Alternate energy and the country - Bio-energy and others

- Energy sources and comparison
- Biomethanation and thermo-chemical conversion
- Combustion and gasification for heat and electricity
- All-India perspective and alternate energy

H S Mukunda, ABETS, CGPL, IISc, Bangalore, 560 012

(mukunda@cgpl.iisc.ernet.in; http://cgpl.iisc.ernet.in)

Energy sources and comparison

Source	Purpose	Features
Solar thermal Photo Voltaics	heat electricity	Intermittent, PLF ~ 30 %
Wind	electricity	Intermittent, PLF ~ 30 %
Micro-hydel	electricity	PLF ~ 50 to 70 %
Biomass	liquid fuel, food heat, electricity, chemicals and fiber	Stored solar energy available on demand, PLF ~ 95 %

PLF = Plant load factor = hours used per year / 8760 hours

We now move on to solid fuels…

What solid fuels? What features?

Material	Examples	Density, kg/m^3	Ash, %
Coal	-	1200	5 to 40
Agricultural residues	Rice husk Ground nut husk Bagasse Sugarcane tops	100 100 100 50	20 3 2 6
Plantation residues	Wood Coconut shell Coconut frond	400 to 700 1100 300	1 1 5
Urban solid waste	Mix	200 to 300	~10

All have C-H-N-O elements; Moisture is inherent to the extent of 50 %
There are some in-organics, For example, rice husk ash has 95 % Silica;
Others have Al-oxide, Mg-oxide, etc in different proportions

Biomass variety

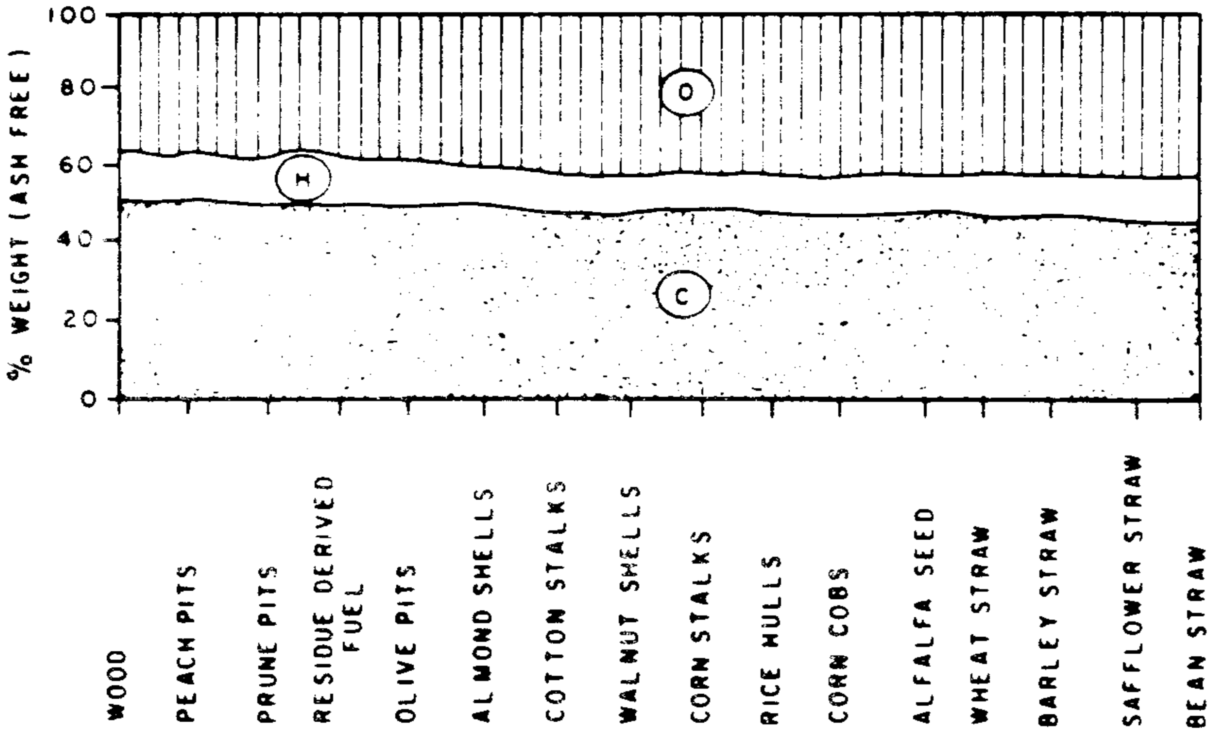
- Sugars (glucose, sucrose, etc)
- Oils
- Starch
- Biomass

  Leafy biomass – Mostly cellulosic + some starch + some lignin

  Woody biomass – 50 % cellulose + 25 % hemi-cellulose + 25 % lignin

- Seeds – Starch and/or oils

Ultimate Analysis of Wood and Coal (32).



Ultimate Analysis of Biomass Fuel Tested at the University of California, Davis.

It is well known that on an ash-free and moisture free basis all biomass have nearly same composition

Biomass composition

- The ultimate composition is *about the same on an ash-free and moisture-free basis*.
- Typically, most biomass has 49 (±4) % C, 6 (±2) % H, 43 (±3) % O and 1 to 20 % inorganic matter (ash).
- Structurally it is made up of cellulose (fibrous), hemi-cellulose (random fibrous and amorphous) and lignin (the matrix that acts as a binder) and proteins and some other chemicals.
- Cellulose is up to 50 % (wt.), hemi-cellulose up to 30 %, lignin up to 25 %, proteins and extractives up to 15 % and ash up to 20 %.

Routes for Biomass Conversion

- Anaerobic digestion – to biogas – natural gas
- Fermentation of sugars to get ethanol
- Thermo-chemical conversion – direct combustion or gasification and combustion in furnaces or engines or gasification and conversion to liquid fuels by FT synthesis.
- Oil extraction from seeds and esterification to get biodiesel.
- Biochemical hydrolysis and subsequent chemical processing to get ethanol
- Biomass → charcoal → DCFC → electricity + CO_2

Conversion strategies

- Sugars + starch → easily digested by bacteria (without or with air)
- Vegetable and leafy wastes → digested by bacteria even though not so completely or easily (time requirement) again, without or with air.
- Woody wastes → difficult to be digested by bacteria; Lignin requires fungi for digestion

Wastes –what do they contain?

For conversion to energy, we exclude those meant for human/animal consumption to avoid conflict

Kitchen wastes – fruits/vegetables/some starchy stuff

Market wastes – similar to the above - Contain large amount of sugars/starch.

Sewage – contains starch/more complex biodegradable matter

Urban solid waste – contains some biodegradable matter and matter that can be converted only by thermo-chemical means (lignin, plastics, etc)

Agricultural and plantation waste – contains a large amount of matter that can be converted by thermo-chemical means

Biomethanation Route

Biomethanation route (under anaerobic operating conditions) has two operating temperatures depending on the bacteria available for conversion

Mesophyllic bacteria operate at 37 °C or less with progressively deteriorate in performance with decrease in temperature and

Thermophyllic bacteria operate between 52 to 55 °C

Operating the reactors calls for pH control since both acidic (pH ~ 3 to 5) and near neutral conditions (pH ~ 6.5 to 7.5) prevail in the two segments of the conversion process – acidification and methanogenic process

Biomethanation route - 2

- Biomethanation route is well known for bovine dung
- China and India have vary large number of plants for domestic and community applications
- The design is simple - a feed system, an extraction system and a reactor with hydraulic residence time of 30 to 40 days at ambient temperature.
- Functions well at tropical conditions with ambient of 20 to 30 ^{0}C; at lower temperatures, performance goes down.
- High rate biomethanation techniques (35 and 55 C operations) can improve the performance. These have not been attempted with bovine dung since the market cannot sustain the capital investment costs.
- In the above cases the solids content is about 10 %.
- For MSW (Municipal solid waste treatment using Biomethanation, there are several processes with some of them working with solids content as large as 20 % (like the DRy ANaerobic COmposting – DRANCO process). Most of these have been developed in Europe.

Biomethanation route - 3

1 kg of solids with 4 to 9 times the water will produce about 50 to 120 gms (30 to 70 liters) of gas.

The composition of the gas is: 50 to 55 % Methane, ~ 1000 to 5000 ppm Hydrogen sulfide and the remaining amount ~ 47 % Carbondioxide

For distillery effluents one uses anaerobic digestion technique to reduce the BOD/COD of the effluent. These plants use generally high rate biomethanation processes. The composition of the gas is 60 to 65 % Methane, 2 to 5 % Hydrogen sulfide and remaining ~ 33 % CO_2.

The gas has a calorific value of 18 to 22 MJ/m^3.

Biomethanation route - 4

The air-to-gas ratio for complete combustion is 9 to 12 (volumetric or mass measure is not very different) depending on the methane fraction in the gas [as a reference, for Methane, the air to fuel ratio is 17 by mass measure and 10 by volume measure].

It can be used to generate electricity via reciprocating engines/gas turbines. The Hydrogen sulfide content has to be brought down to less than 1000 ppm for sure and desirably to a few ppm.

The total installation cost of the Biomethanation plant and power generation system will be around 2 to 2.5 million US $/MWe.

Thermo-chemical conversion technologies

- Use combustion process – on a grate – to provide hot gases to be used to raise high pressure steam and then extract power from steam turbine – generator route (standard).

- The calorific value of dry wood is 16 MJ/kg; rice husk 13 MJ/kg.
- The air-to-biomass ratio at stoichiometry is about 6 note for reference, the calorific value of fossil fuels is about 42 MJ/kg and the stoichiometric air-to-fuel ratio is 15)

- The cost of the power generation system is 0.8 to 1 million USD/MWe. Economical at power levels more than 3 MWe. At lower power levels, the cost goes up to 2 million USD/ MWe.

- The cost of energy is about 0.12 cents (US) per MJ for biomass and 0.75 cents (US) for fossil fuels (in India)

Bio-methanation vs. thermo-chemical conversion

- Bio-methanation has been explored for a long period of time.
- Thermo-chemical conversion of solid fuels is not as well understood. One needs to integrate fluid mechanics and high temperature chemistry – together called aero-thermo-chemistry. Technology needs to integrate materials knowledge .
- For the same throughput, thermo-chemical conversion technology costs less than bio-methanation process unless the feedstock has more than 60 % moisture

Combustion and gasification

- Combustion is aimed at release of heat and raising the temperature by combining the fuel with an oxidant – oxygen or air, usually
- One must use the heat at the location of release of heat.
- Gasification is the conversion of solid fuel into a gaseous fuel through "combustion with air about 30 % of that required for complete combustion"
- It can use air or oxygen/steam mixture.
- The crucial element is to carry this out in a manner that very little undesirable species (tars) are produced.
- The fuel can be transported over a distance and used in furnaces, engines or chemical plants to get hydrocarbons (by a process called Fischer-Tropsch synthesis)

Combustion vs. gasification

- Classical combustion technology with steam power generation is a subset of the multi-stage process with moderate biomass-to-electricity conversion efficiency and either limited interventional capabilities at reasonable cost or expensive interventional capabilities for emissions.
- Gasification technology is multistage combustion process with high conversion efficiency (from biomass –to – electricity) and moderate costs from very low power levels ~ tens of kilowatts to several megawatts in which one derives the benefit of eliminating the undesirables at several stages between the starting point and the end point using the currently available technologies for a variety of intermediate interventions.

In short, it is the equivalent of Clean Coal Technology.

Combustion:

$$CH_{1.4}O_{0.74}N_{0.005} + 0.98\,(O_2 + 79/21\,N_2) \rightarrow CO_2 + 0.7\,H_2O + 3.69\,N_2$$

Gasification:

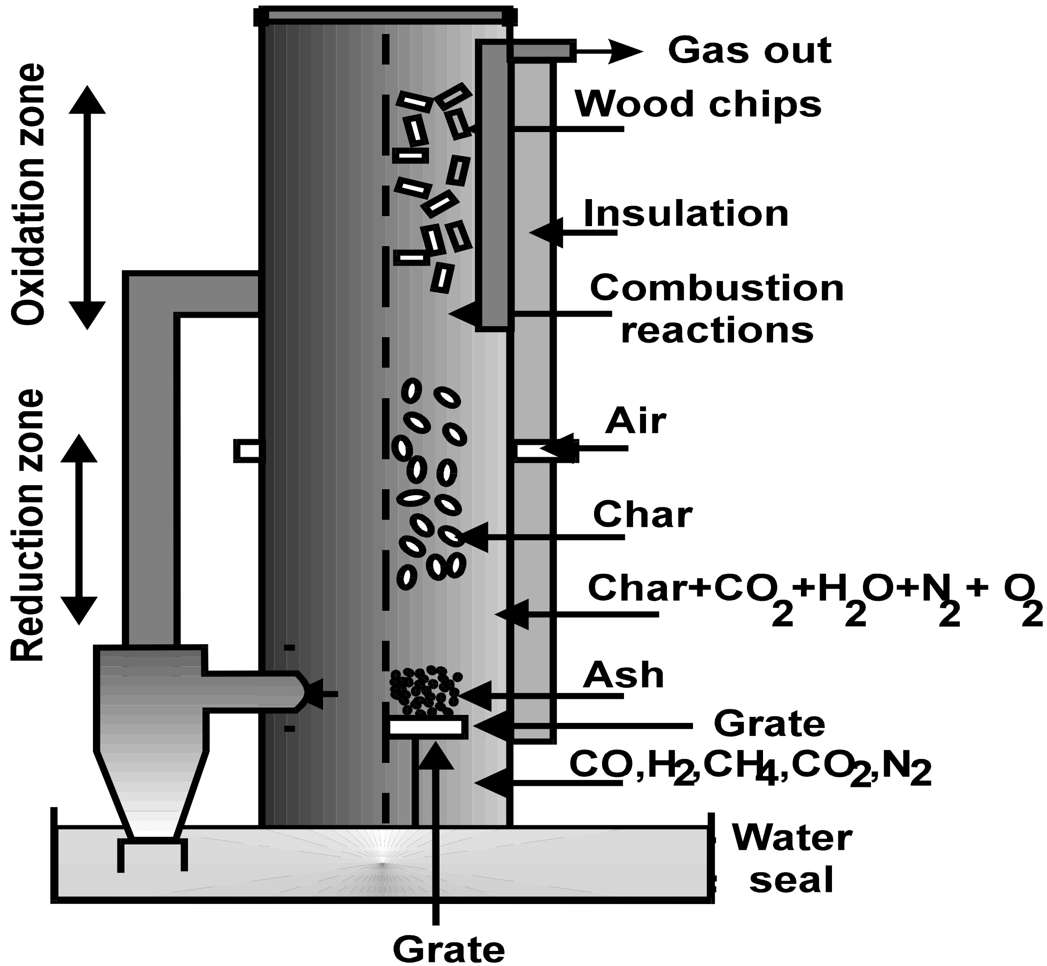
$$CH_{1.4}O_{0.74}N_{0.005} + 0.337\,(O_2 + 79/21\,N_2) \rightarrow 0.57\,CO + 0.485\,H_2 + 0.028\,CH_4 + 0.343\,CO_2 + 0.157\,H_2O + 1.27\,N_2 + 0.028\,C$$

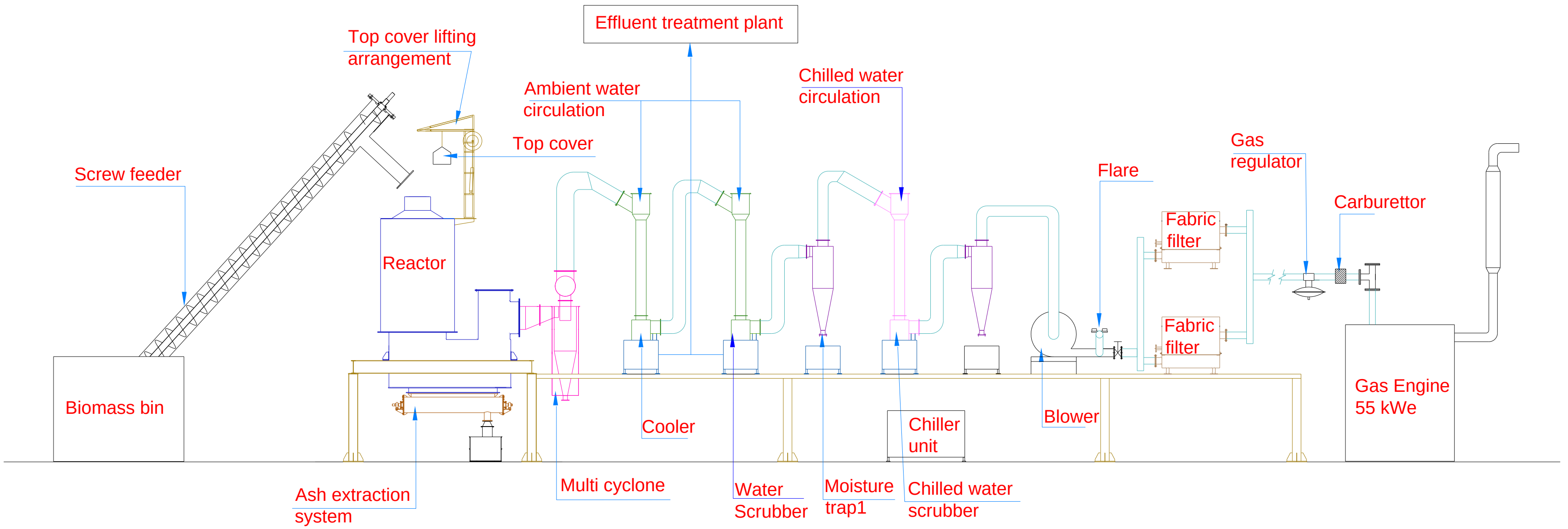
$$\rightarrow 2.857\,(0.2\,CO + 0.17\,H_2 + 0.01\,CH_4 + 0.12\,CO_2 + .055\,H_2O + 0.445\,N_2 + 0.01\,C)$$

$$\rightarrow 0.157\,H_2O + 0.028\,C + 2.7\,(0.211\,CO + 0.18\,H_2 + 0.0105\,CH_4 + 0.1275\,CO_2 + 0.471\,N_2)$$

The products of combustion, CO_2 and H_2O pass through a reduction zone made of hot char bed, to convert CO_2 and H_2O into CO and H_2 and in part, CH_4. The net effect is reduction in air consumed.

The IISc open top reburn design





The Open top reburn fuel-flex IISc gasification system

In the final design that you see, nearly all the WW II design concepts were tried and most of it abandoned in favor of new ones (staged air supply, screw ash extraction, chiller for final dust removal and drying the gas).

Gasification technology

- This gasification process captures 78 to 82 % of the energy in Biomass.
- Every kg of dry biomass generates 2.8 m^3 of gas. The gas has a calorific value of 4.5 to 5 MJ/m^3. The stoichiometric air-to-fuel ratio of the gas is 1.4.
- When used in dual fuel mode in diesel engines, the dry biomass and diesel required are about 0.9 to 1 kg and 60 to 75 ml per kWh.
- When used in producer gas engines, the dry biomass required is about 0.8 to 1.0 kg/kWh. These correspond to biomass-to-electricity conversion efficiencies of 24 to 30 %. Even a small engine of 50 kWe gives about 24 % efficiency. Larger capacity engines can give higher efficiency if the trubo-supercharger is rightly chosen for the application.

Typical Biomass used







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


1KgPH DINJAM PLANT

System cost~
150000 Rs/kWe


BMC GASIFIER PLANT(1700Kgph)

Conversion efficiencies from fuel-to-electricity

(Efficiency values are higher at larger power levels)

Technology	Small systems A few kWe to a MWe	Intermediate capacity 1 – 10 MWe	Large systems >10 MWe
Biogas (Spark ignition engine)	20 to 30 %	36 to 40 %	40 + %
Biomass combustors – steam route	Not economical	25 % (> 3 MWe)	30 to 35 %
Biomass gasifiers – gas engines	20 to 30 %	35 %	Not built yet
Biodiesel (Compression ignition engine)	20 to 30 %	36 to 40 %	40 to 45 %

Typical installation costs of systems

Technology	Small systems, **USD/kWe**	Intermediate size, **USD/kWe**	Large systems **USD/kWe**
Biogas (Spark ignition Engine)	2000 to 2500	1500 to 2000	1000
Biomass combustors – steam route	-	1000 to 1500	800 to 1200
Biomass gasifiers – gas engines	1500 to 2500	1000 to 1500	-
Biodiesel (Compression ignition engine)	400 to 600	500 to 800	400 to 600
Biomass combustor – Stirling engine	3000 to 4000*	-	-
Combustor – steam turbine (new route)	1500 to 2000*	-	-

Liquid Fuels

- Non-edible oil from oil seed bearing trees
- Alcohols from sugarcane and biomass
- Pyrolitic oil through high temperature processing

A large number of trees store in their seeds, starch or oils. Some of these are non-edible. They can be used for power generation.

These are Palm oil (Malaysia), Rape seed oil (Germany), Soybean Anderouba, Soumarouba (Brazil), Jatropha, Jojoba, Pongemia, Cashew, Mohua, Sal, Neem (India and other countries)

Typical oil output from various trees

Crop species	Output oil tonnes /ha
Palm oil	5.0
Coconut	2.2
Brazil nuts	2.0
Jatropha	1.6
Jojoba	1.5
Rapeseed	1.0
Groundnut	0.9
Sunflower	0.8
Pongemia	0.8
Soybean	0.4

Note the wide variation in the productivity of various species. This provides motivation to pursue growing species with higher output.

Liquid fuels - contd

The seeds should be dried, used in an oil expeller to extract the oil, filter the oil, esterifies by adding methyl or ethyl alcohol (depending on what is cheaper and available) – about 5 %; this also reduces the emissions when used in engines.

The oils have a calorific value about 5 to 10 % lower than diesel. They work very well in compression ignition engines. The amount required for producing electricity is 275 to 330 ml/kWh in comparison to 250 to 300 ml/kWh for diesel.

Alcohols are produced from sugar juice through the process of fermentation. They have about 60 % energy compared to fossil fuels and non-sooty in combustion since the oxidizing element – O is in the molecular structure itself – CH_3OH or C_2H_5OH.

Liquid fuels - contd

Alcohol from cellulose is a research and development effort.

Fast pyrolisis – biomass is heated at about 1000 C/s for 0.5 s so that it releases gases which contain a high amount of condensable combustibles leading to the generation of liquid fuel.

- This process requires that the biomass be reduced in size to small particles so that high heating rates can be achieved.
- The liquid fuel that is generated from this technique has 20 to 30 % non-separable water, and acidic components to a degree to require all ducting to be made resistant to acid attack.
- Its calorific value is about 20 MJ/kg. It has difficulties in ignition and when used in reciprocating engines, poses serious problems. It can be used with greater convenience in gas turbine engines (since the combustion process is continuous).
- It is more exciting as a route to further processing to hydrocarbons

Reciprocating engines and gas turbines with liquid fuels, biogas and producer gas – the differences

Reciprocating engines are built in large numbers compared to gas turbine engines. They are built for clean liquid and gaseous fuels – Diesel, gasoline and natural gas. They are built for not-so clean fuels – Light diesel oil (LDO), Low sulphur heavy stock (LSHS) and Furnace oil; in terms of gases, biogas (largely natural gas + carbon dioxide) is a familiar fuel.

Compression ignition (CI) engines that can take diesel oil can also handle non-edible oils with some alcohol or with no alcohol. CI engines dealing with furnace oil can very conveniently accept non-edible oils. In dual-fuel mode, they can take producer gas as well to replace even up to 92 % fossil fuel.

Spark ignition engines can take gasoline with or without blends with alcohols, and alcohols alone.

Reciprocating engines and gas turbines with liquid fuels, biogas and producer gas – the differences

Gas turbine engines demand fuels that are much cleaner compared to reciprocating engines. This is because the turbine blades rotating at high speed tend to erode with impingement of particulate matter and corrode in the presence of sulphur oxides in the hot gas. Gas turbine installation becomes economical only at high power.

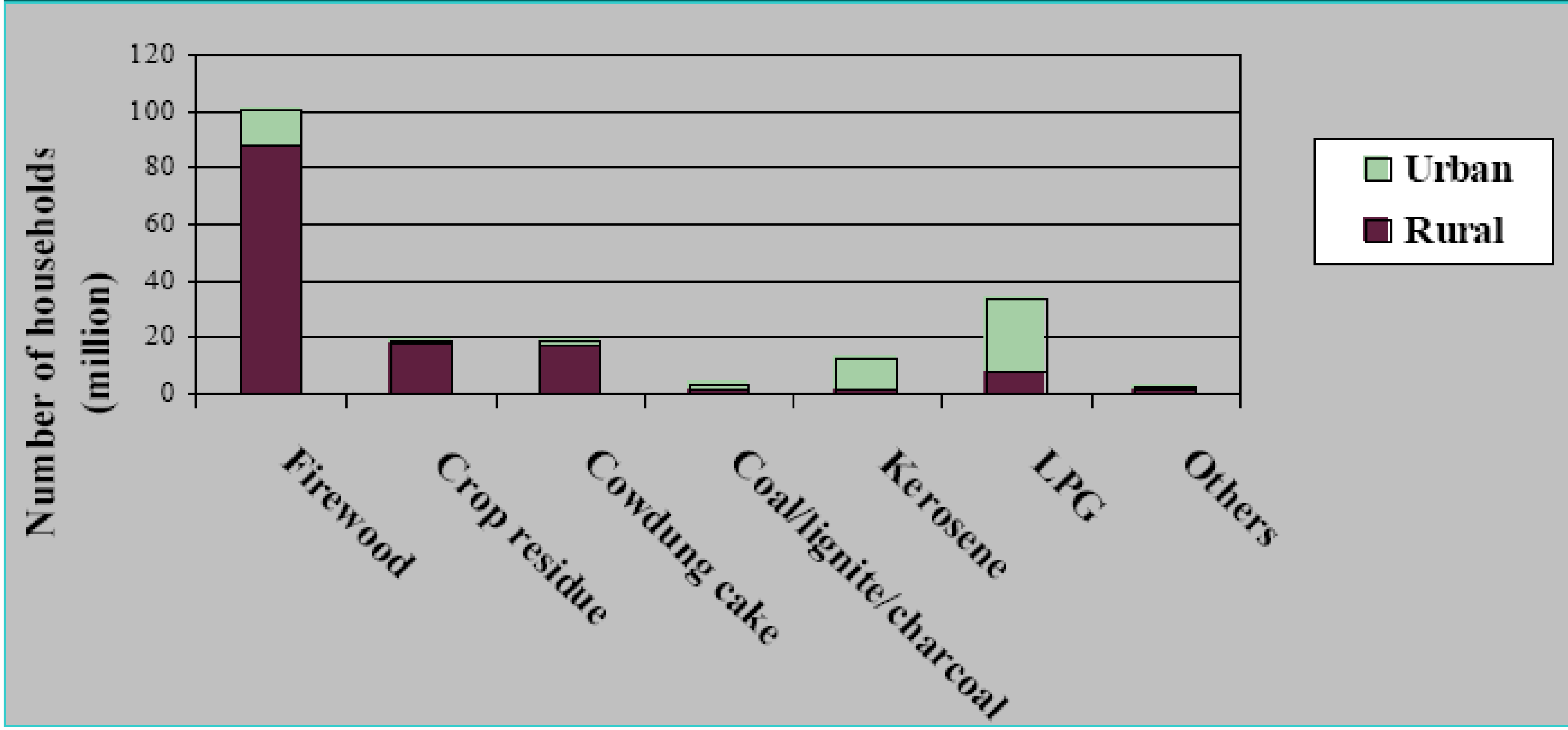
Reciprocating engines are relatively cheaper. Recent trends in the development of high power reciprocating engines (~ 3 MWe class) has shown that one can get very high efficiencies comparable to combined cycle operation (~ 42 %)

These show future trends in the utilization of bio-resources for energy generation.

Meeting domestic heat from biomass

…. What is new? Let us see…

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

The cooking scene across the World

- In India, some 140 million households (average family size = 5.3) depend on firewood, crop residues and dried cow-dung for cooking estimated at nearly 370 million tonnes of firewood (equivalent) per year – equivalent of 0.5 tonnes per person per year or 2.6 tonnes per family per year (difference between these values and international figures needs serious reconciliation)
- 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 possible to generate electricity from solid fuels through gasification

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

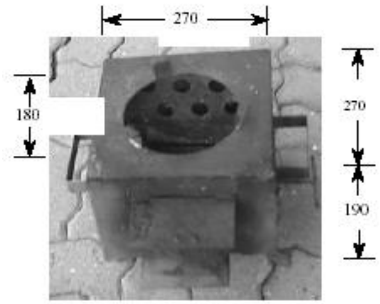
Wood burning stoves - efficiency and emissions

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

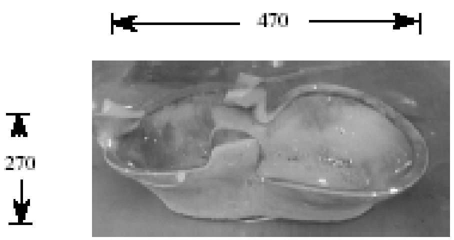


Indian "Harsha" Cookstove

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

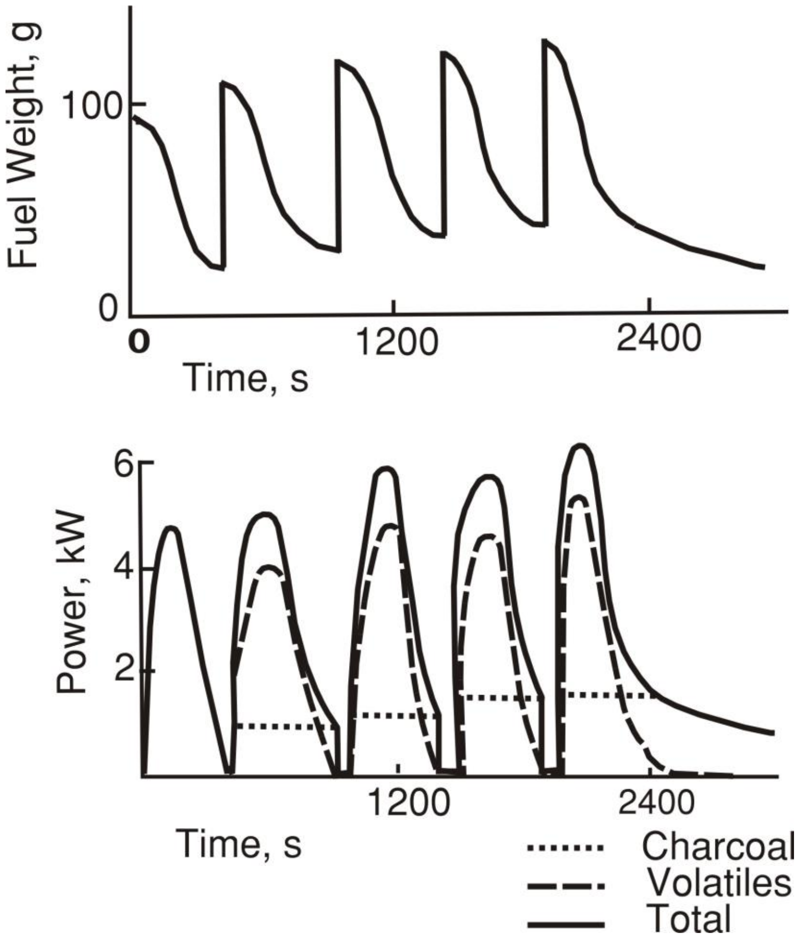
- The cooking is done with “such” devices in “such” kitchens that there are an estimated million deaths due to poor indoor air pollution issues

- 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

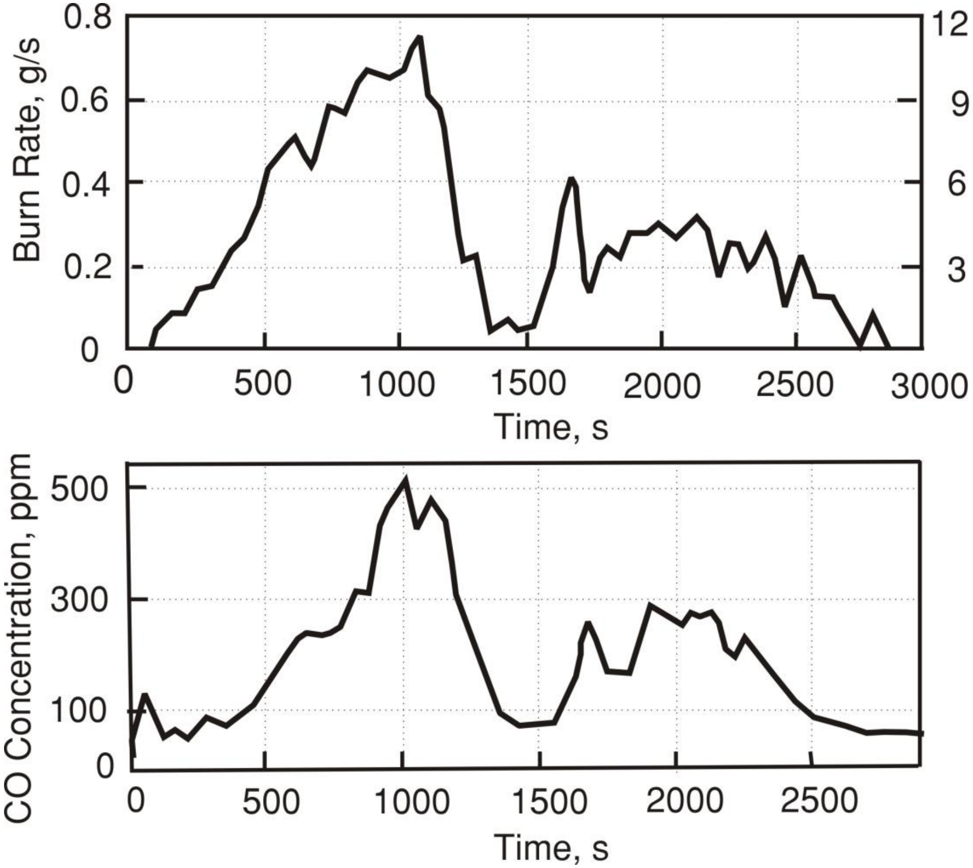
Behavior of conventional stove

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

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
- Kerosene and LPG stoves recorded utilization efficiencies of 65 % and 70 % and wood stoves from elsewhere showed efficiencies of less than 30 % (water boiling tests).
- Question was asked: What is it that limits the utilization efficiency in wood stoves
- Experimental, modeling and computational studies showed that better efficiency could be obtained with:
- <u>Higher peak temperature</u> in the flame and <u>larger vessel</u> with a flat bottom

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

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”)

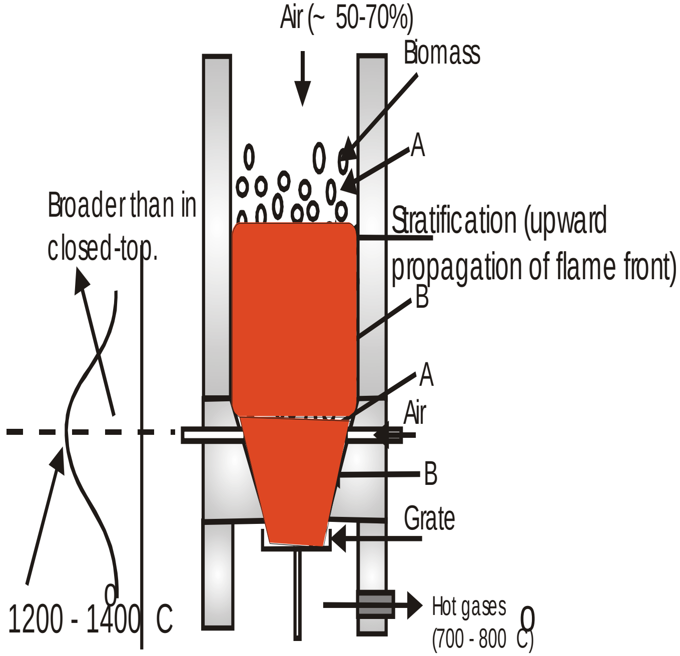
Science of stoves with an eye on high performance

- 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 900 to 1100 kg/m^3 .

- The higher density allows packing the required amount of fuel in a smaller 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.



Principles of operation

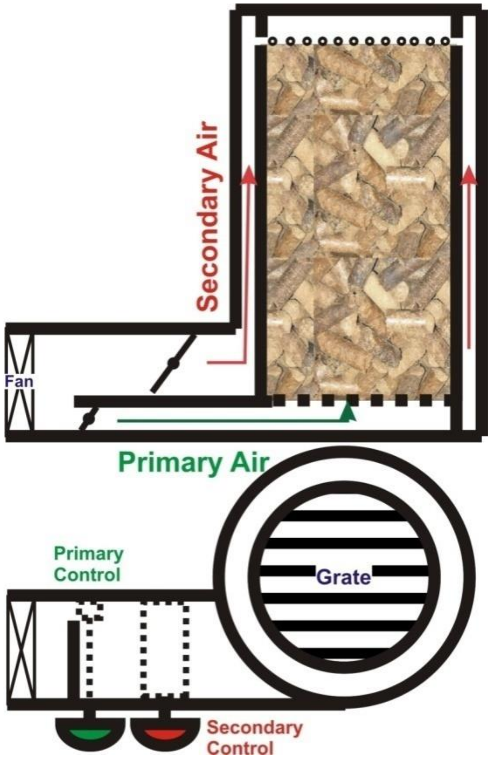
Reverse the classical downdraft gasifier. Push air from the bottom and you get the reverse downdraft gasifier.

Fan provides the air. This fan is about the same as a computer fan

Air from the bottom is called the primary air and

it controls the power (how? The air for gasification is about 1.8 times the mass consumption rate, the number 1.8 related to the biomass composition. The hot char on the top participates in the conversion process).

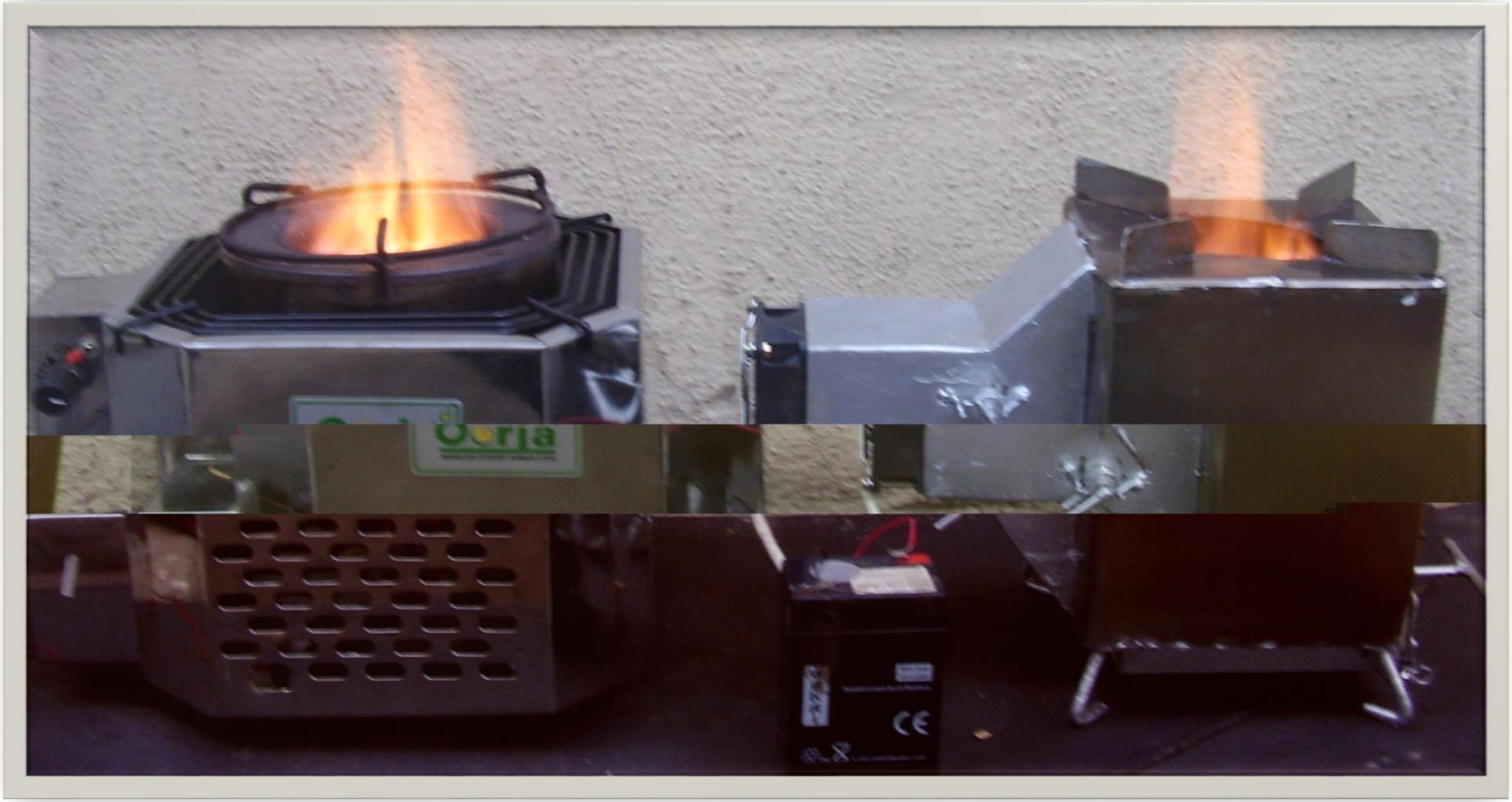
The air at the top is proportioned such that it burns up all the fuel gas. This ensures the air-to-fuel ratio for combustion to be such as the peak temperature close to a maximum.



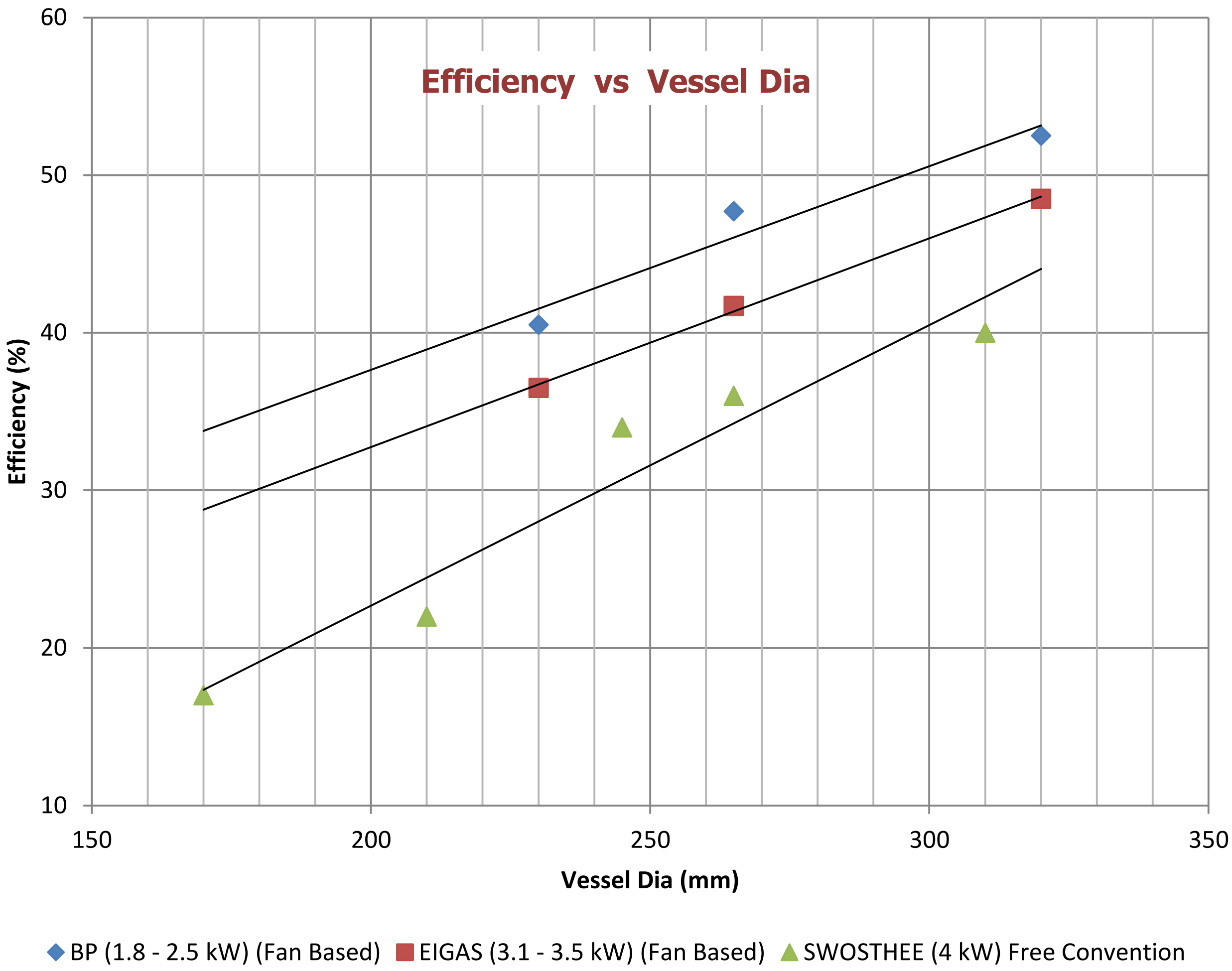
Combustion in a REDS

(Reverse downdraft stove)

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.

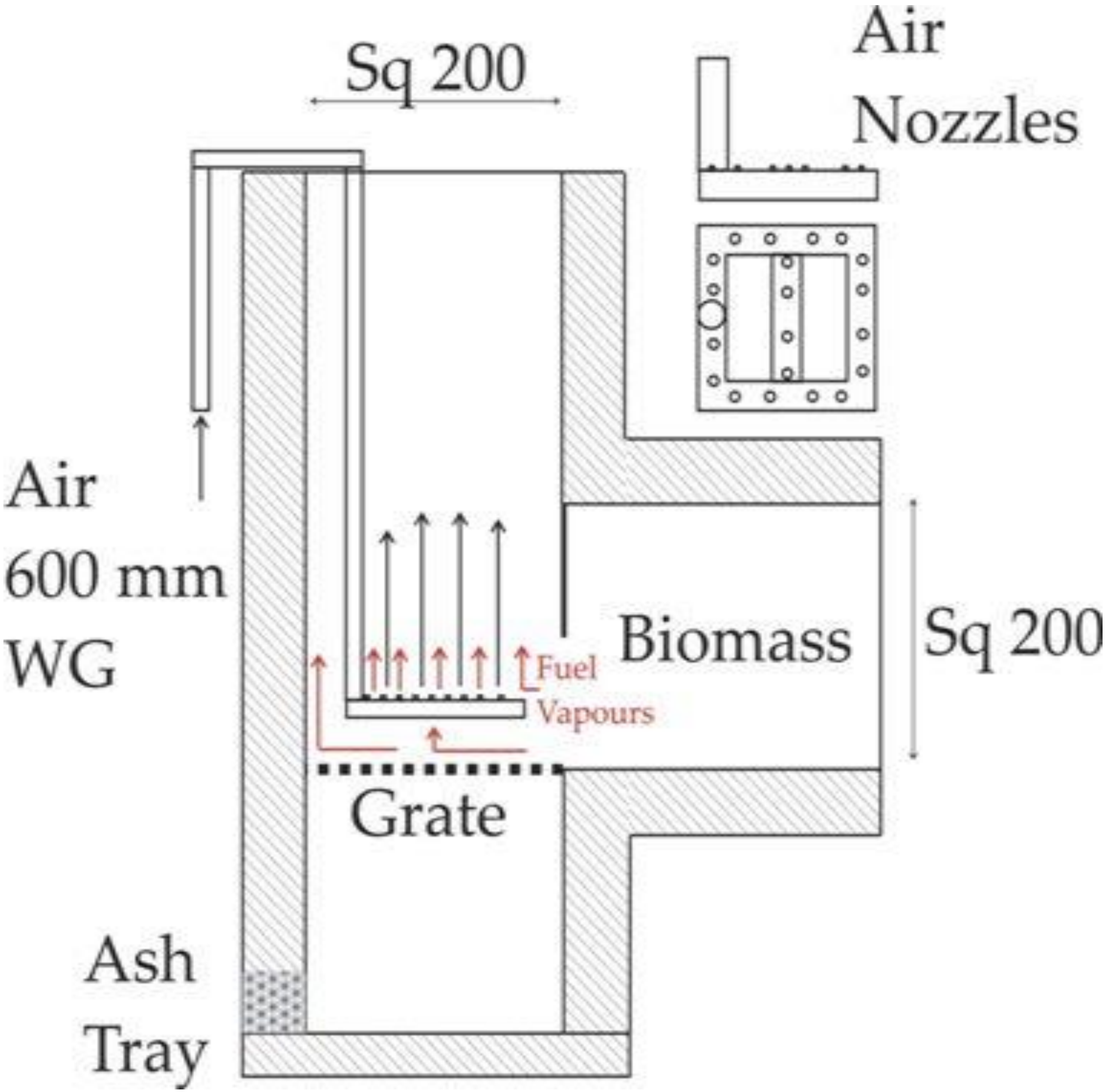


Design 1 (Valveless); Modified Design 2: Two valve type with ash removal tray at the bottom



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

Ejector Stove with a horizontal gasifier(!)



A functioning ejector stove

Current Crude oil utilization in the country

- The country uses about 104 million tonnes of crude oil (fossil fuel). It imports 70 % of this amount at 27 to 30 billion USD (Rs. 120,000 to 140,000 crores)
- The most critical of the uses is in reciprocating engines for heavy transport (road and rail) that has significant impact on inflation index
- Many industries depend for electricity generation on large reciprocating engines and these use furnace oil. Even larger number of industries depends on furnace oil for high grade heat.
- The crude oil prices moving from the 27 to 30 USD/barrel bracket to about 50 USD/barrel bracket in six months and the predictions of this climbing to 100 USD/barrel bracket in an year or so because the world oil production including all sources is peaking at present.

Derivative from crude oil	Amount MT/yr	Nature of use
High speed diesel	40	Heavy vehicle transport
FO/LSHS (Furnace oil/Low sulfur heavy stock)	14	Stationary power generation Combustion in furnaces
Naphtha/NGL LDO (Light diesel oil)	12 2	Stationary power generation Stationary power generation
Total	68	Transport and stationary power
LPG	10	Domestic cooking and Vehicle transport
Gasoline (petrol) Kerosene	9 12	Vehicle transport Domestic cooking/power
Total	31	Domestic / transport /stationary power

MT/yr = Million tonnes per year

What replaces what?

HSD, LDO, LSHS, FO (about 68 million tonnes out of which 65 % is the prime fuel for transport, HSD)

Can be replaced by vegetable oils (non-edible) in part or wholly, some directly and some with refinement – esterification.

Gasoline as transport fuel can be replaced by ethanol from sugar industry, again in part or wholly.

Kerosene as an engine fuel by ethanol

Kerosene as a fuel for lamps by esterified vegetable oil

Kerosene as a cooking fuel by modern electricity supported solid fuel combustion systems

Q: Can we reduce the foreign exchange outgo by indigenous oil production?

Can we benefit by associated activities?

A: Use the assets, namely unused land and water with nutrients to create oil seeds, and use waste biomass from these operations and also use the urban, peri-urban solid wastes to create energy supplies – oil for transportation and solid fuels for rural energy security

Waste potential

- Agricultural wastes
  - Magnitude and distribution over the country deduced from Ministry of Agriculture data, field surveys under MNES, ISRO (RRSSC) all GIS based information
  - 100 – 120 million tonnes, amounting to installed capacity of 150,000 MWe
- Devoted existing plantation output and wastes – crude estimates – 20 million tonnes

Waste potential - 2

- Waste land
  - from several sources, primarily from a study carried out by NRSA with ground truth surveys included
  - **33+ million Hectares of culturable waste land**

- Could be used to grow hardy oil seed bearing trees, and others to optimize the revenue from the land – at 1 tonne per Ha of oil + 4 tonnes of dry solid output or 10 tonnes of dry solid output or a mix – leading to [33+ million tonnes of oil + 130 million tonnes of solid biomass] or 330 million tonnes of solid biomass. The precise choice depends on locally perceived benefits and can be tuned by financial interventions
- These data have been refined with more careful calculations; but the broad numbers are about same

Waste potential - 3

- Urbanization and modern living have resulted in solid wastes that litter the roads and management of these has been a nightmare for the communities and municipalities.

- There are 300+ class I cities with a population of 200+ million people with waste generation of 40000 to 50000 tonnes per day of wastes with 1500 to 2500 tonnes of non-biodegradable organic waste with an electricity potential of 1500 to 3000 MWe.

Waste potential - 4

- On a more relevant waste dump-site basis, the capacity is 50 to 100 tonnes per day of wastes with dry organic matter of 10 to 25 tonnes per day – power generation capacity of 0.5 to 1 MWe.

- A key feature is that middle level towns have very poor infrastructure for waste management. There are technical issues of handling them by *methods that bring in revenue*. Unless, the waste handling is considered as a possible profit center, solutions for clean up become impractical.

Waste Potential - 5

- Modern gasification technologies are the most scale relevant. For 25 dry tonnes of organic waste including about 2 to 3 tonnes of non-biodegradable organic mass, a 1 MWe plant gasification plant with upstream waste handling facility is considered the most relevant and useful system.
- Currently there is no support for development on this effort by the states.

Waste Potential - 6

- The effort required by MNES needs to be augmented particularly in view of continued adverse observations by the Supreme court on the street cleanliness of cities and townships.
- Urban development ministry and Ministry of Tourism also should be seriously interested. However, passing the buck seems to be the fate of waste management.
- The one ministry that should take leadership role even though it is involved in the final stages of waste handling is perhaps MNES. MNES should be even more proactive than it is today on this subject.

Waste Assets – a summary

- 100+ million tonnes of agricultural wastes
- 20+ million tonnes of plantation waste
- 33+ million Hectares of waste land that could lead to 33 + million tonnes of non-edible oil (equivalent of 25 to 27 million tonnes of HSD) and 130 million tonnes of solid biomass
- 40000+ tonnes per day of Urban solid waste

Status of dealing with wastes - 1

- The most modern of these systems can accept any biofuel – agro-residues and/or cleaned urban solid waste including some non-biodegradable material (like plastics at 6 to 10 % throughput, typical of urnan solid wastes) with gaseous emissions within international standards.

- Additional costs of waste handling at dump site would be about Rs. 2 crores per MWe of design electrical output (about 25 tonnes per day of cleaned bio-residue (10 %dry).

Strategy for waste land - 2

- This is the key issue of great concern and should be handled with great care.
- Land is a property of the States. Encouraging their productive use should be centrally planned with a well structured arrangement.
- One of the principal planned outputs should be non-edible oil seeds.
- To encourage this, it is vital that procurement of the oil should be well defined.
- The principal owner of the output could be Indian Oil Corporation.

Strategy for waste land - 3

Success of this initiative is strongly related to wide partnership base –

- Involve industrialists and others who can invest, panchayats in whose domain, the land is located to enable help various actions, and large labor population.
- Industrialists who can be leased the waste land for its development using incentives, perhaps on tax basis.
- Involvement of local panchayats for support and helping settle labor and payment terms for the development of the land under the leadership of the local government.
- The package design should be such that everybody in the chain should financially benefit in a rational way.

What did you hear?

1. Bio-wastes provide for a 24 x7 energy availability
2. Biomethanation and thermochemical conversion are two possible routes.
3. Gasification can also deal with lignin and plastics
4. These systems allow power generation at the same cost per MWe compared to large thermal systems.
5. Urban solid waste is also bio-waste and can be treated similarly
6. Use of waste land to grow oil bearing trees is an important economic driver for the country.