Further R&D, optimization and prototype development of Jatropha based sustainable cooking technology for rural Nepal by enabling environment for technology dissemination and commercial development.

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Abstract - In Nepal, traditional biomass energy source supplies more than 87 per cent of energy needs. Two-thirds of total energy consumption of any kind is done by cooking and more than 75 per cent households use cook stoves fuelled by firewood. Especially, in rural areas, women and children are affected by the smoke and emissions from the traditional stoves making them vulnerable to different respiratory diseases and eye infections, and in some cases leading to premature deaths as well. If we are able to replace the cooking methodology with sustainable bio-fuel, it will help improve the lives of a large number of women who are in the frontline of smoke assault as well as reduce carbon emissions.

The NORAD supported Renewable Nepal program has supported this research project to develop an efficient Jatropha based cooking stove technology suitable for rural Nepal. The research project aims to strengthen and support the capacity of existing designs with locally available resources. The concepts for preliminary design and pre-modifications were drawn on the basis of the studies conducted on existing prototypes of bio fuel stoves. After a series of simulated tests and experiments, final prototype stoves using vapor jet technology and wick burners were developed.

This paper focuses on the methodologies that were adapted during the project period, modifications done on the existing prototypes, its subsequent results and the way forward.

Index Terms - Bio fuel stoves, modifications, burners, wick stove, vapor jet stove

I. INTRODUCTION

For rural communities in Nepal, wood is still the main energy source for cooking. They are dependent on firewood, which is time consuming to collect and are depleting at an alarming rate or expensive oil imports which are beyond their means. Steadily rising firewood consumption for cooking purposes results in deforestation of large forest areas which creates severe ecological, economical and sociological problems. Moreover, the emissions from open fires are extremely harmful to users. Therefore, utilization of locally available alternative cooking energies needs to be identified and promoted.

Depending upon economy level, people started replacing traditional kerosene stove by other commercial sources of energy like LPG gases, solar energy etc. while people with poor economic background are still bound to use the same even though they are forced to suffer the consequences of Indoor Air Pollution. The development and commercialization of the existing Jatropha based stove will not only save women from drudgery of collecting firewood and reduction in indoor air pollution but also make usages of locally available bio energy resources. To replace kerosene and diesel, Jatropha plants can be the best alternative. Jatropha plants also known as physic nut has seed which contains up to 40% oil in them. The seed can be crushed and processed to extract oil from them which can be used as energy source. Hilly regions of Nepal have proper tropical climate for the production of such plants. The Jatropha plants (sajivan) are inedible and their uses are limited just to make barriers, fencing in the rural areas. As a replacement of the conventional energy source, bio-fuel can be used. Local plant oils can be used as a substitute for kerosene oil and fuel wood. This research focused on the use of Jatropha oil as an alternative for kerosene in stoves.

Since 2007, PEEDA is working on Biofuel program in Okhaldunga, Nepal. The developmental goal of PEEDA's intervention is to see households within the target area be able to generate additional income through the cultivation of inedible oil bearing seeds. The seeds will be a sustainable energy resource and income, and thereby reduce their level of poverty. Additional goals are for the Okhaldhunga Community Hospital to reduce their operating costs and reliance on external diesel imports and for the overall environment of the target area to be improved. PEEDA also focuses on R&D activities in order to assess how to utilize the by-products of the oil production process. Depending on the results, the communities will be advised on how to use the by-products to open up further revenue streams. PEEDA already has a supporting mechanism for oil production with an expeller plant managed by the community in place. Further, the mechanism for engaging participatory community involvement with the new technological solution is in place.

II. RENEWABLENEPAL PROJECT

The adoption of the technology is going to be a landmark for further diffusion in other rural parts of Nepal. Renewable Nepal project is supporting this research to carry out the following objectives:

2.1 Objectives of Renewable Nepal Project:

1. Further R&D, optimization and prototype development of existing PEEDA's Jatropha wick stove and CEPTE/KU developed pressure stove and
2. Community testing and commercialization by enabling environment for commercial development and

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dissemination for production of affordable, reliable and sustainable energy cooking sources for rural Nepal.

2.2 Project Funding Plan or Budget Summary

Table: The Project Funding Plan Summary (in NOK)

Funding Source	Budget for All Participating Organizations				TOTAL
	PA-NPRI	M-NPEI	M-NORI	M-NOEI	
Programme Funding	129,779	55,143			184,921
Contribution	25,614	13,571			39,126
TOTAL BUDGET	155,393	68,714			224,107

2.3 Detailed Description of R&D Aspect of the Project

The R&D objective of this project is to develop technically suitable and economically viable Jatropha cook stove that is acceptable to rural households in Nepal. The specific objectives are-

1. Further R&D, optimization and prototype development/enhancement of existing wick and pressure stoves
2. Strengthening and supporting the capacity of the existing design with locally available resources through technological development
3. Community piloting, monitoring and evaluation
4. Enabling environment for the commercial production by developing affordable technology options for rural poor.
5. Develop and disseminate practical technology based interventions to the local and national manufacturers.
6. Disseminate the information and results of the project which will be made freely available.
7. Establishment of the linkages with the different government and non government institutions working in the same sector to bring the technology in mainstream

The approach in this project reflects the key elements needed to achieve and sustain adoption of Jatropha stove technology and behavior change. Past interventions have at times yielded lessons about the failure of one-size-fits-all, technology-driven “stove” programs to achieve long-term acceptance by the community. The greater challenge lies in demonstrating the combination of elements most likely to be effective in the short term for a given community or category of communities and most likely to be replicated and scaled up over the long term. The obtainable formal community structures in place in Okhaldhunga will help in facilitating initial community buying and ultimate ownership and responsibility for long-term results of the stoves. It will be much easier to raise awareness and behavior change within the target population thus creating a market mechanism for the commercial manufacturers and cost effective cooking solution to local rural poor. Technology adoption will be done through participatory approaches with community and validate the performance of these stoves on the basis of indoor air pollution emissions of particulate matter (PM) and carbon monoxide, as well as fuel consumption. Stove performance tests will be conducted in the laboratory as well as under actual household conditions.

Technical assistance and quality engineering service will be sought from Energy, Environment Research & Development Centre (EERDC). At presents the engineers from Kathmandu University who had contributed to its pressure stove program are working full time in the organization.

R&D of the existing PEEDA wick stove will be done in collaboration with Energy and Environment Pvt ltd. E&E has developed 30 good stove designs including 20 natural draft and forced air top lit updraft gasifier stoves and shared them as "Open Knowledge", about 500 people have accessed the design from different parts of the world. E&E wishes to create more such useful resources and disseminate knowledge for communities to adopt. E&E is a qualified manufacturing company and will be assisting in this project as a part of R&D team. The R&D support will help the manufacturer to come up with a robust and reliable technology in the market while giving greater benefits to the customers. The use of various proportions of bio-fuel with kerosene and diesel will help reduce the cost that is being incurred while using the conventional fuels alone. Also, comparing the emissions from kerosene and diesel, bio fuel emits less GHG which will help to reduce potential environment pollution to some extent.

This project aims to provide an alternative cooking solution to rural poor in Nepal. The wide availability of wild and already planted 60,000 high yielding seed variety in Okhaldhunga by PEEDA makes the introduction of bio fuel stoves to be economically beneficial to both commercial producers and local community. The adoption of the technology is going to be a landmark for further diffusion in other rural parts of Nepal.

The project will be carried out in following 5 Steps:

Step 1: Further R&D, optimization and prototype development/enhancement of existing stoves

- Increasing the effectiveness and efficiency of its usages when used with highly viscous Jatropha oil
- Optimization of ignition process and reduction in coke formation.

Step 2: Strengthening and supporting the capacity of the existing design with locally available resources through technological development

- Different tests are to be carried out to be familiar with the characteristics of *Jatropha Curcas* oil.
- Characteristic comparison between the crude oil and kerosene when both used as a fuel in normal stove.
- Efficiency test of the Jatropha fueled stove if they are available.
- Carbon emission test will be to done following the UNFCCC guidelines.

Step: 3. Community piloting, monitoring and evaluation

- Installation in sample household together with the local NGO/CBO, local manufacturers etc

- Participatory Monitoring and Evaluation with community stakeholders
- Feed back/Data Collection and analysis

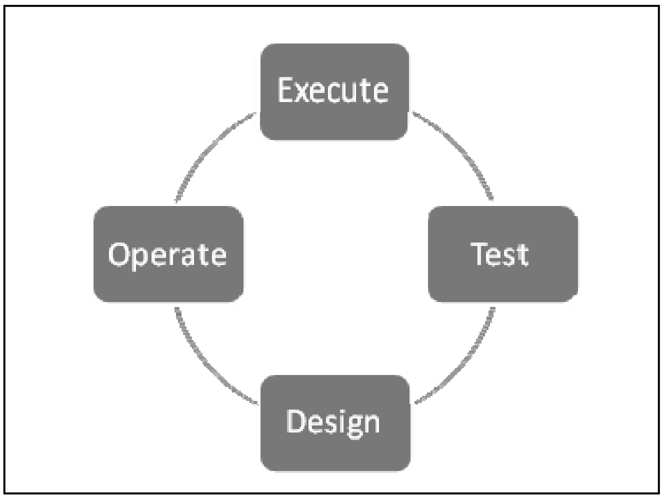
Step 4: Design and Fabrication

- Based on the Lab and field tests, further modification will be done.
- Locally available materials and equipment's will be used to fabricate the prototype of the new design

Step 5: Develop and disseminate practical technology based interventions to the local and national manufacturers.

- Design and distribute manuals/guidelines to commercial manufacturers regarding the technology for widespread replication.
- Trainings to local entrepreneurs and community people

III. R & D METHODOLOGY



Strategize – understand and develop the Jatropha Stove and match it with the project objective and goals

Execute – Set-up People, Processes, Technology, Timelines, Dependencies goals

Lab Test/Field Test –Set-up in the demonstration site, Best Practices Set-up, monitoring and review for continuous improvement

Design – The product as per the field level specification, verification and response

Operate – Disseminate the technology in wider scale with commercial production

IV. TECHNOLOGY DEVELOPMENT

Centre for Excellence in Production and Transportation of Electricity (CEPTE) in Kathmandu University carried out the research to study the atomization characteristics of the Jatropha oil in kerosene stoves. The study of the hybrid stove (Plant Oil stove) was done. The different composition of Jatropha and kerosene have been studied and tested in the local kerosene stoves. The kerosene was used at 5%, 15%, and 30%, with the crude Jatropha oil. Among all these, the 30% mix of kerosene burns without any complications. The test of the stove with trans-esterified Jatropha oil was also done. With the result of the tests and literature review, the new stove was designed and fabricated. Some modifications were also made in the stove burner.

As fuel was viscous, the pressure applied by normal pump system was not sufficient. Further R&D work in testing the atomization pressure of the fuel and apply pressure by other method like mini-hand pump needs to be studied further. This will help in making the technology more robust by finding the exact pressure needed to atomize the fuel thereby changing the pressure application method/design. Similarly, the problem of oil clogging in the burner after a period of time is another major problem in the existing model, there needs to be further R&D in order to devise a model where pre-heating will be sufficient for long time efficient burning.

There exists a Memorandum of Understanding (MoU) between Centre for Excellence in Production and Transportation of Electricity CEPTE/KU and Energy, Environment Research & Development Centre (EERDC) to formalize the acceptance by CEPTE/KU to handover the documents and findings of its Jatropha project to EERDC so that further research required in the project can be carried on by EERDC.

PEEDA has done some R&D in developing a 1.5 Liter Size Multi-wick stove, a barrel shaped stove that has its three support legs caging a flat cylindrical-shaped fuel vessel with the wick burner mechanism exposed. This multi-wick/'range wick' stove is aimed at low-income communities for domestic cooking use. This stove can be used for either indoor or outdoor cooking. The multi-wick mechanism allows for air flow to occur around its enclosed stilt barrel configuration. This has the effect of reducing heat transfer to the fuel vessel and through this reducing the potential fuel loss in the vessel through evaporation. The cooling effect on the stilt wick reduces the transfer of heat to the fuel vessel, and thus the fuel within the fuel vessel remains below the dangerous flashpoint temperature even after long periods of use. Closer to the top of the enclosed stilt areas become hot during stove use. The prototype wick stove is still in their nascent stage, there is need of further R&D especially regarding the effectiveness and efficiency of its usages when used with highly viscous Jatropha oil. Also there is need optimize the stove ignition process as substantial amount of coke is found to be formed in higher ignition temperature of Jatropha oil compared to kerosene. Before commercialization and disseminating it in community, emission tests (following the UNFCC stove protocol) and community pilot testing is also needed.

V. DESIGN/MODIFICATION FACTORS

The modifications done on the previous design was based on the modification principles proposed by Whitney Veigas, suggests the four factors of a successful design as: "function, aesthetics, cost and technology"[1].

Following steps have been undertaken during the design process:

1. Problem identification
2. Observation and testing
3. Re-designing and testing
4. Follow-up

5.1Modified Wick Stove

Previous researches have shown wick stove as one of the best option for rural use of Jatropha oil. It is easily available in Nepal as well as accepted by the community. In Nepal, the presence of kerosene wick stove is decades old. It is based on a relatively simple and long proven technology and modifications for bio fuel usages in wick stoves are relatively simple.

Modifications:

- Fuel is fed to the burner by gravity force
- Simple concept of capillarity is used for its design
- Burner consists of 10 cylindrical features to support wicks
- A valve to stop oil flow
- A perforated aluminium cap is installed around the wicks for optimum oxygen and to protect from wind blows.

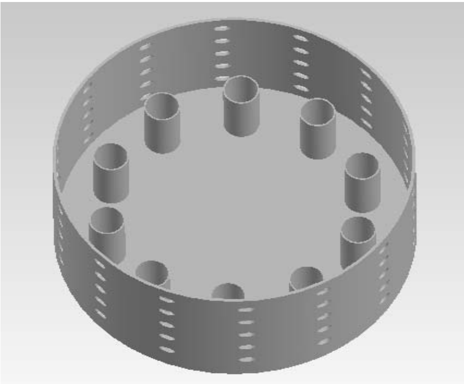


Fig 1: Burner assembly of modified wick stove

Fig 2: Modified Wick Stove (Design)

Fig 3: Modified Wick Stove (Final Product)

5.2 Results:

After modifications, the wick stove seems to be burning with better efficiency. The problem of the stove not being able to burn for a longer period of time (in *case of previous model of wick stoves*) has been solved with the inception of new design.

5.3 Modified Vapor Jet Stove

Due to its high viscosity, high atomization and ignition point, crude jatropha oil can't be used as a sole fuel for cooking purposes in pressure stoves. To aid these constraints, a dual fuel tank and dual nozzle system stove has been developed in which the use of kerosene is used as a preheating agent.

Modifications

After a series of experiments and tests, community demonstration and feedback collection, the final modification made to the prototype are as follows:

- Outlet of circular windings in jatropha fuel pipe fitted with a nipple to concentrate the vapour stream which results in the ejection of flammable jatropha vapour from the fuel pipe
- Dual fuel tank and dual nozzle system (one for kerosene and other for jatropha oil)
- Preheating the stove with kerosene

Fig 4: Burner Assembly of Vapor Jet Stove

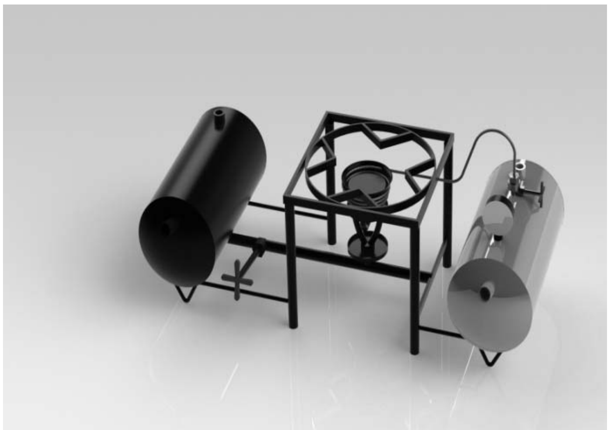


Fig 5: Modified Vapour Jet Stove (Design)

Fig 6: Modified Vapor Jet Stove (Final Product)

5.4 Results:

The coiled fuel pipe design in the prototype has been beneficial in improving the fuel properties of Jatropha by utilizing the exhaust heat from the burner. The problem of tip being caught by fire while operating pressure stove is no longer after the installation of nipple in jatropha fuel pipe. Furthermore, the tests results of operating this stove under simulated conditions are as follows:

Table 1: Test results of Vapor jet Stove Prototype

IWA Performance Metrics	**Units**	**Average Values**	
Operational Fuel Modality		Kerosene only	Dual mode
High Power Thermal Efficiency	%	34	37.6
Average PM Concentration	ug/m^3	229	227
Average CO Concentration	ug/m^3	2.6	2.2
Highest PM concentration	ug/m^3	685	675
Highest CO concentration	ppm	3.9	3.4
	Standard Performance Measures		
Fuel Consumption Rate	g/s	0.96	0.916
Jatropha Fuel Consumption Rate	g/s	-	0.118
Kerosone Fuel Consumption Rate	g/s	0.96	0.87
Burning Rate	g/min	5.102	6.805
Time to Boil	min	20.1	16.2

VI. CONCLUSION

Utilization of plant oil cooking stove has numerous ecological, economical, and sociological benefits. Plant oils are a sustainable energy source ensuring sustainable cooking energy supply**.** Jatropha promises to be superior to other plant oils in Nepal as it has short gestation period, easy handling, high oil extraction and superior quality of bio-diesel. A number of plantation practices and engine test runs have been conducted across the world and also in Nepal, which have been successful to demonstrate that it is the best alternative to conventional fossil fuel. In this scenario, the use of Jatropha based bio fuel stoves in the rural areas for fulfilling energy requirement in Nepal has high possibilities and potentialities.

The primary challenge for the adoption of the stoves will be the assurance of a reliable fuel supply for the rural community. This challenge can be addressed through the establishment of production facilities located strategically near the field test areas with an abundance of wild variety of Jatropha in mid hilly regions of Nepal. Market opportunities would then exist for entrepreneurs to become involved in the production and distribution of stoves in similar geographical location throughout the country. PEEDA is working to develop its market development and marketing strategy, which includes required training, technical support, financing and marketing support. PEEDA has already purchased and placed an expeller unit in Okhaldhunga. PEEDA has already planted 60,000 high yielding variety of Jatropha and anticipates planting of 75,000 high yielding varieties by 2015. In order to ensure widespread access and adoption of these stoves, as well as the supply of related renewable energy fuel products, PEEDA has committed enterprises development activities in its project.

The field investigations and analyses undertaken by PEEDA depict the viability of stove for poor and low income group farmers in Nepal. It is found that the rural communities can greatly benefit from them. The wide ranges of benefits include socio-economic, financial and environmental gains. The technology also provides additional health and environmental benefits when compared with the traditional stoves in place. Thus, the use of Jatropha stove can be a meaningful alternative for rural communities in the long run.

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REFERENCES

[1] E. Stumpf " Plant oil as cooking fuel: development of a household cooking stove for tropical and sub tropical countries". Institute for Agricultural Engineering in the Tropics and Subtropics, Hohenheim University, Germany.

[2] Stumpf, E & Muhlbauer, W."Plant oil cooking stove for Developing Countries".

BIOGRAPHIES

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