Extremely Efficient and Clean Cooking/lighting Device for Rural Households

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SUMMARY
Lanstove, a unique cooking and lighting device for rural areas has been presented in this paper. The specifications and various parameters of Lanstove are presented. Detailed comments and feedback from testing in actual user dwellings have shown that Lanstove can provide tremendous improvement in quality of life of rural poor. An attempt has been made to compare the Lanstove with conventional electric cooking and lighting methods. An energy analysis showed that electric cooking and lighting will consume 3 times more energy than Lanstove. This analysis has been backed by the results of Life Cycle Assessment (LCA), which showed that the environmental impacts such as global warming potential and acidification potential from production and operation of electric bulb and stove are much higher than those of Lanstove.

IMPLICATIONS
Lanstove provides simultaneously light, complete cooking energy needs for a rural family of four or five and clean drinking water. Also because of the excellent combustion in Lanstove, kerosene becomes a very clean fuel – almost equivalent to LPG, for these households. Such clean device can substantially reduce the indoor air pollution in these households and offers the best hope for improving the quality of life of rural poor.

KEYWORDS

Lanstove, life cycle analysis, cooking, lighting, kerosene,

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 (Rajvanshi, 2003). For most of these households the only light they get is that coming out from cook stoves! At the same time they use old and inefficient kerosene lanterns. 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 (WHO, 2007).

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 on kerosene which produces very high light output (almost equivalent to that from 200-300 W bulb) and also cooks 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 a household fuel

Kerosene has been used as household fuel for hundreds of years (Reed and Lerner, 1973). 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 and 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 seemed to have frozen in that time frame.

Our Institute NARI therefore embarked 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 (Rajvanshi, 1987). It was also shown in the design that the heat of the flue gases could be used to do small amount of cooking such as making tea or boiling eggs. Feedback from the users however showed that they would like to do more cooking if adequate heat is available.

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. This invention made the Lanstove as convenient as LPG cooking where with the flip of the valve the flame is lit and cooking is done very easily on clean burning flame.

METHODS

Design and Testing

Lanstove was designed so that the lighting efficacy was improved over the existing kerosene lanterns and the cooking device was developed based upon heat pipe principle so as to maximize the use of flue gases.

The NARI Lanstove has been tested in 16 homes in rural areas around Phaltan including 7 huts which never had electricity. Detailed data was collected for fuel consumption, amount of food cooked, user convenience of the device and indoor air pollution parameter like Carbon monoxide (CO). The CO levels in the huts were measured at 5-6 different locations at the start of cooking, after 1 hour and at the end of cooking. Figure 1 shows the Lanstove testing in actual user dwellings

Figure 1. Lanstove testing in actual user dwelling

Life Cycle Analysis (LCA)

To compare environmental impacts of Lanstove manufacturing and operations with electric stove and incandescent bulb manufacturing and operation, a life cycle analysis (LCA) was performed using the software SimaPro 7.1 (PRé Consultants, 2008). 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” (Guinée, 2002)

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 TRACI 2 V3.00 was used as the impact assessment method. TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) was developed by USEPA (Bare, 2002).

The assumptions used in this LCA are listed as follows:

1. Since combustion data for kerosene in Lanstove was not known, it was assumed that the process is similar to LPG combustion. The reason being that after extensive testing it was found that the CO and PM levels in the air surrounding the Lanstove after 4 hours of use were similar or smaller than those obtained from LPG combustion.
2. All the data for production and operation of Lanstove was obtained from NARI.
3. Electricity production data from India was assumed to be same as that for average Asian electricity production.
4. Electric stove and bulb production data was taken from Ecoinvent and Fraklin database which is inbuilt in Simapro (PRé Consultants, 2008).

RESULTS

Lanstove Specifications

Table 1 shows the details of various parameters of Lanstove.

Table 1. Technical specifications of Lanstove

	Item	Attributes
1.	Lanstove unit	The unit consists of high light output lantern; novel cooker with insulated jacket; and pressurized (~2 atm pressure) 9 liter kerosene cylinder. Items are made of mild steel and stainless steel.
2.	Light output	3000-3200 lumens from thermoluminescent mantle (used in existing Petromax lamps). Existing hurricane lantern produces 65-70 lumens.
3.	Efficacy of lantern	2.0-2.6 lumens/W
4.	Efficiency of stove	40-45% (water boiling tests)
5.	Heat output	1200-1500 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
7.	What it does in 4 hours of running	Provides excellent light; cooks complete meal for a family of 5; and boils 10 liter of water for drinking. Besides it is very silent as compared to existing Petromax lamps.
8.	Cooking: - rice, lentils and vegetables - bread (chapatti/bhakari)	 Via very efficient steam cooker with 3 or 4 pots. The cooker works on the principle of heat pipe. On specially designed griddle (tava) put over the Lanstove.
9.	Water boiling	5 liters of water is boiled in 45-50 minutes.
10.	Expected usage	4 hours at night and 2 hours in the morning.
11.	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. - 2.5 and 10 microns particulate emissions less than WHO standards (inferred – see explanation in the paragraph below the table).
12.	Controls	A valve controls the light output and hence heat from the Lanstove.

The particulate emissions were not measured during the course of experiments but their output was inferred. A recent study done on kerosene and diesel lamps (Apple et al., 2010) showed that the particulate output of pressurized lamps (petromax type) is within the acceptable limits according to WHO standards. The efficacy of the pressurized lamps used in this study was approximately 1.2 lm/W and was much lower than 2.6 lm/W for Lanstove. Correspondingly it is assumed that the particulate emissions from Lanstove will be within the WHO standards

The field testing revealed that the user acceptance and satisfaction of Lanstove was high. Representative list of anecdotal feedback is given below:

- 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.
- 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 is much faster than that from woodstove.
- Very tasty food since no overcooking or burning. Slow steam cooking.
- Chapatti or bhakari (bread) can also be conveniently cooked on Lanstove.

- Will be willing to buy this stove if the price is between Rs. 1,000-3,000 (~US$ 20-60).
- 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 a week) and it is easy to control the flame. The valve should be 90^0 tunable rather than the screw valve presently used.
- 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.
- The bright light of Lanstove makes us feel secure and comfortable, as we stay in an isolated area.

A simple economic analysis of Lanstove is shown in Table 2.

Table 2. Economics of Lanstove

Cost of Lanstove	Present cost (for 2-3 pieces) is Rs. 6,000-7,000/- (US$ 120-140). This cost is estimated to come down drastically in mass production.
Kerosene used	0.8 liters/day (6 hours use; 4 at night and 2 in the morning)
Running cost	Rs. 312/month (~US$ 7) (PDS* kerosene @ Rs. 13/l) Rs. 840/month (~US$ 17) (open market kerosene @ Rs. 35/l)

US$ ~ Rs. 46/-
*PDS is public distribution system where the kerosene is available at subsidized rates for below poverty line consumers.

LCA of Lanstove

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 Lanstove. For evening cooking and lighting only, electric devices (electric stove and compact fluorescent 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. Lanstove efficiency is ~ 40% and hence tremendous energy savings can result via the use of decentralized liquid fuel for cooking and lighting. LCA provides an added support to these conclusions as shown by the following results.

The results for LCA are shown in Figure 2. It can be seen that for all four impact categories considered in this study, Lanstove gives significantly lower environmental impact as compared to electricity.

DISCUSSION AND CONCLUSIONS

The Lanstove 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 India, Lanstove can drastically improve the quality of life of 180 million people.

It can be seen from the technical specifications of Lanstove provided in results section that it is a very efficient cooking and lighting device. It can also be seen that it has a definite advantage over electric lighting and cooking devices in terms of environmental impacts and efficiency.

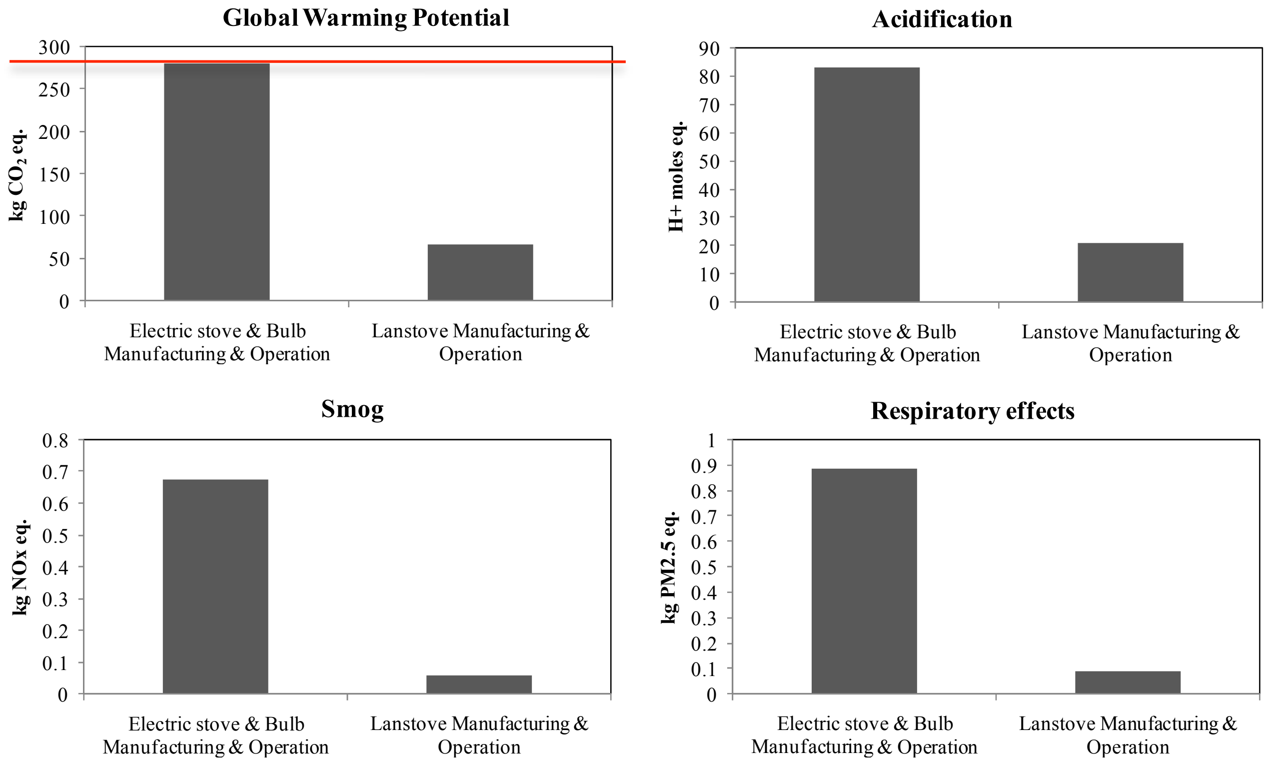

Figure 2. LCA results comparing electric cooking and lighting with Lanstove.

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REFERENCES

Apple, J., et al. 2010. Characterrization of particulate matter size distributions and indoor concentrations from kersone and diesel lamps. Indoor Air. 20, 399-411.

Bare, J.C. 2002. TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. Journal of Industrial Ecology. 6, 49-78.

Guinée, J.B. 2002. Handbook on life cycle assessment: Operational guide to the ISO standards. Kluwer Academic, The Netherlands.

PRé Consultants. 2008. SimaPro 7.1.6 Multi user. Netherlands.

Rajvanshi, A. K., 1987. Design and Development of Improved Lantern for Rural Areas. Published by NARI, Phaltan.

Rajvanshi, A. K., 2003. R&D strategy for lighting and cooking energy for rural households. Current Science. 85. No.4.

Reed, T, B., and Lerner, R. M., 1973. Methanol a versatile fuel for immediate use. Science. 182. 4119, 1299-1304.

WHO, 2007, Estimated deaths and DALYs attributed to selected environmental risk factors by WHO member state, WHO, Department of public health and environment.