Ethanol Lantern cum Stove for Rural Areas [1]

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It is a matter of shame that even 61 years after independence about 60% of rural population in India has no electricity and they use ancient kerosene lantern for lighting. Besides in quite a large number of rural households the only light is from the cook stove (chulha). Lighting which is the basic necessity and a fundamental need of humans is missing from the life of majority of rural population. Without adequate lighting the lives of these people cannot be improved and India cannot join the developed nation's league.

Besides the poor light output kerosene lanterns also produce soot and other pollutants in the confined space of rural households leading to serious lung ailments. Thus there is a need to develop a light source which runs on locally produced fuel, is environmentally friendly and produces bright light equivalent to that from a 100 W electric bulb. This paper presents one such lantern running on low grade ethanol fuel which also doubles up as a cooking stove thereby solving the twin problems of cooking and lighting for rural households. Nimbkar Agricultural Research Institute (NARI) is the first to propose and develop a dual purpose lantern (christened **lanstove**) running on 55-60% ethanol-water mixture.

Ethanol as fuel for lighting

Almost all the liquid fuel lighting in rural areas is kerosene based. The quality of light obtained from flame type devices (hurricane lanterns, candles, etc.) is very poor (< 100 lumens). It is based upon incomplete combustion principle. Hence the yellow flame produces soot, CO and CO_2. In the confined space of rural households, use of such lanterns can be injurious to health. However, light from pressurized mantle lamps (Petromax type) is comparable to that from light bulbs or fluorescent lamps and hence may offer the best option for rural lighting. The good lanterns in this genre have efficient and complete combustion of fuel. Presently available 'Petromax' lamps in India were developed in Europe in early 1920s and have been copied all over the world. In India they are available in hundreds of 'avatars' with varying quality. Their manufacturing is in the unorganized sector and hence the quality of majority of them is quite poor. Recently, there has been an upsurge of liquid petroleum gas (LPG)-powered mantle lamps. However, small gas cylinders are not readily available in rural areas besides being costly.

Also kerosene is a non-renewable fuel, is costly and environmentally unfriendly. Biodiesel which is renewable is not suitable for lighting in the existing lanterns because of high viscosity, tendency of gumming and soot formation. Low grade ethanol is one such fuel which can be locally produced, is environmentally friendly and safe for household purposes.

[1] This project won the prestigious Globe Award which was given by HRH Crown Princess Victoria on 3 June 2009 in a ceremony in Stockholm, Sweden.

Ethanol has roughly similar limits of inflammability (limits of fuel-to-air ratio in which combustion will proceed) to those of the component gases of LPG. Thus the use of pure ethanol for household purposes is dangerous. This problem can be overcome by the use of dilute ethanol mixtures in a suitably designed lantern. Thus 55-60% (w/w) ethanol-water mixture can be used for lighting. The main reasons for the choice of this mixture are:

1. The low grade mixture is less flammable than pure ethanol, making it safe to handle and hence ideal for household cooking purposes.

2. The low grade ethanol-water mixture is easy to distil and can be produced in a one-step distillation process (even using solar energy as the driving force), thus reducing the energy utilized in its production and hence the overall cost of fuel.

3. In rural areas of developing countries, a substantial amount of illicit liquor production takes place in makeshift backyard and rudimentary distillation units, which produce alcohol with 45-60% (w/w) ethanol-water concentration. This alcohol is mainly used for drinking. The use of this as fuel in the ethanol lanterns can hopefully help solve triple problems of drinking, cooking and lighting.

Low grade ethanol lantern

Development of low grade ethanol lantern required the following strategy:

a) It should be able to evaporate ethanol water mixture completely.
b) The lantern had to be designed properly for optimum air fuel mixing so that the weak ethanol mixture could be combusted very efficiently and produce high flame temperatures for lighting the thermo luminescent mantle.
c) It should be less noisy as compared to the existing Petromax lantern.

Consequently a very efficient 55-60% (w/w) ethanol water lantern was designed and is shown in Fig. 1 and the specifications are given in Table 1.

Table 1. Ethanol lantern specifications

Item	Specification
Lantern	Pressurized with rare earth oxide mantle
Pressure	0.60-0.90 kg/cm^2 (g)
Light Output	1100-1400 lumens
Light Efficacy	1.0-1.2 lm/W
Fuel Used	55-60% (w/w) ethanol-water mixture
Fuel Consumption	250-275 g/hr (58% ethanol-water)
Power Consumption	1080-1185 W
Fuel tank capacity	1.1 liters
Weight of lantern	3.5 kg (with full fuel) 2.4 kg (without fuel)
Dimensions of lantern	37 cm (H) X 23 cm (D)
Sound level	55-58 dB (existing Petromax lanterns 65-75 dB)
CO levels	~ 4-5 ppm (matching the background levels)
Construction materials	Mild steel, Stainless steel, Teflon and other high performance plastics
Est. production cost	Rs. 1,000 per lantern (production of > 10,000 pieces/year)

Fig. 1

In most of the mantle type lanterns the efficiency of light output is quite low. It is normally expressed as efficacy (lm/W). For a typical incandescent bulb it is 10-15 lm/W, for compact fluorescent lamps (CFL) it is 50-70 lm/W and for mantle type lanterns it is 1-3 lm/W. Thus major portion of energy in such lanterns is lost as flue gases. Hence it was thought prudent to use these gases for cooking thus making the lantern as a dual-purpose unit.

Consequently an efficient cooking device was developed based on heat pipe principle so as to use the heat of flue gases for cooking a meal for a family of four. This is a slow cooker where the food is brought to boil via steam cooking and thereafter it cooks in its own heat. These types of cookers called "Janata Cookers" were in vogue in India in early 1950s and 60s and used charcoal as fuel. These cookers were made of mild steel and had brass utensils which made them quite heavy. The present stove was modified to make it lighter by the use of lightweight stainless steel for utensils and jacket. It also had an insulated outer jacket to reduce the heat losses **(Fig. 2)**. This cooker was mounted on top of the lantern. **Figure 3** shows how both cooking and lighting is affected by this lantern and Table 2 gives the results of cooking.

Fig 2. Modified Janata Cooker

Fig 3. Cooking on lantern

Table 2. Specifications of Lantern Stove (lanstove)

Sr. No.	**Item**	**Specifications**
1.	Amount of food	: 2.4 kg
2.	Time to boil	: 40 min
3.	Time for food to cook	: ~ 1.5 hrs
4.	Fuel used	: 0.252 kg/hr (58% ethanol water)
5.	Power consumption	: 1089 W
6.	Efficiency of stove	: 27%
7.	Light output	: 1200-1325 lumens (lm)
8.	Light efficiency	: 1-1.2 lm/W
9.	Sound Output	: 53-54 dB

Field testing of this lantern revealed that users had to pump the lantern frequently and this was cumbersome and inconvenient especially when food was being cooked. Also filling the lantern every day with 55-60% low grade ethanol mixture could lend itself to the possibility of misuse and diversion of the alcohol for drinking purposes.

Thus a **new strategy** was employed where the low grade ethanol was filled in a cylinder, pressurized to 5-6 kg/cm^2 and delivered to the user who could attach it to the lantern and use it just like the existing LPG cooking systems. Thus the lantern could be lighted at a flick of a valve and could be run continuously (You tube video) without the user having to worry about pumping. Besides the convenience of lighting, this strategy also ensures that alcohol cannot be used for drinking since the user cannot access it from the system without damaging the cylinder.

Field testing of lanstove is underway and the initial results are very favorable. Figure below shows lanstove with cylinder being used in a rural household where the child can easily read while the food is being cooked. A small video clip shows its use in various rural households.

General comments of users have been:

- Light output is very bright and steady. It can replace all current light sources.
- Light output allows family to carry out more activities during the morning and evening.
- Light output can be used to study or read.
- Stove/lantern is easy to setup and light with no worry of pumping it periodically.
- No smell, smoke or fumes and hence no indoor pollution.
- Less noisy than a kerosene stove and hardly any safety and smell concerns
- Quality of food made with cooker is good. After cooking food I can also heat and boil water.
- Cooking with cooker is easy. I can do other work while food is being cooked since I do not have to watch it.
- Cannot use the stove for making chapattis or bread.
- Can also use my existing pressure cooker.

- Time for boiling indication is missing.
- Like the fact that it is possible to both cook and eat inside the house since light is available.
- Would buy the stove/lantern and will be willing to pay Rs2000 or more for it.
- Monthly costs should be equal to existing LPG or kerosene usage.

The comments from the field test showed that this stove could not make bread (*chapattis*) and hence it was thought prudent to attach NARI's low grade ethanol stove with lanstove so as to make a system which can be used for all cooking and lighting needs. However for those areas where only rice is consumed lanstove can take care of all the cooking needs. Figure on the right shows one such arrangement.

Nevertheless, a recent modification to the lanstove has resulted in making *chapattis* on it quite nicely. This removes the need to have a stove attachment and thus will help save on fuel consumption.

Other 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 compact fluorescent lamps) will consume about 2.6 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 ~ 28% and hence tremendous energy savings can result via the use of decentralised liquid fuel for cooking and lighting. Thus the use of lanstove for rural applications is a step forward towards sustainable solutions for these areas.

Besides the high efficiency, lanstove also provides an excellent opportunity to rid the rural households of pollution caused by using inefficient kerosene lanterns and biomass based wood stoves. According to a World Health Organization study this pollution causes about 1.2 million deaths per year worldwide.

Lanstove can also provide **clean drinking water** for the household since the food is cooked in 1.5 hours and for the rest of the time, when the light is needed, the heat from the stove can be used to boil the water. It boils 5 litres of water in about one hour with boiling efficiency of 36%. Thus for a family of 4 or 5 it can easily boil about 10 litres of drinking water everyday. This single device therefore has the potential of providing light, cooking energy and clean drinking water for rural households.

Presently distillation of alcohol and its end use are governed by very draconian state and central excise laws and hence its use for rural households is prohibited. The main reason

given is that it can be used for drinking purposes. Though many chemical additives are available which can make it completely non-potable, still the archaic excise laws have existed. The present innovation of its supply to lanstove users in pressurised sealed cylinders should allay these fears. In very near future a 100 lanstove pilot project in rural Maharashtra is being planned and should show the benefits of this strategy and technology.

One of the ways to spread this technology in rural areas is to set up a village level low grade ethanol delivery system. This could consist of a 1000-5000 l/day micro distillery which produces the ethanol and supplies it to the consumers in pressurized 25-30 liter cylinders. The fuel supply chain will be just like that for the existing LPG cylinders except the fuel will be produced and used locally. The consumer would need to buy only the lanstove and pay for the fuel in the cylinder. A 25-30 liter cylinder can last for a month for a family of four and will supply fuel for both cooking and lighting needs.

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Recently a short history of work done at NARI on renewable energy for rural households has been written. It is available at this site.

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