Jaagran Detectors to Address Indoor Air Pollution (IAP) in India

Final Design History File
December 3, 2019
(Names hidden for privacy)

Group 3: (names hidden for privacy)

I. Problem Definition and Need

<u>Problem</u>: Millions of households in rural India use solid fuel sources to cook indoors with open fires and traditional stoves. These fuel sources often include biomass such as firewood, cow dung, and crop waste. The burning of these solid fuels leads to indoor air pollution (IAP), which is the emission and retention of harmful pollutants in the house due to open cooking and poor ventilation. Those cooking with biomass fuels are exposed to three times the level of emissions than those cooking with alternative, cleaner fuels [1]. These emissions contain harmful substances such as sulfur dioxide, nitrogen dioxide, carbon monoxide, polyaromatic hydrocarbons, and formaldehyde, which can have deleterious effects on respiratory and cardiovascular health [1]. Exposure to IAP has been correlated with increased risk of respiratory and cardiovascular disease, conditions that are difficult and costly to treat, particularly in low-resource settings such as rural India. IAP is most prevalent among poor, rural communities where households cannot afford cleaner fuel sources [2]. Women and children are disproportionately affected because they are typically involved in household cooking [2,3]. Although the number of premature deaths in India attributed to IAP has declined substantially since the early 1990's, the downward trend has consistently lagged behind that of neighboring China as well as the average middle-income country [2]. In 2017 alone, IAP still accounted for nearly 500,000 premature deaths in India [2]. Despite efforts by the Indian government and non-governmental organizations (NGO's) to reduce household exposure to IAP, it remains a major problem, particularly in rural India. One likely reason is a knowledge gap: those most often exposed to IAP aren't necessarily aware of the health ramifications of traditional cooking methods. Therefore, awareness among rural households is a major barrier to long-lasting changes in cooking habits.

<u>Need statement</u>: A way to increase awareness of IAP and incentivize alternative cooking options to reduce exposure to IAP in rural, Indian households.

II. Research

1. Disease State Fundamentals

1.1 Major diseases

Indoor air pollution (IAP) has a deleterious effect on cardiovascular and respiratory health, leading to health complications including chronic obstructive pulmonary disease (COPD), asthma, high blood pressure, lung cancer, and heart disease [1]. Smoke inhalation alters the defense mechanism of the lungs which can lead to pneumonia, respiratory tract infections, and bronchitis [4]. Domestic exposure to wood smoke can lead to chronic respiratory illnesses including COPD with airway fibrosis, anthracosis, and pulmonary arterial hyperplasia [4]. The burden of these diseases in India is high but could potentially be reduced by preventing exposure to solid fuel sources in the home.

2. Existing Solutions

2.1 Alternative fuel sources

2.1.1 Liquefied Petroleum Gas

Since January 2016, The Government of India has run a program called "Pradhan Mantri Ujjwala Yojana" (PMUY) that is designed to encourage low-income, rural households to use liquefied petroleum gas (LPG) cylinders as their cooking fuel source since LPG is cleaner than biomass fuel sources. The program uses a combination of subsidies and loans to incentivize households to install connections to LPG suppliers and to purchase LPG cylinders. The program has been successful in encouraging the target demographic to make initial investments in LPG fuel connections. From the start of the program to December 2018 (a period of close to 3 full years), approximately 70 million women from poor, rural areas have reportedly benefited from the program [3]. According to a study evaluating the impact of PMUY, the program accelerated LPG adoption by 16 months, meaning without the program, it would have taken 16 more months for consumers to naturally reach the adoption rate recorded at the time of the study [3,5].

However, study data suggests that on average, PMUY participants consumed about half the LPG that rural, non-PMUY participants consumed (2.3 cylinders versus 4.7 cylinders annually) [3,5]. The average rural household would reportedly need to purchase ten cylinders annually to cook exclusively with LPG [3,5], so PMUY fell short of encouraging households to eliminate solid fuel cooking altogether. The average rural household not participating in PMUY also falls short of the estimated target. Furthermore, the study found that on average, rural LPG customers did not considerably change their LPG purchases over a period of five years [3,5], indicating that despite growing familiarity and experience with LPG, these households did not take steps over time to increase their LPG usage to a level that would eliminate the need for biomass cooking. There was also evidence that seasonal changes in agricultural income affected LPG consumption behavior, with lower seasonal income associated with less LPG consumption [3,5]. This may be a barrier to exclusive, year-round use of LPG.

2.1.2 Biomass briquettes

To combat similar public health concerns over IAP in rural Shanxi, China, the provincial government encouraged households to use coal briquettes as a cooking fuel source because it produces a relatively low amount of air pollutants, helping mitigate the problem of IAP [6]. The cost of these briquettes is relatively low [6]. If an analogous fuel source with a similar cost profile could be utilized in rural India, it may decrease the need for a rigorous redesign of cookstoves or significant infrastructure investments.

That analogous fuel source could be biomass briquettes. Ashden Award winner Nishant Bioenergy is an India-based business that produces biomass briquettes. They supply biomass briquettes to schools and bakeries that had historically used firewood as fuel. Biomass briquettes are made using a high-pressure briquetting press that is fed with sawdust from local sawmills and furniture workshops, coffee husk, and other agricultural residues. India has many local briquette producers that offer could offer consumers a cheaper alternative to LPG cylinders. Abellon CleanEnergy, another Ashden Award winner, produces over 70,000 tons of biomass pellets each year from agricultural residues and sawdust. Most are used to replace lignite and coal in factory boilers. These pellets could potentially be used to form biomass briquettes.

One study found that replacing solid fuel sources with their carbonized products significantly reduces the amount of pollutants released by household cookstoves [7]. This suggests carbonized biomass briquettes may be a less harmful fuel source than the unprocessed biomass sources that are typically used for cooking. In general, most research on biomass briquettes in India has focused on reducing emitted carbon dioxide levels rather than IAP.

2.2 Improved Cookstoves

2.2.1 “Chulhas”

NGO’s and the Government of India (through the Ministry of New and Renewable Energy [MNRE]) have run programs to provide rural households with improved stoves called “chulhas” at subsidized prices. These stoves are typically made of mud or clay, have an enclosed flame, and have a chimney that funnels smoke out of the house. The components are designed to be relatively easy to put together. The typical chulha has two burners to decrease cooking time, and households are sometimes trained to use and maintain the stoves. There are a number of brands of chulhas approved by the MNRE and thus available for consumption in India [8].

Researchers from the Massachusetts Institute of Technology (MIT) conducted a randomized controlled trial to evaluate the effectiveness of chulhas in changing household behavior and protecting household members' health against disease attributed to IAP. The study utilized a chulha distribution program run by NGO's that randomly provided chulhas to some households but not others (the control group). The study found that, similar to the Indian government's LPG cylinder program, adoption rates were encouraging, but there wasn't strong evidence of regular, long-term use [9]. Even at the onset of adoption, compared to households in the control group, households that were randomly given chulhas only cooked 3.5 more meals per week (on average) with a chulha. After three years, the difference was only 1.8 more meals per week (on average) [9]. There was also evidence that households sometimes used the traditional (polluting) stoves alongside the chulhas [9]. The study also found that households that were given chulhas decreased their usage of the chulhas over time and did not repair them when they incurred wear-and-tear [9]. The reason may be that households tended to be responsible for covering the cost of stove maintenance, according to the study [9]. This may have inhibited continued use considering the chulhas seemed to be less durable than traditional stoves [9].

2.2.2 Biomass Cookstoves, Biogas ("Gobar") Cookstoves, and Gasifier Cookstoves

A few other types of improved cookstoves serve as alternatives to chulhas, though at a higher cost. But the advantage of these alternatives is that they burn biomass fuels more efficiently, meaning more heat and fewer polluting byproducts are produced per quantity of fuel. This entails reduced exposure to IAP and more timely cooking of food. One example is the biomass cookstove, examples of which are the Greenway Smart Stove and Greenway Jumbo Stove produced by Indian stove company Greenway Appliances. They are designed to burn biomass fuel more efficiently, but the costs of repair or replacement is high, the quality and taste of food may be different from that of traditionally prepared dishes [10], and the stove tends to be limited to cooking one dish at a time. An alternative to biomass cookstoves are biogas (or "gobar") cookstoves, which uses an anaerobic process to convert cow dung or other organic matter into gas that can be combusted to produce heat that cooks food. Another alternative is the gasifier cookstove, which typically takes wood pellets and converts them into a gas that is combusted to produce heat that cooks the food. Gasifier stoves, particularly fan-driven gasifier stoves, are considered to be the cleanest cookstoves that use biomass fuel [10]. However, there are questions about the durability of gasifier stoves [10] and the cost and frequency of repairing their components. In addition, the wood pellets are manufactured and thus cannot be naturally obtained by the locals who would benefit from the cookstove.

2.3 Summary of Prior Art

The below table (Table 1) details some of the related prior art and intellectual property filed in this space. Due to the wide array of possible solutions to indoor air pollution, this table is not an exhaustive list.

Table 1: Summary of prior art.

Name	Patent Number	Date Filed	Major Claims
Portable char burning hearth (chulha)	IN2003DE00839A	6/25/2003	A portable char burning hearth (chulha) comprising a die casted or fabricated metal body open at top and closed at the bottom with cut at the bottom for air passage
Liquid petroleum gas cannister connector	CA2211052C	8/12/1996 (expired 8/7/2017)	An LPG canister connector is for providing a flow path from a canister, containing liquid fuel and having a cap with an outlet, to a combustion appliance
Direct liquid injection of liquid petroleum gas	CA1198494A	9/28/1981	A fuel injector and injection system for injecting liquified petroleum gas (LPG) into at least one air/fuel mixing chamber from a storage means that stores pressurized LPG in its liquid state.

Side-Feed Forced-Air Biomass Burning Cookstove	US20160076774A1	9/11/2014	Systems and devices that aid in reducing particulate emissions from biomass stoves, for example by the use of gases injected in or near the oxidation zone of a combustion chamber.
Air measurement device and control system for preventing indoor air pollution	KR101160986B1	2/27/2012	A signal processor which receives, amplifies, filters, and converts the measured signal detected by the detector into digital data; A control unit which receives the measurement data through the signal processing unit
Recipe and making process of briquette desulfurizing waterproofing and combustion supporting binder	CN198675A	06/27/2007	The briquette low-cost, desulfurizing, waterproofing, supporting and strengthening combustion supporting binder consists of sodium nitrate, magnesium chloride, sodium chloride, ammonium chloride, light magnesia, calcium oxide, and cellulose.

3. Gap Analysis

We examined the pros and cons of existing solutions by constructing a gap analysis table (Table 2). Mehetre et al. (2017) proposed that there are three characteristics the ideal solution should have: 1. Relatively inexpensive (i.e. equal or lower cost compared to traditional stoves); 2. Durable enough to handle everyday use; and 3. Resource-friendly (i.e. conducive to utilizing locally available resources) [8]. We interpreted the first suggestion to mean both the cost of purchase and the cost of repair, replacement, or maintenance. In fact, a separate article from BusinessWorld indicated that the cost of repair and maintenance was a significant challenge to long-term use of alternatives to traditional stoves [11]. The article also indicated that end-users are sensitive to cost when choosing a cooking device and suggested the ideal solution would not require locals to deviate from using cheap and accessible biomass fuels [11]. We combined this criterion with Mehetre at al.'s (2017) third suggestion to create a broader category labeled "resource-friendly for locals."

Table 2: Gap analysis of existing solutions

Alternatives to Traditional Stoves	Relatively inexpensive	Durable	Resource-friendly for locals	Low Emission of Pollutants	User Knowledge of Health Benefits
LPG cylinders	-	+	-	+++	-
Biomass briquette	+	+	++	++	-
Chulha	+	-	++	-	-
Biomass cookstove	-	-	+	+	-
Biogas cookstove	-		+	+	-
Gasifier cookstove	-	-	-	++	-

The most basic criterion for a cooking solution is that it has a low emission of pollutants, thereby reducing household exposure to IAP. Finally, a challenge we consistently encounter in our research is that end-users are not well-educated on the health risks of IAP or the health benefits of cleaner cooking methods. Therefore, we also consider the lack of education surrounding this problem to be a major deficit in the field.

The traditional cooking stove is very inexpensive, so it is difficult to provide a sustainable alternative option at a competitive price. The chulha is currently the most inexpensive option, as it can be built with naturally available mud or clay, thereby making the acquisition price lower than the other manufactured alternatives. However, it has been documented that locals forego repairing chulhas, possibly due to repair costs [8]. Since biomass briquettes are industrially mass-produced and the analogous coal briquette in China is documented to be cheap [6], we would expect biomass briquettes to be easy and cheap to produce and thus cheap for rural households to acquire.

As mentioned, the durability of chulhas, biomass cookstoves, and gasifier cookstoves has been called into question. Lower durability options require higher frequency of repair and thus greater household exposure to the costs of repair, which poses a challenge for the target demographic. The ideal solution would minimize the frequency of repair. The majority of alternative cooking options we have investigated still utilize biomass fuels, making them resource-friendly. By contrast, LPG cylinders do not use biomass fuel, making them less resource-friendly and more expensive. Chulhas are constructed with mud and clay, which makes them even more resource-friendly than the other improved cookstoves. Many of the proposed alternatives are designed to reduce the amount of pollutants released into the air. Chulhas do not reduce the amount of pollutants, but rather direct pollutants out of the house with a chimney. As mentioned, gasifier cookstoves are considered to be the most efficient improved cookstove while LPG cylinders reduce emissions substantially more than improved cookstoves in general. Coal briquettes in China are quite durable and their emissions are relatively low [6]. In the absence of formal emission test of biomass briquettes, we assume biomass briquettes would have a similar profile as an analog to coal briquettes.

Finally, adoption of cleaner cooking methods does not inherently make end-users more aware of the health benefits. End-users tend to prioritize minimizing short-term costs (financial and non-financial) over minimizing long-term health costs, leading them to continue using traditional stoves [11]. Promotion of solutions alone doesn't appear to change their long-term behavior or enhance their awareness. This suggests what might be needed is something educational in conjunction with a device that makes households aware of their own emission levels and an incentive that encourages households to reduce emission levels.

4. Economic impact

Smith et al. (2000) estimated that illnesses associated with IAP account for 1.6 billion-2 billion lost work-days in India annually [12,13]. Further research on the economic impacts of IAP in India is sparse.

On a global scale, the World Health Organization (WHO) Health Report 2002 estimated that IAP accounts for 2.7% of losses in disability-adjusted life years (DALYs) [12]. Specifically in "high mortality developing countries," IAP accounts for 3.7% of losses in DALYs [13]. A systematic review of the improved biomass cookstove literature found that improved cookstoves and LPG were beneficial for health among people in South Asia, Southeast Asia, Africa, and the Americas [8]. Improved cookstoves were more cost-effective than LPG in providing health benefits, according to cost-effectiveness analysis [8]. Shifting from a traditional coal-powered stove to a gasifier cookstove in rural areas in China had a cost-effectiveness ratio of $370/DALY [8]. In other words, it costs $370 in rural China to gain one disability-adjusted life-year by switching from a coal stove to a gasifier cookstove; this is well below the market threshold of $1500/DALY reported by the authors [8]. A cost-benefit analysis of Patsari cookstoves (a type of improved cookstove similar to the chulha) in rural Mexico produced a benefit-to-cost ratio between 11:1 and 9:1 [8]. Several other intervention studies suggested that switching from traditional stoves to improved cookstoves or LPG nets non-monetary benefits such as a reduction in time spent collecting firewood, more opportunities to earn income or pursue education, averted negative health impacts, forest preservation, and a reduction in polluting gases [8].

III. Stakeholder Analysis

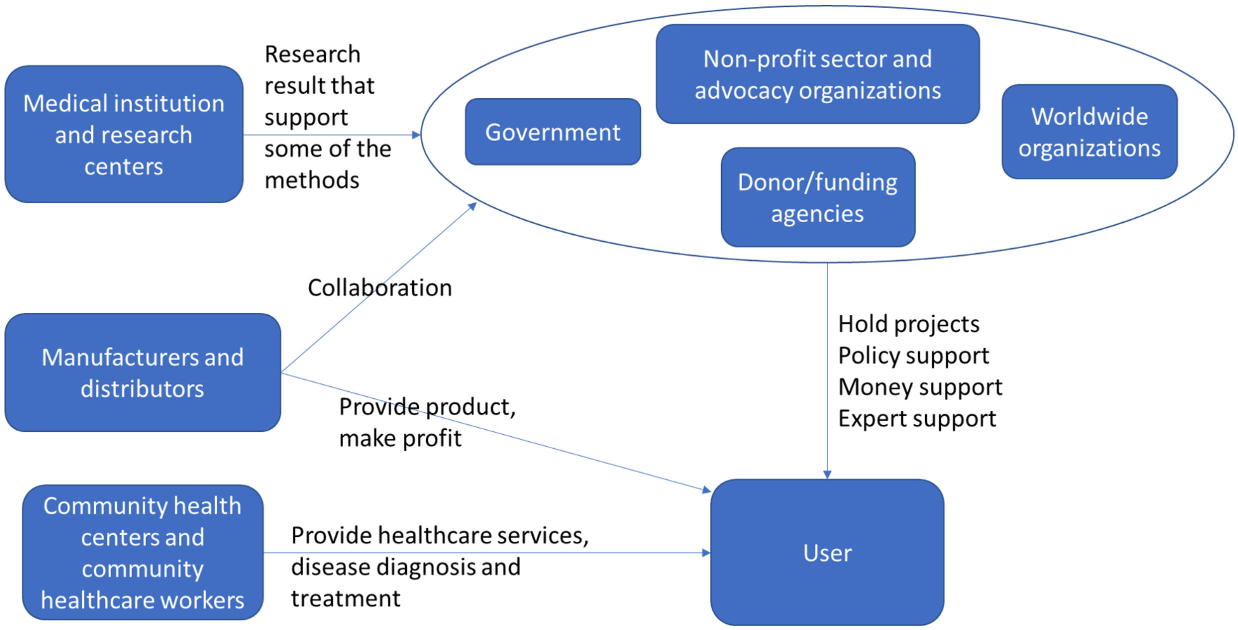
We formulated several hypotheses regarding the factors and motivations influencing each stakeholder. These hypotheses are detailed below under our stakeholder descriptions. We have conducted stakeholder interviews that tested these hypotheses and assumptions.

1. Stakeholders

1) **User:** Families that live in rural India. Indoor air pollution disproportionately affects women children since they are primarily involved in household cooking. The user of our innovation is one of the primary stakeholders in this ecosystem. The role of the user is to interact with our proposed innovation (successfully or unsuccessfully) and ultimately adopt this solution or maintain the previous status quo. It is important to note that while the user will be the stakeholder who most closely interacts with the innovation, they may not necessarily be the “payer” or the “customer.”
2) **Government:** The Government of India Ministry of New & Renewable Energy, Ministry of Health and Family Welfare, Ministry of New and Renewable Energy. The role of the government is to ensure order, draft and enforce laws and codes, and maintain oversight in communities (local and national). Their motivations are complex, involving the well-being of their constituents, the local and national economy, and their own favorability/approval rating.
3) **Worldwide organizations:** UNICEF (interest in the welfare of children), WHO, Clean Cooking Alliance, Ashden (supports and promotes sustainable energy enterprises around the world).

4) **Manufacturers and distributors of materials:** Tata Trust, Greenway Appliances (largest Indian manufacturer of cookstoves), NextLeaf Analytics. The role of the manufacturers and distributors is to make and sell cooking appliances and materials. Their motivations include increasing sales, earning profits, and improving production efficiency.
5) **Donor/funding agencies:** Public Health Foundation of India (private-public partnership organizations). The role of donor and funding agencies is to provide monetary support for viable solutions that will benefit community members. They are motivated by a desire to invest in actionable and practical solutions with long-term viability. They may want their funds to aid in the success of solutions that are broadly applicable.
6) **Non-profit sector and advocacy organizations:** The Energy and Resources Institute (TERI) (Indian nonprofit, policy research organization), Sharp Developments NGO (India). Non-profit organizations and advocates can help understanding and integration with the local communities. In some cases, organizations that have an existing relationship in a community can help advocate for and build trust between a new organization/solution and community members.
7) **Community health centers and community healthcare workers:** The role of community health centers and healthcare workers is to provide care to those living in the surrounding areas. They are motivated by a desire to help people and improve health in their community. Because many of these centers are resource constrained, they may also be motivated to help a lot of people with a small amount of resources, funding, etc.
8) **Medical Institutions and Research Centers:** Indian Council of Medical Research (Receives funding from the Ministry of Health and Family Welfare), Massachusetts Institute of Technology (MIT) (evaluated the effectiveness of “chulhas”). The role of medical institutions and research centers is to improve patient care and outcomes based on collected data and research. They are motivated by a desire to improve public health in their community, country, etc.

2. Cycle of Care



IV. Expert Interviews/Correspondence

Overview of Interviews

We sought to better understand the many relevant stakeholder groups involved in the ecosystem surrounding indoor air pollution. To achieve this aim, we reached out to NGOs, multilateral organizations, researchers, clinicians, and community members. Our goal was to gain insight into the need, the cultural context of indoor cooking and air pollution, and the reason previous attempts at addressing this problem have failed.

Summary of Key Takeaways

1. Interview with the Sharp Developments NGO (India)

(1) LPG follow-up actions: There is a program called the City Gas Distribution that works to construct an LPG network to deliver more LPG resources for people. Based on this LPG network, the India government is planning to launch another campaign to expand LPG connection, which aims to be down to one per family and target 100 smart cities for the provision of gas via the City Gas Distribution (CGD). As the plan, they will expand the penetration of natural gas to about 326 cities by 2022 through suitable changes in

bidding/regulatory practices of Petroleum and Natural Gas Regulatory Board (PNGRB), which may need to build about 10,258 km has pipelines bid out by the PNRGB.

(2) New clean energy: solar and wind power: India is promoting solar energy programs to fulfill the goal of providing electricity to all households on a 24/7 basis. The government has already committed to bring electricity to every village by May 2018 to every household by 2022. Because solar and wind power are clean and recycled, it is an ideal alternative energy for people to long-term use.

2. Interview with Shanxi, China environmental protection agency staff

(1) Same situation faced by Shanxi province and Indian rural area: About 10 years ago, people lived in the rural area of Shanxi province, China using coal for indoor cooking and heating, which causes significant air pollution both indoor and outdoor, especially in winter. The government put a lot of effort for pollution control, from technology and economy perspectives.
(2) Solution for Shanxi province: Government introduce coal briquette into rural areas. Coal briquette will not produce sulfur dioxide, oxynitride or PM 2.5 when burning. The cost of coal briquette is about 1.5 times that of natural coal. For the poor family, the government will provide a subsidy to make coal briquette affordable for them.
(3) The reason of not choosing natural gas: lay down gas pipes in rural areas will cost a lot. Most of the countryside is geographically dispersed, population density is relatively low. Second, China is not a gas-rich country, 60% of natural gas dependence on import. Industry and citizens will be the first line for natural gas supplies.
(4) The reason of not choosing household air clean unit: Air clean units are mainly used in industry, in-house air clean unit is still impossible for now. An efficacy air clean unit will be expensive, a single-family cannot afford it. In the city, an apartment building will share one air clean unit to process cooking fumes. A simple filter cannot clean the polluted air efficiently.

3. Interview with User - (Thikkodi Village - Kozhikode district - Kerala - India)

(1) The user is from a low income household, single parent and she cooks with assistance from her mother for the whole family. She uses both LPG and solid fuel sources for her cooking and owns a non traditional 4 burner stove in addition to the traditional fireplace in her kitchen. The LPG gas cylinders are easily accessible to her but she predominantly uses the traditional stove and wood for cooking. The LPG gas cylinders are not economical for this user and is not sustainable.

(2) The user is not aware of the harmful effects of indoor air pollution. When asked if she would switch to LPG gas cylinders after she would be educated on the harmful effects, she was still skeptical because she would not still be able to afford it. She was not aware of any subsidised government lpg programs or non profits that worked towards reducing the harmful effects of IAP in her community. She said she would prefer to cook and eat within the comfort of her own home and kitchen and was not too happy about the concept of community kitchens and outdoor cooking.

4. Interview with Hannah Chi, Clean Cooking Alliance

(1) Hannah Chi works as the Senior Associate for Demand and Behavior Change at the Clean Cooking Alliance. She has been in this role for about 6 months and was previously at Save the Children. Clean Cooking Alliance has three main areas where they focus their efforts: 1. demand, 2. supply, 3. policy. Ms. Chi provides project management and studies how to increase demand for stoves and clean cooking devices.

(2) We asked Ms. Chi to comment on the opportunities and barriers that Clean Cooking Alliance often encounters when trying to implement new solutions. She mentioned that talking about the health risks associated with indoor cooking is often ineffective, as users witness family members cooking indoors throughout their life with little or no perceived impact on health. The Alliance has found that focusing on other benefits of clean cooking may resonate more with users, for example, by stressing that clean stoves do not damage white clothes and furniture as much. She also explained that a major barrier encountered in Indian communities is the disruptive weather that occurs during monsoon season. This affected the Alliance's ability to distribute new products and to interact with users regularly.

5. Interview with Tara Ramanathan and Rejesh Bose - Director and Project Coordinator at Nexleaf Analytics, India

(1) Rejesh has been working as a project coordinator with Nexleaf for the past year. He spoke to us briefly about the stove trace technology and the challenges they encountered while implementing the technology.

(2) When asked how they identified their target population he mentioned they outsourced this through an NGO that helped them identify rural villages in Orissa and Rajasthan in India that used traditional stoves and biomass and solid fuels like wood to cook. While implementing the stoves and detectors they realised that there would be a gender gap where most of the users would be women and for this reason they also used helped with a local NGO which predominantly used staff who were women to educate the villagers about the technology. Nexleaf also developed their own stoves with the detector and one

of the issues they face here was that the quality of these stoves were not adequate for the population because they would cook at a large scale. They reiterated on the design and eventually made the stoves more durable with the help of external manufacturers and designers. More broadly the biggest challenge they faced was to change the behaviours of these women who cook and influence them to change their style of cooking. However, he said the incentive program really helped overcome this barrier. Their business model of making the women who cook using their stoves and stove trace technology ambassadors of this program and incentivising them to reduce carbon emissions was something that he really believed in and felt that was a unique aspect of the company.

(3) He connected us with the program director of Nexleaf - Tara Ramanathan with whom we have a meeting scheduled in the future to speak further about the technology they developed for us to design our prototype better.

V. Market Analysis

1. Market Dynamics

The analysis of the potential market is based on The Government of India's cost data for subsidizing LPG adoption. To fund this program, the government has provided subsidies for LPG cylinders. Figure 1 below shows the cost trend from 2013-2017. In 2013, it reached a peak of $7.4 billion USD. However, cost declined to about $1.8 billion USD in 2016. In 2017, there was a slight rebound in cost, which rose to over $2.9 billion USD. Because the cost to the government is positively related to the number of LPG cylinders distributed, this trend may indicate that there was increased demand for LPG cylinders from 2016-2017. We speculate this is an indication that the market for LPG as an alternative fuel source for cooking grew from 2016-2017.

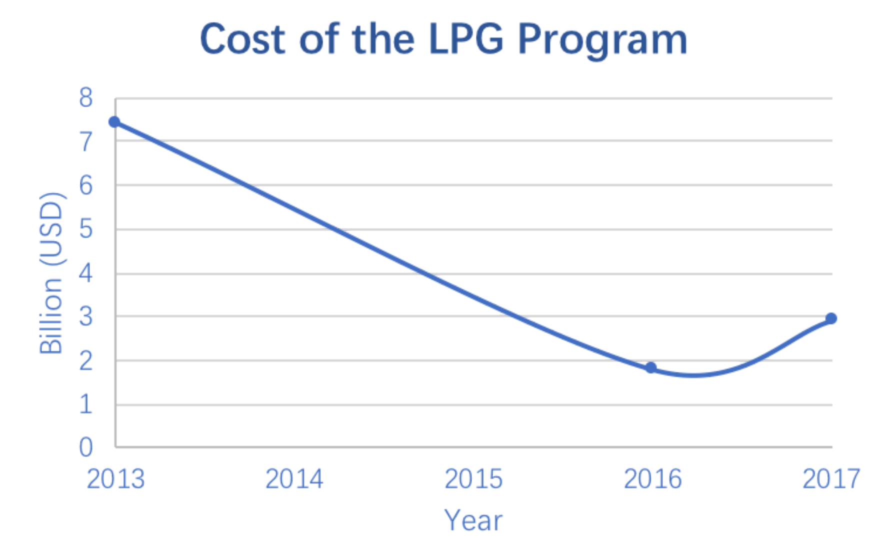


Figure 1. Subsidy costs of LPG program by Government of India

2. Target Market

A solution that provides a sustainable means of addressing IAP could benefit many low-and-middle-income countries (LMIC) where this practice is prevalent. Our initial target market is rural Indian communities. We chose this market due to our team's connection to healthcare workers and community members in India, the volume of research and innovations directed toward rural India, and the Indian Government's track record of supporting efforts in the clean cooking space.

3. Market Size

We conducted a top-down market analysis to estimate the market size for an innovation that reduces exposure to IAP. We started with the total population of India, which is approximately 1.4 billion people [14]. We found that about 64% of India's total population relies on solid fuel sources for household cooking [15], and about 66% of the total population lives in rural areas [16]. Multiplying these numbers together, we calculated that there are approximately 590 million individuals in rural India who are exposed to solid fuel source emissions from household cooking. The calculation is below:

1.4 billion individuals * (0.64) * (0.66) = 591,360,000 ~ 590 million individuals.

Cooking devices are typically used to prepare food for multiple people in a single household, meaning one unit of a device would serve several people at once. In other words, one unit of a device would be sold or distributed per household rather than one unit per person. Therefore, we researched the average number of people per household and found that it's 4.9; this is approximately 5 people per household [17]. We divided the number of individuals exposed to in-home biomass fuel emissions (591,360,000) by the average household size (5) to estimate the number of households in rural India that would benefit from an alternative to traditional stoves. We calculated that there are approximately 118 million such households. The calculation is below:

591,360,000 individuals / 5 individuals per household = 118,272,000 ~ 118 million households.

4. The cost of existing solutions

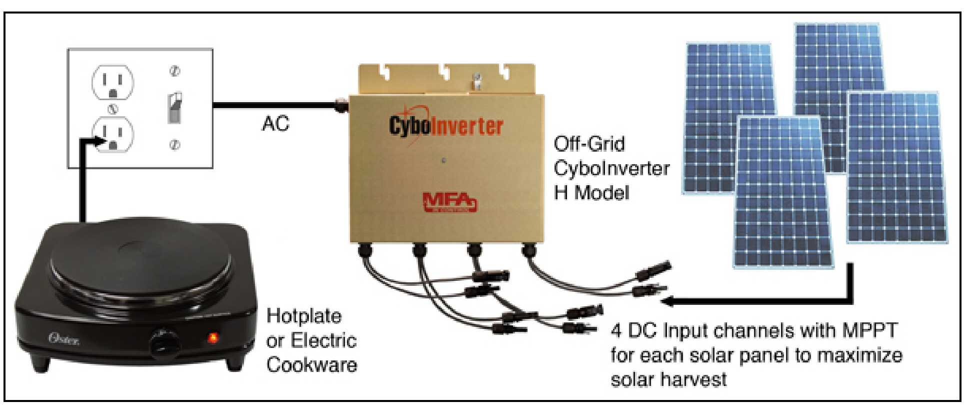
To reduce IAP, the Indian Government has implemented LPG subsidies to improve access to a cleaner cooking fuel source. This cost the Government of India up to $2.9B (USD) [18].

VI. Initial Solutions

1. Electric powered stoves - solar or wind:

If the supply of electricity can be stable and satisfy the daily demand of an average family, solar and wind power could enable people to cook with electricity, which is much cleaner than solid fuels. This solution would eliminate emissions from solid fuels if it is fully implemented.

Figure 2. Schematic diagram of solar-powered electricity solution to cooking.



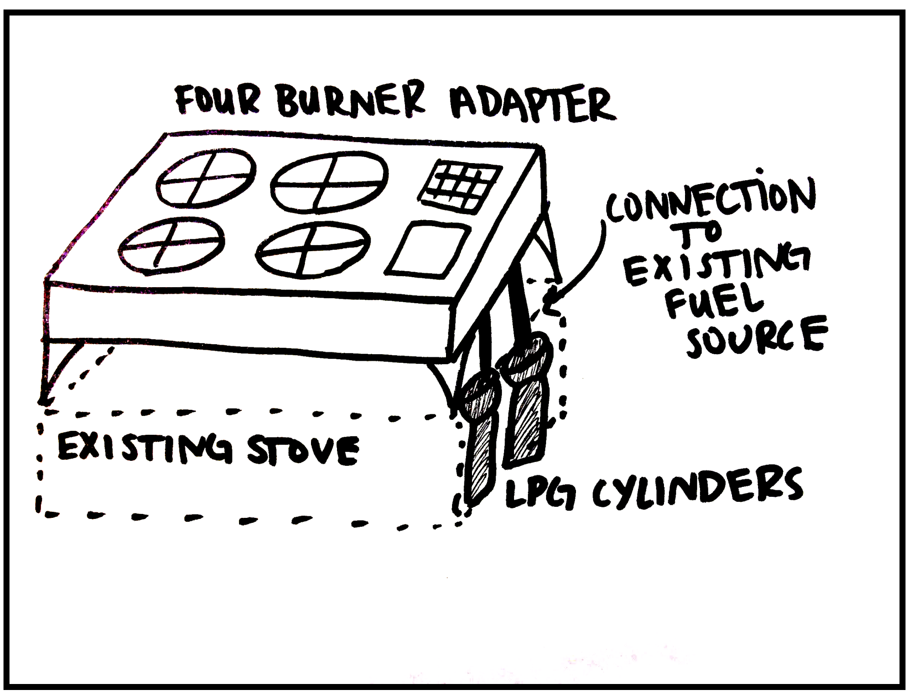
Pros: This solution depends entirely on cleaner sources of energy. Therefore, it provides clear advantages over biomass fuels because no harmful emissions are released. The infrastructure and appliances would only need to be installed once in a household, eliminating the need for continual supply/restocking associated with other alternative fuel options.

Cons: The cost of paying for electricity may be a barrier for most people in rural India. In addition, connecting rural household to a solar- or wind-powered electric grid would likely be an expensive infrastructure project that would require substantial investment from the Government of India, local electricity suppliers, and NGO's interested in connecting rural Indian households to modern methods of power supply.

2. Multiple burner adapter for existing alternative fuel stoves

Through our research, we learned that although many homes have stoves that support the use of LPG, community members still use traditional burning stoves in parallel. This is often caused by the limited volume of food that can be prepared on the alternative stoves. Frequently, these stoves feature only one or two burners, which is not sufficient for preparing food for larger meals or a larger family. By designing and implementing an adapter, we can integrate with and expand upon existing solutions in this space. Our design would enhance the use of existing alternative stoves that use LPG and prevent the continued use of traditional stoves by allowing families to cook larger amounts of food at one time.

Figure 3. Envisioned design of a four-burner adapter.



Pros: This system integrates with existing alternative cookstoves. Therefore, it builds on existing solutions and addresses one of the major barriers preventing more widespread use of alternative cookstoves.

Cons: This solution modifies an existing device. Therefore, the use of this adapter is limited to those households that already have alternative LPG burning stoves. This solution also does not address issues with education surrounding IAP, nor does it incentivize refilling the LPG cylinder or buying a new one when it is empty.

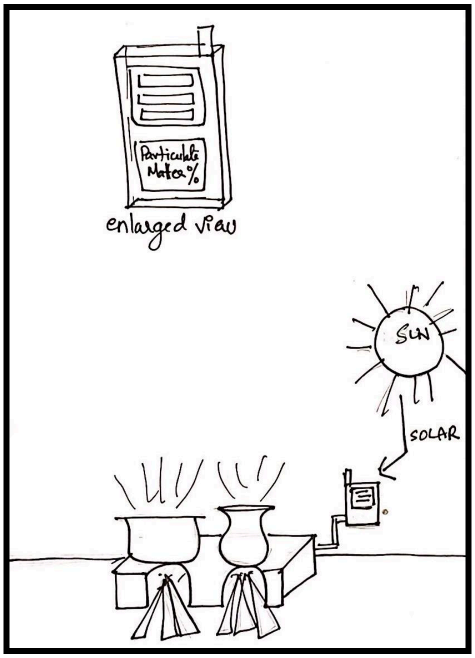
3. Detector with low emissions incentives, linked to WhatsApp

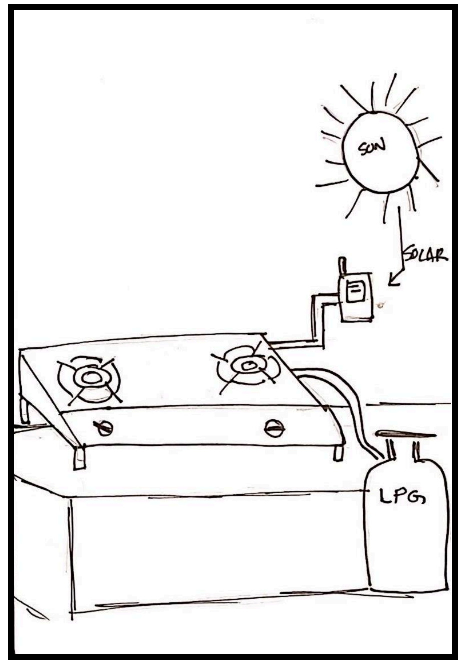
Previous attempts to introduce and maintain the use of alternative fuels in India have demonstrated initial adherence with poor sustained use. This is possibly due to lack of awareness regarding the harmful consequences of solid fuels as well as cultural and behavioral factors. Most of the rural population in India prefers cooking with traditional open-fire stoves using biomass fuels because it's a cultural norm. One intervention to address the cultural norms is to install solar-powered signal detectors into cookstoves to monitor levels of indoor air pollutants in these households. The detectors would be accompanied by a manual written in the predominant local language that informs users how the detectors work and about the health effects of IAP (with pictorial aids). The antenna can send a signal to nearby health centers or government offices with data on the level of particulate matter. Additionally, the detector can also provide data on the intensity and frequency of the usage depending on what kind of stove and fuel the households use. With this data, government agencies and NGO's can develop interventions.

Once we obtain this data we can incentivize users to lower their cooking emissions either by reducing their use of traditional cooking methods or increasing their use of cleaner cooking methods. The incentives would be social in nature. We envision establishing community-based WhatsApp groups to facilitate informational campaigns about IAP and how traditional cooking methods contribute to IAP. In addition, we would use these WhatsApp groups to publicize household rankings in terms of how much households reduced their indoor air pollutant levels. We expect this to create friendly competition among households via social reinforcement. In other words, we expect households to want to "win" the competition by reducing their indoor pollutant levels the most within their community, thereby incentivizing them (socially) to reduce their use of traditional cooking methods or increase their use of cleaner cooking methods. To reinforce the incentive even more, we would have free prizes for the "winners" that primary household cooks would value such as improved cookstoves and other cooking-related supplies.

Figure 4. Envisioned design of a detector that connects to traditional stove and an LPG cookstove.

Group 3: (names hidden for privacy)





Pros: Community health centers and government agencies would have access to real-time data on the levels of indoor air pollutants among the target population. This tool also helps make users aware of the amount of harmful emissions in their home and educate them on the negative effects of emissions from traditional cooking practices. Also, the households would benefit monetarily from the incentive payments, which would benefit them economically and encourage them to modify their behavior towards a healthier cooking method.

Cons: Nexleaf Analytics is an organization that implements a similar innovation and thus could be a potential competitor in terms of customers, partnership, funding. It may be difficult in developing the technology of the detector and to obtain funding to implement it in large populations. In addition, it could be challenging to implement mobile incentive payments to a rural population that may not have regular access to mobile technology.

4. Biomass briquette

According to an interview with environmental protection staff from the local government of Shanxi, China, coal briquettes were utilized in rural areas to combat the issue of IAP [6]. A coal briquette is a compressed block of coal dust or other combustible biomass material (e.g. charcoal, sawdust, wood chips) used for fuel to start a fire. A briquette can be processed into a desulfurized, waterproof fuel, which leads to lower levels of harmful emissions. The biomass briquette would be an analogous fuel source in India.

Figure 5. Coal briquettes (left) and biomass briquettes (right).

Pros: The cost of production and thus the sale price to consumers would be low. Based on prices of biomass briquettes on the Indian e-commerce site IndiaMART (https://dir.indiamart.com/impcat/biomass-briquettes.html), the industrial cost range of biomass briquettes is 3,500-7,000 rupees per metric ton, which is approximately $49-$98 USD per metric ton. This comes out to $0.02-$0.04 per pound or $0.05-$0.10 per kilogram. Since the cost of production would be low, manufacturers could afford to sell these briquettes to consumers for a very cheap price, which would be beneficial for the rural households we are targeting. Also, this solution easily integrates with existing appliances since it is still a biomass fuel source. There wouldn't be a need for a household to pay for a new stove or gas connection, both of which could be expensive for the target market. India is one of the top biomass waste-producing countries, so there is domestic capacity to produce biomass briquettes for domestic consumers. The briquetting process might also lead to a reduction in harmful emissions as noted before.

Cons: Research on emitted pollutants from biomass briquettes is very sparse, so it is not concretely known what the emission profile of these briquettes looks like. Also, there would still be some pollutants emitted from the combustion of these briquettes.

5. Top Solution

#3 - Detector with low emissions incentives, linked to WhatsApp

We have chosen the detector-plus-incentives strategy as our top solution.

As mentioned before, Nexleaf Analytics has a similar solution where they connect household stoves to a detector and make "climate credit payments" to households based on how much they reduce their cooking emissions. According to its website (https://nexleaf.org/cookstoves/), Nexleaf has installed their devices in over 700 households across 30 villages in India. Rounding the number of Nexleaf-adopting households to 700 and using our estimate of the total market size (118 million households), we estimate that Nexleaf has attained much less than 1% of the market share. This suggests almost the entire market is available for another group like us to implement a detector-based solution. Nexleaf's small market share may also indicate that it's challenging to implement a detector-based solution, but their research suggests that incentive-driven behavior change (at least in the form of more frequent cooking with improved cookstoves) is achievable among households that do adopt the technology [19]. Therefore, if we can find a way to scale and market our own detector-plus-incentive program effectively, we have the potential to cause long-lasting behavior changes among many more people, something that has eluded clean cooking programs to date. We have decided to call the detector Jaagran which is a Hindi word meaning 'awakening or being aware of something.'

VII. Implementation (Business) Strategy

1. Stakeholder-specific value propositions

The detector that links with WhatsApp can raise public awareness with its warning function and social attributes. Through stakeholder analysis, we learned that users engaging in household cooking do not fully understand the severity of the indoor air pollution problem and associated impact on health. According to research, even some users who own improved cookstoves do not use them due to low awareness of the health benefits and an inability to pay for repairs and upkeep of the cookstoves. Using the detector system, users can monitor the air pollution level in their home in real time. WhatsApp is one of the most commonly used social media applications in India. Combining our detector system with an existing, popular social media app can provide incentives to users via social reinforcement. We have developed the following stakeholder-specific value propositions:

(1) **User:** Our solution will increase their awareness of the indoor air pollution problem. The social media attribute can add social incentives for people in a community. After collaboration with a local clean energy program or clean cooking program, our solution will reduce exposure to indoor air pollutants by 20% per family per year.

(2) **Government:** Our solution can increase the effectiveness of clean energy program or clean cooking programs at a low cost. Ultimately it would reduce government spending on IAP related illness by 10%.

(3) **Worldwide organization:** UNICEF (interest in the welfare of children), WHO, Clean Cooking Alliance, Ashden (supports and promotes sustainable energy enterprises around the world)..

(4) **Manufacturers and distributors of clean-cooking related products (e.g. improved cookstoves):** The data we provide to manufacturers and distributors would provide them knowledge of local markets where there is latent demand for their products. The data would also provide them knowledge of product improvement needs. We expect our innovation to increase overall demand for clean-cooking related products, thereby increasing the commercial viability of those products.

(5) **Donor/funding agencies:** Our solution will provide good return on investment for our partner foundation organization (e.g. Clean Cooking Alliance).

(6) **Non-profit sector and advocacy organizations:** Our solution (implemented in partnership with non-profit and advocacy organizations) will achieve long term sustained use, with at least 75% of installed units still in routine use at 2 years post-installation.

(7) **Community health centers and medical institutions:** With a higher usage rate of cleaner cooking fuels or reduced emissions from biomass cooking fuels, fewer people will be affected by IAP-related disease. Our solution will reduce incidence of IAP-related illness by 20% in 5 years after implementation in a community.

2. Sales, marketing and distribution strategy

2.1 Sales: Commercial agency

Reason: The detector works as an alert system to notify people of high levels of air pollutants in their home. Though the user will primarily benefit from lower levels of IAP, the government, clean cooking fuel companies, and improved cookstove companies could also benefit from this implementation. By educating community members on the harmful effects of IAP and showing them, in real time, their pollution levels, we will encourage people to use LPG or other alternative fuel sources or improved cookstoves. This can create a landscape that is more commercially viable for companies that sell related products and more socially viable for a government agency to implement a clean cooking program. Therefore, our commercial customers would be national and local governments and relevant private companies. This would entail a B2B business model, so our sale method would involve selling detectors to private and government entities.

We would build local commercial agency teams by hiring community members who are more familiar with local culture and organizational functions. Those agency teams would be divided into two teams: one focused on building collaboration with government agencies and the other focused on services on the ground.

2.2 Marketing

1) Online

We will engage in advertising through local public media such as radio, TV, and newspaper advertisements. The advertisements will focus on the incentives program and the harmful consequences of indoor air pollution.

2) Off-line

During the launch of our platform, we will target customers through local, in-person outreach (door-to-door) and community based workshops. For example, we could simulate a typical indoor cooking environment and use our detector to measure the air quality. A demonstration similar to this was documented to educate an end-user in a case study by Nexleaf Analytics [20]. We can provide some low-cost detectors to those who enroll in the program in its early stages. Early efforts will be focused on building trust within the communities.

2.3 Sales and Distribution

Since our target population is individuals in rural India that would be Below Poverty Line (BPL) ration card holders, the product will be brought and funded by a separate donor or charitable organization. The key stakeholders identified for this initiative to build strategic partnerships would be the Government of India – The Ministry of Health and Family Welfare. Data can be obtained from the Ministry to identify the most vulnerable population to which our detector can be delivered in our pilot project. We also plan on partnering with the PMUY program to obtain funding for our service in return for identifying whether the LPG cylinders are being used in a sustainable manner by installing our detectors in the kitchens of the households that are eligible for the distribution program. Once the target population is identified, we intend to distribute our product by partnering with companies in India such as Greenway Appliances. We intend to provide detectors to the consumers using the improved cookstoves that Greenway manufactures. This way, our product can be sold along with stoves as an add-on service to promote sustained use of the stove products.

2.4 Marketing and Incentive Program

Once the sales strategy is developed and funding sources are negotiated, we intend to market our product through a combination of educational campaigns and a WhatsApp based community incentive program. This phase will require partnerships with local NGO's that can help us address the local challenges such as the language and gender gaps. The educational campaigns will be done through ASHA (Accredited Social Health Activist*) workers and a local NGO in our target rural communities. We envision multiple seminars/talks in the local language for the families in the villages that focuses on the adverse effects of IAP. These educational campaigns will also introduce our users to the incentive program that involves community engagement through WhatsApp groups. WhatsApp has over 1.5 billion users globally, of which India accounts for about 400 million users alone. Also, in a survey of 1,018 individuals in rural India, the New Delhi-based nonprofit organization the Digital Empowerment Foundation found that 81.4% of respondents used WhatsApp at least one hour per day [21]. They also found that 77.3% of respondents exchange more than ten messages per day [21]. Furthermore, 58.7% of respondents reported being in more than five WhatsApp groups [21]. Lastly, a different survey reported that active WhatsApp usage in rural India grew from 10% in 2017 to 20% in 2018 [22]. Based on our market size estimate, this would mean up to 23.6 million rural Indian households exposed to IAP have a household member who is an active WhatsApp user.

Based on this information, we have identified WhatsApp as the portal to form a network of women who cook and use our detectors. The WhatsApp group system will ideally be subgroups of women who cook in rural areas along with an ASHA worker (a staff member from the partner NGO who helps monitor and evaluate the use of improved cookstoves and the detector). Since the detector can help provide real-time data on the use of improved cookstoves and indoor air pollutant levels to NGO/community health workers, we can identify who are the most prominent users of improved cookstoves or LPG and reward them with free cooking-related items and possibly some sort of badge or certificate they could display to friends and neighbors. Depending on our level of funding, this may be scaled up to monetary incentives to engage more sustained use of LPG gas cylinders and improved cookstoves.

*An **accredited social health activist** (**ASHA**) is a community health worker instituted by the government of India's Ministry of Health and Family Welfare (MoHFW) as a part of the National Rural Health Mission (NRHM)

3. Business Model

3.1 Cooperate with clean energy companies

1）Proposed business models：We have two potential business models in mind. The first business model we would use is the razor-and-razor blade model. As mentioned, we envision the detector being sold as an accessory item with clean cooking-related products such as an improved cookstove or LPG cylinder. Cookstove manufacturers would have to purchase the detector from us in order to connect it to the cookstoves they ultimately sell. The other business model we would use is a data-driven model where we would share the information on stove usage we collect from households to government agencies, NGO's, and cookstove manufacturers in exchange for financial support. The information we provide would help government agencies and NGO's tailor their clean cooking promotion strategies. The information we provide to cookstove manufacturers would inform them which local markets show the most promise in terms of increasing improved cookstove adoption. In turn, manufacturers would know which local markets may be commercially viable for their cookstoves and related products.

2) How we'll generate revenue: We envision making revenue in two ways: 1. by selling physical detectors to cookstove manufacturers, government agencies, and NGO's and 2. by selling stove usage data we collect and analytical reports to those same three entities. Therefore, we would be selling a good and a service. Because this model would essentially be B2B transactions, the number of products will be very large. Therefore, we can set our price very low, which would make us an appealing business partner. In regards to the physical detectors, if our buyers wants to buy larger quantities, we could sell them the detectors in bulk at a lower cost per unit. Also as mentioned, the data that we share would be provided in exchange for revenue.

3) How we'll deliver value to consumers: In India, many clean cooking programs and companies have tried to encourage people to switch their cooking from traditional stoves to improved cookstoves or to switch their fuel usage from biomass to LPG. However, long-term, sustainable adoption of improved cooking methods has been poor, suggesting these programs along are not creating long-lasting behavior change. One reason may be an information gap on the harms of IAP. In conjunction with educational seminars and user manuals, the detectors would alert users they are being exposed to high levels of pollutants, which they may have been unaware of before. After primary cooks become more aware of the level of pollutants in their home, we would expect them to increase their willingness to use cleaner cooking methods. This increased willingness (i.e. demand) would create a more commercially viable landscape for private companies that sell improved cookstoves and related products, leading to increased sales for those companies. Because of the large population base, this could bring them enough revenue to exceed the cost of buying detectors from us.

4) Similar successful business model: In the case of Life Force Kiosks case, the aim of the program was to provide sanitized water to poor communities in Nairobi slums [23]. Local water vendors were able to generate additional revenue through an agreement with Life Force Kiosks where they (the local vendors) would retain half the payment of the sanitization service [23].

5) Price & Pricing strategy:
   a. High price elasticity: The product we provide is not a necessity for the end-users and may not be considered a necessity by our primary customers (cookstove manufacturers, government agencies, and NGO's), so we should try to keep our price reasonably affordable.

b. Penetration Pricing Strategy: By considering the primary aim of our product is to educate rural households and increase their awareness of IAP, earning a large profit margin is not our end-goal. Thus, our products need to enter into the market quickly and will not be a long-term projects locally. We should try to set an affordable price that can help us build future collaboration with partner organizations.
c. Sale Price: We have found a detector that can test HCHO, pm2.5, and TVOC, which are significant pollutants people are exposed to when cooking with biomass fuels. The price range for this product is $30-40 USD. This would be our acquisition cost. The final sale price to our customers would be at-cost, so $30-$40.

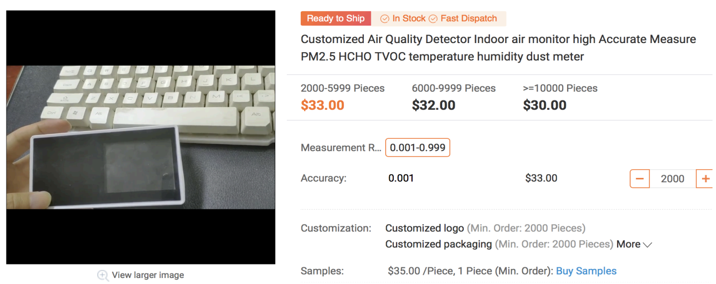


Figure 6a

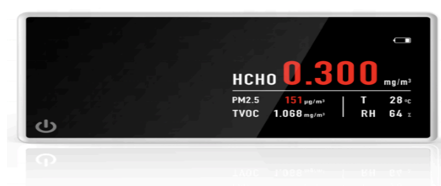


Figure 6b

Fig 6. Reference price and product. a) reference price for different transaction volume; b) reference products that can test HCHO, PM2.5, TVOC, main pollutants during cooking.

6) Market size: The potential market size is the same as the previous calculation. We view everyone in that market as potential end-users, regardless of their current usage patterns of traditional cooking methods and cleaner cooking methods. We would assume early on that one household would be provided one detector, so the volume of detectors would be 118,272,000 ~ 118 million detectors. Because we set the price at $30-40 per detector, we estimate the market size in dollar terms to be approximately $3,547,160,000-$472,000,000 USD.

3.2 Cooperate with research institutions and government agencies

Group 3: (names hidden for privacy)

1) Proposed business model: the enterprise type is non-profit at the beginning but may become a hybrid in the future. The business model is data-driven. We want to build a platform that can collect IAP data from rural Indian households and provide warning signals to both households and government agencies. Our mission is to educate local families, help research institutions obtain first-hand data of IAP for further research, create a commercially viable landscape for cook-stove manufacturers, and help government agencies and NGO's establish tailored strategies to mitigate IAP based on objective data.

2) Mechanism for generating revenue: Our project would be non-profit at first. The revenues would mainly come from the government and non-profit sectors as well as advocacy organization investment. There is a gap in understanding surrounding the severe health consequences of continued exposure to IAP. Even when families have access to alternative methods to traditional stove with solid fuel, they may still refuse to use the alternative method. Our product seeks to address this by warning users of high levels of IAP and creating a social network surrounding decreased air pollution. The monitor system can help both government and related research institutions to track behavior patterns concerning local air pollution. After collecting large amount of data, and monitoring indoor air quality for many rural areas, some companies, like clean energy companies and research institutions, may want to buy the data and service, for strategy setting or field test of product.

3) Delivering value to consumers:
The warning function of detector and education components supported by the app will help to inform local families about the harms of traditional cooking. The social attributes of the app can create a positive atmosphere that will encourage community members to engage in healthier cooking practices. The government can receive air quality data collected by the detectors, which may help them to set proper strategy to solve the problem. Consistent use of the detector and healthy cooking practices may ultimately decrease medical expenses associated with IAP by decreasing incidence of respiratory and cardiovascular illness. Research institutions can obtain value from our product by accessing the data collected concerning indoor air pollution level. The detector and the collected data can help them to follow real-time (e.g. daily, weekly) use of different cooking sources. Researchers interested in developing new alternatives to traditional stoves could see value in our detectors as a means of assessing the impact of their implemented solution.

4) Similar successful business models: the case ANACOR have define a cash neutral R&D strategy by cooperating with non-profit foundation. We can cooperate with non-profit foundation, government and research institution, to initially build a cash neutral model.

5) Price & Price strategy:

Price: the price of product include an air pollution detector and an APP that have client terminal and enterprise terminal. Price: We have found a real detector which can test HCHO, PM2.5, TVOC that are main pollutant when people are cooking by using traditional fuel. The price of this kind of products is in range of $30-40 (Figure 6). The final transaction price depends on the volume of that transaction. The price of APP can set down to $5.

Pricing strategy: the whole product, including APP and detector, will sale in one package, about $40 if we can start with a large volume. After building a large database, and covering large scale of rural families, we can ultimately make a profit from selling our product and the collected data.

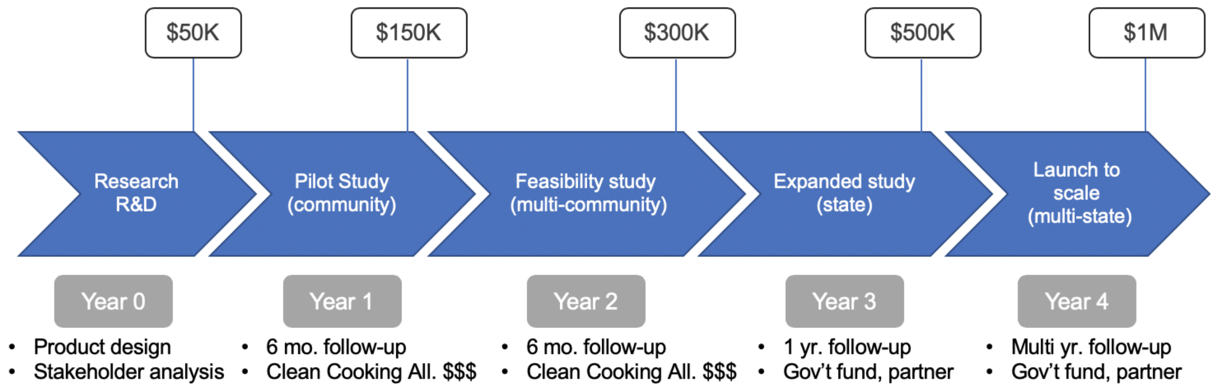
6) Market size: since the target population group are Indian families that live in rural areas, the market size are same as calculated before.

4. Commercialization Roadmap

4.1 Time, money, and effort needed

Our goal as a team is to begin a pilot study on the ground in India in early 2021 (~1 year from now). This would be a proof-of-feasibility pilot study focused on one community with a target of at least 30 homes/users. For the next 12 months (Year 0), we would pursue aggressive stakeholder analysis, including through interviews and by visiting communities in India. The pilot study will take 6 months to complete, and then we will aim to secure additional funding/partnerships with NGOs and the Indian government. In Year 2 of this project (2022), we aim to expand into our ‘community feasibility phase’ with 10 communities and at least 300 homes using our device. Again, we will monitor these families for 6 months. We think that this work will cost: $50,000 for the first 12 months, including travel to India and prototype/app development. We aim to raise this money through friends, family, and business/pitch competitions. For Year 0 this will involve part-time efforts from all team members. In Year 1, we will have one full-time employee based here and 1-2 full-time employees on the ground in India. We budget $150,000 for Year 1 studies, including in supplies, travel, and employee salary. These funds will be raised through partnering with external organizations, such as Clean Cooking Alliance. For Year 2, when we scale the operation to 10 communities, we budgeted $300,000. These funds will be raised through a partnership with the Government of India as well as follow-up funding from Clean Cooking Alliance. We would also plan to obtain a convertible debt agreement with the Small Industries Development Bank of India (SIDBI).

4.2 Key milestones and value inflection points



Our key milestones include our R&D phase, pilot study (one community), feasibility study (multi-community), expanded study (state-wide), and launch-to-scale (multi-state). This work will span 5 years (Year 0 - 4). Our funding sources will be Clean Cooking Alliance partnership, other NGOs, Indian Government funding, and convertible debt agreement from the Small Industries Development Bank of India.

4.3 Financing strategy

We envision a financing strategy that secures grant funding from the Government of India, nonprofit foundations, and corporate giving. We would also explore a convertible debt agreement with the Small Industries Development Bank of India (SIDBI).

4.3.1 Government funding

We would seek funding from the Ministry of Health and Family Welfare within the Government of India. We know from the PMUY campaign to increase LPG among poor, rural households that the Indian Government is invested in reducing IAP, particularly among rural households. The Ministry of Health and Family Welfare has demonstrated interest in collaborating with stakeholders in the Indian clean cooking space in the past [15]. Therefore, we think this government agency would be willing to fund an initiative like ours that seeks to incentivize clean cooking in rural India.

4.3.2 Nonprofit foundations

Clean Cooking Alliance

The Alliance works with a global network of partners to build an industry that makes clean cooking accessible to everyone throughout the world. The Alliance is driven by consumer demand and aims to provide investment to scalable businesses. The Alliance seeks to fund organizations that deliver affordable, appropriate, high-quality clean cooking products. They advocate for effective policies and generation of trusted, relevant data to serve the communities in need. Funding opportunities currently available for us to explore through the Alliance include grants such as: Energy Access Booster, GetInvest Finance Catalyst, Small and Growing Business Fund, Aspire Small Business Fund, and Development Innovation Ventures. We would also seek to partner with the Alliance to build trust on the ground, connect with communities, and tap into their established network in this space.

The Mulago Foundation

The Mulago Foundation has supported Nexleaf Analytics, which is another innovator in the Indian clean cooking space that has developed a detector-plus-incentive program of their own. In addition, The Mulago Foundation is interested in funding projects that could benefit at least one million people and create a long-lasting behavior change [24]. In fact, the foundation's Head of Investment has stated "We think about Mulago as a behavior change organization. That's what we look for. That's what we fund" [24]. Our estimates indicate there are about 590 million people in rural India who are affected by IAP, which easily exceeds the one million minimum set by the foundation. To serve the minimum, we would only need to impact the lives of less than 1/5th of 1% of the target market, which should be highly attainable.

Furthermore, the overarching goal of our detector-plus-incentive program is to foster behavior change among rural Indian households that is conducive to long-term adoption of clean cooking practices such as the increased use of improved cookstoves or LPG and the decreased use of traditional stoves. In other words, the ideal result of our program is that families in rural Indian households perceive clean cooking practices as a normal way of life, which would have the dual benefit of improving long-term health outcomes and creating a more commercially viable landscape for future innovations in clean cooking. This mission is in-line with the Mulago Foundation's desire to fund projects that can lead to long-term behavior change, so we think they would be willing to partner with us.

The Clinton Foundation

The Clinton Foundation has been involved in the global clean cooking space for a number of years, primarily through the Clinton Global Initiative. Thus, the foundation has a clear interest in the space. Furthermore, as Secretary of State of the United States, Hillary Clinton helped launch the Clean Cooking Alliance, which is a key stakeholder in the space [10,25-26]. While Clinton was Secretary of State, the U.S. government contributed $50 million over five years to an initiative by the Clean Cooking Alliance to switch 100 million households to improved cookstoves [10,25-26]. Given this information, we think the Clinton Foundation feels very invested in the clean cooking space and thus would be willing to fund our project.

4.3.3 Corporate giving

Vodafone Americas Foundation

Vodafone has commercial interests in India, evident by their partnership with Nexleaf Analytics to enable mobile incentive payments to households. In addition, Vodafone's market share of the Indian mobile market has grown from about 18% in 2010 to an estimated 31.5% in 2019 [27]. We think this suggests Vodafone would be willing to use their charitable arm to fund our project and increase their visibility even further in India.

Qualcomm Wireless Reach

Through its social responsibility initiative Wireless Reach, Qualcomm funded Nexleaf Analytics, indicating they may have interest in funding our program.

Tata Trusts

Tata Trusts is the charitable arm of the Tata Group, a large multinational holding company based in India. It is India's largest company, valued at about $19.5 billion (USD). As the biggest company in India, we expect they would have the resources to invest in our project. They have also worked with Nexleaf Analytics [20], and we think they would be willing to invest in a project that could impact tens of millions of households in their home country and possibly increase their brand recognition.

4.3.4 Convertible debt agreement with SIDBI

The Small Industries Development Bank of India (SIDBI) is a development bank that makes loans to small businesses. SIDBI undertakes microfinancing projects in a way similar to the World Bank but limited to businesses in India. In case our team finds it challenging to procure grant funding, we think it would be beneficial to explore a convertible debt agreement with SIDBI as a contingency plan. We envision that the bank would supply us with microloans that can be exchanged for equity when we have reached certain milestones. We think as a development bank, SIDBI would be interested in funding a project that seeks to improve the lives of hundreds of millions of people in its home country.

VIII. Evaluation Strategy

To evaluate the effectiveness of the detector-plus-incentives solution in lowering household exposure to IAP in rural India, we would use a similar study design as the MIT researchers who evaluated the effectiveness of a chulha distribution program [9]. Thus, we would implement a randomized controlled trial. We would identify households in rural parts of India to be part of the study and then implement the detector-plus-incentives strategy among a random sample of those households (i.e. the comparison group); the remaining households would comprise the control group. We would run this study before a large-scale rollout of the detector-plus-incentive program because we would want evidence that a resource-intensive rollout would potentially achieve the intended benefits. In other words, this study would be a pilot study. We could also present the results of the study to funders to help obtain financial support.

Our analysis would examine differences in pollutant levels over time between the control group and the comparison group after the implementation of the detector-plus-incentives program. With this study design, we would seek to answer the following question: does the detector-plus-incentive program lead to lower indoor pollutant levels among the comparison group compared to the control group? To allow ample time to observe the effects of the program and collect sufficient, long-term data, we would run the study for a year. If the comparison group exhibits decreasing levels of indoor pollutants over that year and their exposure to indoor pollutants is lower than that of the control group at the end of the year (at a statistically significant level), it would help validate the effectiveness of our solution. Our hypotheses are that (1) the program would lead to a decrease in indoor pollutant levels among the detector group over the study period, and (2) the detector group would exhibit lower pollutant levels than the control group at the end of the study, (3) that users would report increased level of awareness about the health risks of indoor cooking/IAP.

Over the course of the study period, we would also collect data on changes in cooking methods among the detector group and control group to determine possible mechanisms that explain the differences in pollutant levels (assuming we see differences develop over the study period). Furthermore, there would also be a qualitative component where we conduct focus group interviews among a portion of the detector group similar to what Nexleaf Analytics did when evaluating the efficacy of their program [19]. In these focus groups, we would ask participants the following questions: 1. Did you change your cooking methods after receiving the detector and user manual?; 2. (If cooking methods changed) Why did you change your cooking methods?; 3. Did you think the detector was easy to use?; 4. How has your opinion of traditional cookstoves changed after using the detector and learning about the negative health effects of traditional cookstoves?; 5. Will you inform your friends, family, and neighbors about the health effects of traditional cookstoves?; and 6. (If yes) How will you inform them?

We hypothesize that the detector group would shift more of their cooking towards improved cookstoves and/or alternative fuels, compared to the control group. This would an interesting finding because it would suggest the detector-plus-incentive program causes households to modify their behavior, potentially strengthening the efficacy of the program.

IX. Conclusion and Next Steps

In conclusion, we believe that with multi-stakeholder alignment, our detector can be distributed to rural Indian households as a viable solution to make them aware of the harmful effects of IAP and reduce their exposure to IAP. The built-in incentive program will be instrumental to modifying existing behavior towards clean cooking, thereby reducing our target population's likelihood of IAP-related respiratory and cardiovascular diseases. We identified certain implementation challenges, of which the biggest concern is gaining cooperation from the Government of India Ministry of Health and Family Welfare and convincing them about the efficacy of the product. Negotiating with our potential funders for financial support and convincing community health centers to cooperate with our mission are other potential challenges.

However, with our background research, market analysis, business model, and evaluation strategy, we hope to overcome these challenges and develop our solution into market-ready innovation. We are committed to continuously improving our detector-plus-incentive solution, and through collaborative efforts, we intend to refine and improve our product design and business model. An example of improvement in product design would be integrating a financial incentive payment into the detector-plus-incentives innovation, similar to Nexleaf. We would take steps in the future to work with telecom and mobile data companies to allow end-users to receive mobile payments tied to the volume of reduction of air pollutants in their home. This would reward households who participate in our program including those who do not win the prize for the greatest reduction in their community. We would have to ensure that these households have access to the technology that enables mobile payments, and we would have to set up a fund that procures cash from a willing investor and delivers payments. These would be part of our next steps.

An example of an improvement to our business model in the long-term would be monetizing our data collection and data analysis capabilities. In the future, we would consider establishing our own research and consulting arm. We would provide commercial strategy consulting services to companies that have profit incentives and policy consulting services to government agencies and NGO's interested in reducing IAP in rural India. This would give us a service-based business to complement our product-based business. The service-based business would be a higher margin business that could help us become financially self-sufficient. It may also fund expansion in the product-based business, thereby bringing our detector-plus-incentives innovation to more homes in rural India that can benefit from it.

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