Participatory Design in the Himalaya: Understanding Himalayan Home Cooking and Heating Practices

by

Arnav Y. Patel

Submitted to the Department of Mechanical Engineering
in partial fulfillment of the requirements for the degree of

Bachelor of Science in Mechanical Engineering

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2021

Author .....
Department of Mechanical Engineering
May 14, 2021

Certified by .....
Daniel Sweeney
D-Lab Research Scientist
Thesis Supervisor

Accepted by .....
Kenneth Kamrin
Associate Professor of Mechanical Engineering
Undergraduate Officer

Participatory Design in the Himalaya: Understanding Himalayan Home Cooking and Heating Practices

by

Arnav Y. Patel

Submitted to the Department of Mechanical Engineering
on May 14, 2021, in partial fulfillment of the
requirements for the degree of
Bachelor of Science in Mechanical Engineering

Abstract

Communities in the Himalaya continue to use biomass-fueled cooking and heating arrangements, which have the potential to introduce harmful levels of household air pollution (HAP) and use fuels inefficiently. Utilizing participatory design practices, fifteen surveys were conducted in three villages in the Chakrata district of Uttarakhand, India to assess household cooking and heating problems and needs. The scale of the survey implementation was in part limited due to the COVID-19 pandemic and its devastating impact on India during 2020 and 2021. The results of these surveys indicated a need for more efficient cooking and heating systems that emit less HAP. These households presented different needs than surveys of other regions of the Himalaya, underscoring the necessity of participatory design and co-creation at even the village level for possible cooking and heating solutions. Following this preliminary survey, next steps were created on clarifying answers from the community, gathering measurements of household cooking and heating methodologies, and evaluating priorities and potential solutions.

Thesis Supervisor: Daniel Sweeney
Title: D-Lab Research Scientist

Acknowledgments

This thesis would not have been possible without the help of so many people. Thank you to my supervisor, Dr. Daniel Sweeney, for always lending a helping hand and being an incredible mentor through my D-Lab classes, research, and thesis writing. Thank you to MIT graduate student Lisa Tang for always being ready to help out and lead the way for our research group. A special thanks to the UPES team, Dr. Nilanjana Banerjee, Dr. Pranava Chaudhari, Dr. Amit Thakur, and Dr. Rahul Kumar for conducting the surveys and providing essential insight throughout the research process. Thank you to ICT-Mumbai's Dr. Jyeshtharaj Joshi and Anil Kelkar for providing important direction for our entire team. Thank you to Shramyog NGO for helping conduct the surveys. And, of course, thank you to the villages of Koruwa, Jadi, and Mangrauli in Chakrata, India for participating in the surveys.

I would also like to thank MIT D-Lab's community for showing me how research can impact the world and providing me a space to feel comfortable and creative throughout my university studies. And, as always, thank you to my friends and my family for always providing me the support I needed during my time at MIT.

Contents

1 Introduction **13**

1.1 Traditional Cooking and Heating 13

1.2 Cooking and Heating in the Himalaya 14

1.3 Participatory Design 15

2 Methodology **19**

2.1 Survey Location and Household Participants 19

2.2 Survey Topics, Material, and Iteration 21

2.3 Chakrata Preliminary Survey Implementation 23

2.4 Coding Answers 24

2.5 Limitations to Methodology 24

3 Results and Discussion **25**

3.1 Results of the Chakrata Preliminary Survey 25

3.1.1 Fuel Use 25

3.1.2 Chulha 26

3.1.3 Cooking 26

3.1.4 Heating 28

3.1.5 Finances 29

3.2 Design Considerations 32

3.3 Unanswered Questions and Information 33

3.4 Next Steps and the Chakrata Extended Survey 35

4 Conclusion **37**

A Chakrata Preliminary Survey **39**

B Additional Results from the Chakrata Preliminary Survey **47**

C Draft of the Chakrata Extended Survey **49**

List of Figures

2-1 Map of India highlighting Uttarakhand and map of Uttarakhand denoting the location of Chakrata 20

2-2 Example of house in Chakrata (Photo credit: Dr. Pranava Chaudhari, UPES) 20

3-1 Chulha arrangement in a Chakrata household (Photo credit: Dr. Pranava Chaudhari, UPES) 27

3-2 Stovetop for the household chulha (Photo credit: Dr. Pranava Chaudhari, UPES) 28

3-3 Daily heating and cooking times 30

3-4 Seasonality of fuel consumption, heating, and smoke pollution (HAP) 31

B-1 Calculation for determining fuel costs 47

List of Tables

3.1 Household fuel breakdown by type and use 26
3.2 Positives of current cooking arrangement 28
3.3 Improvements for current cooking arrangement 29
3.4 Positives of current heating arrangement 30
3.5 Improvements for current heating arrangement 30
3.6 Financial resources for households 32

B.1 Average costs of fuel per person per month 47
B.2 Wood collection time per trip 48
B.3 Occasion to build new chulha 48
B.4 Gender of chulha manufacturer 48
B.5 Materials in chulha as mentioned by households 48

Chapter 1

Introduction

1.1 Traditional Cooking and Heating

Over 2.9 billion people around the world depend on traditional, or solid, fuels for cooking and heating [1]. Most of these people are from low-income countries with limited infrastructure and exposure to modern household energy products. The use of traditional fuels for cooking and heating creates dangerously high levels of household air pollution (HAP) [2]. HAP can result in numerous health issues to household inhabitants including acute lower respiratory infections, chronic obstructive pulmonary disease, lung cancer, and asthma [3]. HAP can even be lethal and contributes to 4.3 million deaths worldwide per year [4]. Furthermore, biomass-fueled cookstoves and heating infrastructure may not be as efficient as other forms of cooking or heating technologies [5]. Traditional fuel powered systems also require fuel collection and gathering, which is often a strenuous activity [4]. All of these issues also have the potential to significantly affect women more than men given that female members of households tend to be responsible for cooking, home maintenance, and fuel collection [6]. Additionally, the continued use of traditional fuels contributes to the climate crisis by generating carbon emissions and causing deforestation [7, 8].

There have been many efforts to improve cookstove efficiency and decrease hazardous HAP through the dissemination of new products such as the improved biomass cookstove (ICS) [9, 10]. While these efforts have resulted in varying degrees of suc-

cess, many point towards important barriers to clean cookstove adoption in local communities [9, 10, 11, 6, 12, 13]. Affordability remains a widespread barrier to clean technology adoption, especially in low-income communities. Cultural factors may also play a role, especially if the use of new cookstove technologies requires significant behavioral changes or the displacement of traditional cooking practices [14].

Recent developments, including the introduction of ICS to many communities around the world, have resulted in a practice known as "stove stacking", when households use a combination of stove and/or fuel types to supplement their cooking, even if household income allows for cleaner arrangements [15]. Stove stacking results in households still using their solid fuel cooking arrangements even if they own newer and cleaner technologies. This results in only minimal improvements to HAP and fuel efficiency.

Similar to cooking technology adoption, research in the last couple decades has aimed to improve home energy efficiency and sustainability in the developing world, including the Himalayan Region [16]. Even so, many households continue to utilize traditional fuels, such as coal and wood, for household heating [17, 18]. Like cooking infrastructure, unvented heating with solid fuels contributes to high HAP within households [1, 18].

1.2 Cooking and Heating in the Himalaya

In India, specifically, rural areas continue to use traditional fuels for cooking and heating. Different regions have different types of cooking and heating practices, which use a variety of different fuels [19]. In the Himalaya, a wide variety of different cooking arrangements are used, the most common of which is the traditional *chulha* [20]. Chulha is a traditional firewood or biomass-fueled mud and stone cookstove. Households place pots, pans, and other cooking items on the chulha to be heated up by firewood and other fuels next to and below the hot surface.

Within the Himalaya, numerous cookstove programs have been implemented in order to provide cleaner cookstove options for residents. The first of which, the

National Programme on Improved Cookstoves/Chulha by the Indian government, was implemented in the 1980s and continued for a number of decades [6]. Since then, other cookstove programs, especially those led by non-governmental organizations (NGO), have introduced many types of cleaner cookstoves to the Himalayan region with limited success [21]. There are many reasons why the introduction of clean cookstoves in the Himalayan region have not been as successful as other regions in India and the world. Many studies point towards economic barriers that prevent local communities from buying cleaner but more expensive ICS [19, 22]. Studies have pointed to the lack of communication between stakeholders about the merits and demerits of introduced cookstove options [21]. Other studies have suggested that local NGOs and government agencies need to prioritize educating the general public in these regions about the harms of utilizing traditional fuels to health [6]. There are also issues with supply chains and market development [9]. Still, others underscore the importance of traditional methods of cooking, including the taste of food, and the easy availability and accessibility of fuels, such as wood [9, 23]. Many cookstoves also have the dual function of being a heat source, and ICS options tend to not offer that dual feature. The complexities of local preferences suggest that there cannot be a "one-solution-fits-all" format for the Himalayan region.

Technologies have also been introduced regarding space heating in the Himalaya, with the Indian government leading efforts to provide renewable sources of energy for heating [16]. While many households use their chulha for space heating, other approaches exist depending on the sub-region of the Himalaya [16]. The introduction of new heating technologies face similar challenges as those faced when introducing ICS and other clean cooking infrastructure, and firewood usage is directly correlated to elevation and cold temperatures [16, 24].

1.3 Participatory Design

The complexities associated with introducing cleaner and more efficient cooking and heating technologies require solutions that are relevant to the local community [21, 22].

Participatory design can be implemented in different forms and techniques, and it can be described by several guiding principles including "equalized power relations," "mutual learning," and "democratic practices" [25]. Participatory design includes considering and including people living in the context of where a design will be implemented, which requires designers to spend time understanding the preferences, history, and culture of the communities they work with [26]. Co-creation and co-design can be included in a participatory design approach, in which target communities and designers work together to create solutions. Participatory design has become more commonly used by designers and implementing organizations, with many pointing out the importance of communicating directly with target communities and balancing co-creation appropriately and effectively through different means of data collection, prototyping, and implementation [26, 27, 28, 29]. ICS implementation, specifically, has been shown to be more effective when co-creation is included [10].

Understanding culture and other factors relevant to participatory design requires methodologies to gather information about people within those communities. While there are many methods associated with gathering that type of information, surveys have been shown to be the most time efficient and direct [30, 31]. Surveys can also help to build trust with local communities and include them early in the design process [31].

Massachusetts Institute of Technology (MIT) D-Lab has implemented numerous co-creation techniques through its research and course projects. Several contributions by D-Lab aim to make participatory design more accessible and practical for different stakeholders, including the User Research Framework, Lean Research Framework, the Handbook for Biomass Cookstoves, and the Energy Assessment Toolkit [31, 32, 33, 34].

This thesis presents the results and analysis of survey-based research done in Himalayan villages in Chakrata, India. The survey activities are part of a larger collaboration, Livable Himalayan Homes, between MIT D-Lab, the Institute of Chemical Technology (ICT, Mumbai, India), and the University of Petroleum and Energy Studies (UPES, Dehradun, India). Inline with the project's participatory design approach,

these surveys were the first steps toward improving household cooking and heating with local Himalayan communities. Specifically, the surveys gauge the current cooking and heating challenges in the Himalayan region of Chakrata. These results will provide important insights into follow-up surveys, design requirements, and directions to take the project moving forward.

Chapter 2

Methodology

2.1 Survey Location and Household Participants

Given the team's prior connection with these communities, the sub-district of Chakrata in the state of Uttarakhand was chosen as the location to conduct household surveys (Figure 2-1). Chakrata is located 90 kilometers north from Dehradun, which is the capital city of the state of Uttarakhand, India. Within this sub district, fifteen households were surveyed in the villages of Koruwa, Jadi, and Mangrauli. These villages were chosen due to UPES' connections with the villages and leaders, the low migration rates, and the accessibility of households.

All three villages have populations between 400 and 500. They are located at elevations between 1500 and 2300 meters. The climate in this region is humid subtropical, with temperatures throughout the year ranging from 5°C and 35°C [35].

Like other households in the Himalaya, households in Chakrata use a type of chulha that is specific to their needs and preferences. Prior interactions with these local communities suggested challenges with HAP emitted from the chulha. Previous work by MIT D-Lab in other Himalayan villages of India and Nepal had also found heating to be a significant challenge in those communities [36]. As such, the proposed survey instruments would include questions related to cooking, heating, and HAP.

Figure 2-1: Map of India highlighting Uttarakhand and map of Uttarakhand denoting the location of Chakrata

Figure 2-2: Example of house in Chakrata (Photo credit: Dr. Pranava Chaudhari, UPES)

2.2 Survey Topics, Material, and Iteration

In order to evaluate general cooking and heating needs in Himalayan households, the survey (henceforth referred to as the Chakrata Preliminary Survey, abbreviated as CPS) provides a preliminary overview of cooking and heating needs in the villages of Chakrata. Data collection took place during December 2020 and the results will be used to design follow-up data collection in spring and summer of 2021. While follow-up surveys were expected to be implemented earlier in the spring, the challenges of the COVID-19 pandemic and its devastating impact on India have pushed back the timeline for the surveys. COVID-19 has continued to create challenges in accessing communities safely, and the course of the pandemic will dictate how and when surveys will be implemented.

The Energy Assessment Toolkit created by MIT D-Lab was used as a reference for many of the Chakrata survey questions [34]. The Energy Assessment Toolkit allows for the standard baseline questions to be modified based on the nuances with households, the already apparent trends, expertise of the researchers, and the scope of the research. Given that the scope of the research was particularly about cooking and heating needs, any standard questions in the Toolkit outside of that scope were removed.

Additionally, specific questions about the chulha and timing and seasonality of cooking, heating, and HAP were added to provide information regarding daily and annual trends.

The CPS was reviewed and revised through a strict iteration process to align the contents of the survey with Lean Research Principles [32]. The principles require surveys to be:

1. Rigorous - The survey should capture the important information to gather an understanding of household challenges, needs and preferences and guide potential directions to take the project.

2. Respectful - The data collection should occur in a convenient location for the participants and be arranged with advance notice and consent to participate,

photograph the home, and collect home dimensions. Institutional Review Board (IRB) exemption was obtained prior to conducting the surveys (MIT COUHES E-2663). All survey responses were anonymized to protect the identities of the respondents.

3. Relevant - While other aspects of household energy could be useful for other projects, the scope of the research was to remain limited to cooking and heating, while still offering flexibility for open-ended responses.

4. Right-Sized - The survey was to be short as possible without compromising the data needed to make relevant conclusions.

The outline of the CPS instrument is as follows:

1. Background Information - This section collected demographic information about the respondent including their gender, location, and contact information.

2. Fuels Information - This section collected information about the types of fuels and consumption patterns over time and by use type. Additionally, respondents were asked about fuel collection behaviors and time and financial costs.

3. Cooking Information - This section collected information about cooking needs, features of the household cooking arrangement, and likes and dislikes. This section also asked specific questions about the chulha and information related to construction materials, methods, maintenance and costs.

4. Heating Information - This section collected information about heating behaviors, features of the household heating arrangement, and likes and dislikes. This section also included questions about HAP.

5. Finances - This section collected information about the financial services used by households.

Appendix A provides the full version of the CPS.

2.3 Chakrata Preliminary Survey Implementation

The Livable Himalayan Home team from UPES implemented the CPS during December 2020 and January 2021 in each of the three villages in Chakrata. The villages were divided into equal geographical sections in order to survey households in each of those sections. The surveying team also made sure to include a variety of different types of households given that older homes are commonly constructed of wood while newer homes are constructed of brick and mortar.

While the written survey provided explicit questions, the actual survey was conducted in a semi-structured format. This format is consistent with participatory design, allowing respondents to drive the conversation and provide relevant information that they think is important to the challenges they are experiencing [31]. Additionally, the informal nature of the conversation also allowed surveyors to explore certain topics in depth and check responses across households. For example, respondents indicated that there were challenges related to irrigation in the fields where local farmers work. This was not an explicit question or directly related to household cooking and heating, but these insights would not have been provided without the intentional flexibility of the survey.

The CPS was conducted in the Hindi language and within the households to provide ease and comfort for respondents. Additionally, respondents were able to directly point to aspects of their homes, including cooking and heating arrangements. With the consent of respondents, photos were collected of some of the households and their respective cooking and heating arrangement. The duration of the CPS was between 40 and 60 minutes.

The surveyors also tried to address multiple members of the family, both men and women. In total, eight men and seven women were surveyed.

With the respondent's permission, surveys were recorded and then reviewed at a later time to check for accuracy and missed responses. After the survey data was transcribed, the responses were coded into several categories to enable analysis.

2.4 Coding Answers

Responses from the fifteen surveys were coded into an anonymized and closed-access Google Sheets spreadsheet. Coding was done manually and based on common themes among the responses.

2.5 Limitations to Methodology

While these surveys provided important information that would be useful in providing direction for the future project, any apparent trends only represent a small sample of the total village communities. Out of approximately 100 available households, 15 were surveyed. The COVID-19 pandemic limited the team's ability to visit villages multiple times and survey a large sample size safely. Future work needs to include larger sample sizes within these villages (on the order of 30 houses or more total) in order to be able to more confidently determine specific and more detailed trends, especially across genders. Additionally, only one person per household was surveyed. There could be differences across preferences within households and this dynamic was not evaluated in the current study.

Furthermore, the coding of the survey answers was a manual process. For future surveys that ask more detailed questions, it will be important to have a very precise protocol for coding more detailed qualitative answers.

Chapter 3

Results and Discussion

3.1 Results of the Chakrata Preliminary Survey

This section provides an overview of the results from the CPS. Additional survey results are included in Appendix B.

3.1.1 Fuel Use

All of the surveyed households indicated wood as the primary fuel source for their cooking and heating needs. Some households had access to liquefied petroleum gas (LPG), a few had access to electricity, and one utilized solar energy (Table 3.1). The average cost of using LPG and electricity was 36 Rs/month/person and 29 Rs/month/person, respectively. Firewood had no financial cost to households because it was gathered from nearby forests, although this may incur a "time cost" on women in the household who are responsible for gathering firewood. However, no respondents explicitly mentioned the time associated with gathering fuel as a problem. Firewood was often supplemented with other forms of biomass, such as mustard grass and straw. This was especially the case during the rainy season when it is difficult to gather and store sufficient quantities of dry wood. The surveyors categorized all types of biomass, including firewood, as "wood" for the purposes of the CPS.

Table 3.1: Household fuel breakdown by type and use

	Cooking	Heating water	Space heating	Lighting
Electricity	4	1	0	15
Kerosene	0	0	0	0
LPG/gas	11	3	0	0
Wood	15	15	15	0
Solar	0	1	0	1

3.1.2 Chulha

All of the surveyed households indicated that they own and use a chulha (Figure 3-1). The common chulha was constructed from different materials including mud, stone, brick, grass, cow dung, cow urine, goat hair, goat urine, and starch. Households utilized the chulha for space heating in addition to cooking. While mud and stone provided the foundation and structure, other materials were also important including livestock urine, which was used as a disinfectant and culturally important as well. The chulha was commonly built and maintained by women, with an average maintenance frequency of four to five months and chulha reconstruction every two to three years, usually during an auspicious festival.

3.1.3 Cooking

While all households indicated using their chulha, some households also used LPG fueled stoves and other cooking appliances. While information was not gathered on the different uses of cookstoves, households commented that LPG was primarily used for quickly preparing water for tea and other warm drinks, while the chulha was the primary cookstove for regular meal preparation. Many households indicated that the LPG stove was used sparingly due to the cost of operation compared to wood and biomass, which were indicated as free of cost and accessible.

Meals were usually cooked twice per day, once in the morning and once in the evening, with some households also preparing a midday meal. The households indicated that the current cooking arrangements had a variety of positive attributes, the most common being the taste of the food and the low costs associated with cooking

Figure 3-1: Chulha arrangement in a Chakrata household (Photo credit: Dr. Pranava Chaudhari, UPES)

Figure 3-2: Stovetop for the household chulha (Photo credit: Dr. Pranava Chaudhari, UPES)

Table 3.2: Positives of current cooking arrangement

Reason	Total households	Female respondents	Male respondents
Taste of food	11	6	5
Cost	11	5	6
Less LPG use	5	2	3
Type of food	3	2	1
Other	3	2	1
No response	1	0	1

(Table 3.2). The most common areas in need of improvement were smoke emissions and quantity of wood consumed (Table 3.3). Across genders, males and females both commented on positives and negatives similarly, with the only notable difference being that females responded with a greater variety of potential improvements to their cooking arrangement. This is likely consistent with women's greater familiarity with cooking and thus more feedback for areas of improvement.

3.1.4 Heating

All of the participating households considered their homes warm and comfortable throughout the year. Most households used the chulha as their primary means of space heating. Homes are usually heated in the morning and evening (Figure 3-3).

Table 3.3: Improvements for current cooking arrangement

Reason	Total households	Female respondents	Male respondents
Smoke	11	5	6
Amount of wood used	11	5	6
Cooking time	8	4	4
Other	4	4	0
Heat in the summer	3	2	1
Carbon deposition	1	0	1
No response	1	0	1

Additionally, more indoor heating was necessary during the winter season, which also coincided with a reported increase in fuel consumption (Figure 3-4).

Like cooking, households indicated that their home heating arrangements had several positive attributes and areas for potential improvement. The most common positive attribute was the wooden walls, which respondents considered to help maintain a comfortable indoor environment during the hot and cold summer and winter seasons, respectively. This was of note because wood is a better insulating material than concrete, brick and mortar but is not ideal compared to common insulating materials. Households also commented they liked the dual use of the chulha for cooking and heating (Table 3.4). When asked explicitly if their current heating arrangement cause high levels of indoor smoke, all households indicated that this was a problem. HAP was reportedly most common during the winter when the need for heating was higher (Figure 3-4). The most commonly reported areas of heating improvement were smoke reduction and fuel consumption (Table 3.5). Like cooking, there was little difference across genders for heating preferences and needs. The only major difference was that men commented more about the importance of the wooden walls. The reason for that discrepancy is unclear.

3.1.5 Finances

Almost all of the households had access to bank accounts, more than half had access to savings accounts, and nearly half had credit cards (Table 3.6). Understanding the financial opportunities available for households provides important context on the

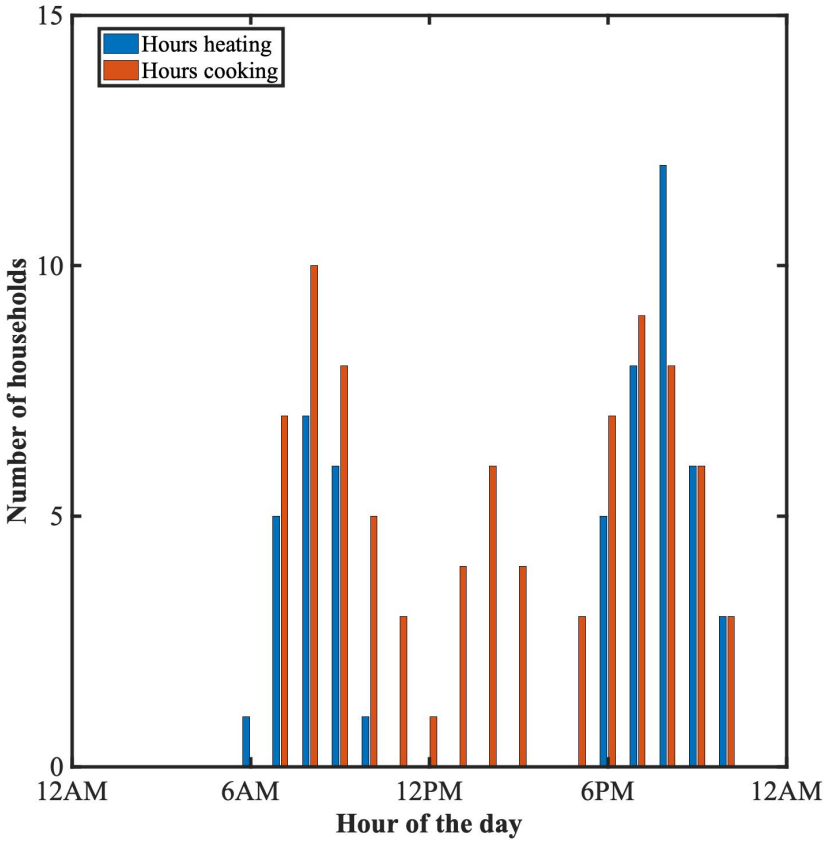

Figure 3-3: Daily heating and cooking times

Table 3.4: Positives of current heating arrangement

Reason	Total households	Female respondents	Male respondents
Wooden walls	10	3	7
Use of kitchen chulha	8	4	4
Cost	6	3	3
Use of angeethi	3	2	1
Cultural reasons	2	1	1

Table 3.5: Improvements for current heating arrangement

Reason	Total households	Female respondents	Male respondents
Smoke	12	6	6
Amount of wood used	12	6	6
Other	2	1	1
No response	1	0	1

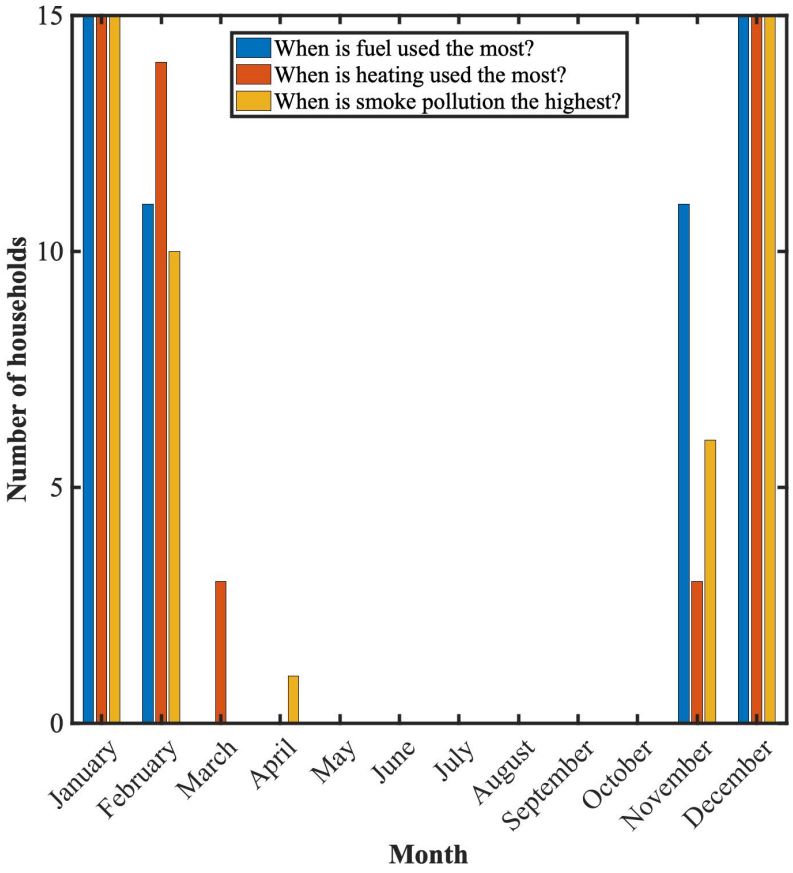

Figure 3-4: Seasonality of fuel consumption, heating, and smoke pollution (HAP)

Table 3.6: Financial resources for households

Financial resources	Number of households
Bank account	14
Savings account	8
Kinsa credit card	6
Mobile money	2
Money transfer	1
Village savings	1

financial feasibility of future solutions for cooking and heating problems in the region. This will be an important design parameter when evaluating current technologies on the market and developing new ones in the communities.

3.2 Design Considerations

The results of the CPS provided important insights into potential solutions to household energy challenges in the Chakrata communities:

1. Accessibility and Cost - Current wood and biomass-fueled cooking and heating arrangements are free of financial cost because materials are locally sourced and built. Future solutions would need to consider these price points although houses may be willing to pay for a new appliance if the financial costs can be justified by lower time requirements (less time to gather materials or cook food).

2. Cultural - Respondents commented on the cultural importance of the chulha and the chulha's impact on the taste of the food. While this metric may be hard to quantify, future solutions need to be user tested extensively to ensure the quality of food is similar to that of the current arrangement. Additionally, this finding could indicate that a future solution may not be the introduction of another cooking or heating device but rather modifications to the existing chulha.

3. Dual Cooking and Heating Features - Respondents also commented on the dual feature of the chulha for cooking and heating. Solutions may need to con-

sider this dual feature, especially if a solution will incur a financial cost to the household. Once again, this may point towards solutions being modifications of current arrangements rather than new designs.

These insights highlight the importance of co-creation at the local level throughout the design process, especially because different regions of the Himalaya surveyed in other studies had differing opinions on cooking and heating. A study in the Lug Valley found most households surveyed in that region used cookstoves with chimneys (Himanshu tandoor) [23]. Like the households surveyed in Chakrata, households in the Lug Valley indicated LPG stoves were expensive compared to traditional stoves [23]. Households in that region also commented on their seasonal use of different cooking appliances. LPG stoves were used more in the summer because they provided less heat [23]. This type of pattern was not observed from the CPS households. Villages in Punjab also indicated LPG to be more expensive than their traditional cooking infrastructure (fueled mostly by cow dung instead of wood) [37]. Unlike in Chakrata, nearly half of the surveyed Punjabi households had outside kitchens which offer improved ventilation [37]. Survey research in Salambu, Nepal found that households saw LPG as undesirable due to high costs compared to traditional wood-fueled stoves, similar to the responses from the CPS [36]. However, unlike those of Chakrata, Salambu households indicated more heating challenges, and many households responded that their homes were not warm enough throughout the year [36].

These differences in cooking and heating needs point towards necessary co-design and co-creation activities with the communities to create solutions that are suitable to the specific local needs. The localized nature of such problems means that participation of the community is an important facet of the design process in this and other cases.

3.3 Unanswered Questions and Information

Given that the CPS demonstrated clear needs for the Chakrata communities for cooking and heating, more specific questions need to be asked in order to provide a

strong foundation to co-create solutions with the villages.

The unanswered questions can be arranged into three categories:

1. Observe - This data can be documented without a discussion with the households. Observation can help provide context to certain responses and also provide input in a way that would not otherwise be explainable through surveys [31]. Specifically, areas that would benefit from observation includes details about ventilation (including chimneys), pot and stove information, and cooking behavior.

2. Measure - Certain aspects of cooking and heating procedures can be measured directly. For example, fuel consumption can be measured using a variety of simple methods including the Kitchen Performance Test [38]. Sensors can also be installed to measure cookstove use and HAP over time [15]. Specifically, data needs to be gathered about the amount of wood and biomass burned per unit time of cooking; indoor and outdoor temperatures throughout the day and the year; carbon dioxide (CO_2), carbon monoxide (CO), and particulate matter levels ($PM_{2.5}$ and PM_{10}); and dimensions of the cooking arrangement.

3. Survey - Additional questions need to be directly asked to households. These constitute a survey which will include questions that elaborate on the fuel (amount, types, and collection timeline), the use of the chulha (foods prepared, usage timeline, comparison to LPG), and specifics about design priorities for the households (affordability, HAP, ease of cooking/convenience, ability to build/maintain by oneself, taste/type of food or traditional cooking methods, safety, dual cooking/heating capability, amount of fuel consumption).

The additional survey questions began to be instituted into a protocol for an extended follow-up survey (see Appendix C). This extended survey (henceforth called the Chakrata Extended Survey, abbreviated as CES) will include questions related to observations where the surveyor will record notes on aspects of the household they observe. There will also be space to include measurements that can be taken on the day of the survey rather than monitored through sensors.

Time permitting, the CES will also include questions about potential solutions by providing respondents pictures or the opportunity to try existing solutions. A protocol will be developed to test these solutions and provide feedback over time.

3.4 Next Steps and the Chakrata Extended Survey

In order to better understand the community and continue the co-creation process, a timeline for the CES and sensor setup was created. Originally, these surveys were to implemented in late spring, but given the rise of COVID-19 cases in India, the timeline was pushed back. This timeline is subject to change depending on the current COVID-19 pandemic and other factors and only provides a rough guideline for next steps:

1. August 2021 - Households will be asked questions for the CES. Additionally, sensors will be installed and measurements collected.

2. August 2021-January 2022 - Depending on the responses from the CES, workshops will be set up to continue the co-design process.

Chapter 4

Conclusion

Traditional biomass-fueled cooking and heating practices can be dangerous to households because of high emissions of HAP. In addition, many traditional means of cooking are inefficient compared to improved and modern appliances. In the Himalaya, traditional methods continue to be used for cooking and heating with limited adoption of new technologies.

Through a participatory design approach, the Chakrata Preliminary Survey (CPS) for household cooking and heating needs was implemented in the Chakrata region of the Himalaya to initiate co-design efforts to address household energy challenges. The CPS was implemented in fifteen households in Chakrata. All fifteen households utilized the chulha, a traditional biomass cookstove that also functions as a space heater. Households indicated that while the chulha utilizes fuel that comes at a zero financial cost and has an important role in the local culture, the current arrangement consumes too much firewood and emits large amounts of smoke. Similarly, given that the primary space heater is the chulha in many of these households, household members appreciated the low costs but believed there should be improvements to efficiency and smoke emissions for their heating needs as well.

These surveys provided useful information about potential barriers to implementation of future solutions, including cost and accessibility, the interconnected nature of cooking and heating, and cultural factors. These barriers may differ from other regions of the Himalaya, underscoring the importance of participatory design even at

the most local level.

Given the results of the CPS, an additional survey will need to be implemented to provide more context and information to generate design specifications and begin the solution co-design process. This survey, the Chakrata Extended Survey (CES), will be conducted during 2021 when conditions permit the research team to visit the communities and will provide D-Lab and our research partners the necessary information to gauge the effectiveness of solutions already on the market, determine the viability of new solutions, and lay the foundation to begin workshops to design and disseminate technologies.

While the surveys presented here only build on a long history of research on cooking and heating in the Himalaya region, the research presented in this thesis demonstrates the importance of implementing broad participation of different stakeholders at every step of the design process. This approach is likely to be effective not only in other regions of the Himalaya but also in communities around the world who are facing similar cooking and heating challenges.

Appendix A

Chakrata Preliminary Survey

The following pages provide the questions of the CPS. The sections of the survey are labeled the following:

1. Identification and Basic demographics
2. Questions about Fuels
3. Cooking/Pollution Problems
4. Home Heating Problems
5. Financial Questions
6. Wrap-Up

The CPS also included questions for interviewers to note down dimensions of the houses and other physical features. These were not relevant to the outcome of this thesis and thus were not included in this Appendix.

Survey for Himalayan Home User Needs – Preliminary Survey Winter 2020

This outline is for a preliminary survey of households in the Himalayas that will be administered in November. The results from this preliminary survey will help provide necessary information to develop a more involved and longer survey to be conducted in the spring, understand household needs and challenges, and inform new solutions.

Equipment List

- Camera
- Scale (to measure fuel)
- Tape measure
- Audio recorder/tape recorder/phone

A. Identification and Basic Demographics

1. Interview date and time _____
2. Interviewer name _____
3. Respondent name _____
4. State _____
5. Local Government Area _____
6. Community/village _____
7. Other location information _____
8. GPS coordinates (with phone if possible) _____
9. Altitude (with phone if possible) _____
10. Respondent gender _____
11. Age of respondent _____
12. Number of people that live in home _____

B. Questions about Fuels (4 minutes)

1. What energy sources do you use for the following activities (fill out table)?

Energy Source	Cooking	Heating water	Space Heating	Lighting
Electricity (ask about source)				
Kerosene				
LPG/gas				
Wood				
Solar				
Dung				
Other				

2. For the energy sources that had an answer above, please answer the following questions.

Energy Source	What is the cost?	How much used on a daily basis?	How do you collect the energy source/fuel?
Electricity (ask about source)			
Kerosene			
LPG/gas			
Wood			

Solar			
Dung			
Other			

C. Cooking/Pollution Problems (4 minutes targeted)

1. Please describe your cooking appliances.

2. During the day, when do you use your cooking appliances? (check mark)

12am		12pm	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	
11am		11pm	

3. During which months do you use the most fuel for cooking and heating? (check mark)

January		July	
February		August	
March		September	
April		October	
May		November	
June		December	

4. What do you like about your current cooking and heating appliances?

5. What would you improve on your current cooking appliances?

6. Questions about chulha (if applicable) (take picture of chulha or draw schematic after survey)
   i. How often do you buy or build a new chulha?

   ii. What are examples of when you buy or build a new chulha?

   iii. Who builds the chulha?

   iv. What materials are used to make the chulha?

   v. How much money does it take to buy or build a new chulha?

D. Home Heating Problems (4 minutes targeted)

1. Is your home warm and comfortable throughout the year?

i. During what hours do you heat your house each day? (check mark)

12am		12pm	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	
11am		11pm	

ii. During what months in the year does your home require the most heating? (check mark)

January		July	
February		August	
March		September	
April		October	
May		November	
June		December	

2. What do you like about your home heating system?

3. What would you improve on your home heating system?

4. Do you experience smoke or other air pollution when cooking and heating in your home?

i. [if yes] Are there any months during the year when pollution is worse than other months? (check mark)

January		July	
February		August	
March		September	
April		October	
May		November	
June		December	

E. Financial Questions (1 minute targeted)

1. What of the following financial services have you used?

Bank account	
Mobile Money (e.g. PayTM, Google Pay)	
Money transfer (e.g. NEFT, UPI)	
Savings account	
Business account	
Village savings and loan/self help group	
Microfinance loan	
“Thandal” informal loan	
Other	

F. Wrap-Up (2 minutes targeted)

1. Is there anything else you would like to tell us about cooking and heating in your household or in your community?

2. Are you interested in receiving updates and more information about this project and future activities?

[yes] [no] (circle)

i. [if yes] What type of communication would be best?

ii. Contact information

Appendix B

Additional Results from the Chakrata Preliminary Survey

The following tables are additional results that have not been presented earlier in the thesis.

Table B.1: Average costs of fuel per person per month

Fuel	Cost (Rs)
Electricity	36
LPG	29
Wood	0

	Household Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	# of people in household	6	7	4	7	13	8	10	9	9	5	6	5	6	7	8
Electricity	Cost (Rs/month)	200	125	600	575	125	175	250	450	125	100	100	200	100	190	375
	Cost (Rs/month/person)	33	18	150	82	10	22	25	50	14	20	17	40	17	27	47
	Use/day (units/day)	10	7.5	30							7.5	7.5	10			
	Use (units/day/person)	1.7	1.1	7.5	0.0	0.0	0.0	0.0	0.0		1.5	1.3	2.0			
LPG	Cost (Rs/cylinder)	600		600	600			650			600	600	600	750	630	675
	Cost (Rs/month)	480	#DIV/0!	171	200	0	#DIV/0!	433	#DIV/0!	#DIV/0!	343	240	171	250	210	450
	Cost (Rs/month/person)	80	#DIV/0!	43	29	0	#DIV/0!	43	#DIV/0!	#DIV/0!	69	40	34	42	30	56
	Months of use	1.25		3.5	3	3		1.5			1.75	2.5	3.5	3	3	1.5
	Days of use	37.5	0	105	90	90	0	45	0	0	52.5	75	105	90	90	45
	Cylinders/person/day	0.004	#DIV/0!	0.002	0.002	0.001	#DIV/0!	0.002	#DIV/0!	#DIV/0!	0.004	0.002	0.002	0.002	0.002	0.003
Wood	Collection	carry cylinder to town		carry cylinder to	carry cylinder to town			carry cylinder to town			carry cylinder to	carry cylinder to	carry cylinder to town			
	Cost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Use (kg/day)	5.5	5.5	5.5	5.5	5	6.5	6	15	10	5.5	5.5	5.5	10	13.5	
	Use(kg/person/day)	0.9	0.8	1.4	0.8	0.4	0.8	0.6	1.7	1.1	1.1	0.9	1.1	10.0	13.5	
	Time to collect (hrs)	3+	3+	Less than 2	3+	2-3	Less than 2	Less than 2	Less than 2	Less than 2	2-3	2-3	3+	3+	3+	2-3

Figure B-1: Calculation for determining fuel costs

Table B.2: Wood collection time per trip

Time	Number of households
<2 hours 5	
2-3 hours	4
3+ hours	6

Table B.3: Occasion to build new chulha

Reasons	Number of households
Festivals	7
Broken	6
No response	6
Auspicious day	2
Other	1

Table B.4: Gender of chulha manufacturer

Reasons	Number of households
Female	14
Both male and female	1
Male	0

Table B.5: Materials in chulha as mentioned by households

Material	Number of households
Cow Urine	15
Mud	14
Brick	13
Grass	12
Stone	7
Goat hair	5
Cow dung	2
Starch	1

Appendix C

Draft of the Chakrata Extended Survey

Prior to the submission of this thesis, work was being done on a follow up extended survey to conduct on households interviewed in the preliminary study. The following pages provide one of the initial iterations of this survey. This version will continue to be worked and iterated on until it is ready to implemented in the summer or fall of 2021. The full survey will be completed by MIT D-Lab, UPES, and ICT-Mumbai.

General Observations

1. Chimneys
    a. Does the house have a chimney? _____

    b. What is the chimney made of?

    c. Comments on the chimney's size, construction, etc.:

2. Cooking Pots
    a. Do the cooking pots have lids? _____

    b. Comments on the cooking pot's size, shape, material, etc.:

3. What cooking utensils are used?

4. Stove
    a. Is the cookstove fixed or portable?

    b. How many pot holes does the stove have?

    c. Additional comments on the stove:

5. Observations of family cooking (**TAKE VIDEO WITH CONSENT**)
    a. Batch or metered fuel feeding?

    b. Other observations:

6. Firewood
    a. Take measurements of the dimensions, shape, and weight of a few pieces of firewood, to be used in determining the firewood's density

    b. Take measurements of the firewood's moisture levels at a few different locations along the length of the wood

7. Additional observations (**TAKE PICTURES AND VIDEO WITH CONSENT**)

Questions about Fuel Usage

1.

Fuel	Frequency of Gathering (Every X days/weeks/months)	Time to Gather (X hours)	Amount of fuel gathered per trip
Wood			
LPG			
Cattle dung?			
Other Biomass			

2. What species of wood is used? What species of other biomass is used in place of wood?

3. How is wood cut and stored (or prepared)?

4. Are certain fuels used more depending on the season?

    a. When is non-wood biomass used to cook?

5. What will people do with the time saved by collecting fuel?

Questions about Current Cooking and Heating Setups

1. What specific cooking operations are used on the *chulha*? (e.g. boiling, grilling, bread-making, etc.)

2. What foods are commonly made on the *chulha*?

3. How much time per day is the chulha used for cooking?

4. How much time per day is the chulha used for heating in winter (not counting the amount of cooking hours)?

5. How much wood is used per day?
    a. Summer _____ kg
    b. Winter _____ kg

6. What else is the *chulha* used for beyond cooking/heating? (Water heating, bathing?)

7. What noticeable effects have the chimneys had with respect to cooking and heating safety and effectiveness? (if applicable)

8. How much time per day is the LPG stove used for cooking? _____ hours

9. What foods/drinks do you prepare using the LPG stove?

Questions about Potential Solutions

1. Rank your top 3 most important attributes towards an improvement to your cooking setup. (1=Most important….)

Affordability	
Pollution/Smoke	
Ease of cooking/cooking time	
Ability to build/maintain yourself	
Taste/type of food or Traditional cooking methods	
Safety	
Dual cooking/heating capability	
Amount of fuel consumption	

2. What of the following are your top 3 most important attributes towards an improvement to your heating setup? (Select 3)

Affordability	
Pollution/Smoke	
Ease of heating/heating time	
Ability to build/maintain yourself	
Safety	
Dual cooking/heating capability	
Amount of fuel consumption	

3. How important is building your own cooking/heating setup within cultural/traditional practice?

a. How does your *chulha*/current heating or cooking setup fit into your cultural practices?

4. What is the availability of the following materials? Who would be able to work with these materials?

    a. Metals

    b. Ceramics

5. How much are you willing to pay for an improvement to your cooking or heating setup?

Bibliography

[1] WHO, 2014. Burden of disease from Household Air Pollution for 2012. Tech. rep., Geneva.

[2] Greenstone, M., Nilekani, J., Pande, R., Ryan, N., Sudarshan, A., and Sugathan, A., 2015. "Lower pollution, longer lives: Life expectancy gains if india reduced particulate matter pollution". *Economic and Political Weekly,* ***50***, 2, pp. 40–46.

[3] Pandey, R., 2012. "Disease burden due to fuelwood combustion pollutants in rural areas of Himalayas, Uttarakhand". *Italian Journal of Public Health,* ***9***, pp. 1–9.

[4] Putti, V. R., Tsan, M., Mehta, S., and Kammila, S., 2015. "The State of the Global Clean and Improved Cooking Sector". pp. 1–179.

[5] Bonan, J., Pareglio, S., and Tavoni, M., 2017. "Access to modern energy: a review of barriers, drivers and impacts". *Environment and Development Economics,* ***22***(5), pp. 491–516.

[6] Aggarwal, R. K., and Chandel, S. S., 2004. "Review of Improved Cookstoves Programme in Western Himalayan State of India". *Biomass and Bioenergy,* ***27***(2), 8, pp. 131–144.

[7] Johnson, M., Edwards, R., Ghilardi, A., Berrueta, V., Gillen, D., Frenk, C. A., and Masera, O., 2009. "Quantification of Carbon Savings from Improved Biomass Cookstove Projects". *Environmental Science & Technology,* ***43***(7), 4, pp. 2456–2462.

[8] Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T., DeAngelo, B. J., Flanner, M. G., Ghan, S., Kärcher, B., Koch, D., Kinne, S., Kondo, Y., Quinn, P. K., Sarofim, M. C., Schultz, M. G., Schulz, M., Venkataraman, C., Zhang, H., Zhang, S., Bellouin, N., Guttikunda, S. K., Hopke, P. K., Jacobson, M. Z., Kaiser, J. W., Klimont, Z., Lohmann, U., Schwarz, J. P., Shindell, D., Storelvmo, T., Warren, S. G., and Zender, C. S., 2013. "Bounding the role of black carbon in the climate system: A scientific assessment: BLACK CARBON IN THE CLIMATE SYSTEM". *Journal of Geophysical Research: Atmospheres,* ***118***(11), 4, pp. 5380–5552.

[9] Pattanayak, S. K., Jeuland, M., Lewis, J. J., Usmani, F., Brooks, N., Bhojvaid, V., Kar, A., Lipinski, L., Morrison, L., Patange, O., Ramanathan, N., Rehman, I. H., Thadani, R., Vora, M., and Ramanathan, V., 2019. "Experimental evidence on promotion of electric and improved biomass cookstoves". *Proceedings of the National Academy of Sciences,* ***116***(27), 4, pp. 13282–13287.

[10] Urmee, T., and Gyamfi, S., 2014. "A review of improved Cookstove technologies and programs". *Renewable and Sustainable Energy Reviews,* ***33***, 4, pp. 625–635.

[11] Kumar, M., Kumar, S., and Tyagi, S. K., 2013. "Design, development and technological advancement in the biomass cookstoves: A review". *Renewable and Sustainable Energy Reviews,* ***26***, 4, pp. 265–285.

[12] Mehetre, S. A., Panwar, N. L., Sharma, D., and Kumar, H., 2017. "Improved biomass cookstoves for sustainable development: A review". *Renewable and Sustainable Energy Reviews,* ***73***, 6, pp. 672–687.

[13] Simon, G. L., Bailis, R., Baumgartner, J., Hyman, J., and Laurent, A., 2014. "Current debates and future research needs in the clean cookstove sector". *Energy for Sustainable Development,* ***20***, 6, pp. 49–57.

[14] Debbi, S., Elisa, P., Nigel, B., Dan, P., and Eva, R., 2014. "Factors influencing household uptake of improved solid fuel stoves in low- and middle-income countries: a qualitative systematic review". *International journal of environmental research and public health,* ***11***(8), 8, pp. 8228–8250.

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

[16] WWF-India, and TERI, 2020. Sustainable Space Heating Solutions in the Himalayan Region. Tech. rep., WWF-India.

[17] Kerimray, A., Rojas-Solórzano, L., Amouei Torkmahalleh, M., Hopke, P. K., and Ó Gallachóir, B. P., 2017. "Coal use for residential heating: Patterns, health implications and lessons learned". *Energy for Sustainable Development,* ***40***, 10, pp. 19–30.

[18] Fullerton, D. G., Bruce, N., and Gordon, S. B., 2008. "Indoor air pollution from biomass fuel smoke is a major health concern in the developing world". *Transactions of the Royal Society of Tropical Medicine and Hygiene,* ***102***(9), 9, pp. 843–851.

[19] Menghwani, V., Zerriffi, H., Dwivedi, P., Marshall, J. D., Grieshop, A., and Bailis, R., 2019. "Determinants of Cookstoves and Fuel Choice Among Rural Households in India". *EcoHealth,* ***16***(1), 3, pp. 21–60.

[20] Chatti, D., 2018. "Cows, Cookstoves, and Climate Change: A Non-Anthropocentric View of Household Energy Use in the Rural Indian Himalayas". *Relations,* ***6***(1), 7, p. 1.

[21] Jagadish, A., and Dwivedi, P., 2019. "Deconstructing networks, unearthing consensus: Diffusion of "cleaner" cookstoves in rural Himalayas of India". *Energy, Sustainability and Society,* ***9***(1), 4, p. 5.

[22] Pattanayak, S. K., Jeuland, M. A., Lewis, J. J., Bhojvaid, V., Brooks, N., Kar, A., Morrison, L., Patange, O., Philippone, L., Ramanathan, N., Rehman, I., Thadani, R., Vora, M., and Ramanathan, V., 2015. "Cooking up change in the Himalayas: Experimental evidence on cookstove promotion". *DUKE ENVIRONMENTAL AND ENERGY ECONOMICS WORKING PAPER SERIES*, pp. 0–28.

[23] Jagadish, A., and Dwivedi, P., 2018. "In the hearth, on the mind: Cultural consensus on fuelwood and cookstoves in the middle Himalayas of India". *Energy Research \& Social Science,* ***37***, 3, pp. 44–51.

[24] Bhatt, B. P., Rathore, S. S., Lemtur, M., and Sarkar, B., 2016. "Fuelwood energy pattern and biomass resources in Eastern Himalaya". *Renewable Energy,* ***94***, pp. 410–417.

[25] Luck, R., 2018. "What is it that makes participation in design participatory design?". *Design Studies,* ***59***, 4, pp. 1–8.

[26] "Incorporating Contextual Factors Into a Design Process: An Analysis of Engineering for Global Development Literature".

[27] Mattson, C. A., and Wood, A. E., 2014. "Nine Principles for Design for the Developing World as Derived From the Engineering Literature". *Journal of Mechanical Design,* ***136***(12), 12, p. 121403.

[28] Wood, A. E., and Mattson, C. A., 2016. "Design for the Developing World: Common Pitfalls and How to Avoid Them". *Journal of Mechanical Design,* ***138***(3), 3, p. 31101.

[29] Seshadri, P., Joslyn, C. H., Hynes, M. M., and Reid, T., 2019. "Compassionate design: considerations that impact the users' dignity, empowerment and sense of security". *Design Science,* ***5***, 4, p. e21.

[30] Wood, A. E., and Mattson, C. A., 2019. "Quantifying the effects of various factors on the utility of design ethnography in the developing world". *Research in Engineering Design,* ***30***(3), 7, pp. 317–338.

[31] Smith, R., and Leith, K., 2015. User Research Framework. Tech. rep., Massachusetts Institute of Technology - MIT D-Lab, Cambridge, MA.

[32] Hoffecker, E., Leith, K., and Wilson, K., 2015. The Lean Research Framework. Tech. rep., Cambridge, MA.

[33] D-Lab, 2017. Handbook for Biomass Cookstove Research, Design, and Development. Tech. rep.

[34] Verploegen, E., 2016. Energy Assessment Toolkit. Tech. rep., Cambridge, MA.

[35] WorldWeatherOnline.com, 2021. Chakrata Monatliche Klimadurchschnitte, 2.

[36] Paudel, B., 2020. Energy Need Assesment and Thermal Home Insulation in Salambu Village of Nepal. Tech. rep., Kathmandu University.

[37] Sharma, D., Ravindra, K., Kaur, M., Prinja, S., and Mor, S., 2020. "Cost evaluation of different household fuels and identification of the barriers for the choice of clean cooking fuels in India". *Sustainable Cities and Society,* ***52***(May 2019), p. 101825.

[38] Bailis, R., 2007. Kitchen Performance Test (KPT). Tech. Rep. January, Shell Foundation.