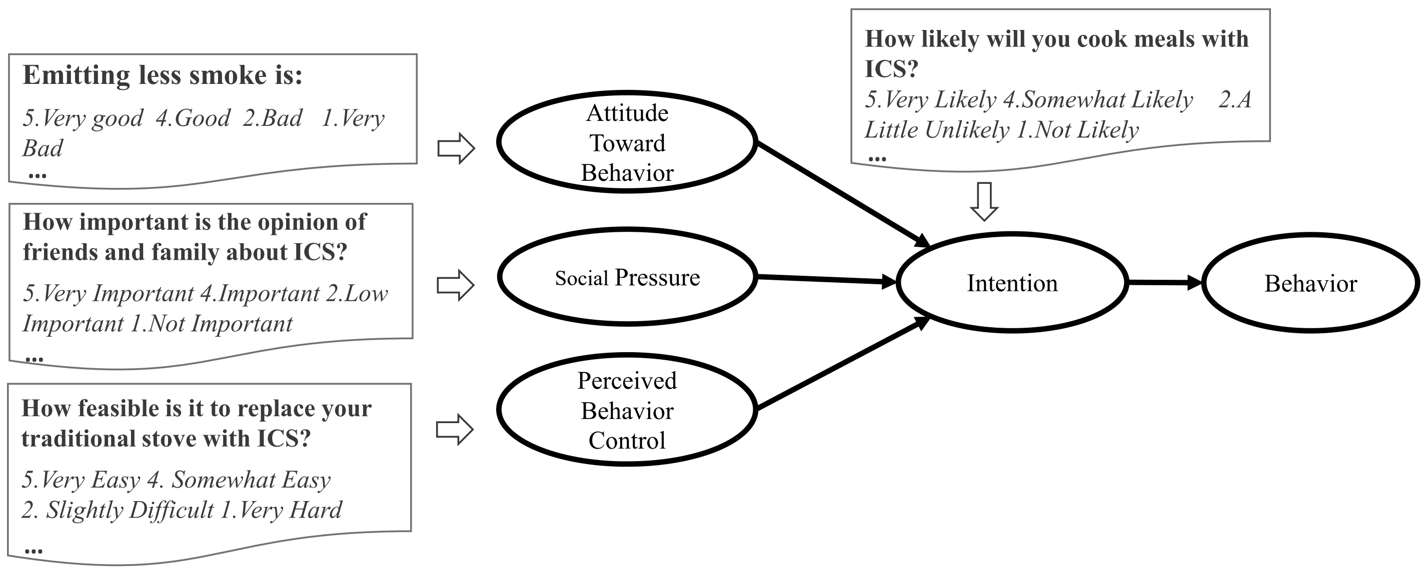
to choose ICS for cooking meals is the main determinant of their actual technology adoption behavior, and that the intention can be quantified using the three categories of attributes of TPB (Figure 2 [46]). The intention component is explained based on three categories of attributes including attitude toward behavior, social norms, and perceived behavior controls. These attributes are quantified through application of TPB survey methods presented in the literature [31]-[39] as illustrated by the sample questions shown in Figure 2. As a result, a causal relationship between three categories of variables with intention to cook main meals with ICS are estimated using multiple regression analysis.

Survey questions were designed to represent each category of TPB. Multiple questions for each category were asked to accurately capture beliefs. Coded responses develop a regression function with intention as the dependent variable and various measures of attitude toward adoption, social pressure, and perceived behavior control as the explanatory variables.

All research with human subjects was overseen by the Oregon State University Institutional Review Board under study number 7257.

Data collection

This study collected data from a total of 489 households, including 379 households in the Copan Ruinas region of



a general impact assessment survey before and after distribution of ICS to the participating households. The households in Honduras sample received their ICS fully subsidized, while in Uganda's sample the stove price of 8,000 to 10,000 Ugandan Shillings (~ $2.20-$2.70 USD),equivalent to 40% of the average weekly income of the head of household was partially subsidized. In the baseline surveys taken prior to ICS distribution, the households' experiences with traditional stoves and their impacts on livelihood, as well as expectations regarding an improved cookstove were measured. After a trial phase for the cookstove (60 days in Honduras and 30 days in Uganda), the follow-up survey was conducted to re-measure the TPB attributes, and to evaluate user experiences and behavior impacts of ICS adoption. The demographic data of the sampled households are presented in Table 1.

The TPB questionnaire served as a sub-section of the main survey and contained 28 questions in the Honduras project and 18 questions in the Uganda project to cover different aspects of beliefs and behavior components. A pilot study with a few open-ended questions was designed to identify dominant beliefs in the target communities related to the research's objectives. Results of the pilot study were used to develop survey questions that accurately and comprehensively capture users' perceptions and beliefs regarding cooking practices in each context.

For each of the three attributes of TPB, three to five questions were asked to capture a multitude of beliefs related to that category. Responses of each question were designed to be simple and understandable for the respondents, and used to capture a range of options based on a Likert scale. The responses were coded from '1' representing 'strongly disagree' or equivalent to '5' representing 'strongly agree' or equivalent.

TABLE 1. DEMOGRAPHIC INFORMATION OF STUDY'S SAMPLES

	Honduras	Uganda
Sample size	379	110
Number of villages	8	2
Affected population	1765	581
Number of children (under 17)	684 (39% of affected population)	204 (35% of affected population)
Main cook's age distribution	Minimum: 15 Maximum: 94 Average: 37.4 Std. dev.: 14.5	Minimum: 15 Maximum:75 Average:36.16 Std. dev.:15.32
Income average (per week)	770 HNL (~ 32 USD)	24000 UGX (~ 6.70 USD)
Education (primary income earner)	No education 70% Incomplete primary 30%	No education 10% Incomplete primary 17% complete primary 28% Incomplete secondary 12% Complete secondary 20% College/university 11%

TABLE 2. SAMPLE TPB SURVEY QUESTIONS

	Sample Questions
Attitudes Toward Behavior	-Consuming less fuelwood is: _________ *5.Very important 4. Important 3.Doesn't matter 2.Not important 1.Not important at all* -Less smoke emission is: _________ *5.Very important 4.Important 3.Doesn't matter 2.Not important 1.Not important at all* -How much do you agree or disagree with the following sentence: I will cook more meals with ICS, if it looks beautiful *5.Strongly agree 4.Agree 3.Neither agree nor disagree 2.Disagree 1.Strongly disagree*
Social Norms	-If you use an ICS do you think your friends and family support you or discourage you? *5.Very supportive 4.A little supportive 3.Neither supportive nor discouraging 2.A little discouraging 1.Very discouraging* -How much do you value opinion of the people whom are important to you about your decision to use ICS? *5.Very much 4.A little bit 3.I don't know 2.Not particularly 1.I don't care* -How much do you value doctors' opinion about using ICS? *5.A lot, try to comply 4.I respect their opinion but it doesn't influence me 3.I don't pay attention 2.I ignore them 1.I try the opposite*
Perceived Behavior Control	-How much do you think ICS is designed to meet your needs? *5.Very well designed 4.Its fine 3.I don't know 2.It's not the best design for my needs 1.It's not designed based on my needs* -Can you decide to use ICS, or you need to consult someone? *5.I can decide myself 4.I feel I can decide myself 3.I don't know 2.I prefer to consult 1.I need to consult* -Overall, how easy or hard do you think it is to use an ICS instead of your traditional stove? *5.Very easy 4.Easy 3.Neither hard nor easy 2.A little difficult 1.Very hard*
Intention	-How many meals do you think you will cook with the ICS during each week? *5.More than 10 4.Between 7 to 10 3.Between 5 to 7 2.Between 3 to 5 1.Less than 3* -How many meals do you expect to cook each day with ICS? *None 1 2 3* -How often do you cook your principal meals with ICS? *5. Always 4. Often 3. Sometimes 2.Rarely 1. Never*

were coded as missing observations to avoid any bias in the analysis caused by putting statistical weight on a respondent's inability to pick a side. Some examples of the survey questions are presented in Table 2.

Analysis

Using the results of the survey, attitude toward adoption (Att), social norms (SN), and perceived behavior control (PBC) served as explanatory variables and weight of their correlation with intention as the dependent variable was estimated. The error term captures every other explanatory variable of intention that are not included in the model. Following the statistical guidelines discussed by Hankin, French, and Horne [48], multiple regression analyses were used to find the most relevant attributes with the highest model significance. The level of each category's influence on the intention was then determined by conducting ordinal logistic regression to calculate the weight of each category.

$$Intention = \beta_0 + \beta_1 (Att) + \beta_2 (SN) + \beta_3 (PBC) + \varepsilon$$

The intention as dependent variable in the regression model was captured by asking multiple questions regarding households' willingness to cook more meals with ICS, main meals of the day with ICS, or approximate number of meals they estimate to cook with it each week. Since the outcome variable is non-interval and ordered, this study applied ordered (or ordinal) logistic regression analysis. Results are presented in terms of odds ratios in Figure 3 and Figure 4. The standard interpretation of the odds ratios is that one unit increase on the Likert scale in the explanatory variable is associated with the respective coefficient's change in the levels of dependent variable, all other variables held constant. For instance, one unit increase in the individual's attitude toward smoke reduction improves odds of higher levels of their intention to cook more meals with ICS β times. To validate the models, the assumptions of ordinal logistic regression were examined. The questions that showed high pair wise correlation were removed from the multiple regression model to avoid multi-collinearity. Robust standard errors were used to address potential existence of heteroscedasticity. The ordered logistics regression analysis was used for model analysis.

The collected data from this study suffers from under-representation of some choices in the dataset, meaning that majority of respondents picked one side of the range of responses. Lack of significant variation in observations could lead to separation in ordered logistic regression analysis. Separation refers to complete or quasi-complete prediction of outcome variable by one explanatory variable that could result in biased estimated coefficients [49]. To avoid separation, this study conducted separate regression analyses for each category of TPB attributes. The most significant observed variable in each regression analysis were selected to represent that category's explanatory variable on the final model. Results of the Brant test suggest that the parallel regression assumption is not violated in the model, indicating that estimated coefficients are valid for comparison within every category of outcomes [50].

RESULTS AND DISCUSSION

The results of analysis in the two countries are presented in Figures 3 (Honduras) and 4 (Uganda) [51], [52]. Each box on the left shows the category of TPB with the specific survey question that was determined to be most statistically significant to predicting intention.

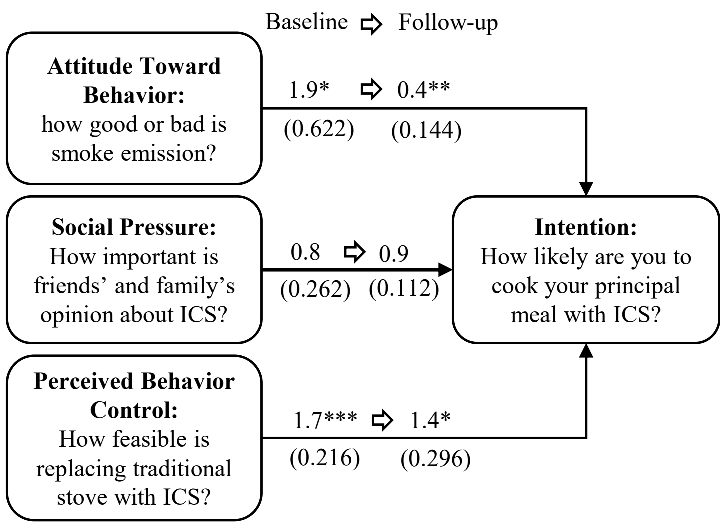


FIGURE 3. RESULTS OF TPB REGRESSION ANALYSIS IN HONDURAS [51]
(ROBUST STANDARD ERRORS ARE IN PARENTHESIS)
* P-VALUE < 0.10, ** P-VALUE < 0.05, *** P-VALUE < 0.01

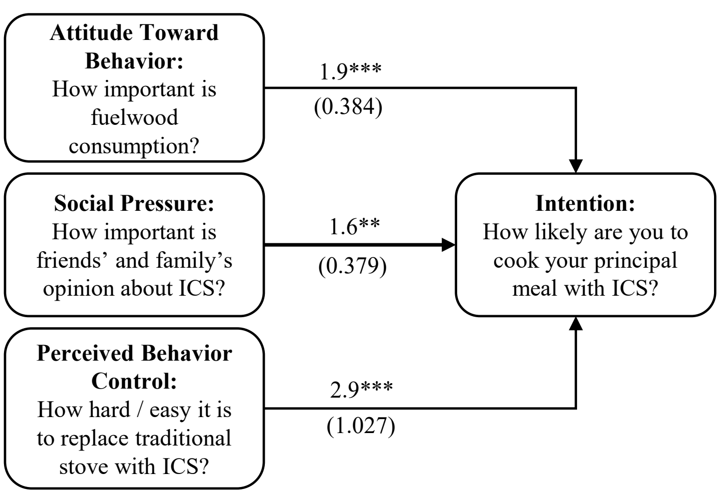


FIGURE 4. RESULTS OF TPB REGRESSION ANALYSIS IN UGANDA [52]
(ROBUST STANDARD ERRORS ARE IN PARENTHESIS)
* P-VALUE < 0.10, ** P-VALUE < 0.05, *** P-VALUE < 0.01

In Honduras, the most significant predictor of adoption in terms of attitude toward behavior was reduced smoke emissions over fuel savings, time saving, social pressure, or ease of use. Baseline results indicate that for an individual with slightly stronger (1 unit on Likert scale) attitude about importance of less smoke emissions, the odds of cooking more meals with an ICS are 1.9 times greater, given the other variables are held constant. However, after using the stove for a period of time, the odds for an individual with slightly stronger beliefs about importance of less smoke emissions are 0.4 times as likely to cook principal meals with ICS, given other variables held constant. This could suggest that the households' expectation of smoke emission reduction has not been fulfilled by adopting the ICS. Therefore, after a trial period their intention to continue using the ICS decreases because of their attitude regarding reduction in smoke emissions. Meanwhile, the odds for an individual with a slightly stronger (1 unit on Likert scale) perception of the feasibility of changing the type of the stove she uses are 1.7 times more to cook principal meals primarily with the ICS, indicating perceived behavioral control is the second strongest indicator of intention to adopt. After the trial period, this value decreases slightly to 1.4, suggesting that after the trial period, households' control beliefs, or the evaluation regarding how feasible is replacing traditional practices becomes less important. As a result, users' motivation to use the new technology is less affected by their perceived ability to change their habits. In terms of social norms, the results of both baseline and follow-up consistently suggest that social pressure of friends and family about stove choice is not significantly influencing their intentions relative to other individual based attributes.

In Uganda's baseline study, the more significant determinant of households' intention to cook their principal meals primarily with an ICS centered on consuming less firewood rather than reduced smoke emissions, aesthetics, timesaving, or feasibility of replacing traditional stoves. Results suggest that the odds for a household with slightly stronger (1 unit on Likert scale) belief regarding the importance of firewood consumption are 1.9 times greater to cook principal meals with ICS. The peer pressure attribute has odds ratio of 1.7, meaning that in average the odds for an individual that feels slightly more (1 unit on Likert scale) peer pressure to adopt an ICS are 1.7 times as likely to cook principal meals with ICS, in contrast to the Honduras study which showed negligible effects of social pressure. The odds for a household that perceived replacing traditional stove with an ICS as slightly easier (one unit on Likert scale) on average are 2.8 times greater to cook principal meals with ICS, given other variables held constant.

A cross-cultural comparison of the results suggests that in Uganda social pressure is likely to influence intention directly, while in Honduras social pressure is not likely to be a significant determinant of the intention. In Honduras, households' attitude for using ICS in the first place is likely because of their expectation for less smoke emissions, while in Uganda it is likely because of their expectation for less firewood consumption. In both communities, the level of effort that households estimate is required to avoid using traditional stove is highly correlated with their intentions to use ICS. In the baseline phase this perception of the ease or difficulty of replacing the traditional stove is based on their expected performance of the ICS and how significantly the introduced technology addresses their concerns. However, the follow-up study in Honduras reveals that as the expectation of such a behavior change becomes more realistic, households may find the new behavior less burdensome and therefore less influential to their intention to use the clean technology. The importance of such a finding is that early stages of technology adoption significantly contributes to long-term habit changes.

CONCLUSIONS AND FUTURE WORK

This study presents a quantitative methodology for comprehensive evaluation of user intentions to adopt clean energy technologies, developed with the intention of improving design, marketing, and ultimately adoption rates and environmental impact. Through systematic evaluation using ordinal logistic regression of surveys that capture the three aspects of behavior intention including attitude toward behavior, social norms, and perceived behavior control, the most important priorities and therefore indicators of technology use in households are modeled. The application of TPB in adoption of clean technologies is evaluated through the case study of improved cookstoves in low resource settings. The practiced framework of this research could be applied in any residential scale clean technologies in low-income regions such as clean water technologies, as well as more advanced technologies in developed contexts such as hybrid vehicles.

Results of this study suggest that households' intentions to use a clean technology changes before and after a trial period, and that different objectives are prioritized in different cultures. In the Uganda study, fuel saving was likely to be the most significant determinant of the users' attitudes for ICS adoption, while in Honduras reduced smoke emissions were most important in formulating such attitude. However, after the trial phase, on average, the stronger they believed in importance of reducing smoke emissions, the less likely they were to use the ICS. This suggests that the technology did not satisfy household's expectations in this regard. Thus, using this method enables project managers to design technologies that reflect the concerns of the community more effectively. For example, one can expect higher adoption rates in the Honduras community if the ICS designs reduced smoke emissions more effectively. Similarly, one can expect in Uganda, an ICS that is more fuel efficient will be more readily adopted.

In terms of social influences, in Honduras social pressure captured by evaluating importance of the opinion of friends and family did not have a significant correlation with intention to cook meals with ICS. Although unexpected, these findings do not suggest that social influences are not important in the context of stove adoption. In contrast, the society's role is either channeled through informing individuals' personal beliefs and perceptions directly, or influences community members other than those evaluated in this study including doctors, teachers, or NGOs. Such findings may provide more accurate and effective planning for behavior change communications and information campaign strategies.

The perception of households regarding their control over behavior change was also found to significantly influence the intention to adopt ICS in both contexts. As households become more familiar with the new technology, their evaluation regarding their control over changing behavior became more realistic. Findings of this study suggest that continuous use of new technology results in decreasing importance of user perceptions regarding hindrances for changing behavior. This suggests that the behavior change becomes easier over time as users engage with the technology. As a result, the new behavior eventually replaces the traditional habit. This important finding illustrates how user compatibility with the technology in early stages of technology use is essential to reshape the long-term habits. In addition, providing maintenance and customer support during the early stages of technology usage is very important during the time period when the users are gradually changing their perceptions regarding a new technology. Therefore, project managers should be careful about early stage performance of the distributed technologies to minimize difficulties as users familiarize themselves with the new technology.

Applying TPB as a systematic approach to analyze users' decision-making process for adopting clean technologies presents a comprehensive approach that highlights the technology up-take phase for designers and implementers. The method provides insight for technology designers to pay attention to the design attributes that could reasonably fulfill users' expectations and priorities. Technology distribution policies could also benefit from this method by holding targeted information campaigns that lead users to realistic expectation of the technology performance, as well as customer support and follow up that reflects the dominant concerns of users.

It should be noted that an intention to adopt a technology does not always translate directly to behavior. Other factors may be associated, such as a lack of access or affordability. Future work is planned to monitor cookstove choice and adoption behavior in the studied households. In addition, eliciting the detailed responses required to quantify the aspects of TPB is challenging in the context of low resource settings where language, culture, and level of education can introduce biases that could introduce uncertainty in the recorded data. Therefore, careful attention to design and execution of survey questions is needed. During the multiple data collections required for this study, the research team was able to apply lessons learned to reduce many biases by training surveyors and updating survey designs to be more accurate.

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