**Proceedings of the ASME 2021**
**International Design Engineering Technical Conferences and**
**Computers and Information in Engineering Conference**
**IDETC/CIE2021**
**August 17-20, 2021, Virtual, Online**

# DETC2021-70438

# ASSESSING THE SOCIAL IMPACTS OF IMPROVED COOKSTOVES IN PERI-URBAN AND RURAL UGANDA USING CARD SORTING

**Erin Peiffer**
Oregon State University
Corvallis, OR

**Nordica MacCarty**
Oregon State University
Corvallis, OR

## ABSTRACT

*Card sorting is one method that can be used to solicit meaningful insight from end users on the design and assessment of technologies. The objective of this paper is to present methods for and results from a card sorting activity exploring the social impacts experienced by households that have adopted improved cookstoves in peri-urban and rural Uganda. Using a framework consisting of eleven social impacts (population change, family, gender, education, stratification, employment, health and well-being, human rights, networks and communication, conflict and crime, and cultural identity/heritage), households were asked to sort the cards into most, somewhat, and least impacted categories with conversations facilitated around each card placement. Results from this activity reaffirmed positive impacts for family, gender, health and well-being, and education that have been well documented in the literature while also identifying social impacts often overlooked in the sector such as changes in networks and communication, cultural identity and heritage, and human rights. Reflections on these results in terms of cookstove design as well as improvements that could be made in future card sorting activities are discussed.*

Keywords: Design, engineering for global development, field study

## 1. INTRODUCTION

Soliciting meaningful information from end users to inform the design of and assessment of products can be difficult. Card sorting is one method that can be used to help overcome some of these challenges by generating more meaningful conversations. Card sorting utilizes conceptual cards which participants use to address a given prompt and has been promoted by user centered design groups such as IDEO [1]. Common applications of this method include website design where participants group cards to develop a folksonomy, or user defined classification system, representative of their mental model as well as the design of new products [2-3].

In product design contexts, card sorting can be used with end users to identify design attributes that they would prioritize in a final design and to generate conversations around why they value specific attributes over other ones. While participants are sorting the cards, important insights can be gleamed by having them narrate their actions as they go, further providing insight into their mental models of the information presented. There are several benefits of using card sorting such as being quick, easy, inexpensive, as well as being more engaging than interviews or surveys. Recently, the authors used card sorting to identify social impacts most affected since participants adopted improved cookstoves during a field study in rural and peri-urban Uganda.

Around 35% of the world's population uses biomass to meet their energy needs [4]. In Uganda specifically, biomass accounts for 90% of the energy consumed within the country resulting in around 10,000 premature deaths each year from exposure to smoke [5-6]. Improved cookstoves are one technology aimed at reducing adverse health impacts and quantity of fuel required to cook and heat homes compared to inefficient open fires. Social impacts commonly attributed to improved cookstove use include improvements to livelihood, gender equity, and health and well-being [7-10].

Rainock et. al [11] developed a social impact framework for technology adoption that expands on the social impacts typically considered for improved cookstoves consisting of eleven social impacts and processes (population change, family, gender, education, stratification, employment, health and well-being, human rights, networks and communication, conflict and crime, and cultural identity/heritage) (Table 1). The framework pulls from both the social sciences and engineering literature on the

social impact of products with the purpose of assisting both academics and practitioners in designing products that maximize impact. Future work identified by the authors included "[leveraging] experimental methods or [examining] product adoption in a number of settings to develop a more complete picture of whether certain consequences are broadly applicable or context-specific".

As such, this framework was used to explore the social impacts experienced by improved cookstove users. The objective of this paper is to present results from a card sorting activity exploring the eleven potential social impacts experienced by households that have adopted improved cookstoves in peri-urban and rural Uganda and how these insights provide new perspectives on cookstove design.

## 2. METHODS

In early 2021, semi-structured interviews on cookstove adoption and a card sorting activity on social impacts were carried out in Lira, Napak, and Nakapiripirit districts over the course of two weeks with field support from International Lifeline Fund (Lifeline). Lifeline is a is a 501(c)(3) organization that began working in refugee and displacement camps, emergency settings, and emerging markets in 2006 to enable sustainable access to fuel-efficient cooking technologies and reliable safe water. These specific locations were selected as Lifeline has an ongoing relationship in the communities. Additionally, these locations provide insight into social impacts experienced in both the peri-urban (Lira) context as well as rural contexts (Napak and Nakapiripirit). Data collection was carried out with the goal of reaching data saturation, or the point at which no new information is being collected. All participants currently own Lifeline stoves and were conveniently sampled using Lifeline stove distribution records. Lifeline offers both firewood and charcoal improved cookstoves in a range of sizes that are fuel efficient and produce less smoke compared to traditional methods of cooking, such as over an open fire. The stove is portable and utilizes an insulated ceramic combustion chamber. Prior to data collection, participants were briefed about the study and gave their verbal consent. Participants were compensated for their time following the interview and card sorting activity. All research with human subjects was conducted with oversight by the Oregon State University Institutional Review Board under study number 7257.

The card sorting activity was carried out after semi-structured interviews on stove acquisition and use were conducted. For the card sorting activity, cards visually depicting the eleven social impacts (population change, family, gender, education, stratification, employment/livelihood, health and well-being, human rights, networks and communication, conflict and crime, cultural identity and heritage) were presented in this order to the participants and described using both general [11] and concrete examples, shown in Table 1. For example, the family social impact was described as "changes in the roles individuals play within the family, stressors that result in strained family relationships, distribution or perception of work, roles family members are expected to fill or lead" with the examples "fewer fights between family members because food can be prepared faster, changes in who helps with meal preparation, cooking, cleaning, fuel collection, mothers can now spend more time doing business because children can prepare meals without the help of their mother, etc.".

The participants were then asked to sort the cards into one of three cups: 1.) most impacted, 2.) somewhat impacted, and 3.) least impacted since acquiring their improved cookstove. The enumerator requested that no more than four cards be placed in each cup. The intention of limiting each cup to four cards was to encourage prioritization and avoid instances in which participants put all of the cards into one cup. Since the goal of this activity was facilitating more robust conversations, the specific placement of the card was a secondary focus. Conversations were facilitated after each placement of a social impact card, the conversations of which were recorded with consent and translated to English throughout the activity. A translator was used in Napak and Nakapiripirit while Lifeline staff provided translations to English for the Lira participants. These conversations were then transcribed for each of the impacts discussed, the range of results of which are summarized here.

## 3. RESULTS AND DISCUSSION

While the initial task required participants to sort the social impact cards into three cups, while carrying out the activity, many wanted to place most of the cards in the "most impacted" cup. As such, the results and discussion presented here focus mostly on the explanation participants gave for placing each card in a specific cup. Table 2 provides the range of responses from participants for the eleven social impacts as well as corresponding cookstove design attributes [12] that influenced the social impacts experienced. Data collected through the semi-structured interviews are not included in this paper.

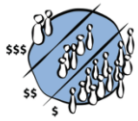
In total, fifteen households participated in the card sorting activity: seven households in Napak, six households in Nakapiripirit, and two households in Lira. More households in Lira participated in the semi-structured interview portion of data collection but were not comfortable being recorded for the card sorting activity, thus did not take part. All of the households that participated in the card sorting activity in Napak and Nakapiripirit were given an improved cookstove for free from Lifeline during a promotional event. The two households in Lira purchased their improved cookstoves and described their primary means of income as vendor/business owners. In contrast, eight households in Napak and Nakapiripirit earned their primary income through selling either firewood, charcoal, or alcohol. The remaining five households earned their income through agricultural work.

Some differences in responses from those in peri-urban Lira compared to rural Napak and Nakapiripirit were noted for the livelihood social impact, although there were only two participants in Lira. One participant in Lira described how she is now able to sit and work at her tailoring machine while also cooking which was not possible when she was using a three stone fire. As such, she has had more time to dedicate to other income

earning activities. For the respondents whose main source of income is through agricultural work, several mentioned having more time to dedicate to farming since food can cook while they are away without fear of children getting hurt or the fire going out. Many respondents from the Napak and Nakapiripirit also described saving money on fuel that their household now spends on food and electrical services. Similar changes in livelihood opportunities have been documented in cookstove literature [7,10]. The tailor specifically linked these changes to higher social status. Most of the other respondents felt an increase in social status from community members admiring the stove they acquired through the promotional event.

Similar responses were noted for population change, networks and communication, and cultural identity and heritage. The inherent overlap of the various social impact factors was discussed by Ottosson et. al [13] with regard to this social impact framework. Participants discussed having more visitors during the day to stop over for food or local brew because friends and

**TABLE 1.** SOCIAL IMPACT DEFINITIONS, EXAMPLES, AND CORRESPONDING CARDS

| Definition | Examples | Card[a] |
|---|---|---|
| **Population change** – includes changes in migration to/from the community, relocation of families, presence of a seasonal leisure population, influx of temporary or permanent workers, and changes to the age structure of the community | Family members living longer do to reduced exposure to smoke, reductions in deforestation from fuel collecting that have reduced the need to relocate, increased number of visiting relatives in the household during the harvesting season because food can easily be cooked faster with their improved cookstove, etc. |  Population Change |
| **Family** – includes changes in the roles individuals play within the family, stressors that result in strained family relationships, distribution or perception of work, roles family members are expected to fill or lead | Fewer fights between family members because food can be prepared faster, changes in who helps with meal preparation, cooking, cleaning, fuel collection, mothers can now spend more time doing business because children can prepare meals without the help of their mother, etc. (focus on family member role) |  Family |
| **Gender** – includes changes in gender norms/roles | Men can cook because the stove is easy to use and they no longer fear to go in the kitchen, cleaning, fuel collection, etc. (focus on gender) |  Gender |
| **Education** – includes changes in formal in school learning and informal skill acquisition. | Increased school attendance due to reduced time spent collecting firewood or reduced expenditures on fuel, increased school attended due to availability of ready meals on time since stove saves time spent on cooking, etc. |  Education |
| **Stratification** – includes changes in inequality between/within communities, introduction of new classes or sub-communities, social mixing, social status indicators, and prestige | Schools and households that use improved cookstoves are admired and regarded highly by those that do not have them, Improved cookstoves are seen as a status indicator leading to getting better in some communities, their stove has helped household move to a better social status, etc. |   Stratification |
| **Employment/Livelihood (how you support your household)** – includes changes in job opportunities, change in work environment, change in employment status, changes in industrial diversification or change of economic focus, changes in income, and how money is saved | Money that would have gone towards buying more fuel can now be saved and used towards other things like stock more food or hire staff, reduced time spent cooking has allowed for the primary cook to make and sell things in the market, etc. |  Livelihood |
| **Health and well-being** – includes changes in secure/safe living conditions, safety and security (real/perceived), activity/exercise, mental health, physical health, mortality, life/health improvements from product, lingering feelings from usage (frustration, positivity, etc.), perceived future opportunities/goals, and diet | Reduced respiratory illnesses due to less smoke from Ecosmart cookstove, reductions in burns, less eye and chest irritation, less fighting has improved overall wellbeing of household members, less frustration cooking, etc. |  Health and Safety |

| | | |
|---|---|---|
| **Human rights** – includes changes in democracy or decision-making participation based on identity (gender/ homeless/ disabled/ indigenous) | With more free time, main cook can now attend community meetings and participate in local decision making; household member now has enough time to enroll for a skills course due to the fact that the stove cooks fast and saves time, etc. |  Human Rights |
| **Networks and communication** – includes changes in networks (relations between people), relationships between community stakeholders, impaired or improved personal relationships, how communication is carried out, reliance on participation in the decision-making process | Because of minimal smoke produced by the stove which makes cooking go unnoticed, household no longer invite visitors for meals which has impaired relationship with friends; the need for less fuel resulted in less time spent with friends and family members collecting fuel, main cook attending community meetings expanded her circle of friends, etc. |  Social Networks and Communication |
| **Conflict and crime** – includes changes in potential conflicts, homicide and violent crimes, non-violent crime, corruption, informal regulations/norms, and increased or decreased substance abuse | Less household conflict due to meals being prepared faster, more peace in the household, less risk of potential conflict while collecting firewood; fewer violent crimes like rape towards women and girls due to reduced number of trips make to the forests to collect firewood, etc. |  Conflict and Crime |
| **Cultural identity and heritage** – includes weakening or strengthening of values, changes in cultural/ ethnic/ religious ideas and believes, cultural intolerance, cultural/religious rites and practices, cultural/religious artifacts and places, religious demographics, individual identity reliant on cultural identity, and understand of the universe and the role one plays in it | Change in traditional meals prepared because of new cookstove, fewer family gatherings because new cookstove no longer provides warmth that once brought everyone together to talk and share stories, etc. |  Cultural Identity and Heritage |

[a]Social impact cards were created by Dr. Christopher Mattson at Brigham Young University

family know that their improved cookstove can prepare food and drinks very quickly compared to three stone fires. This increase in daytime visitors was seen as a positive change by those interviewed. Alternatively, most participants (12/15) discussed reduced nighttime gatherings with friends and family members that used to take place around the three stone fire for warmth. If people do come over, the food is prepared quickly and since their improved stove provides no warmth, their guests eat and leave soon after. Some saw this as a negative change impacting their cultural identity and heritage.

The speed at which meals can now be cooked compared to their three stone fire was attributed positively for several of the social impacts. Notably, many participants discussed how fights have decreased between themselves and their husbands since food can be prepared much more quickly which is consistent with past research conducted in collaboration with Lifeline [7]. Additionally, if food gets cold, it can be reheated easily on their improved cookstoves, further deterring fights. One participant discussed how her daughters fight less over the chore of cooking since the new stove is much more pleasant to use. Several participants also discussed how they had experienced reductions in school absenteeism for children as food for breakfast and lunch could be prepared quickly allowing children to get to school on time. In contrast, a couple participants noted neither change in household fighting nor educational opportunities.

Many participants discussed how the simplicity and safety of their improved cookstove has led to increased sharing of domestic tasks within the family and improved health and well-being. Most women also reported increased participation at local community meetings since they felt comfortable leaving their children with the task of cooking with the improved cookstove without fear of burns and unwanted fires. All of the participants experienced reduced irritation due from exposure to smoke and some noted reductions in burns. An additional positive impact from switching to improved cookstoves was no longer needing to kneel to tend their fire. With regard to gender, many women reported increases in help from men in cooking tasks, although some women report no change in shared cooking responsibilities.

While providing insight into social impacts most affected since adopting their improved cookstove(s), most of the impacts described are tied to specific design attributes of the stoves themselves. Cooking speed, safety, usability, and reductions in smoke and fuel consumption, to name a few, all contributed directly to the impacts experienced by households. These stove attributes have been widely acknowledged as important for stove adoption [8, 14]. Understanding the tangible affects that design has on end users can help in the design of more appropriate and impactful solutions that are readily adopted. Due to the small sample size and sampling method, conclusions relating specific

stove type/attributes, occupation, and other demographic data to social impacts was not possible, though could be a fruitful venue for future research using this methodology.

## 4. CONCLUSION

Card sorting is a useful method to facilitate conversations around design and prioritization or ranking of concepts. When applied to a field study in peri-urban and rural Uganda assessing social impacts from cookstove adoption, many impacts previously under-represented in the literature were identified as highly impacted including changes to cultural identity and heritage, increased participation at community meetings, and changes in networks and communication. The card sorting activity also illustrated how product design directly and indirectly affects the social impacts experienced by end users. This insight can be used in the design of products to meet user needs, increasing the adoption of technology while also increasing the likelihood that users experience positive social impacts.

While card sorting proved to be a useful tool for this study, there are several aspects that should be taken into consideration for future studies as is the case with other qualitative research

**TABLE 2.** SOCIAL IMPACTS EXPERIENCED BY IMPROVED COOKSTOVE OWNERS

| Social Impact | Response | Related Design Attributes |
|---|---|---|
| Population Change | More visitors to the home during the day as they know they can receive local brew quickly.<br><br>Some come to see the stove.<br><br>It is rare [that I have visitors], they sit inside, and no one sees [my improved cookstove]. No one sees the smoke anywhere. | Performance: time<br>Performance: health pollutants<br>Usability: attractiveness |
| Family | [We have] fewer fights because food is prepared quickly.<br><br>There are still [a] few fights in the family.<br><br>There are fewer fights. For her who has two girls, they used to fight over who has to cook. The oldest one would always want to make the youngest one cook. With this new stove, no one fights over who has to cook because when it is [their] turn they accept it because it doesn't produce smoke that causes irritation. | Performance: time<br>Performance: health pollutants<br>Usability: user interface |
| Gender | Even men cook. For her who has sons, her son always cooks when her daughters are not around. [She] can set the fire, do other things, come back and check on it and it is still cooking.<br><br>Men cook due to ease of using the stove<br><br>Men do not cook. They are very excited about the stove when [their] friends come, but [he] still has her cook and will go look for her to cook if she isn't home when visitors come. | Usability: user interface<br>Performance: safety<br>Usability: tending<br>Usability: cleanliness |
| Education | Early in the morning when the children are going to school, she can make porridge in the morning. [Because] the stove retains heat, she can cook food quickly to make sure they get to school on time. She can put beans/maize [on the stove] when the children come back for lunch to eat and go back [to school]. It has reduced absence [from school] because if it takes too long they would come home and eat then not return to school.<br><br>When children were in school, there was lots of absenteeism as children would want to wake up and eat before going to school so they would be late. Since the stove was given, anytime she can wake up in the morning for porridge and then go to school on time. Then they return at 3 or 4 pm and can find beans. Even if they come at a different time, she can set it up and cook very fast without a problem. | Performance: time<br>Usability: time saved |

| | | |
|---|---|---|
| | No changes [in education since acquiring her improved cookstove]. | |
| Stratification | People admire the way she uses the stove and others feel they should get this stove.<br><br>Her status is high. They don't see any smoke from her house or know what she is cooking since she is inside. For those who cook with an open fire, everyone who passes knows that they are cooking and what they are cooking. Her status is better than the rest. Everyone wants this stove.<br><br>Even with the people that didn't get the stoves, they are still together and most just admire, not that her social status has changed or anything. | Performance: health pollutants<br>Usability: cleanliness<br>Performance: time<br>Affordability: fuel consumption<br>Usability: portability<br>Usability: user interface |
| Employment/ Livelihood | [They] have reduced the cost of purchasing fuel, [which they] now can spend on buying food and other necessities.<br><br>They are farmers. Most of the time when she is at the farm she can place beans on the stove and leave it there and when she gets back they are done. She can do other things outside cooking as the food gets ready.<br><br>Since she earns a living from selling charcoal and firewood, most of the time she goes to the bush to collect firewood and proceeds to the market to sell it. In the morning she cooks food then goes. When she gets back she sees that the fire is still going. When she gets back she only adds firewood.<br><br>They spend less on charcoal and firewood. They use more on buying food and other electric services.<br><br>It has given her more time to do other income generating activities since she can work on her tailoring business as she leaves her food to cook. Also it cooks faster so she has more time to dedicate to her work. | Affordability: fuel consumption<br>Usability: tending requirements |
| Health and Wellbeing | When she used to use a three stone fire, she had to kneel down and blow, and she gets smoke in her eyes and she has to cough. The open fire is hitting your skin all over while sitting mingling by the fire. [Now, she] can sit on the other side of improved stove with no heat from the fire.<br><br>There is no smoke, no coughing, even her, an old woman, can sit and add firewood and the food will get ready, no need to bend and blow on the fire.<br><br>The stove is safe, and her children are safe from any burns which makes the stove an improvement | Performance: health pollutants<br>Performance: safety |
| Human Rights | You can go for any meeting as the food is boiling and just maybe put a little bit of firewood there with a young child overseeing the fire. With the three stone fire, they would be worried that the child would get burnt by the fire, but with the new stove, they don't have to worry and can go to meetings.<br><br>She can now attend meetings and join friends and have some time with them. With this stove you just set it and put food and even a young child can take care of it and add firewood as the mother is busy. Not like a three stone fire. You worry that maybe the wind will blow and catch another person's hut on fire. | Performance: safety<br>Usability: tending requirements<br>Usability: user interface |
| Networks and Communication | Gathering around fires in the evening is reduced since the new stove does not provide much fire compared to the three stone. | Performance: energy efficiency |

| | | |
|---|---|---|
| | They take time to prepare their food individually. They don't come to gatherings together like they used to.<br><br>People really admire the stove. If someone comes, they sit on chairs. With a three stone fire they have to be near the ground, but with the new stove they can sit in a chair and mingle comfortably and no heat. Her friends always come over just to watch and admire the stove.<br><br>She receives a lot of visitors as people know there is always a fire there. Even if there isn't a fire, if they come at any time it is very simple for them to cook for them fast. They get fire automatically instead of looking for someone that already has a fire ready. | Performance: time<br>Performance: health pollutants<br>Usability: attractiveness<br>Usability: user interface |
| Conflict and Crime | There is no conflict anymore because people cook faster and then the food, if it gets cold, they can easily put it back on the stove because the stove stays warm. Men used to beat women because of cold food and maybe late breakfast. When they wake up they find the fire still going and can make tea and food for children and husband. | Performance: time<br>Performance: health pollutants<br>Usability: user interface |
| Cultural Identity and Heritage | With the three stone fire, they sit and there is much light and everyone gathers around to tell stories. With the new stove that is inside the house, they don't have time for other people outside. You just go and cook your own food. Even with the traditional food. Two days ago they had visitors for a marriage ceremony, but they had to use their three stone fire to prepare the food.<br><br>With this stove that is inside, even when you want your friends to come and stay, the food is cooked too fast so people come and leave and don't share stories.<br><br>[There has been a] big change given that in the past they used to cook using the three stone fire but now because of her stove she is using charcoal which makes a big difference in the culture and heritage | Performance: energy efficiency<br>Performance: time<br>Performance: health pollutants<br>Usability: attractiveness<br>Usability: user interface |

methods. If conducting a card sorting study on any sensitive material, it is important to understand how the presence of other people, whether acquaintance or stranger, to the participant may affect the candidness of responses. This is particularly important when discussing topics that have a gendered component. For example for this study, a male translator was used for some of the card sorting activities, the impact on responses of which was not further explored due to limited sample sizes and is one limitation of this study. Additionally, if carrying out the study in which a translator is required, it is advisable to provide thorough training on the card sorting methodology such that the translator can facilitate more robust conversations around the activity and why certain decisions were made while sorting.

One challenge when conducting a card sorting activity in which the cards are more conceptual or abstract is deciding whether or not to use examples to guide the conversation. One benefit of providing examples, as was done for this study, is ensuring that participants have a better understanding of the concept. Alternatively, providing examples can limit the scope of the card to just those examples, as was observed during this field study. One was to avoid the use of direct examples that may limit the range of responses, examples of the social impacts for another technology that is contextually relevant could be provided. For example, if we were to carry out this field study again, we could give examples of social impacts related to a locally available water filter instead of improved cookstoves.

Lastly, if carrying out a card sorting activity in which the goal is to explore both positive and negatives associated with the conceptual cards, this should be explicitly verbalized. For this field study, sorting the social impacts into most, somewhat, and least impacted implied positive social change. As such, participants mostly provided positive examples. If this study were to be carried out again, a fruitful addition would be explicitly asking about any negative impacts that have been experienced providing a more holistic picture of each impact. This could be accomplished by adding more cups such as very negatively impact, negatively impact, neutral, positively impacted, and very positively impacted.

Technology has a very real impact on end users and society. The better understanding that engineers and designers have of how these impacts manifest, the better they can design products that maximize positive effects while minimizing the negative.

This paper demonstrates how card sorting can be utilized to understand the connection between design and impact on end users. Future research should continue to explore social impact and design in the pursuit of design principles and practices that maximize positive change.

## ACKNOWLEDGEMENTS

The authors would like to thank International Lifeline Fund for their considerable efforts in executing this study, especially those of Rebecca Apicha and Doreen Asio Faso. We would also like that thank Christopher Mabey and Dr. Christopher Mattson at BYU for support with planning the card sorting activity. We also appreciate the financial support of NSF CMMI grant #1662485 and NSF INTERN supplemental funding, and the School of Mechanical, Industrial, and Manufacturing Engineering at Oregon State University.

## REFERENCES

[1] IDEO, "Card Sort," from https://www.designkit.org/methods/card-sort

[2] Spencer, D., and Warfel, T., 2004, "Card sorting: a definitive guide," Boxes and arrows, **2,** pp. 1-23.

[3] Wood, J.R., and Wood, L.E., 2008, "Card sorting: current practices and beyond," Journal of Usability Studies, **4**(1), pp.1-6.

[4] International Energy Agency (IEA), 2020, "SDG7: Data and Projections," from https://www.iea.org/sdg.

[5] The Republic of Uganda Ministry of Energy and Mineral Development, 2015, "Strategic Investment Plan 2014/15 – 2018/19," from http://npa.go.ug/wp-content/uploads/2018/01/Energy-Sector-Development-plan-Final.pdf.

[6] Institute for Health Metrics and Evaluation (IHME), 2018, "Findings from the Global Burden of Disease Study 2017". Seattle, WA.

[7] Wiedmer**,** D., Jouslin-de-Noray, P.**,** Graveaud, F., and Jahangiri, V., 2015, "Socio-Economic impacts of the deployment of improved Fuel Efficient Stoves: the ILF Uganda Commercialization Program," Field Actions Science Reports, **8**, pp. 1-7.

[8] Ruiz-Mercado, I., Masera, O., Zamora, H., & Smith, K. R., 2011, "Adoption and sustained use of improved cookstoves," Energy policy, **39**(12), pp. 7557-7566.

[9] Jagoe, K., Rossanese, M., Charron, D., Rouse, J., Waweru, F., Waruguru, M., et. al, 2020, "Sharing the burden: Shifts in family time use, agency and gender dynamics after introduction of new cookstoves in rural Kenya," Energy Research & Social Science, **64**, 101413.

[10] Gitau, J. K., Mutune, J., Sundberg, C., Mendum, R., & Njenga, M., 2019, "Implications on livelihoods and the environment of uptake of gasifier cook stoves among Kenya's rural households," Applied Sciences, **9**(6), 1205.

[11] Rainock, M., Everetta, D., Pack, A, Dahlin, E., Mattson, C., 2018, "The social impacts of products: a review," Impact Assessment and Project Appraisal, **36**(3), pp. 230-241.

[12] 2017, "Handbook for Biomass Cookstove Research, Design, and Development," Global Alliance for Clean Cookstoves and the MIT D-Lab.

[13] Ottosson, H. J., Mattson, C. A., and Dahlin, E. C., 2020, "Analysis of Perceived Social Impacts of Existing Products Designed for the Developing World, With Implications for New Product Development," Journal of Mechanical Design, **142**(5), pp. 1-13.

[14] Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N., and Rehfuess, E., 2013, "Systematic review Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies," EPPI-Centre, Report Number 2109.