Lanstove™ for Rural Households†

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Introduction

Majority of rural households world over lack clean cooking fuel and electricity for lighting. For example in India alone around 60% of rural population lives with almost non existent electricity and uses ~ 200 million tons/year of biomass to cook on primitive cook stoves. For most of these households the only light they get is that coming out from cook stoves! Lighting which is a basic necessity and the fundamental need of humans is missing from the lives of this rural population.

Wherever there is no electricity, old and inefficient kerosene lanterns are used. These lanterns by and large produce inadequate light besides producing harmful indoor air pollution. It is estimated that 1.5 million people die every year worldwide because of indoor air pollution created by inefficient kerosene lanterns and biomass cook stoves.

Thus there is a need to develop an efficient device which works on readily available liquid fuel to produce high quality light for illumination purpose and heat for cooking. This paper presents one such lantern running either on **kerosene or diesel** which produces very high light output (almost equivalent to that from 200-300 W bulb) and also cooks a complete meal for a family of five in the heat of the flue gases.

The device christened Lanstove™ (lantern combined with cook stove) is to our knowledge the first such device where both lighting and cooking are combined together resulting in tremendous energy efficiency and saving of fuel. **The word Lanstove™ has been coined by our Institute NARI to denote the dual purpose nature of this device.**

Kerosene as household fuel

Kerosene has been used as household fuel for hundreds of years. However with the advent of electricity for lighting and natural gas for cooking it receded from the horizon of western countries and hence became a fuel for developing countries. This naturally had the affect that no worthwhile improvement in technology was carried out in the last 70-80 years with the result that the cooking and lighting devices running on kerosene are very inefficient, polluting and hence environmentally unfriendly. In early 1920s when the maximum research efforts took place in improving kerosene devices, the air pollution standards had not been enacted and hence the design got frozen in that time frame.

Our Institute NARI was probably the first Institute in early 1980s to make a serious effort in improving the efficiency of kerosene lamps. This resulted in the invention of an efficient pressurized mantle lamp called Noorie. It was also shown for the first time that the heat of the flue gases from Noorie lantern could be used to do small amount of cooking such as making tea or boiling eggs. Feedback from the users had showed that they would like to do more cooking if adequate heat is available.

† Lanstove development is a part of R&D done on household energy devices at NARI. A short history of R&D is here.

NARI then embarked on the program of developing the kerosene Lanstove with the added advantage of storing the fuel in a pressurized cylinder, thereby overcoming the drawback of existing pressurized lanterns (including Noorie) where frequent pumping is required. Frequent pumping resulted in shaking the lantern and thus breaking the fragile mantle. Besides it led to over pressurizing the storage tank which sometimes resulted in explosions and fires. The pressurized kerosene storage in cylinder therefore made the Lanstove very safe and as convenient as LPG cooking. Thus with the flip of the valve the kerosene gas flows in Lanstove where it is lit and cooking is done very easily on the clean burning flame.

The concept of kerosene lanstoves has now been extended to work on diesel fuel also.

Lanstove attributes

NARI Lanstove consists of a 9 liter pressurized kerosene/diesel cylinder, a high light output mantle lantern and very efficient steam cooker which is based on heat pipe principle. Fig. 1 shows the cooker on lantern and Table 1 gives the details of the Lanstove.

Table 1

Sr. No.	Item	Attributes
1.	Lanstove unit	The unit consists of high light output lantern; novel cooker with insulated jacket; and pressurized (2-3 atm pressure) 9 liter kerosene cylinder. Pressurization of cylinder is done by hand operated small bicycle pump. Items made of mild steel and stainless steel.
2.	Light output	3400-3800 lumens from thermoluminescent mantle (used in Petromax lamps). Existing hurricane lantern produces 65-70 lumens only.
3.	Efficacy of lantern	1.5-2.6 lumens/W
4.	Efficiency of stove	41-47 % (water boiling tests)
5.	Heat output	1400-1700 W
6.	Kerosene consumption	1.7-2.5 g/min
7.	Specific fuel consumption	1.5 to 2 kg of food cooked/100 g of kerosene
8.	What it does in 4 hours of running	Provides excellent light; cooks complete meal for a family of 5; and makes 10 liter of water potable. **Besides it is silent as compared to Petromax lamps.**
9.	Cooking - rice, dal and vegetables - chapatti/bhakari	 Via very efficient steam cooker with 3 or 4 pots. The cooker works on the principle of heat pipe. **Unassisted cooking so no fear of burning of food.** On specially designed griddle (*tava*) put over the Lanstove.
10.	Water boiling	5 liters of water is boiled in 35-45 minutes.
11.	Expected usage	2-3 hours at night and 1 hour in the morning.
12.	Pollution parameters	- No smoke, smell or burning in eyes. - CO levels < 3 ppm even after 3-4 hours of working in a very small enclosed room (with chulha it is ~ 200-400 ppm). - Particulate emissions less than WHO standards
13.	Controls	An on/off valve at the base of Lanstove slightly controls the light output and hence heat.

The particulate emissions were measured using a very innovative method. The actual soot production was 1.8-2.5 mg/kg of kerosene fuel used which translates to 15-20 $\mu g/m^3$. The average hut volume used in our work is 25 m^3 and using the norm of one air exchange in two hours for such buildings (with one door and a small window), the amount of soot per volume of air was calculated. This volumetric particulate emission is **equal or lower to that measured in the air of some of the cleanest cities of the world**, thus confirming the non-polluting nature of lanstove.

This development effort has also shown that a fuel is dirty depending on its combustion. **The same kerosene which is vilified all over the world as dirty fuel for lighting has been made very clean for lighting and cooking via lanstove.** We have now distributed 25 Lanstoves to unelectrified huts in four villages around Phaltan for long term testing and evaluation and till today (August 2013) they have accumulated a total of **more than 6800 hours of operation**. A short video of these tests is here

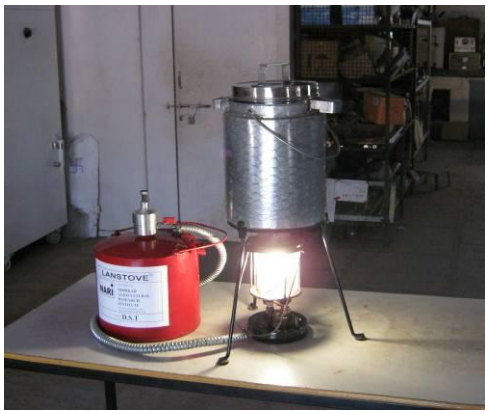

Fig. 1. Lanstove™ configuration

Lanstove™ in actual user hut

Comments of women using Lanstove (based on last six months data)

- Very bright light. Since no supervision is required during steam cooking, can do other household work like sewing, cleaning grain etc. and is also helpful for children to study.
- Very easy to light and use it. No smell or soot unlike in regular kerosene lanterns or stoves. No burning of eyes as happens in chulha cooking. See figure on next page.
- **Very silent as compared to existing pressurized kerosene stoves and Petromax lamps.**
- Very good for small businesses which can produce handicraft items in the light.
- Lanstove cooking time is comparable to that from woodstove.
- Very tasty food since no overcooking or burning. Slow steam cooking.
- Chapatti or bhakari can also be conveniently cooked on Lanstove though it takes longer time than that on woodstove.

Chapatti making on Lanstove™

- Will be willing to buy this stove and can give Rs. 20-30/day (US 45-65 cents/day) payment installments. Some indicated that the price should be around Rs. 2500-3000.
- Liked the water boiling aspect of the stove. In the morning used for heating bath water.
- Works just like LPG stove since no pumping is needed other than that required to pressurize the cylinder (done once or twice a week) and it is easy to control the flame.
- The Lanstove is safe to handle and does not involve risks of fire outbreak as is the case with regular kerosene lanterns, pressurized kerosene stoves and conventional chulhas.
- The use of Lanstove can eliminate the physical exertion in collecting wood/biomass. The time saved can be used to relax at home or doing other work. Most women commented on this advantage.
- The bright light of Lanstove makes us feel secure and comfortable, as we stay in an isolated area.
- I can get my children to do homework since there is good light with the lanstove.
- We cannot get adequate kerosene from the Public Distribution System (PDS) shops. If it is made available then we can use it for many more applications.

Smoke in hut with chulha cooking

Hut condition with lanstove

Economics

1. Cost of Lanstove	Present cost (for a batch of 25) is Rs. 6,000-7,000/- (US$ 120-140). This cost is estimated to come down drastically in mass production.
2. Kerosene used	~ 0.5 liters/day (3 hours use; 2 at night and 1 in the morning)
3. Running cost	Rs. 225/month (~US$ 4.5) (PDS kerosene @ Rs. 15/l) Rs. 600/month (~US$ 12) (open market kerosene @ Rs. 40/l)

Note: US$ ~ Rs. 50/-; PDS is public distribution system where the kerosene is available at subsidized rates for below poverty line (BPL) consumers.

Safety Issues

The outer jacket of steam cooker gets hot during cooking and hence it is covered with a layer of chicken mesh so that accidentally touching it will not burn the user. Similarly by keeping the kerosene in a separate cylinder the lanstove is as easy and safe to use as LPG cooker.

Recently there has been a great push for light emitting diodes (LED) based solar lanterns for rural households. However it has also been shown that LED light is very harmful to the eyes and produces irreparable damage to retina.[*] On the other hand the light from lanstove is just like daylight and is equivalent to that coming from a blackbody radiation source of 3500^0K and hence is pleasant to the eyes.

Energy Issues

Electricity is the preferred "fuel" for both cooking and lighting in modern society. Hence it is instructive to compare the overall energy efficiency of electric cooking/lighting with our Lanstove. For evening cooking and lighting only, **electric devices (electric stove and incandescent lamps) will consume about 3 times more energy than Lanstove.** This is because the efficiency of electric power plant is 30% and with 20% losses in transmission and distribution the overall efficiency of electric power at the household socket is only 24%. With the electric stove efficiency of 60% the overall efficiency of electric cooking is only 14%. Similar is the efficiency of electric lighting. Our Lanstove efficiency is ~ 40% and hence tremendous energy savings can result via the use of decentralized liquid fuel for cooking and lighting. Thus the use of Lanstove for rural applications is a step forward towards sustainable solutions for these areas.

Availability of kerosene

The biggest issue presently is of getting adequate kerosene for rural households. Presently the free sale of kerosene is banned by the Government of India (GOI) and hence all the kerosene is for rural poor and is heavily subsidized and sold at Rs. 15/liter. This makes it a prime candidate for adulterating diesel, since diesel is sold at Rs. 40-45/liter in open market. Also the GOI policy allows only 5 liters/household of subsidized kerosene per month for below poverty line (BPL) families. This is wholly inadequate for the lanstove applications. Besides, most of the time even this much kerosene is not available in PDS shops since it is siphoned off for adulteration. A policy change on part of GOI is needed to allow the sale of kerosene without subsidy and in open market. This can help rural poor to get adequate supply.

A possible mechanism could be that the detachable kerosene cylinders of lanstove are brought by users to local kerosene dispensing shops and filled. The BPL families get subsidized kerosene through their Unique Identification Data (UID) cards. These kerosene dispensing shops will also pressurize the cylinder and since the kerosene will be made available openly without subsidy the siphoning off of kerosene can be prevented.

This strategy will be akin to that of liquefied petroleum gas (LPG) cylinders which are easily available presently all over the country.

The ease of kerosene fuel availability as outlined above will go a long way in making lanstove a very good product for rural households.

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[*] Eva Chamorro, et.al. "Effects of Light-emitting Diode Radiations on Human Retinal Pigment Epithelial Cells In Vitro". *Photochemistry and Photobiology*, 2013, 89: 468–473

Other issues

Recently our Institute NARI has developed a very unique method of sterilizing water. It involves passing the dirty water through four layered cotton sari cloth and then heating the water to around 60^0 C to completely remove and destroy all coliforms so that the water is fit to drink. This strategy allows a much more efficient use of lanstove so that energy is not wasted in boiling the water and the water can be heated in 15-20 minutes instead of 35-40 minutes taken for boiling.

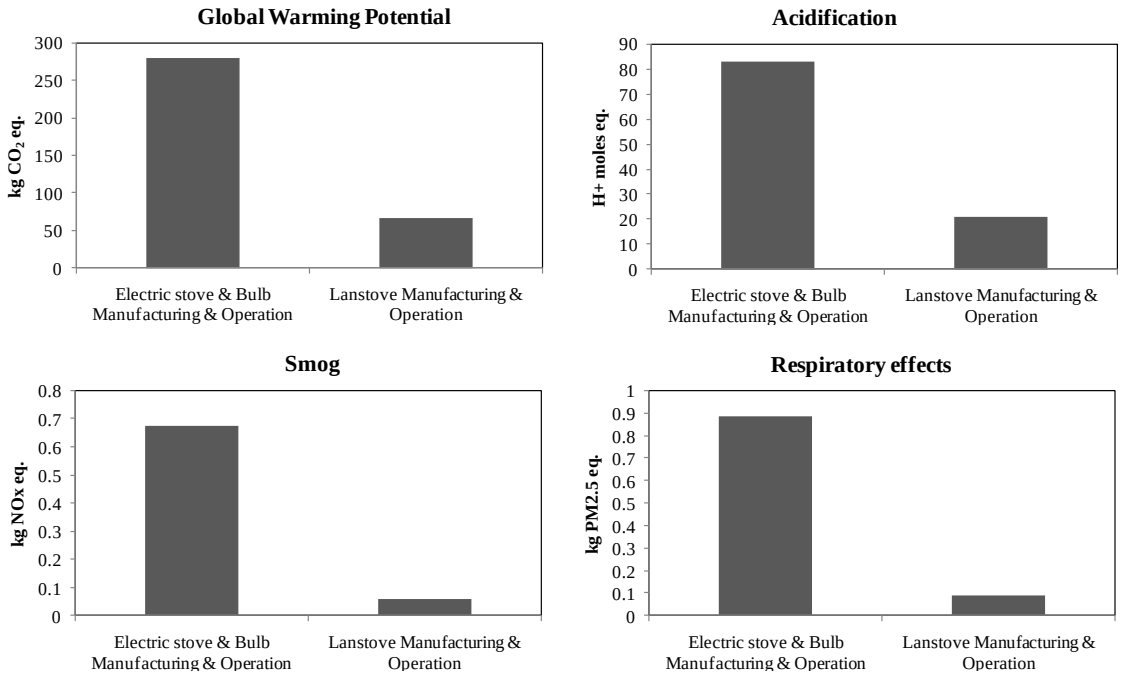
Life Cycle Analysis (LCA)

The energy efficiency of Lanstove vis-à-vis electric cooking and lighting is further strengthened by doing a Life Cycle Analysis (LCA) for both manufacturing and operations. LCA is an environmental impact assessment technique based on ISO 14040 standards and is defined as the "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle". The LCA was done to compare environmental impacts of Lanstove manufacturing and operations with electric stove and incandescent bulb manufacturing and operation. It was performed using the software SimaPro 7.1.

Since the process involves two different parameters, viz. cooking and lighting, two interdependent functional units were used. To boil 5 liters of water on the Lanstove, it takes 50 minutes. Hence it was assumed that light from the mantle will be available for the same amount of time. One Lanstove is assumed to be comparable with a combination of electric stove and incandescent light bulb. Hence the functional unit for this study is a combination of two parameters: 1) time required to boil 5 liters of water on electric stove and 2) electricity required to light a 100W incandescent light bulb for 50 minutes.

It should be noted that in LCA, incandescent bulb data instead of that for the more efficient compact fluorescent lamp (CFL) has been used. This has been done since in rural areas of India, incandescent bulbs are used much more because of their lower initial cost – CFLs are about 20-30 times costlier than the bulbs. Besides the poor quality of manufacturing makes the CFLs last only for a year or two.

The results of LCA are shown in figure below. It can be easily seen that Lanstove scores much better in almost all parameters as compared to electric cooking and lighting.



LCA for Lanstove

Conclusions

To the best of our knowledge this is the first time anywhere in the world where one device provides simultaneously light, complete cooking energy needs for a family of four or five and clean drinking water. **Also because of the excellent combustion in Lanstove, kerosene or diesel becomes a very clean fuel for rural households – almost equivalent to LPG.**

The Lanstove, therefore, has the ability to immediately improve the quality of life for bottom of the pyramid people in rural and urban areas. With the existing kerosene consumption of 9 million tons/yr for India, **Lanstove can drastically improve the quality of life of 62 million households. This is 82% of all rural households using kerosene for lighting.**

The availability of kerosene, though, to rural poor needs to be streamlined for lanstove to succeed. Presently a major portion of it is siphoned off for diesel adulteration and till it is adequately available lanstove expansion in rural areas may not take place.

Data and response from field testing of lanstoves in rural homes near Phaltan has been very positive. In near future we hope to expand this program in other parts of rural India.

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Lanstove news has been covered in Times of India, DNA, IBN-CNN, Better India, Indiatimes and a feature story came in Statesman newspaper.

Lanstove development is a part of extensive R&D done at NARI on household energy devices. A short history on these efforts is available here.

HOME