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Nepal Energy Efficiency Programme (NEEP)

'Short Term Expert (STE) Mission for the Support of the Technical Development of Improved Cooking Stoves (ICS) under the Nepalese National Dissemination Program'

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COOPERATION NEPAL GERMANY

Nepal Energy Efficiency Programme (NEEP)

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Submitted by

Dr. Mouhsine Serrar

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Executive Summary

Background

In Nepal close to 90 % of the total national energy consumption is biomass (wood, dung) making it by far the most important primary energy source in the country. Nearly two thirds of this biomass is used for cooking foods.

The Terai belt of Nepal has experienced massive deforestation in the last generation, and this densely populated belt, the 'bread basket' of Nepal, is now forced to burn animal dung and other mixed fuels on stove technologies that have not been able to keep pace with changing fuels.

Where wood is still available, its inefficient use contributes to the increasing deforestation, and has led to landslides and major loss of life in hilly areas, especially during the Monsoon periods.

Mission objective

The mission objective was to support the technical development of the disseminated ICS based on a technical assessment of the currently disseminated stove technology and existing prototypes. This objective would achieved by defining the potential for improvement of the disseminated stove technology considering the Nepal setting, and by recommending possible technology modifications to improve the ICS for both fuel wood and for mixed fuel (wood & dung) applications.

Activities

The mission started with field visit in the Terai, to better understand local cooking fuel environment, and to review current improved cook stoves as well as traditional stoves being used.

During the field visits simple practical improvements to current stove designs seen were tried, and recommendations given to improve durability of current portable stoves. This was followed up on return to Kathmandu with practical stove building sessions, held at AEPC's testing lab, to build the first two iterations of a mixed fuel ICS mud stove design proposed.

A half day workshop on safety and stove testing was held at the premises of NAST which was well attended by key stove organizations in from the INGO sphere. International testing procedures were outlined, metrics discussed along with the rationale for considering safety and testing when improving the design of a stove.

Based on this field visit and discussions with AEPC staff, a set of stove improvement techniques and four new stove designs in total were created.

Designs were drafted for three new Improved Institutional Cook Stoves (IICS), and one mixed fuel household stove, to improve, enhance and widen the AEPC stove portfolio. It was agreed that AEPC engineers would construct and evaluate the modifications, and stove designs, towards which an evaluation plan along with recommendation process was agreed upon. Also recommendations for an expanded role of AEPC to support a sustainable stove industry were given.

Findings and Recommendations

Due to declining wood supply in the Terai and increased used of mixed fuels, a need for a multi-fuel improved cooking stove to be added to current ICS portfolio in Nepal was identified. It was seen that many users are burning dung or mixed biomass fuels on inefficient traditional, or indeed ICS stoves that are not optimized for mixed fuels due to smaller combustion chamber and lack of efficient air supply.

The ‘portability’ of stoves seems to be appreciated. However, a good efficiency/performance and durability of the available portable mud stoves is still to be proven.

Builders of standard mud stoves show generally good skills, builders of institutional improved cook stoves, (IICS) require a higher level of technical skill to customize the design of the stove to fit requirements of the cooks (important marketing skill). The stove builder training program should have a module on business skills; builders of IICS should be able to gain enhanced technical knowledge.

Fuel (wood and dung) were often found too humid with relevant impact on stove performance, both fuel consumption and emissions. Humidity in fuels used should be monitored in the field, and an attempt to develop a solution to reduce humidity in used fuel may have a significant impact on stove performance. Technologies and methods for fuel improvement should be tested.

Possibility/relevance of making densified fuels from agricultural residues should be evaluated. We recommend undertaking a business analysis over a year to evaluate and select alternative biomass fuels densification

The majority of biomass stove users have only mud ICS as an option. The current ICS portfolio is limited, there appears to be a need for specialized cooking stoves, stoves with added value, and stoves with better performance. There is a strong user’s aspiration for more modern cooking solutions for example portable-metal stoves to replace these mud stoves. This need for more modern stoves is something that has been seen in other countries where users were willing to pay higher prices for stoves that offered high performance, durability, and which looked attractive.

There is a need for an improved stove market place in Nepal, and it is felt that AEPC can become the umbrella organization to coordinate, uplift, accredit and facilitate the country's many stove builders and organizations.

Not all of these stove organizations may be able to produce stoves that pass international testing and certification. However they may, from design lessons learned elsewhere and shared by AEPC engineering team, be able to produce better stoves, at little or no extra cost. Stoves could then be assessed and ranked according to their performance, before offered for sale.

The mud brick ICS technology is ready for partial replacement in Nepal, as indeed it has been elsewhere. A tested and certified portable metal stove's performance exceeds mud ICS performance in terms of fuel consumption, emission, speed, and usability. These stoves also contribute to a cleaner kitchen area, cleaner pots, and a more comfortable cooking experience. While portable metal stoves may cost more than mud stoves, their perceived value will create the incentive to purchase for the ‘middle class’.

Dissemination of improved stove to the ‘middle class’ is also an effective marketing tool to promote such a stove to poorer users who would want to emulate the middle class, and indeed, can it is believed, invest if the right product is made available.

Opportunities exist for AEPC to offer a range of certified stoves designs that other organizations and fabricators can produce, though presently the current stove design portfolio seems focused largely on mud stoves; household or commercial. So an improved and widened range of current generation (tier 3 +) stoves designs, to serve commercial and household markets is needed

Currently a high altitude stove design is made by 32 approved companies, and it is recommended that this same initiative is reviewed and expanded to include new generation stoves for offer in the Nepal market.

Acronyms and Abbreviations

AEPC	Alternative Energy Promotion Centre
CBS	Central Bureau of Statistics
CO	Carbon Monoxide
CRT/N	Centre for Rural Technology Nepal
CTVET	Council for Technical Education & Vocational Training
CWS	Child Welfare Scheme (Kidasha)
DDC	District Development Committee
DEECC	District Energy and Environment Coordination Committee
ESAP	Energy Sector Assistance Programme
FNCCI	Federation of Nepalese Chamber of Commerce and Industry
HHs	Households
ICS	Improved Cook Stove
IICS	Improved Institutional Cooking Stove
INGO	International Non-Governmental Organization
Kg	Kilogram
LPG	Liquefied petroleum gas
NAST	Nepal Academy of Science and Technology
NBSM	Nepal Bureau of Standards and Metrology
NEA	Nepal Electricity Authority
NEEP	Nepal Energy Efficiency Programme
NGO	Non-Governmental Organization
NRs	Nepalese Rupee
RECAST	Research Centre for Applied Science and Technology
RET	Renewable Energy Technology
RRESC	Regional Renewable Energy Service Centre
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat

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1. Background

In 2009 within the context of bilateral development cooperation Nepal and the Federal Republic of Germany agreed on the joint implementation of the "Nepal Energy Efficiency Programme" (NEEP). The program aims at making the energy use for domestic and productive purposes in Nepal more efficient. GIZ is acting in execution of the commission with which it has been charged by the Government of the Federal Republic of Germany. On behalf of the Government of Nepal the Water and Energy Commission Secretariat (WECS) acts as the Executive Agency of the program and also implements the component that targets the improvement of the framework conditions for energy efficiency on policy level. Other implementing partners are the Nepal Bureau of Standards and Metrology (NBSM) and the Nepal Electricity Authority (NEA) for the component "Energy Efficiency in Households, (electrical household appliances)", the Alternative Energy Promotion Centre (AEPC) for the component "Energy Efficiency in Households, (biomass cooking stoves)", and the Federation of Nepalese Chambers and Commerce and industries (FNCCI) for the component "Energy Efficiency in Industry".

In Nepal close to 90 % of the total national energy consumption is biomass (wood, dung) making it by far the most important primary energy source in the country. Nearly two thirds of this biomass is used for cooking.

However the utilization of firewood and dung for cooking in traditional mud stoves or simple three stone stoves is characterized by low fuel efficiency creating severe health implications through high levels of Indoor Air Pollution (IAP) and burning hazards, especially for women and little children who spend between 2 to 7 hours per day in kitchen areas.

The inefficient use of biomass also contributes to the increasing deforestation and forest degradation in parts of the country, and has led to landslides and major loss of life especially during the Monsoon periods.

Looking towards the lowland areas of Nepal (Terai) it can be seen that fuel wood is generally in very short supply, having completely disappeared in some areas within the last generation. Dung that people are now forced to burn is either mixed with fuel wood or used as sole fuel, contributing severely to IAP. Additional the dung, which was valuable resource for agricultural production, is not now used on the fields, replaced by chemical fertilizers causing soil degradation.

The ICS promoted through the AEPC national program can only be classified as lower tier stoves and do not satisfy all major needs of people, contributing to an only modest level of interest in this technology.

2. Mission Description

Focusing on the aim to improve the ICS models, which AEPC currently distributes through its national stove dissemination program in the Terai districts of Nepal, the objective of the mission was to support the technical development of the disseminated ICS and IICS. A full description of the mission can be found in TOR PN 2008.2230.4 in Annex 1.

A technical assessment of the currently disseminated stove technologies and existing prototypes was scheduled, defining the potential for improvement of the disseminated stove technology considering the Nepal setting. The opportunity was taken to recommend possible technology modifications to improve the (existing) IICS & ICS stove technologies, and also suggest new stove designs, for both fuel wood and for mixed fuel (wood & dung) applications.

Apart from defining modifications for the technical improvement and the development of 4 new draft ICS models AEPC core staff has been trained on safety aspects for ICS and on the currently discussed standards and benchmarks for stove safety. (Annex 3)

3. Itinerary Description

The field visit planned and organized by AEPC was made to the Rupandehi and Kapilvastu Districts of Nepal, in the central Terai (lowland) area of the country. These districts were chosen to reflect cooking trends, fuels used, and intervention technologies available, that can be seen to the east or west of the country along the Terai belt. Also all ICS models distributed in the Terai can be assessed there

Traditional dung burning (artisan clay) and open 3 stone fire stoves were seen in action, alongside ICS and also IICS (Institutional Improved Cook Stoves) in a wide variety of settings.

The AEPC improved portable single pot models were also seen, including a stove construction demonstration.

A visit was made to see work carried out by CWS and Engineers Without Borders (Australia) who had developed a portable two pot metal dung burning stove alongside dung washing and briquette process, including a locally fabricated briquette press.

At the end of the field visit a trip to the World Vision Area development program in Makrahar VDC (Village Development Committee) was made where 15 contemporary (Aprovecho certified) two pot metal wood burning chimney stoves were seen installed in homes.

The findings and insights gained during the field visits were summarized and translated into recommendations for the improvement of currently disseminated stove technology and for new ICS models. During a workshop with core staff of AEPC these findings and recommendations were presented (Annex 2) and discussed as well as some future steps in advancing ICS technology in Nepal planned and agreed upon.

4. Findings

4.1. Traditional stoves

Construction with mud in general (housing) and stove in particular is part of the local tradition. Wood is primary cooking fuel in the Terai. For poorest household with no access to wood, cow dung is the primary cooking fuel. The use of mixed fuel in traditional stoves is very inefficient. When traditional wood stoves are fueled with cow dung, they are extremely smoky.

Rice husk is not commonly used for fueling cook stoves. The current rice husk stoves are seen as not practical and also too smoky.

A highlight of the field visit was the observation of traditional stoves fueled with cow dung. The amount of smoke generated by cow dung stoves is extreme. This traditional cow dung stoves have no chimney. Cooks and their children are exposed directly to this extreme smoke. Development and dissemination of improved chimney multi-fuel (cow dungs and other fuels) should be a priority.

Illustration 1: Traditional wood stove

Traditional wood stove (illustration 1) allows no control on the amount of air admitted, and is not insulated. The stove does not have a grate. All this elements combined, the combustion is a traditional cook stove is inefficient and results into excess production of smoke. Lacking a chimney, cooks are exposed to all the smoke generated by traditional stoves.

4.1.1. Winemaking stove

We found different type of stoves in households. Besides cooking, stoves are used to prepare animal feed or to make wine (Illustration 2). These stoves are larger versions of the cooking stove to handle larger pots. Fuel used and stove design is similar to cooking stoves.

Illustration 2: Winemaking stove

4.1.2. Fueling stove with cow-dung fuel

Cow dung patties fuel the traditional stove in Illustration 3. Users use a straw as fire starter and to help continuous firing of the dung.

Illustration 3: Fueling stove with cow-dung fuel

Illustration 4: Smoke from traditional cow-dung stove

As can be seen in Illustration 4, traditional cow-dung stove are extremely smoky. They are smoky even while the dung is burning. Unfortunately, very often, the dung fire would extinguish throughout the cooking process, and even more smoke is released till the fire is re-ignited.

4.1.3. Rice-husk stove

We found common rice husk stoves (Illustration 5) in several households. This stove seems to be used as a last resort mainly because they are seen as very smoky and difficult to operate (fire control).

Illustration 5: Rice-husk stove

4.2. Improved stoves ICS and IICS design

Double burner chimney mud stove, Improved Cooking Stoves (ICS, see Illustration 6) are widely used and very well adapted to local needs. These stoves are effective at removing smoke from kitchens.

We visited several houses using new portable mud stoves. The ‘portability’ of the mud stove seems to be appreciated. Nevertheless, we are not sure about performance of the portable mud stoves. The geometry of these stoves is based on the ‘rocket’ design principle from Aprovecho but these stoves do not have an especially insulated combustion chamber. Main concern about these stoves is speed to boil that could be a major usability issue. Speed to boil; along with other performance criteria (fuel consumption, emissions) need to be evaluated in the lab. Test protocols for the stove (lab, field) were not available through AEPC. Also field-testing and acceptability pilot of the portable mud stoves need to be conducted before investing in large-scale dissemination.

Only very few Improved Institutional Cooking Stoves (IICS) were shown to the consultant. Those seen in two restaurants seem rather well adapted to the needs of the cook. Nevertheless, these stoves are similar to portable mud stoves. They are based on rocket design principle geometry but do not have an insulated combustion chamber. Lab and field-testing, and a pilot should be conducted before investing in large dissemination.

4.2.1. Household Mud-Chimney improved cooking stove (ICS)

The Household Mud-Chimney improved cooking stove (ICS) (Illustration 6) is very

Illustration 6: Household Mud-Chimney ICS

common in the region visited. It is effective in removing smoke from the kitchen and well adapted to local cooking requirements.

4.2.2. Portable mud stove

Portable mud stove (Illustration 7) is appreciated for its portability which allows customers to choose where to cook, indoor when it is rainy, move to cooler/shaded space when it hot. Nevertheless, there is concern about the performance of such stove (may be too slow) with current dimensions and without using an insulated combustion chamber. Proper field testing and lab testing is recommended.

Illustration 7: Portable mud stove

4.2.3. Improved institutional cooking stove (IICS)

The improved institutional cooking stove (IICS) as in Illustration 8 was well adapted to requirement of this restaurant owner. Stove has proper height, door (fuel) size, and speed needed by cook. Not many IICS have been disseminated yet and field observations were hence limited.

Illustration 8: Improved institutional cooking stove (IICS)

4.3. ICS and IICS construction

Mud stoves are well suited for dissemination in the Terai. Builder of improved mud stoves ICS are effective in building different size stoves, both fixed and portable stoves. They use tools/templates to produce stoves to specifications and to support their productivity.

Builders of institutional improved cook stoves, (IICS) that we met seem to be able to customize the design of the stove to fit requirements of the cooks. This is an important marketing skill and offering for institutional users who have different priorities from each other's. Some IICS users have speed as most critical features, while others who may be spending significant money on fuel may have fuel efficiency as a priority. IICS builders should therefore have the appropriate in-depth training to be able to customize stove construction.

4.3.1. Mud ICS builders making different types of portable stoves

The mud ICS builders (Illustration 9) we met mastered material preparation, selection of mud, mixing with organic additive (various recipes), and construction technique.

Illustration 9: Mud ICS builders making different types of portable stoves

4.3.2. Mud ICS with additional stand to place pots

In communities such as the Tharu communities, stove builders add additional features, both functional and aesthetic features that increase value of the ICS. Illustration 10 shows an extra platform that creates an additional usable cooking space for users, and therefore adds value to stove. Continuous surveying of stove use and their customization will bring additional knowledge and new techniques. Features that add value to stove could be integrated into the ICS/IICS portfolio.

Illustration 10: Mud ICS with additional stand to place pots

4.3.3. Winemaking stove with aesthetic features

A winemaking stove shows that poor people do invest in making their stove and house aesthetically appealing. Owner of the stove in illustration 11 did extra effort to make a lid and door for the stove to hide the soot-covered inner of the stove. This stove also illustrates the high level of local mud construction skills.

Illustration 11: Winemaking stove with aesthetic features

4.4. Fuels

4.4.1. Wood humidity

Wood and cow dung fuel found in the field had high humidity content, often exceeding 20% (Illustration 12). High moisture content has a high impact on the stove performance. The presence of moisture in fuel reduces temperature in the combustion chamber, which directly reduces the efficiency of the combustion, resulting into more smoke emissions.

Illustration 12: Wood humidity exceeding 20%

For the combustion to actually happen, the water contents of the fuel needs to be brought to boiling temperature and then has to be completely evaporated. The evaporation process will consume a significant amount of energy present in the fuel. For comparison, soft wood would have a calorific value of 20MJ/k when totally dry, 18MJ/Kg at 5% humidity, and only 14MJ/Kg at 25% humidity.

4.4.2. Dung

Cow dung is usually used in a ‘cake or flat bread’ format (Illustration 13) which is easily formed and dries rather well. Some users prefer to form cow dung as a ‘stick’ (Illustration 14) normally mixed with a larger percentage of other residues. People reported that the sticks burn better than the cakes but require longer drying, probably owing to the higher contents of other residues. Also the stick form seems to be more practical for burning in the existing stoves.

Illustration 13: Traditional drying of cow-dung 'cakes'

Illustration 14: Cow dung formed in a 'stick'

4.4.3. Other fuels

Illustration 15: Stoves at urban restaurants using coal as fuel

In city, some restaurants the use of coal as fuel (basic stove with electrical fans) (see Illustration 15) could be observed.

5. Possible Improvements

5.1. Fuels Improvements

Wood and cow dung found in the field had a humidity content exceeding 20%. Humidity in fuel has a major impact on stove performance, both fuel consumption and emissions. Humidity in fuels used should be monitored in the field, and an attempt to develop a solution to reduce humidity in fuel used will have a significant impact on stove performance.

Illustration 16: 'cow dung washing' press

5.1.1. A 'cow dung washing'

For use of cow dung as fuel, we recommend to closer look at technique 'cow dung washing' recently piloted in the Terai (see Illustration 16). This technique has potential to increase combustion performance. The liquid extracted from cow dung washing is also believed to be an effective fertilizer. It will be helpful to get more data about this technique, and also to look deeper into other forms of processing to increase energy value and reduce harmful compounds.

Illustration 17: Agricultural Residue

5.1.2. Agricultural residue, fuel briquettes

During our visit during harvesting time, we noticed significant agricultural residue (Illustration 17). Available agricultural residue could be understood (quantities, seasons, current use) and possibility/relevance of making briquettes from this fuel evaluated. We recommend undertaking a business analysis over a year to evaluate and select alternative biomass fuels densification, find out which fuel in what quantities are available, select processing methods, and evaluate economic aspects, both at households' level and at either community or commercial level.

5.2. Design Improvements

5.2.1. Portable mud stove cracking

Cracks above the door of a mud, the weakest region in a mud stove, are due to combination of impact during transport and non-uniform thermal expansion during use. These cracks cannot be avoided completely, but the using metal wire around the stove will prevent crack from propagating and prevent stove from collapsing.

Illustration 18: Metal-wire to prevent stove from collapsing

5.2.2. Reduce smoke from cow dung combustion

A slow flame in traditional cow dung traditional stove indicates a lacks of oxygen and turbulence. Dung combustion will be improved by increasing air mixing: adding a grate and a door to force air to enter under the fuel for better mixing, Dung combustion will also improve by adding insulation (higher temperature) inside the combustion chamber.

Illustration 19: Inefficient cow dung combustion in traditional stoves

5.2.3. Low cooking speed

New rocket-type stoves deployed have no insulation in the combustion chamber. From a usability point of view the stove appears to be too high and the door too small. Reducing stove height and increase door/combustion chamber size will improve speed of cooking and fuel consumption.

Illustration 20: Reduction of stove height and increase of door/combustion chamber size for better speed and fuel consumption

5.2.4. Under-ground air inlet

An under-ground air inlet gives the advantages of a grate without having to purchase a grate. Without a grate, or an under-ground air inlet, the air enters the combustion area above the wood and air/fuel/flame mixing is limited and the combustion is incomplete. With a grate or an under-ground air inlet, the air comes into the combustion under the wood. This creates a better mixing of air/fuel/flame and results into a more complete combustion.

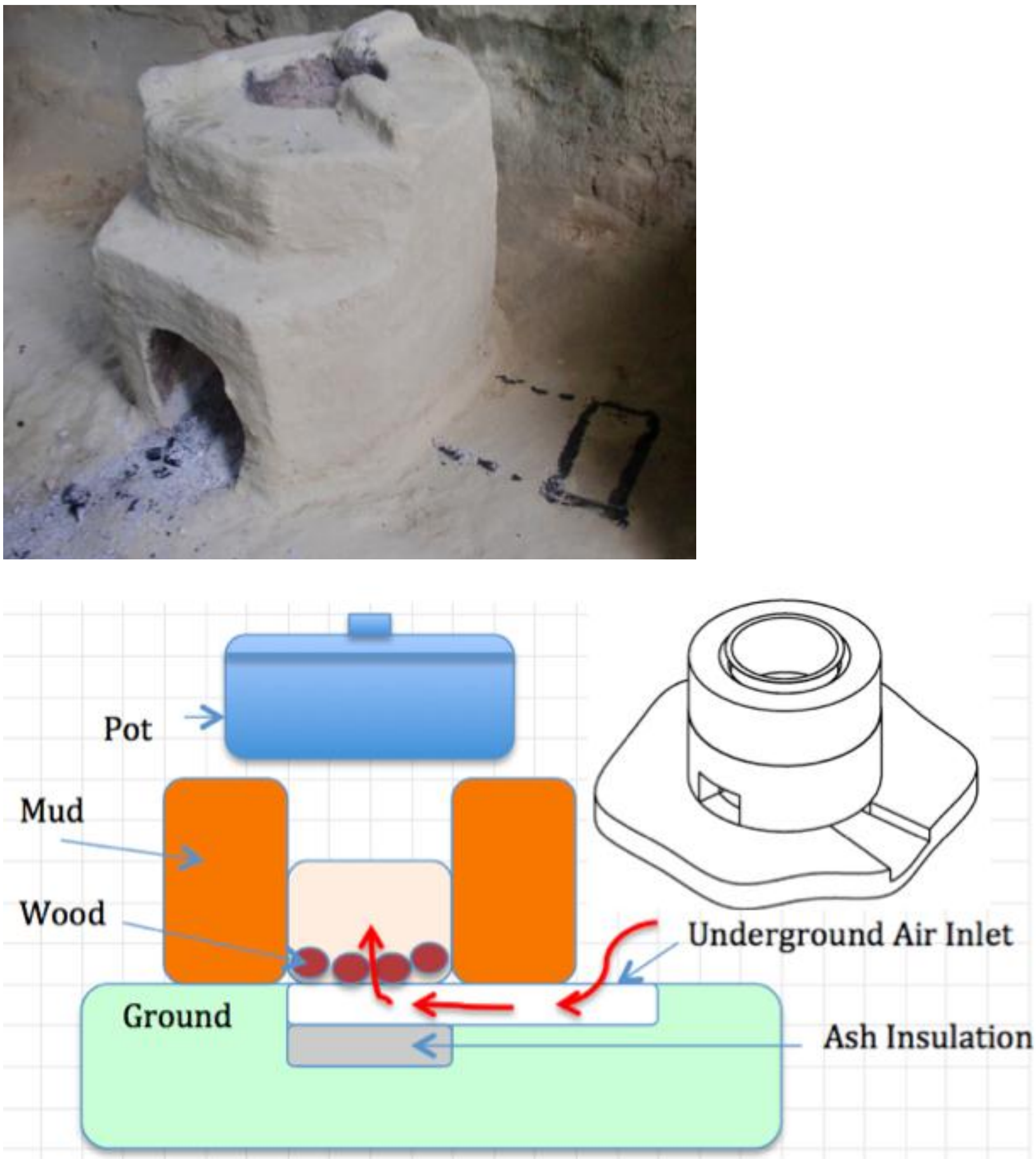

Illustration 21: Under-ground air inlet

Using an under-ground air inlet also allows wood to lie on the floor, which is preferred to ‘elevated’ wood when a grate used.

5.3. Marketing Improvements

5.3.1. Training of stove builders:

While visiting restaurants we could observe that some IICS builder did customize the stove design per requirements of the cook. This ability to customize IICS is critical for marketing of IICS. This customization ability should be enhanced and institutionalized within IICS builders and promoters. Technical, along with business training, and marketing material should be developed and provided to IICS builders and promoters.

5.3.2. Willingness to pay

Poor people are willing to pay for ‘value’. This was observed when we found pressure cooker in all households visited (illustration 22). In one of the houses, the husband pulled us to the side and asked “why do you still bring us mud stoves while the rest of the world has moved to modern technologies?” The above are indications that when offering stove options to users, value/performance stoves options should also be offered, and one should not offer only the cheapest stove.

Illustration 22: Omni-present pressure cookers

5.3.3. Multiple-stoves for the same household

Users need different size stoves (illustration 23). When marketing stoves, the need for multiple stoves should be considered and used to maximize impact**.**

Illustration 23: A double-burner stove combined with a high-power (large pot) single burner stove

5.3.4. Stove non-cooking tasks

When marketing stove, one should take into account non-cooking but critical tasks of the stove. In illustration 24, smoking meat is a critical function of the stove. If, the new stove offered does not allow smoking meat, then the solution won't be accepted.

Illustration 24: Using stove to smoke meat

5.3.5. Other requirements related to cooking

When marketing stove, one should take into account other requirement for the kitchen. In illustration 25, users wanted to have lighting around the stove. For this purpose, they are using a locally built, artisanal LED light. Marketing an effective lighting solution together with the stove will enhance the marketability of the stove.

Illustration 25: Artisanal LED light used above the stove

6. Recommendations for ICS and IICS

6.1. Modifications and Construction of New Stoves

After meeting with AEPC engineers and managers, it was agreed to build, test and evaluate four new stoves design and four design modifications. The recommendations are results of the field visit and discussions with AEPC staff during the final presentation of findings and conclusions (Appendix 2).

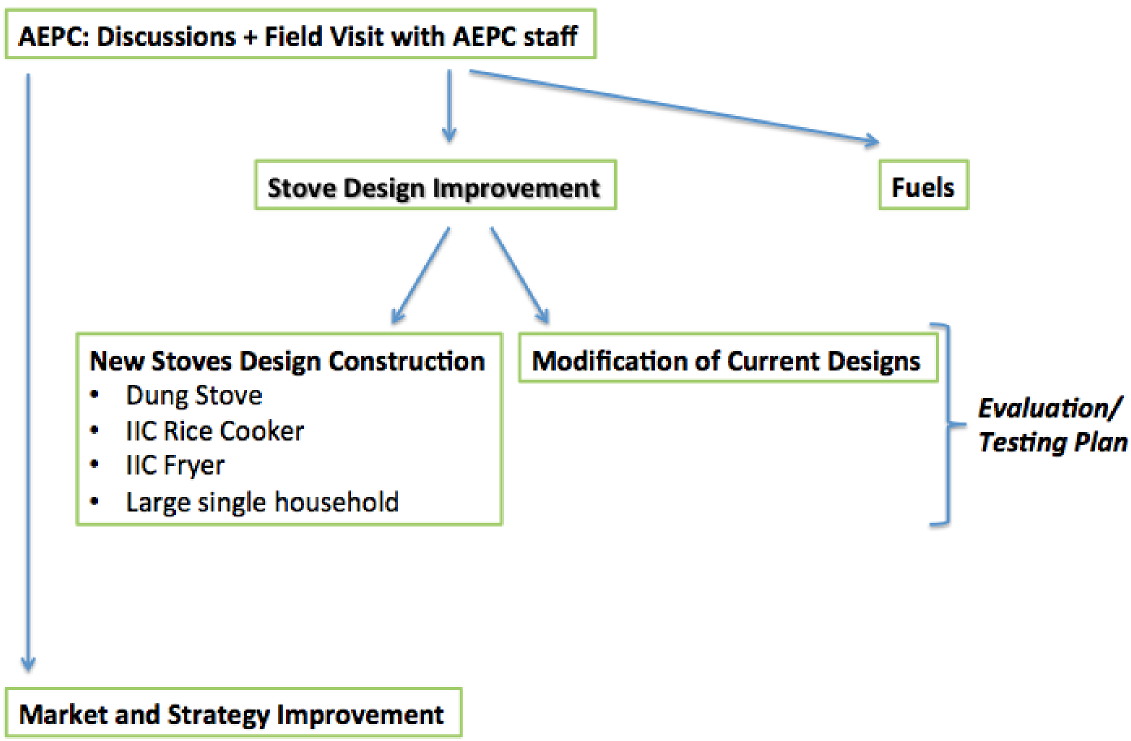

Illustration 26: Recommendation Process

During the process the following list of new stoves designs and modifications was drafted that will be built and evaluated by AEPC. AEPC will determine when and where the prototypes will be tried out and based on the results of the trials decide whether to 'incorporate/not-incorporate' the new designs and design modifications into the AEPC portfolio.

		To be built/ tested? Yes/No	How?	Who?	Where?	When Test?	When Decision To Include or not?
New Stove Design	Dung Stove with Chimney	Yes	Build				
	"IICS-Dekchi" Rice/Sauce	Yes	Build				
	"IICS Karai" Frying	Yes	Build				
	"ICS-Afeed" animal feed, household, Single burner, no chimney, Skirt	Yes	Build				
Existing Stove Modification	"ICS-HighInlet" modified ICs double burner chimney, high air inlet	Yes	Modify				
	"Mod-Rocket" modified rocket	Yes	Modify				
	" ICS w/wo grate" (grate-less grate effect)	Yes	Modify				
	"Wire Portable"	Yes	Modify				

Table 1: Overview New Stove Design and Modifications

6.2. New Designs

The following description of new designs assumes some familiarity with general biomass stove design principle. We recommend the manual "Design Principles for Wood Burning Cook Stoves" by Larry Winiarski, The Aprovecho. Manual can be downloaded at this link:

http://www.aprovecho.org/lab/index.php?option=com_rubberdoc&view=doc&id=22&format=raw

6.2.1. Multi-Fuel chimney stove

Why

- Complete combustion of cow dung requires more air and air turbulence than wood. Cow dung also produces large amounts of ash. Both these characteristics contribute to making combustion of cow dung in traditional stoves extremely smoky.

What/How:

- Make a stove that reduces the amount of smoke:
  - Add a grate for maximal air/fuel mix
  - Add door to maximize air coming through grate (base of the fuel)

- Add insulation to maximize temperature in combustion chamber and improve combustion efficiency

- Make a stove that removes all/most smoke from kitchen:
    - Add a chimney

Key Decision criteria

- **Additional cost of grate**: The cost of the grate will be minimal as simple piece of construction re-bars can be used. About 5 pieces of re-bar, 8mm to 12 mm diameter, 20cm long will be used. These pieces don't need to be welded together. The total cost of the 5 pieces will be under NRs.100. For maintenance, only pieces that fail, one or two pieces per year, need to be replaced. The maintenance cost will be less than NRs.40 per year.

- **Size of the stoves**: The suggested design features should not make the stoves too big to practical for users. All the suggested modification can be applied to the 'inside' of a traditional stove; therefore, the new stove will have same external size as a traditional stove.

Technical Drawing

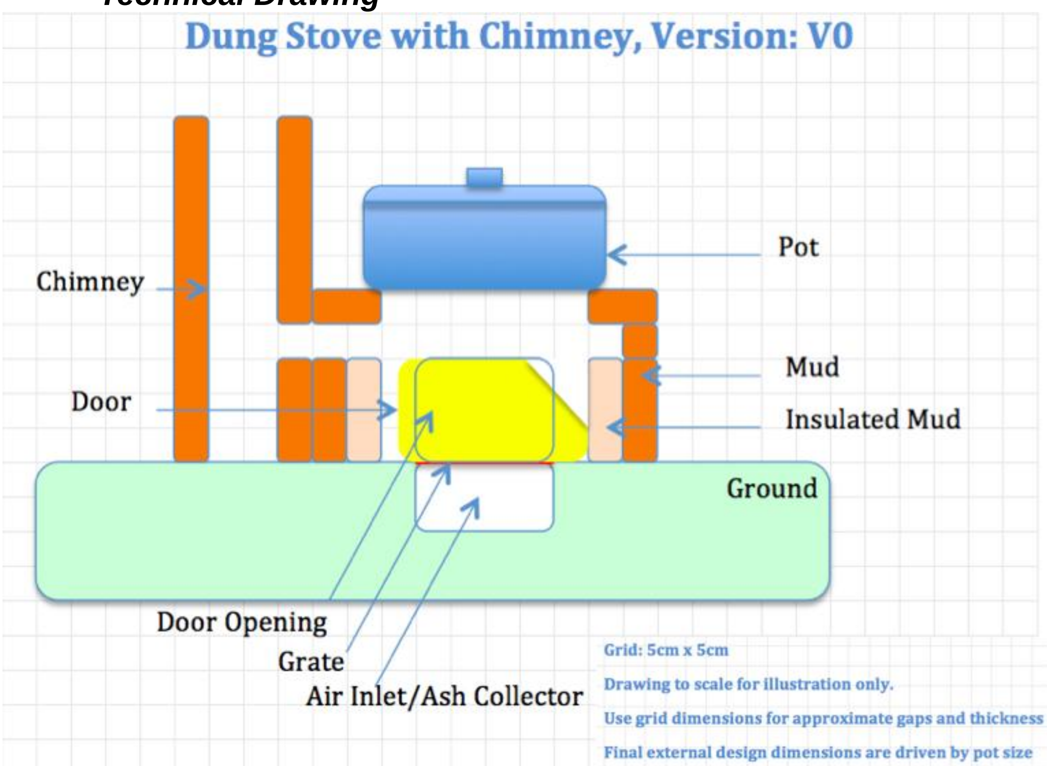

Illustration 27: Drawing Dung Stove with Chimney

Various notes and rules of thumb

General Approach:

- The multi-fuel design features suggested (grate, door, insulation, chimney) could all be added to traditional stoves. This will insure that new design will not compromise stove usability.

Dimensioning:

- Follow traditional stove dimensions to insure proper usability and comfort of use

Wall Thickness

- Use typical wall thickness used by mud-stove builders

Insulation

- To find out the lightest mix (highest amount of organic material) that has an acceptable strength while having the maximal insulation, do experiment, varying proportions of mud/organic material. Select the lightest mix that has sufficient strength

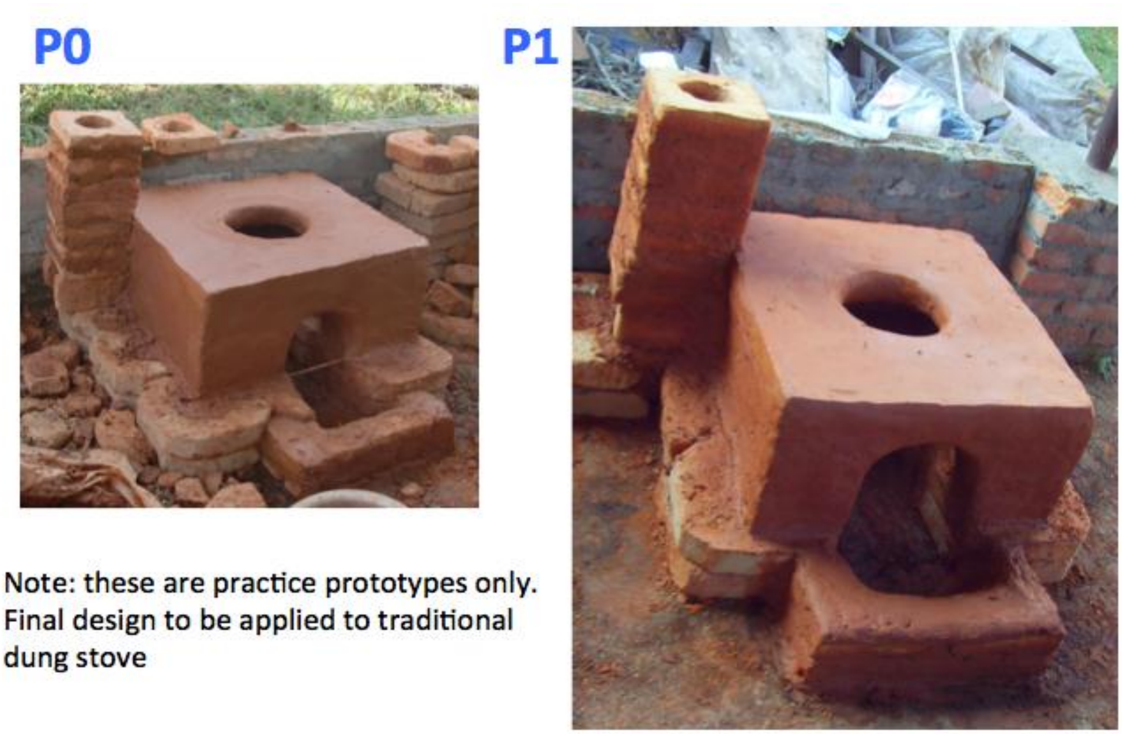

Illustration 28: Early prototypes of multi-fuel chimney stove

6.2.2. ICS-Single Skirt stove

Why:

- A skirt alone can save fuel by up to 50% and speed up boiling by factor 2.

What/How:

- Skirts will double the surface area of the pot receiving heat from fire

Drawing

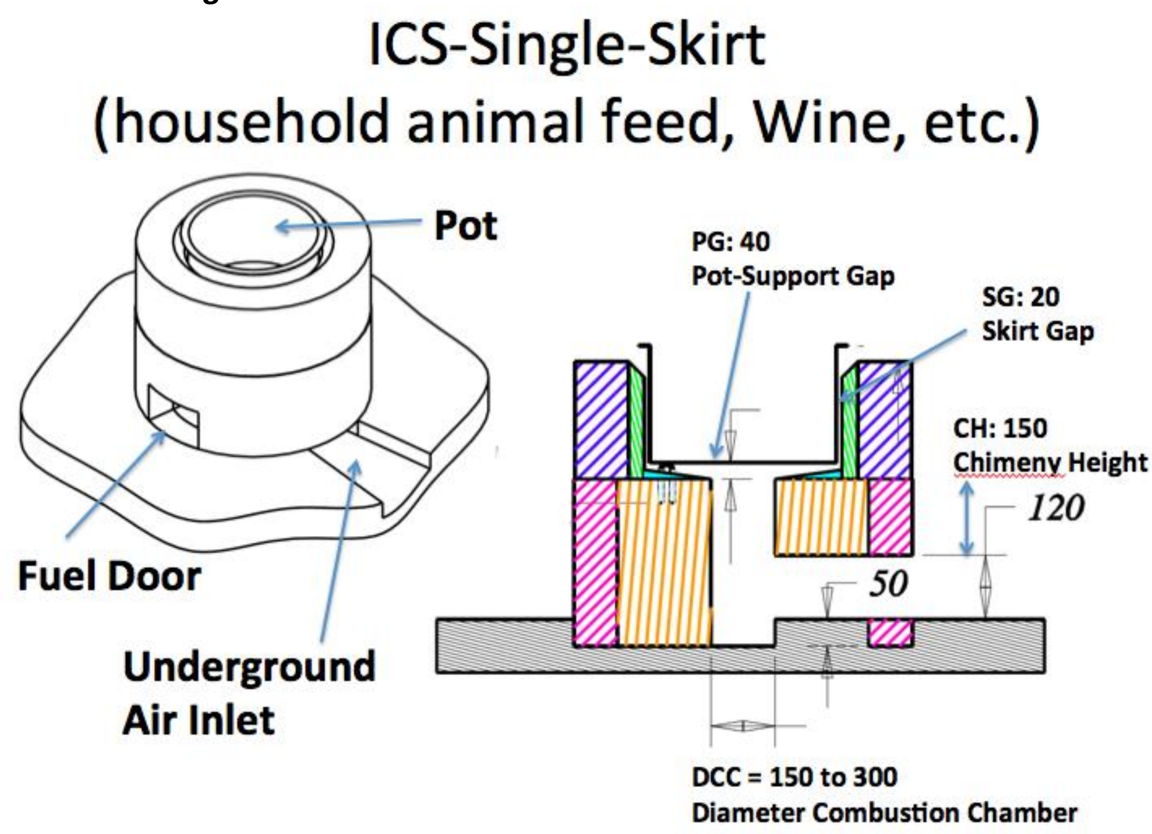

Illustration 29: Drawing Stove

Various notes and rules of thumb

Combustion chamber diameter for non-insulated material

- Diameter will vary from 150mm for household size (up to 10 liter pot), to 300mm for large institutional pot (+100L).

Skirt height

- Skirt height can be reduced as much as required by cook (ease of removing pot).

- Most performance from skirt obtained in lower part of the skirt.
- Minimum skirt height = 1/3 of pot height.

Skirt gap:

- One finger. Be able to slid hand in the gap

Pot support gap:

- Three fingers. Be able to place three fingers between bottom of pot and top of stove

6.2.3. IICS-Dekchi Chimney-Skirt

Why:

- A skirt alone can save full by up to 50% and speed up boiling by 2x
- A chimney will eliminate smoke for customers
- A flow lake will prevent chimney from reducing effect of skirt (fast and uniform heating of pot)

What/How:

- A skirt will double the surface area of the pot receiving heat from fire

Key Decisions:

- Using a ferro-cement platform (or any rigid top) will allow a good fit around pot to prevent smoke leaks. A rigid top is needed to allow support above the ‘flow lake’

Drawing

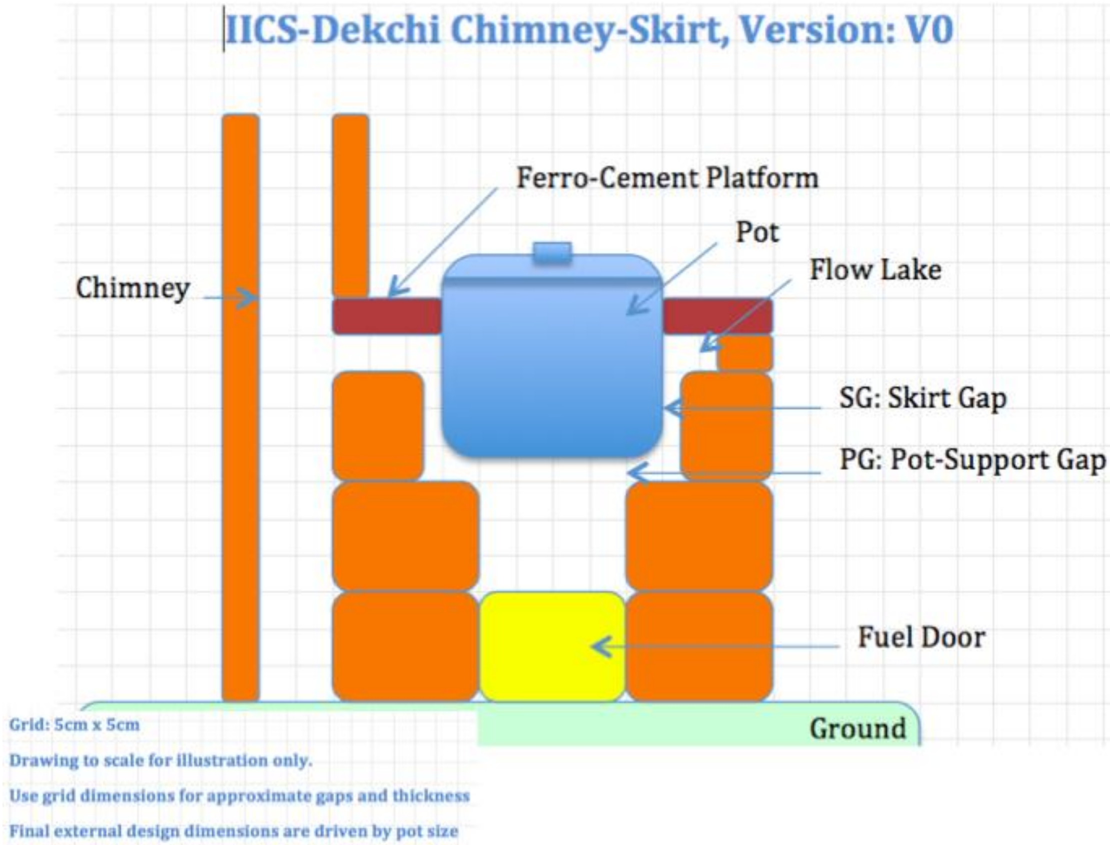

Illustration 30: Drawing Stove

Various notes and rules of thumb

Combustion chamber diameter for non-insulated material

- Diameter will vary from 150mm for household size (up to 10 liter pot), to 300mm for large institutional pot (+100L).

Skirt height

- Skirt height can be reduced as much as required by cook (ease of removing pot). Most performance from skirt obtained in lower part of the skirt.
- Minimum skirt height = 1/3 of pot height.

Skirt gap

- One finger. Be able to slid hand in the gap

Pot support gap

- Three fingers. Be able to place three fingers between bottom of pot and top of stove

6.2.4. IICS-Karai (fryer) Chimney-Skirt

Why:

- A skirt alone will save fuel and speed up frying
- A chimney will eliminate smoke for customers
- A flow lake will prevent chimney from reducing effect of skirt (fast and uniform heating of pot)

What/How:

- A skirt doubles the surface area of the pot receiving heat from fire

Key Decisions:

- Using a ferro-cement platform (or any rigid top) will allow a good fit around pot to prevent smoke leaks. A rigid top is needed to allow support above the 'flow lake'

Drawing

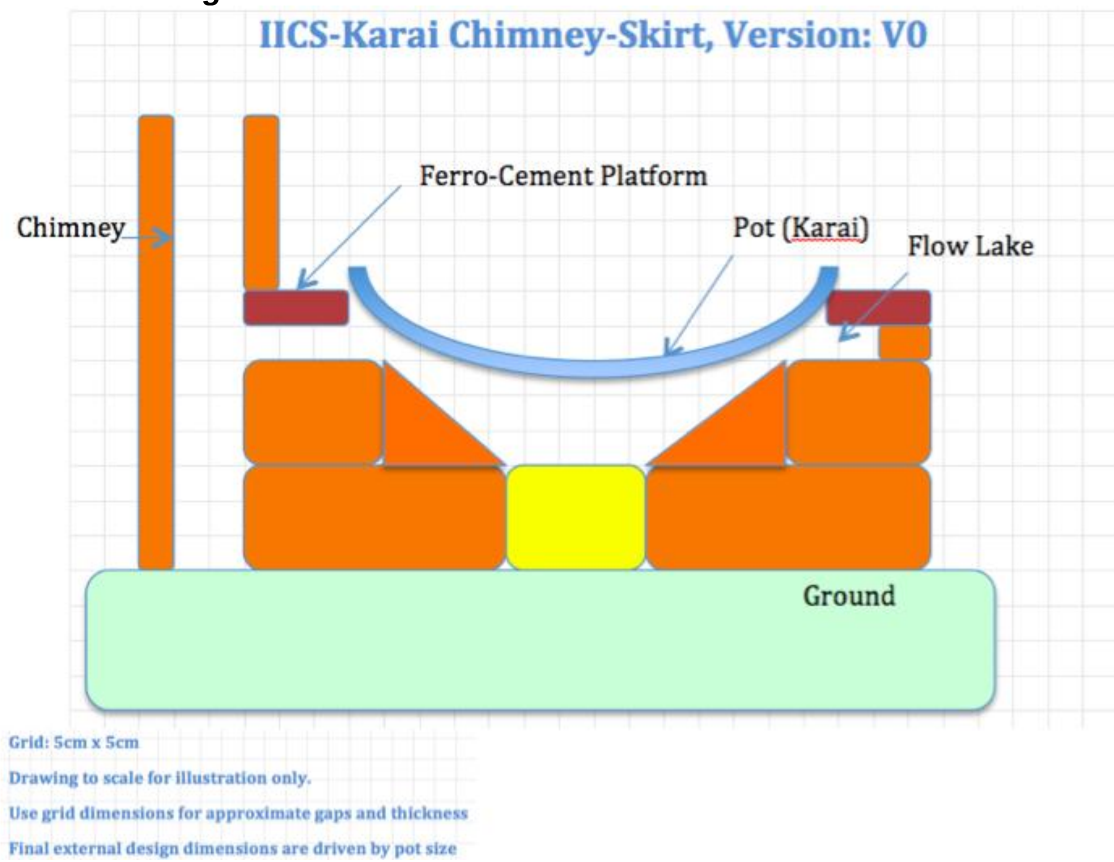

Illustration 31: Drawing Stove

Various notes and rules of thumb

Combustion chamber diameter for non-insulated material

- Diameter will vary from 150mm for household size (up to 10 liter pot), to 300mm for large institutional pot (+100L).

Skirt gap:

- Small gap on edge of pot, about one finger
- Gap increasing from outside and toward center of pot

6.3. Design Modifications

The following of design modifications assume some familiarity with general biomass stove design principle. We recommend the manual "Design Principles for Wood Burning Cook Stoves" by Larry Winiarski, Aprovecho. Manual can be downloaded at this link:
http://www.aprovecho.org/lab/index.php?option=com_rubberdoc&view=doc&id=22&format=raw

6.3.1. Higher air tunnel in double burners

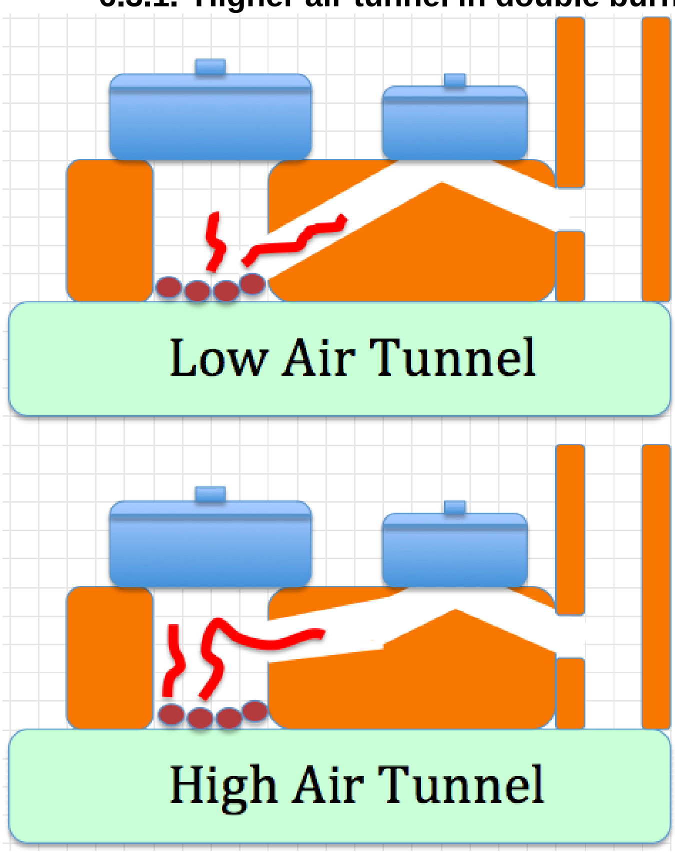

Illustration 32: Higher air tunnel in double burner ICS

The air tunnel between combustion chamber and the second pot is relatively too low (illustration 32). By placing the air tunnel higher, the first pot will get more power without impacting power to the second burner significantly.

6.3.2. Modified Rocket

Illustration 33: Current Rocket-type stove

Rocket-type stove promoted (illustration 33) use dimensions for stove using insulated combustion chambers. We expect that with such dimensions that this rocket-type stove will be too slow to boil. In order to increase speed, the combustion chamber could be increased to 150 mm minimum. The rocket chimney height above the door, currently equal to 1.5 times the combustion chamber diameter, could be reduced to 1.0 times the combustion chamber diameter.

6.3.3. Under-ground air inlet 'grate-less'

The under-ground inlet is 5 cm deep (illustration 34). In the combustion area, dig an additional 5 cm that will be a magazine for ash. Ash which will be left at the bottom is an excellent insulation and will reduce heat losses from the fire to the ground.

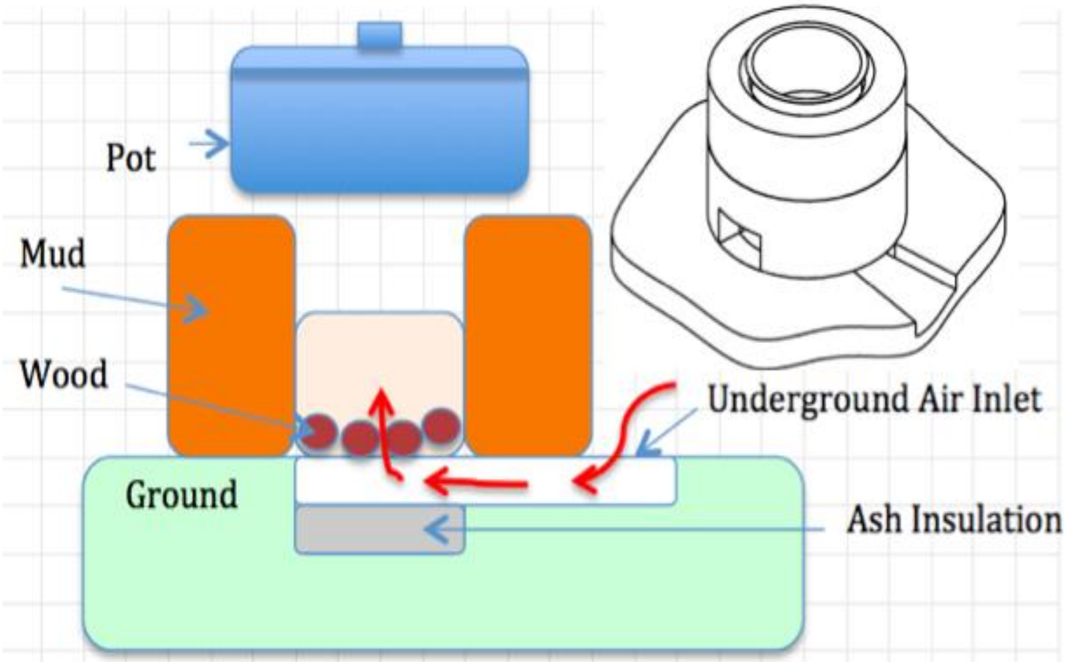

Illustration 34: Under-ground air inlet

6.3.4. Wire portable

Illustration 35: Using a metal wire to keep stove together after cracking

A metal wire (illustration 35) can be placed on portable mud stove above the door opening. The metal wire will prevent cracks commonly founds just above the door from propagating.

7. Recommendations for ‘middle class’ portable metal stove

7.1. Market Need

The majority of biomass stove users have only mud ICS as an option. We gained the impression that there is a considerable user’s aspiration for more modern stoves for example portable-metal stoves as an alternative to mud stoves. This was noted as an anecdote when the husband in one of the houses we visited in the Terai pulled a side and scorned us “why do you continue to bring us mud solution while the rest the word moved to modern solutions”. This impression corresponds with experiences in other parts of the world (e. g. Uganda, Haiti) where users were found willing to pay higher prices for stoves with better performance, high durability, and which looked aspirational. In the case of Nepal, finding that majority of households purchased relatively expensive pressure cookers without subsidies or promotion effort indicates that poor Nepali households are willing to invest in a cooking solution, in this case a pressure cooker, if the solution has value for them.

Tested and certified portable metal stoves performance exceeds mud ICS performance in terms of fuel consumption, emission, speed, and usability. These stoves also contribute to a cleaner kitchen, cleaner pots, and a more comfortable cooking experience. While portable metal stoves cost more than mud stove, their value should creative enough incentive to purchase for the ‘middle class’.

From a general marketing strategy, it is essential to provide customers options and choices. Customers should have access and choices to both mud stove and metal stoves.

Dissemination of improved stove to the ‘middle class’ is also an effective marketing tool to promote improved stove to poorer users who want to emulate the middle class.

A scalable and effective distribution of portable metal stoves requires stove enterprises that combine all activities required:

- Design & engineering,
- Production,
- Marketing,
- Distribution, and
- Customers’ financing.

Establishing such stove enterprises has been and is still a challenge all over the world. AEPC could take the lead to support establishment of a strong local stove industry in Nepal.

7.2. AEPC Role

Below is a list of activities and roles that AEPC could assume to support the stove industry:

7.2.1. Establishing standards and benchmarks

- Develop quantifiable standards for a new generation of stoves that is internationally recognised.
- Certify stoves that meet this standard
- Guidance and support to stoves producers to achieve this standard
- Certification to manufacturers who can produce stoves

7.2.2. Selection and Validation of stove companies to support

- Evaluation/Selection criteria:
- Technology
- Stoves quality
- How much local production/local materials
- Marketing and distribution strategy adapted to local market
- Innovation track record (design, production, distribution)

7.2.3. R&D support

- Testing and stove design optimization
- New combustion technologies
- New materials
- Manufacturing technologies
- Carry out trainings for existing stoves engineers, align this training with CTVET
- Ensure this training reaches the smallest of the small manufacturers and fabricators

7.2.4. Marketing support

- National promotion of stoves
- Facilitate access of customers to stove micro-financing

7.2.5. Industry financing support

- Tax free import certificates that will be recognised and accepted
- Provide Seed capital and loans
- Facilitate carbon financing

7.2.6. Focus and Potential conflict of interest

- Focus less on being a stove developer to avoid a conflict of interest with the industry that needs support

7.2.7. Metrics to evaluate AEPC performance

- Propose metrics to evaluate performance of AEPC supporting stove industry: number and impact of stoves deployed by stove industry

7.2.8. Short term activities

- *Early Wins / Success stories*
  - ➢ Evaluate/Select two to five stove companies
  - ➢ Find out their specific priorities and provide them with support they currently need
- *Tax free import of stove materials/components*
  - ➢ Provide tax free import certificate to selected stove companies
- *Carbon registration:*
  - ➢ Support carbon registration for selected stove companies
- *Mapping*
  - ➢ Reach out and carry out a nationwide mapping of all stove manufacturers ensuring the smallest are included

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