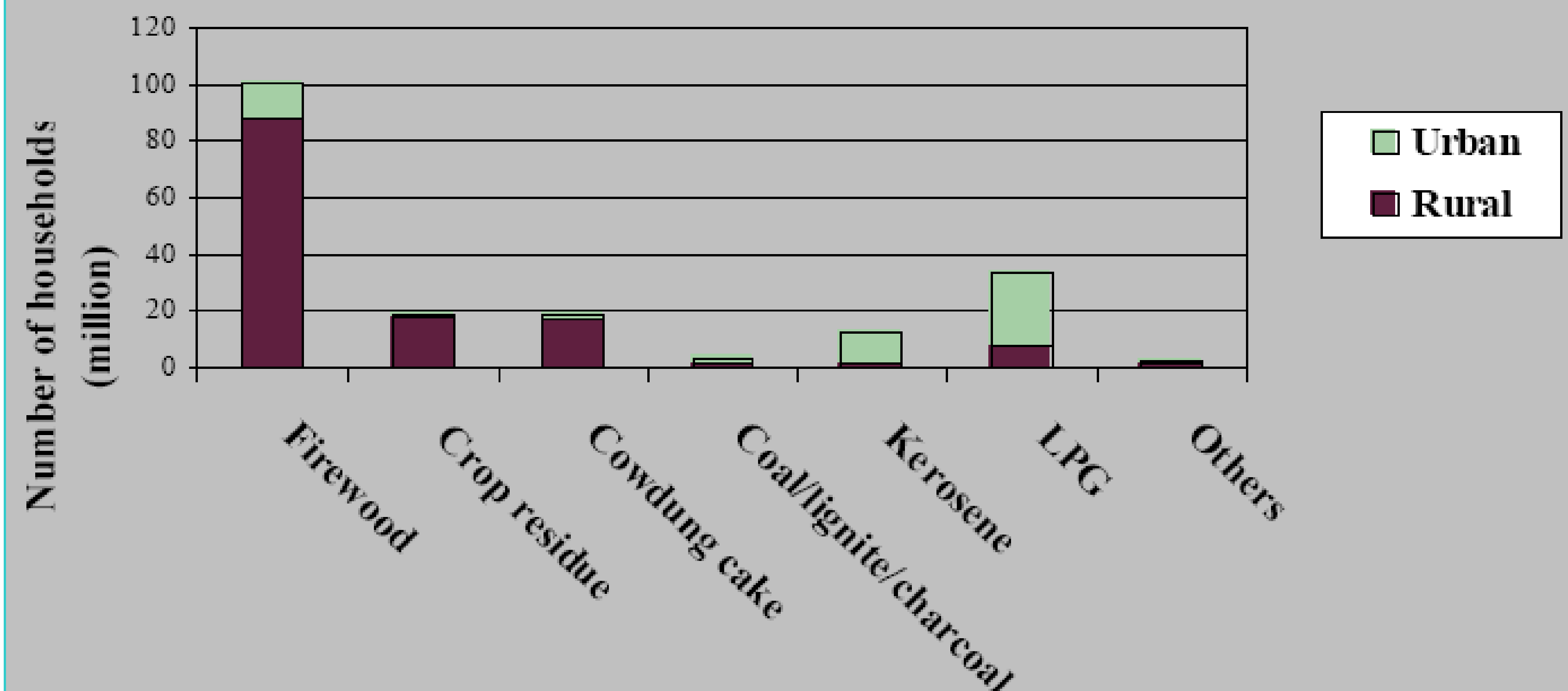
Modern cooking energy – progress@ 2009

1. Cooking fuels
2. What solid bio-fuels and why?
3. Cooking heat
3. Prepared fuels supply for cooking

H S Mukunda,
ABETS, CGPL, IISc, Bangalore, Feb 2009
http://cgpl.iisc.ernet.in

Indian household use of cooking fuels
(Census 2001)



The spectrum of cooking fuels – note urban sector also uses firewood,
Crop residue fraction in rural cooking ~ 25 %

Fuel usage over rural and urban households and their efficiency (mmt = million metric tonnes)

Fuel	Rural HH million	Urban HH million	Fuel used mmt/year	Tonnes /yr/HH
Fire wood	87	15	250	2.5
Agro-residue	20	2	120	5.5
Cow-dung cake	20	2	35	1.6
Coal	2	2	6	1.5
Kerosene	2	8	5	0.5
LPG	9	25	8	0.24
Others	1	2	-	-
Total	141	57		

Note: While all bio-fuels are used inefficiently compared to LPG/Kerosene

Agro-residue use is most inefficient!

Efficiency comparison through water boiling tests:

LPG stove eff ~ 70 %, kerosene stove ~ 65 %, biomass stoves ~ 5 to 30 %

In practice, stoves may operate for a time with no cooking.
But this is significant with biomass stoves

Fuel-wood Consumption by Sectors
mmt = million metric tonnes

Sector/ End-use	mmt
1. Household	
(a) Forested Rural	93
(b) Non Forested Rural	95
(c) Urban Areas	17
Sub Total	**205**
2. Cottage Industry	**32**
3. Rituals	**6**
4. Restaurants etc.	**12**
Total	**250**

Biomass bought vs. collected for household use

Fuels	Rural, %			Urban, %		
	Bought	Collected	Home Grown	Bought	Collected	Home Grown
Firewood	18	54	28	78	11	11
Dry Dung	13	22	65	59	8	33
Crop-residue	13	52	35	77	23	0

Collection of Fire-wood by rural household:

Time spent per day ~ 1.5 hours (quarter to five hours)

Distance travelled about 2.5 km (max: 6 km)

Collection ~ 4 to 6 kg firewood

Further….

- Cooking in several countries (Indo-Chinese culture and in Africa) depends on wood-charcoal produced at 16 to 20 % of wood.

- The amount of charcoal used by a family for cooking is about the same as wood by other families (*this amounts to the use of six times the biomass for cooking by charcoal!*)
- Urban solid wastes are truly wasted mostly.

It is good to remember that handling solid fuels offers greater challenge because it is technically far more difficult to handle due to size, shape, moisture effects

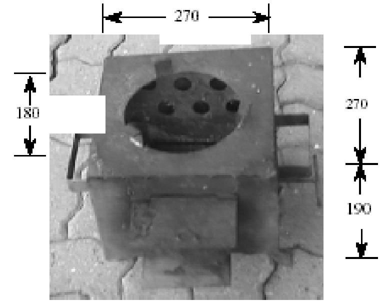
Wood burning stoves - efficiency and emissions

24 wood and charcoal stoves of east Asian origin from Bhattacharya et al (2002)

Thailand, η =14%,
CO 26.4 g/kg fuel

Traditional Rungsit stove

Thailand, 12%
25.2 g/kg fuel

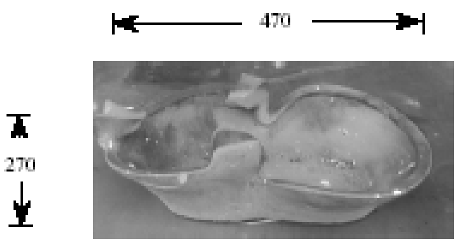


Indian "Harsha" Cookstove

India, 25.2 %
41.2 g/kg fuel

Malaysian traditional

Malaysia, 9.5%
28.7 g/kg fuel



Nepalese one-pot ceramic

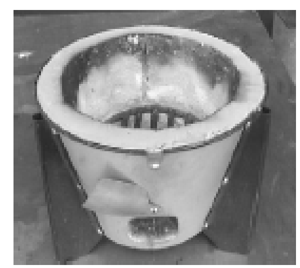
Note: All dimensions are in mm

Fig. 12. Nepalese one-pot clay stove.

Nepal, 10.5 %
CO 136 g/kg fuel

Lao traditional stove

Lao, 14.3%
27.3 g/kg fuel



Phil. traditional

Philippines, 12%
28.6 g/kg fuel

Vietnamese traditional

Vietnam, 15%
38.6 g/kg fuel

Impact of Emissions

- Smith (1996) has discussed the impact of emissions on global warming using Global Warming Potentials (GWP) of different gases.
- Different gases have different interactions with other gases, life times and heat trapping abilities summarized by Hayes and Smith (1993)

The result:

- 20 to 45 g of CO per 500 g carbon in a kg of wood is emitted.
- CO thus emitted has a GWP equivalent to 90 to 200 g CO_2 over 20 year time horizon.
- He has therefore argued that *an efficiently burning fossil fuel stove* has *lesser GWP* than *a poorly burning bio-fuel stove!*

Hence, in the current era (after climate change report is considered inescapable)

Motivation is higher to understand and design efficient bio-fuel stoves – both in terms of combustion and heat transfer.

The Size and nature of the cooking problem

- Apart from global warming, the cooking is done with "such" devices in "such" kitchens that there are an estimated million deaths due to poor indoor air pollution issues

Therefore, a question is posed:

- Can we not make cooking from solid bio-fuels as close to that with LPG? – because LPG occupies the highest position in the development ladder (in the minds of all), even if aspects, namely, instant ignition and fast control cannot be achieved

Biomass Cooking devices

- Biomass stoves are widely explored. There is even a website on this subject. Informative and interesting.

- Stove designs are enthusiasts' field area.
  Very little relevant science is used in designs.
  Simple specifications like power level, and burn time are not presented always. Vessel size and shape are outside the scope of consideration.

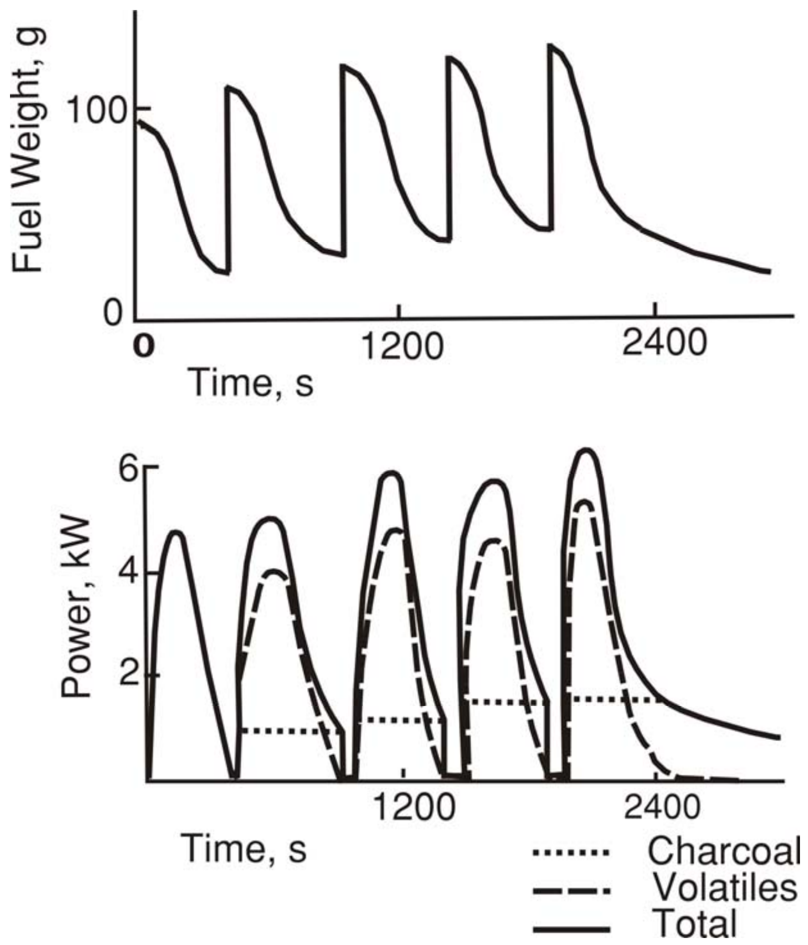
- Even the scientists involved seem to get immersed in the variety with little attention to science of the designs

- We will see what happens in a conventional stove where you feed fuel periodically and see what scientific understanding and current technology can do……..

Behavior of conventional stove

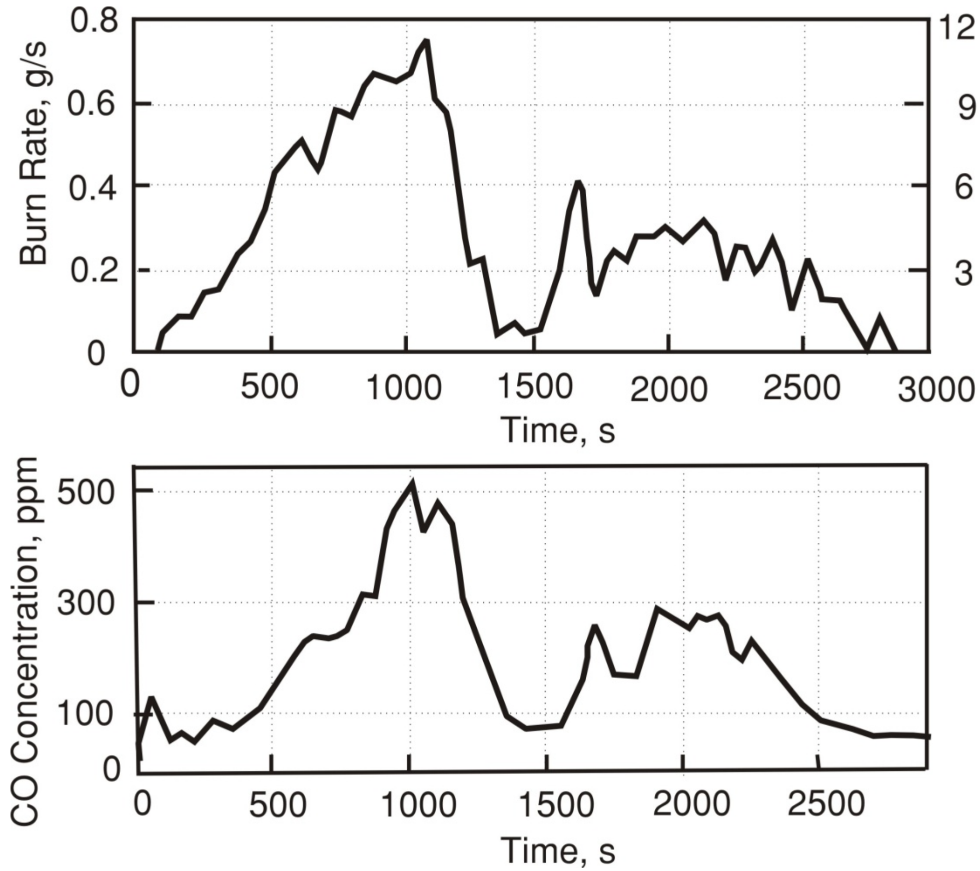
Conventional wood stoves requiring periodic supply of fuel are characterized by volatile generation with large peaks: leading to large fluctuations in a/f - sooting & smoking.

CO & other products of incomplete combustion (PIC) also get emitted.



Emission patterns

There is a clear link between higher CO emissions with intermittent fuel feeding



Ballard-Trameer et al.1999

Operation of a typical one pot metal stove with periodic fuel supply

Science of stoves with an eye on high performance

- In 1985 – 87, research was conducted at Indian Institute of Science on stoves
- In view of higher efficiencies of LPG and Kerosene stoves (70 and 65 %), a fundamental question was posed.
- What is it that limits the utilization efficiency in wood stoves?
- Experimental, modeling and computational studies showed that better efficiency could be obtained with:
  Higher peak temperature in the flame and *larger vessel* with a *flat bottom*

  ⟶ *Operation of the stove near stoichiometric conditions*

Science of stoves with an eye on high performance

- Solid bio-fuels for stoves are non-standard. This is often extolled as a virtue – they are considered affordable as they are picked by the poor by travelling distances – the general principle being "finders – keepers"
- All other fuels are processed to specs, sold commercially and they perform to specs.
- Would it be scientifically appropriate to expect a wood stove to accept wood fuel what ever size, shape and moisture fraction and perform with high eff. and low emissions?
- The answer is a clear NO. Unfortunately, All the stove programs of the world (other than the one addressed at IISc recently) disregard the issues.
- Hence – No stove commercialization effort will work ***unless the fuel is standardized and supplied commercially (perhaps with a subsidy to the "poor")***

Also…

1. Let us recollect that the worst amongst bio-fuels is the use of agro-residues for cooking with a use of 5.5 t/hh/yr compared to 2.5 t/hh/yr for firewood.
2. This translates to 15 kg/hh/day of agro-residues compared to 7 kg/family/day of firewood
3. While eff. improvements for wood stoves should continue (and in fact the only item on the agenda for most researchers and Govts), something serious was needed to be done on the use of agro-residues

Hence efforts at IISc were concentrated on the use of agro-residues and a new design around gasification principles.

Cooking fuels used in India and their characteristics (H =calorific value at 10 % moisture)

Fuel	Density t/m^3	Shape	Size mm	Ash %	H MJ/kg
Fire wood	0.3 – 0,.7	Regular	10-100	~ 1	15
Agro-residue	0.05 - 0.1	Fine, odd	1 - 10	1 - 20	15 - 13
Cow-dung cake	~ 0.15	Regular	100	~ 10	~ 12
Coal	~ 1.2	Pieces	5 to 50	30 - 45	18 - 16
Kerosene	0.78	-	-	-	42
LPG	0.5	-	-	-	48

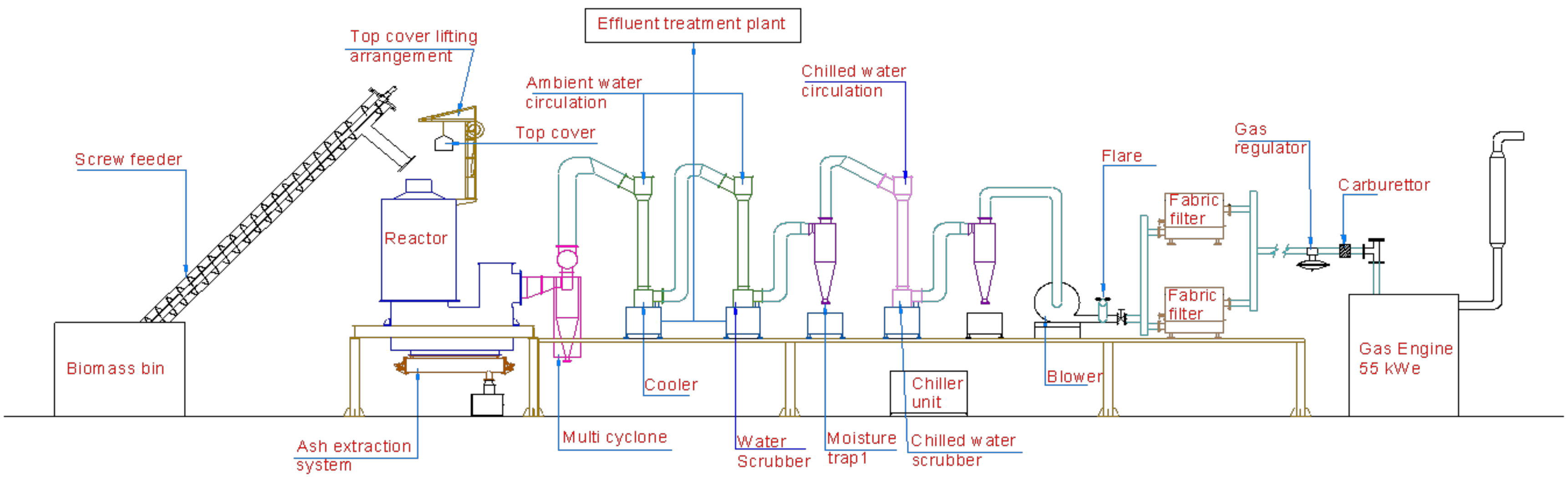
The use of agro-residues implies the material must be dried, pulverized and pelleted to the required density, shape, and size before use. The mix of agro-residues is chosen to get the right ash content and ease of pelletizing.

Gasification principles

gasifier for electricity generation

reactor –cleaning-cooling system

Hundreds of systems built – the technology is commercial



1KgPH DINJAM PLANT

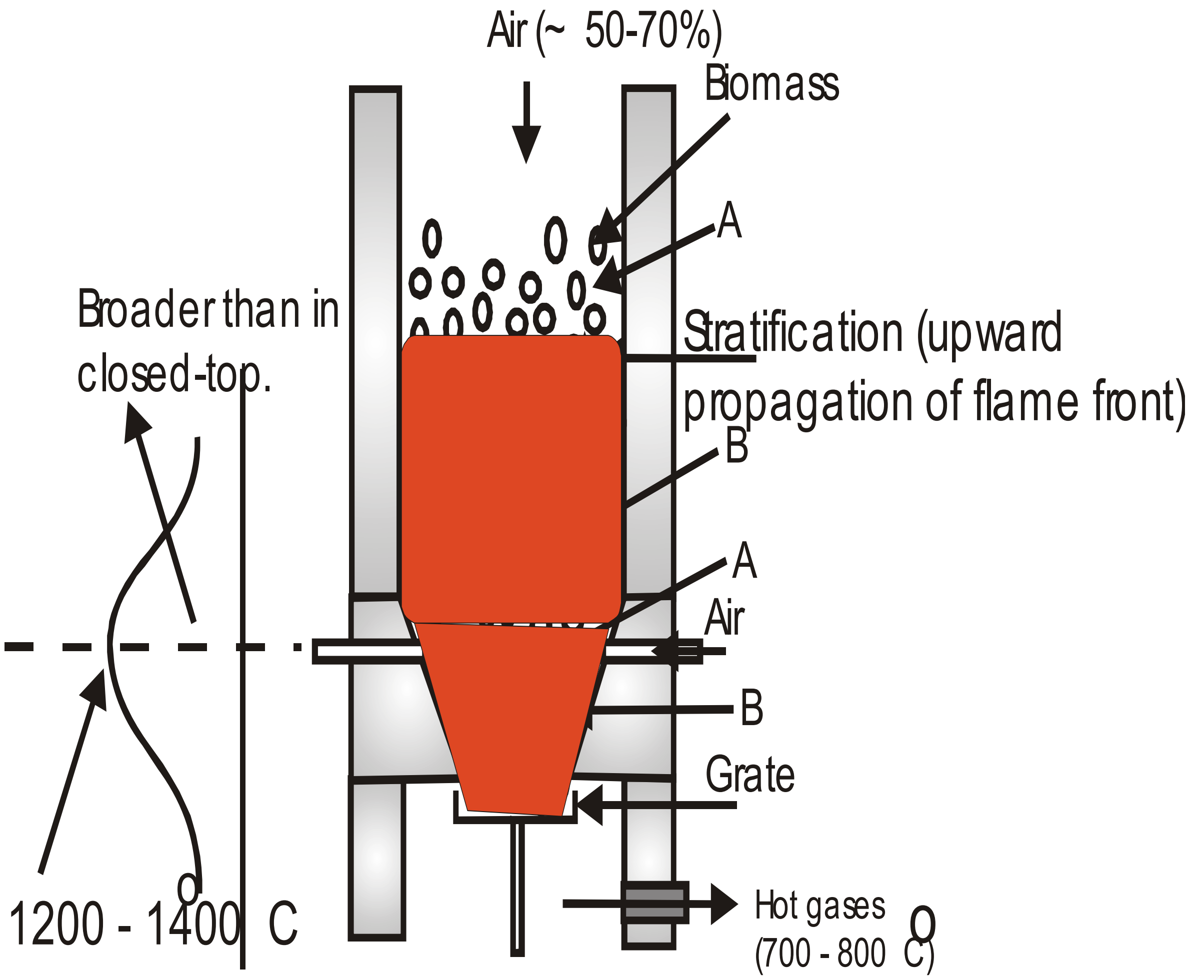
1 kg/h system
Cost ~ 150000 Rs/kWe

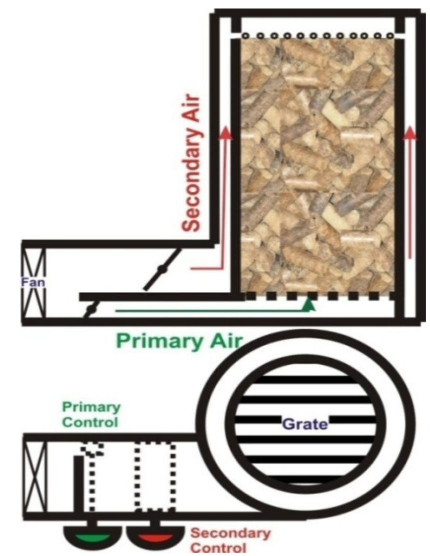
1 MWe system; prosopis juliflora as fuel
Investment ~ 55 million Rs/Mwe
Fuel cost : 1.5 to 2 Rs/kWh,
O & M ~ 1.0 Rs/kWh
Financial cost ~ 0.5 Rs/kWh

Cost of energy ~ 3.00 to 3.50 Rs/kWh

BMC GASIFIER PLANT(1700Kgph)

Inverting gasifiers to get stoves!

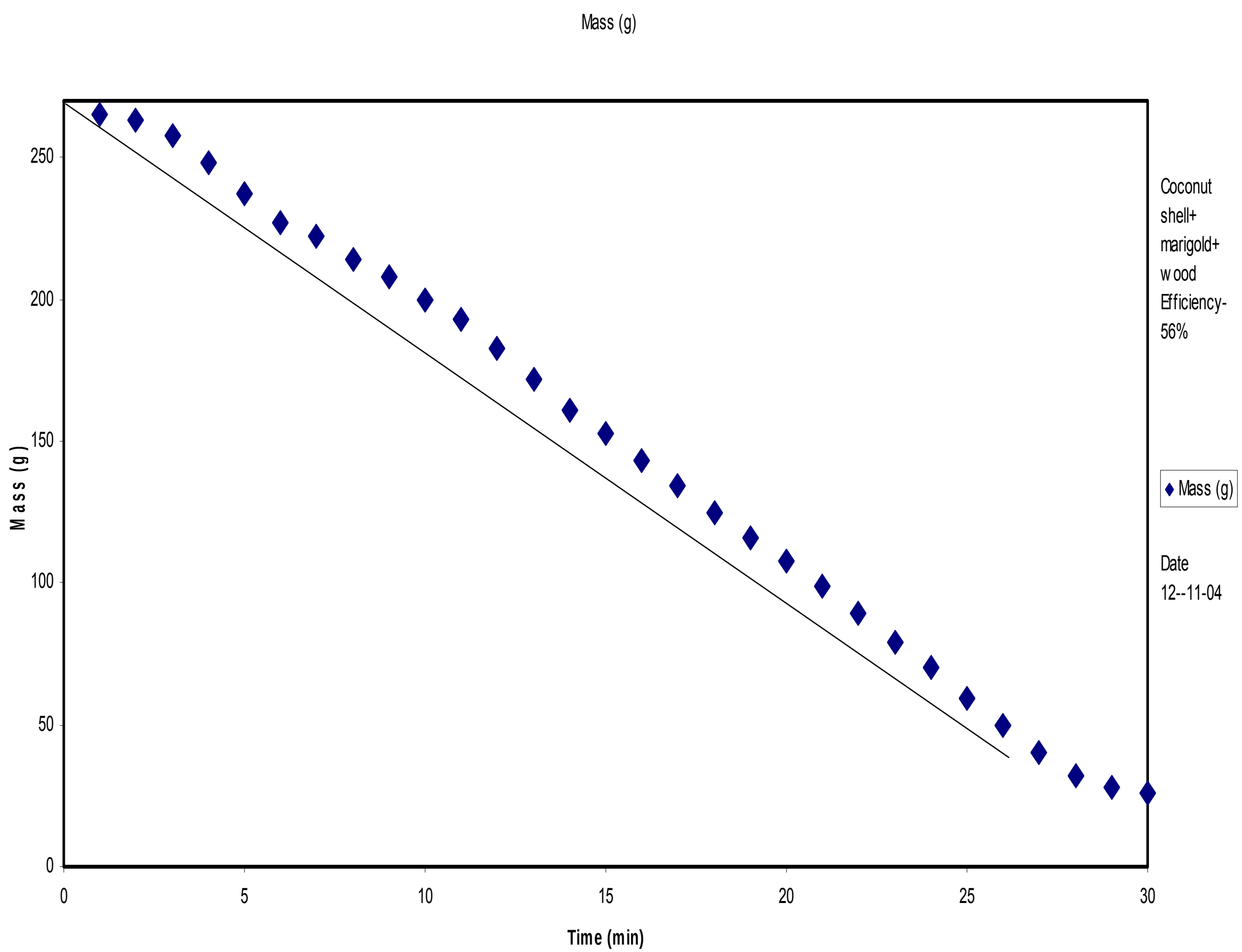




Close the side air nozzles; invert the gasifier

Power variation in a gasifier stove.

(mass loss varies linearly – power is nearly constant)



Why this constant power?

1. In combustion, when the fuel pile is burnt from bottom to top, the process is exothermic. Even at fixed air flow rate, more fuel means more gas having more of PIC (products of incomplete combustion)
2. When the same fuel pile is burnt top-to-bottom with a fixed amount of air, the presence of excess charcoal causes endothermic reactions and stabilizes the power. This process is a gasification process.
3. Consequently, the power is self-regulating at a fixed air flow rate in a gasification process.
4. These combustible gases at constant flow rate are burnt by providing combustion air (secondary air).

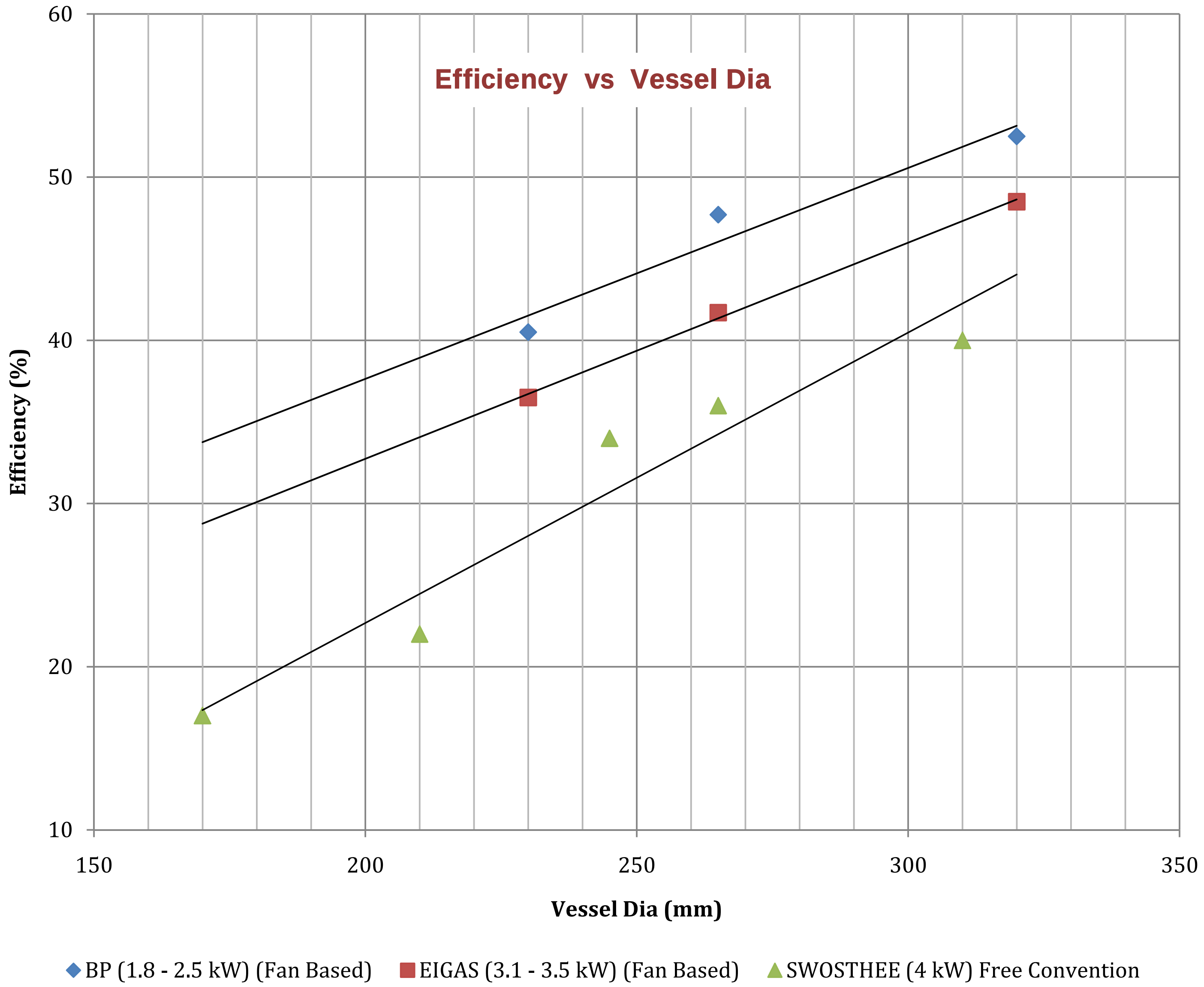
Science of stoves with an eye on high performance

- Stoves were built and tested with prepared pellets from agro-residues all to a size of 10-11 mm dia, 15 mm long, ash content ~ 6 – 10 % and moisture content of 5 to 7 %. The average density of these pellets is 700 to 800 kg/m^3 .
- The higher density allows packing the required amount of fuel in a given space.
- These stoves use a ceramic walled combustion chamber and use fans obtained largely for computer industry (so, inexpensive)
- Water boiling efficiencies of 40 to 55 % for vessels of practical range (200 – 320 mm). Cooking for a family gets completed with 600 g in 60 to 70 mins – 1.2 kg/day.


சூடானது! தொடவேண்டாம்!
ಬಿಸಿ! ಮುಟ್ಟಬೇಡಿ!
गरम! हाथ ना लगायें!
oorja


oorja

This stove works by gasification principle – air from the bottom controls the amount of hot combustible gases generated and hence power and air provided at the top burns up the hot gaseous fuel. Clean combustion at right A/F helps attainment of high peak temperature and reduction of incomplete products of combustion.



Water boiling efficiencies in flat Al vessels with 230, 265, and 320 mm diameter carrying 2.5, 6 and 10 liters of water.

How much fuel for cooking?

Food item	Firewood g/kg cooked food	Kerosene g/kg cooked food
Rice 1kg + water 2.7 kg	70	15
Dal 0.25 kg + vegetable 0.3 kg + water 1.65 kg	150	50
Ragi 0.5 kg + water 1kg	80	20
Chapati flour 0.5 kg + water 0.25 kg	250	60

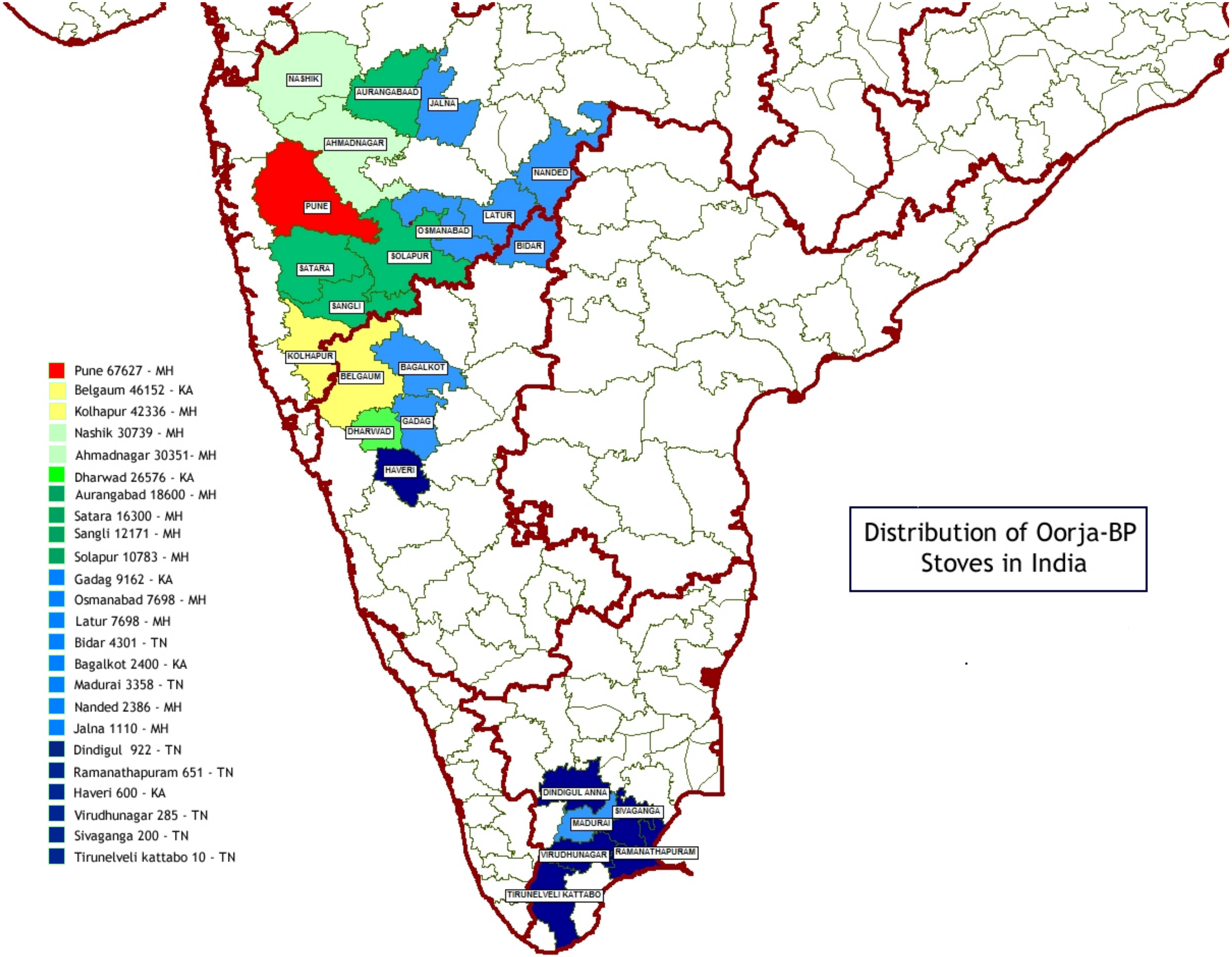
50 gm firewood energy is adequate to cook 400 gm food
(50 gm chapatti + 150 gm rice + 150 gm sambar + 50 gm curd)

50 gm firewood for 350 gm stove based food.

600 gm of fuel will give 4 to 4.8 kg food depending on the usage style

Science of stoves with an eye on high performance

- Tech transferred to **BP (India)** who have commercialized it.
- Over 400,000 stoves have been sold to rural households in over 2500 villages in 4 states of India (2000 stoves every day, now).
- The expectation is that a million will be sold before 2009 – a clear landmark when it happens, I think.
- Over 500 tonnes of prepared pellets of the above specs are supplied every week.
- These pellets are made from a mix of residues – bagasse, peanut shells, tamarind shells, de-oiled rice bran, etc
- There are still certain basic aspects of fuel pellet preparation in terms of throughput that need to be resolved. These are being currently addressed.



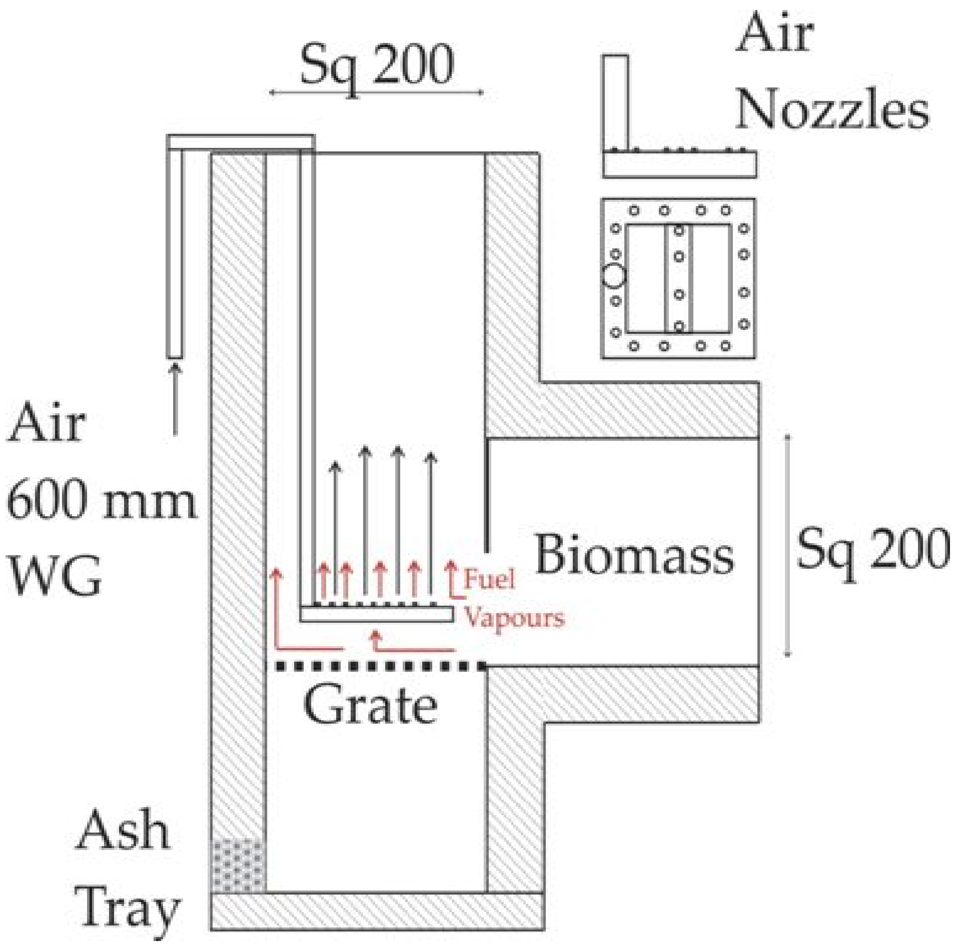
Distribution of Oorja-BP Stoves in India

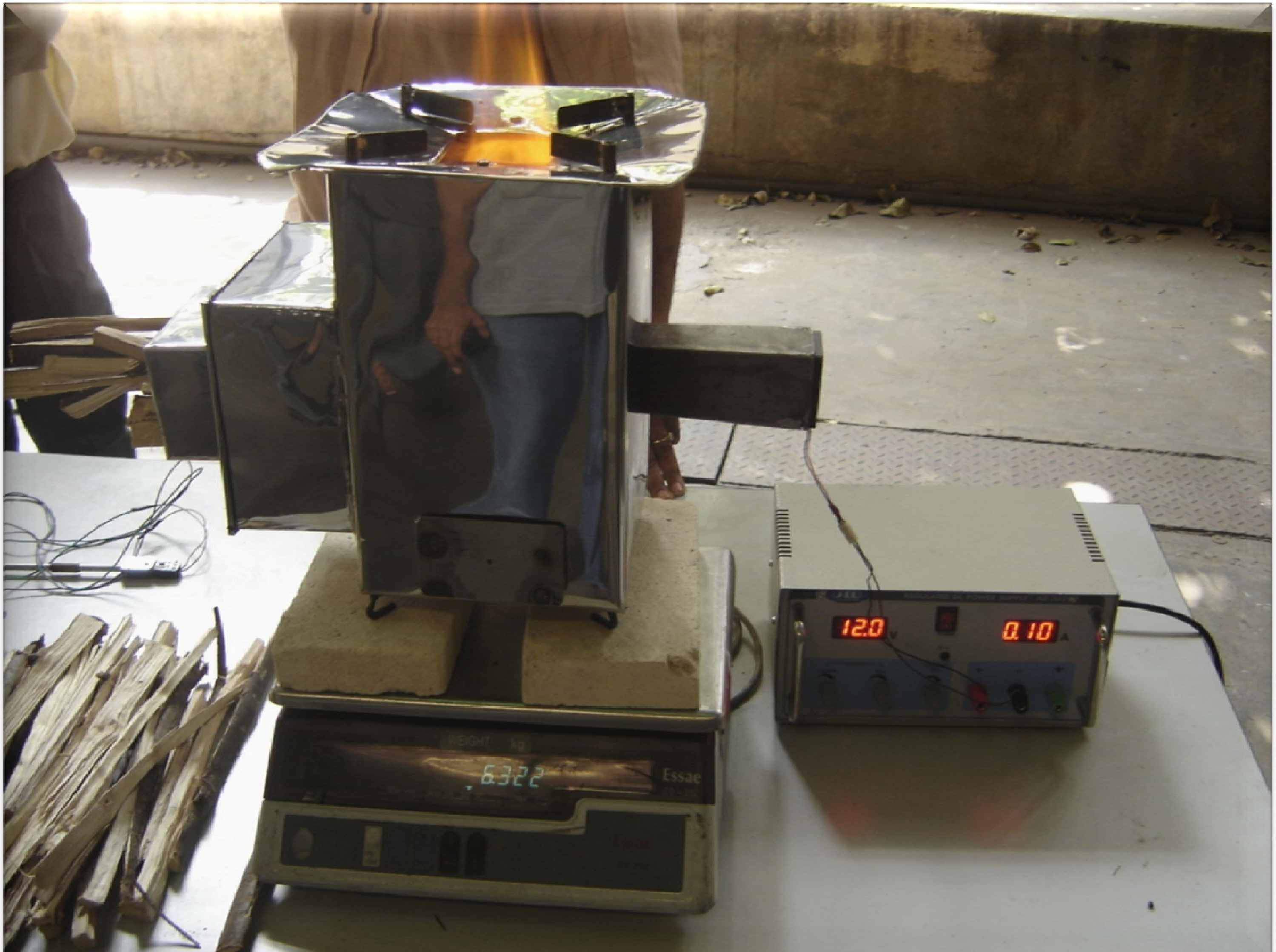
Stove and fuel economics

- Two versions called Oorja 1.3 and Oorja 2 are currently in the market.
- Oorja 1.3 has the same elements as Ooja 1 but with a ceramic combustion chamber.
- Oorja 2 has facilities for ash removal more user friendly and can take more fuel
- They are sold at Rs. 1090 and 1150.
- The fuel was being sold at Rs. 5 per kg. The selling price has gone up to Rs. 6 per kg.
- Questions about the high fuel prices are being debated.

New stove designs for firewood using the ideas of gasification and subsequent combustion of the gases.

Ejector Stove with a horizontal gasifier(!)

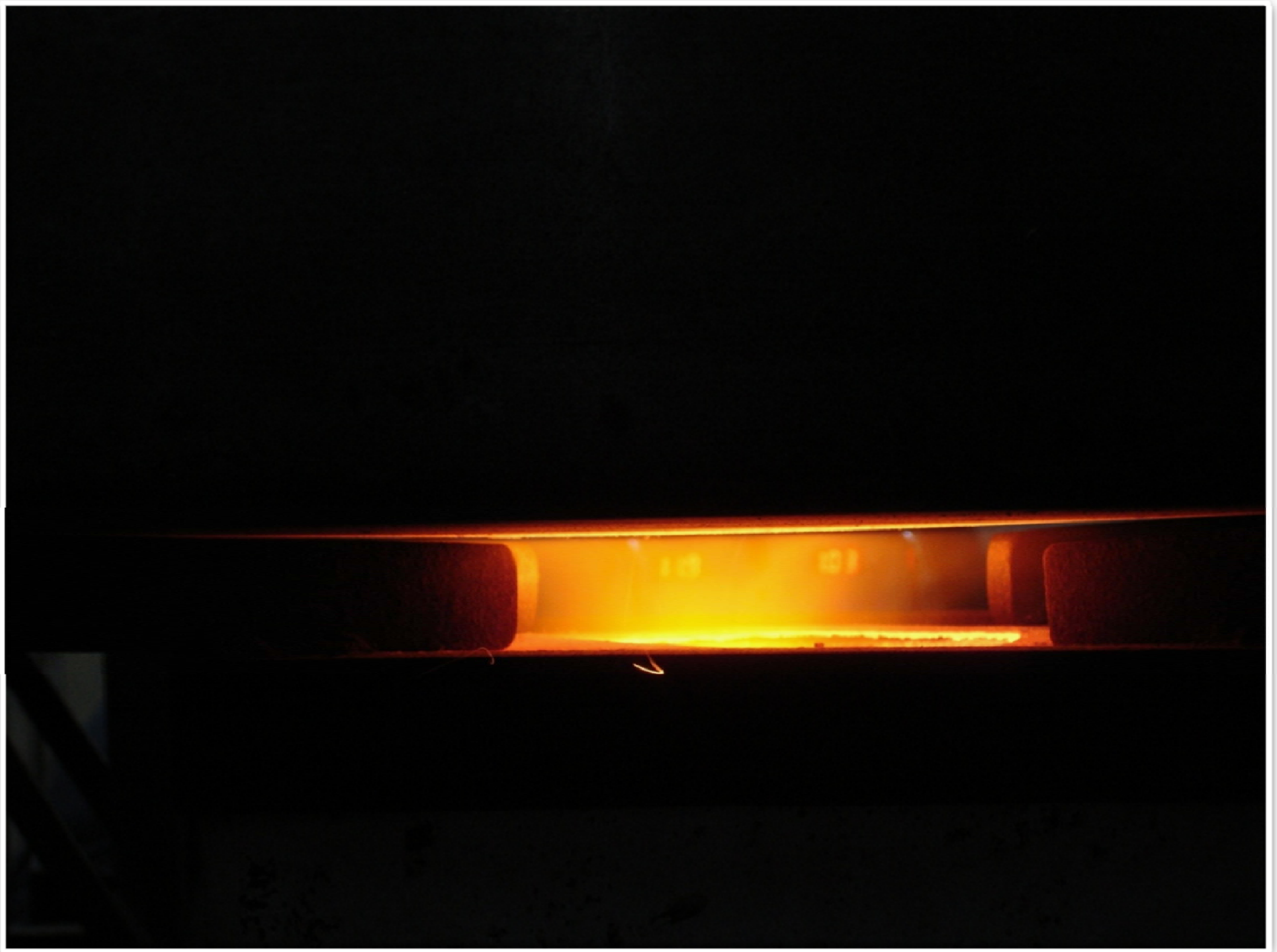




Design of a low emission fire wood continuous stove with new ideas – Ejector induced air flow and horizontal gasifier (EIGAS stove).
The power drawn is 1.2 W for 4.5 kW thermal output.   Eff. ~ 40 to 50 %

Comparison of stoves for bringing to boil 5 liters of water

Stove	Fuel g	CO g	PM g	CO g/MJ	PM g/MJ
Three stone Fire	**1118**	56	2363	3.13	42.27
Ghana Wood	**996**	50	4287	3.14	68.32
20L Can Rocket	**733**	15	1289	1.28	15.12
Wood Flame Fan	**626**	**9**	48	**0.90**	**0.48**
Wood Gas Fan	**459**	**7**	**27**	**0.95**	**0.20**
Mali Charcoal	**674**	113	260	10.48	2.80
Gyapa Charcoal	**694**	135	587	12.16	6.52
Indian VITA Test 1	**1135**	38	1490	2.09	27.06
T-LUD	**933**	25	694	1.67	10.36
Institutional 310 Rocket	**483**	6	414	0.78	3.20
Lutfiyah's Improved Stove	**823**	16	1231	1.22	16.21
T-LUD	**1296**	18	437	0.87	9.06
BP Stove (IISc)	**380**	**4.5**	**6**	**0.75**	**0.06**
EIGAS – 1 (IISc)	**400**	**7.2**	**9.6**	**1.12**	**0.1**



Ejector induced gasifier stove (10 kg/hr, 45 kWth) with a vessel at the top – uses 12 W power with an advanced high speed fan with levitating bearings . Notice the near transparent flame;
used now for making Pattu in Kerala

Summary

1. Despite four decades of effort we are still far away from a commercial supply of affordable biomass stove for domestic cooking.
2. Gasification based stoves provide technical solutions environmentally consistent.
3. Commercialization demands multi-pronged strategies.
4. Things are just beginning to happen.
5. We need to wait and watch the developments in the next five years.

.....Thank you.....