Bio-energy for India

- Current situation vis-à-vis all energy usage
- Bio-energy versus other renewable energies
- Routes of conversion
- Liquid fuels (called Bio-fuels generally)
- Improvements in solid fuel use
- Environmental-international issues
- Way-forward

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Current situation - all energy usage

- Coal – 500 mmt/y – Centralized electricity gen
- Diesel (HSD) – 50 mmt/y – Heavy transport (Road + railroad)
- Fuel oil – 12 mmt/y – Standby power gen (Comp. ignition engine) + furnaces
- Gasoline – 12 mmt/y – Light motor vehicle (LMV) transport
- LPG – 10 mmt/y – Domestic cooking + LMV
- Kerosene – 12 mmt/y – Domestic cooking + transport (illegally)
- Biomass (firewood, agro-residues, cow-dung) – 500 mmt/y – largely for cooking, heat and energy

mmt/y = million metric tonnes per year

Fuel import and efficiency of use

Fuel	Imported, how much	Efficiency of use
Coal	~ 5 - 10 %	32 % average, 37 % peak (elec) Equivalent heat ~75%
Diesel, Gasoline, FO, Kerosene	Based on 70 % crude import (30 billion USD)	Diesel, FO, Gasoline – good Kerosene – average to poor
LPG		~ 60 - 70 % domestic heat
Biomass*	-	15 % average, 30% peak

FO = Furnace oil or fuel oil,

* Biomass - Firewood, Agro-residues, cow-dung

Bio-energy versus other renewable energies

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

Bio-energy as renewable energy

Sure, Who says No?

…………Is it really for so sure?

Generally, most people including bureaucrats suffer from fourth source syndrome. They wish to begin by SPV, go through Wind (both of which are intermittent), allow hydro but ignore bio-energy most of the time!

Mark Jacobson, Stanford University and Mark Delucchi, Uni California, Davis in Scientific American, November 2009

…Wind and Solar photovoltaics adequate as renewable energy adequate in 2030. Widely discussed, trashed, argued back…..

They think biomass is a problem and solution is SPV and Wind. Even Google's energy plan is along these lines!

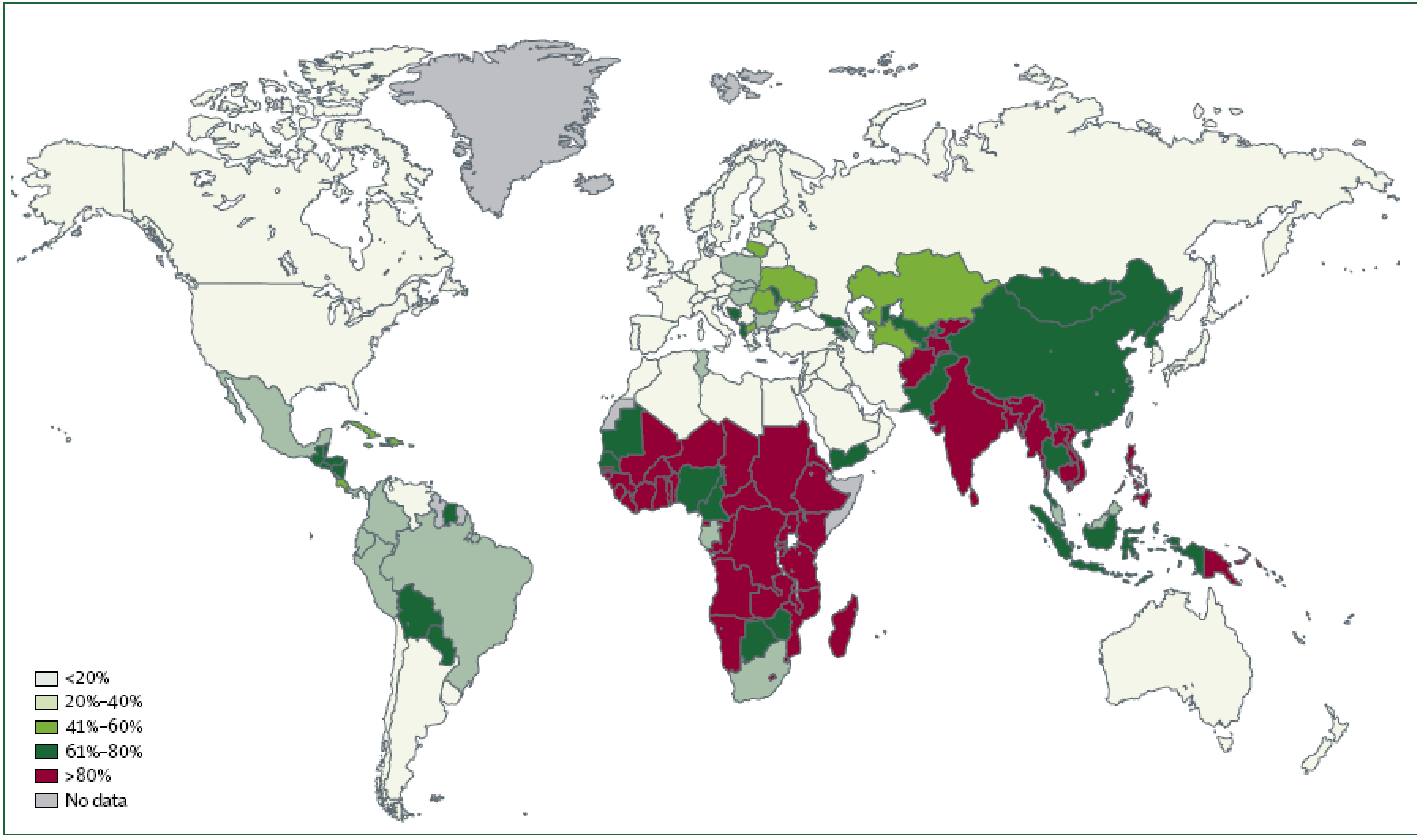
It appears to many of us that biomass is the solution, and could be a cheap one at that,

Let us review some facts

…Reviewing facts..

- We already noted that in India the amount of biomass used for cooking is 500 mmt every year at 10 to 20 % eff and that the amount of coal used for power generation is 500 mmt.
- Roughly stated, food for 650 million people is cooked on biomass!
- World over about 2.5 billion people cook on biomass. In African, in many countries, 95% dependence is on biomass!
- Will this situation be altered in the next thirty years? It is unclear how. Also, really, why one should move away from biomass. Cannot we not solve the problems related to biomass?

House-hold cooking on biomass… In India ~465 mmt/year
(Coal use ~ 500 mmt/year)



In India - Bio-wastes…how much?

- 100+ mmt of agricultural wastes for cooking fuel/electricity
- 20+ mmt of plantation waste for electricity
- 33+ million Hectares of waste land that could lead to 33 + mmt of non-edible oil (equivalent of 25 to 27 million tonnes of HSD) and 130 mmt of solid biomass.

  This promises at least 60 million jobs (unskilled + skilled) in the tree culture of the waste land. The choice of waste land for bio-oil avoids the fuel vs. food debate in the USA and other countries. These jobs can be arranged to provide monthly remuneration that eliminates farmer suicides due to agriculture-related problems
- 40000+ tonnes per day of Urban solid waste that could become briquetted fuel or electricity.
- Liquid wastes – sewage, industrial wastes from food processing industries, amounting to 7 million metric cubic meters per day.

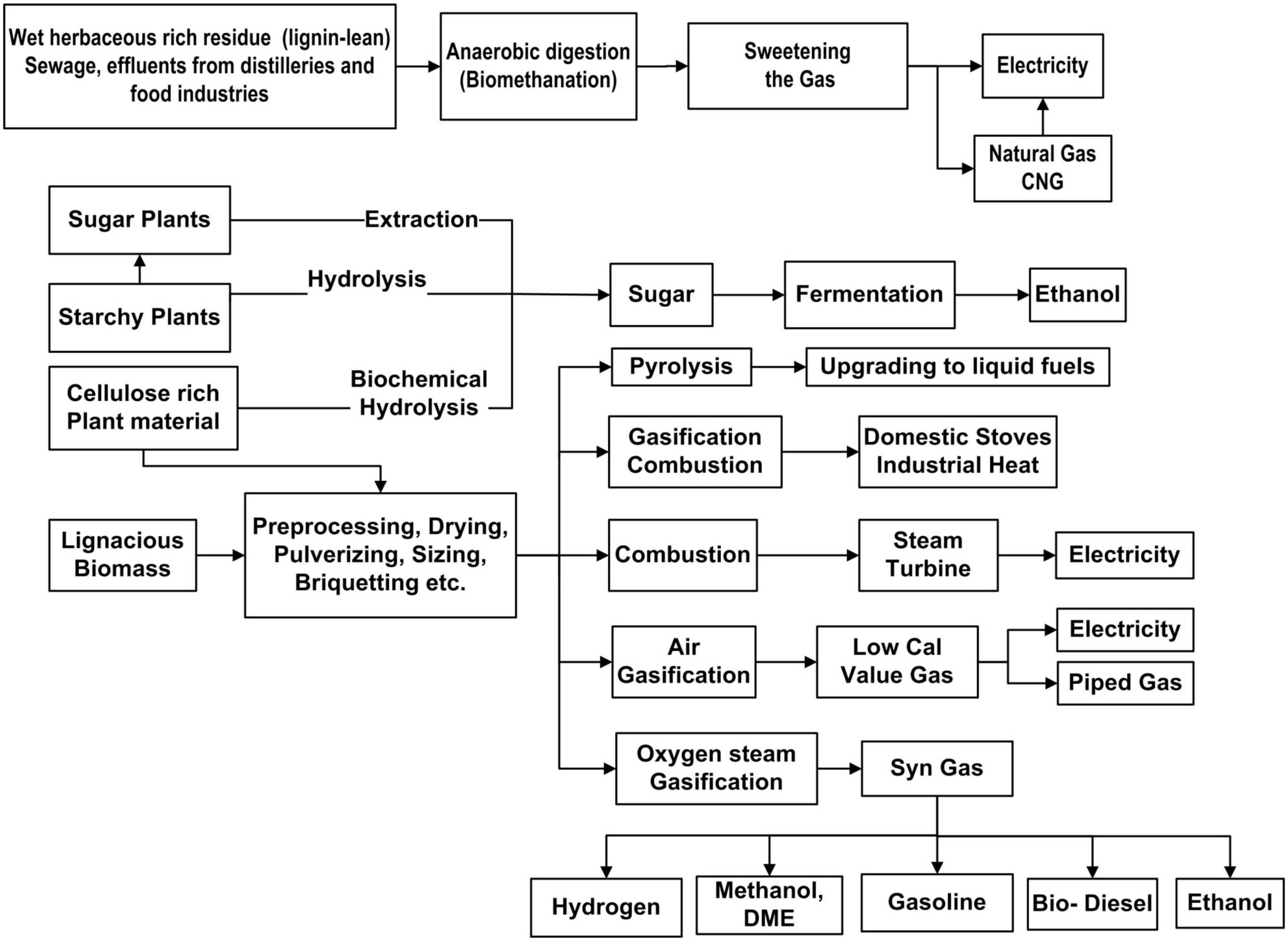
Only a few % has been capitalized upon. Much can be done and needs to done to help the economy straighten up.

What solid fuels? What features?

Material	Examples	Density, kg/m³	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

Routes to conversion – 95 % thermo-chemical conversion



Broad performance details

Technology	Fuel/ capacity	SFC kg/kWh
Steam	Biomass, fossil fuel • < 100 kW • 100 - 500 kW • 500 - 2000 kW • ~ 4000 kW	 ~ 6 -8 kg/kWh ~ 4 - 6 kg/kWh ~ 2 - 3 kg/kWh ~1.5 – 2 kg/kWh
Gasification •Dual fuel and gas alone operation •Gas turbine with recuperater	Agro residues • < 100 kW • < 100 - 500 kW • ~ 1000 kW	 ~ 1.2 – 1.5 kg/kWh ~ 1.0 – 1.3 kg/kWh ~ 0.8 - 1.0 kg/kWh
Stirling engines	Can be agro residues • < 100 kW	< 1.5 kg/kWh
IGCC	Agro residues > 2000 KW	 ~ 0.7 – 0.8 kg/kWh

Liquid fuels from biomass – Bio-fuels

Liquid Fuels

- Non-edible oil from oil seed bearing trees (1st Gen)
- Alcohols from sugarcane and biomass (1st Gen)
- Pyrolitic oil through high temperature processing
- Hydrocarbons from gasification – F-T synthesis and other processes

- 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. If we can produce excess of edible oils, they can also be used (with some controls)

- 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 /h
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

Solid residues constitute 70 – 80 % of the feed stock

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

Liquid fuels…

- The seeds should be dried, used in an oil expeller to extract the oil, filter the oil, esterified 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 (or others in which starch should be converted to sugars) through the process of fermentation. They have about 60 % energy compared to fossil fuels

Improvements in solid fuel use

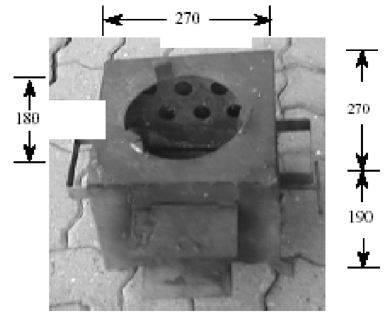
Conventional stoves: Efficiency and emissions

Bhattacharya et al (2002) have tested efficiencies and emissions from 24 different wood and charcoal stoves of east Asian origin.

Thailand, η 14%,
CO 1.7 g/MJ

Traditional Rungsit stove

Thailand, 12%
1.6 g/MJ

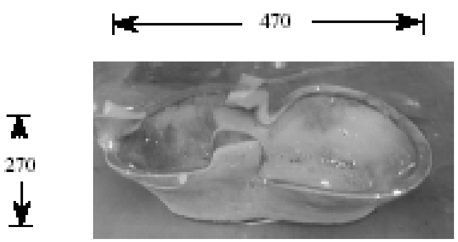


Indian "Harsha" Cookstove

India, 25.2 %
2.6 g/MJ

Malaysian traditional

Malaysia, 9.5%
28.7 g/kg fuel



Nepalese one-pot ceramic

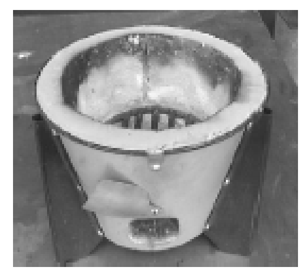
Note: All dimensions are in mm

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

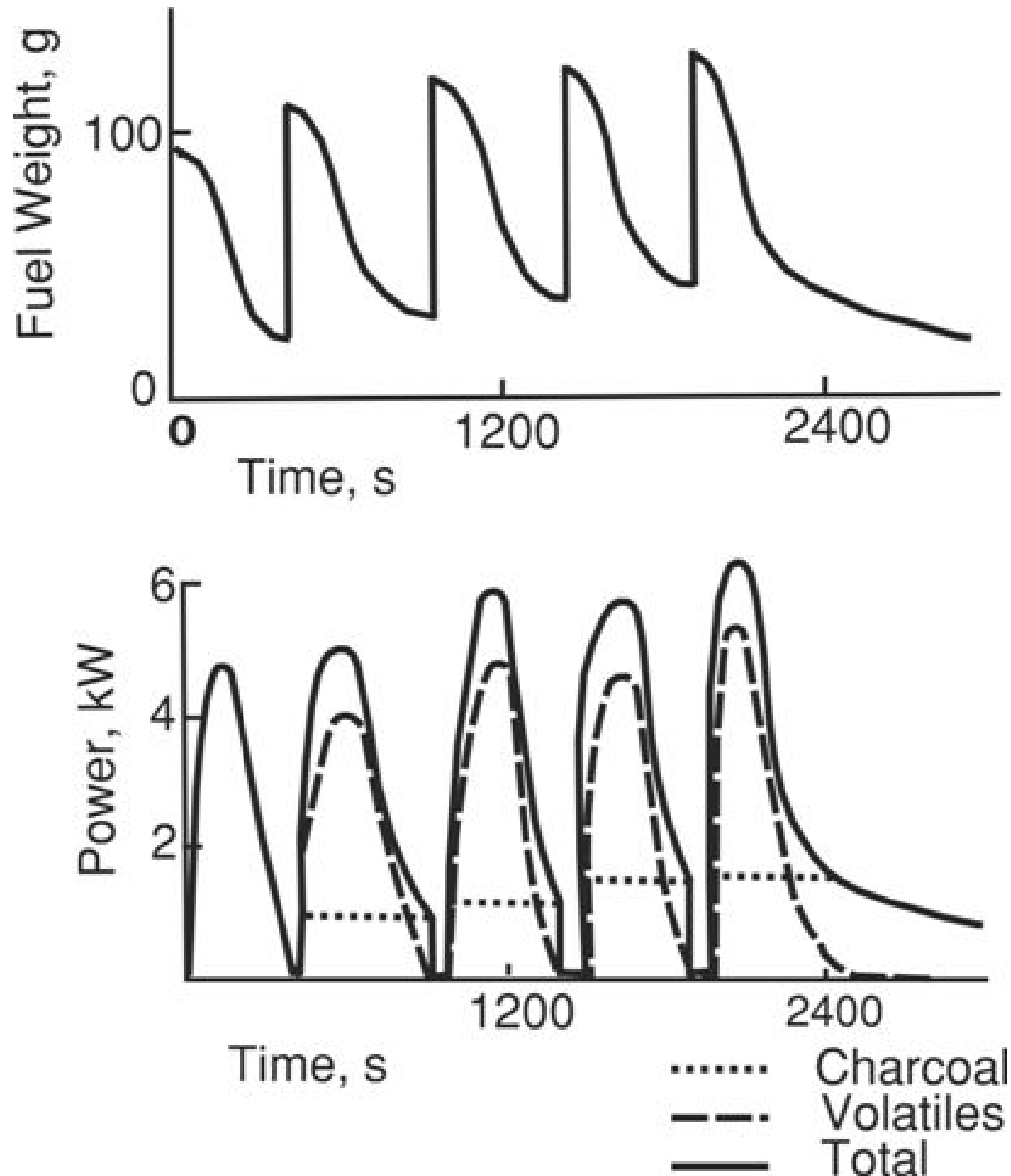
Philippines, 12%
28.6 g/kg fuel

Vietnamese traditional

Vietnam, 15%
38.6 g/kg fuel

Fuel and Power vs. time in an conventional biomass stove

When biomass is loaded, power Increases a little afterwards, since it takes a few seconds to a few minutes depending on the size for the wood to heat up and begin to give off volatiles. When all the volatiles are consumed, biomass becomes char whose weight is about 20 to 25 % of the biomass. After this char oxidation occurs.

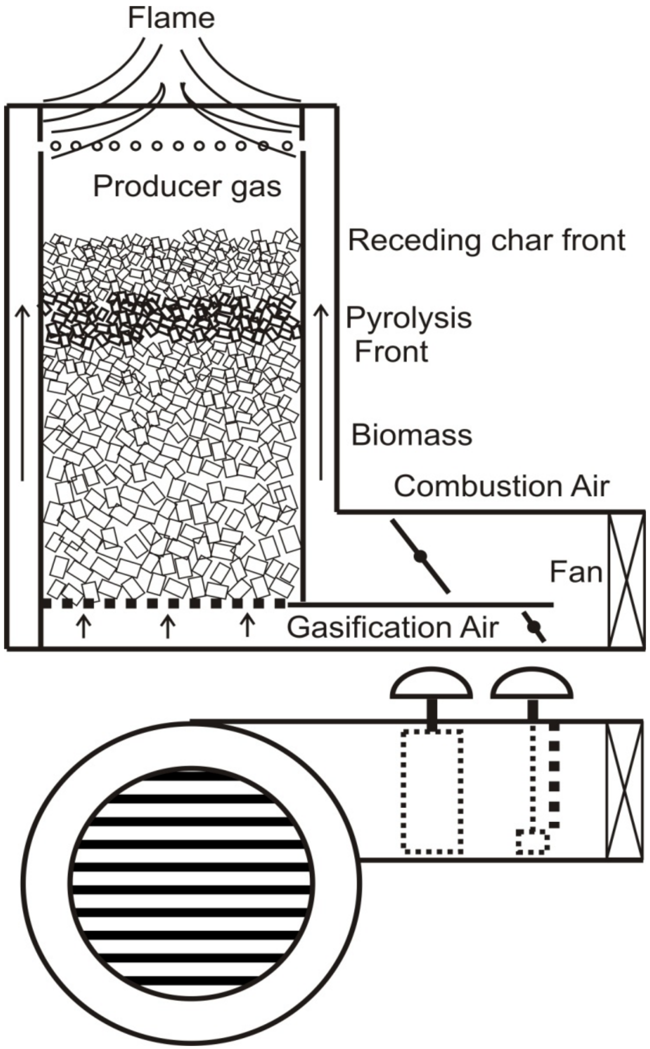


New methods for
– Domestic cooking/heating needs

Principles - first technique – fire and forget/control

1. Burn from top to bottom of a pile instead of bottom to top (practiced for several thousand years)
2. Recognize that this is a two stage combustion process in which sub-stoichiometric combustion occurs first and then combustion of the gases is completed at near-stoichiometric conditions. The first phase is also termed gasification. Such devices are called "Gasifier Stoves"
3. The power output is proportional to the air flow rate. Hence, controlling it helps vary the power.

The gasification stove.



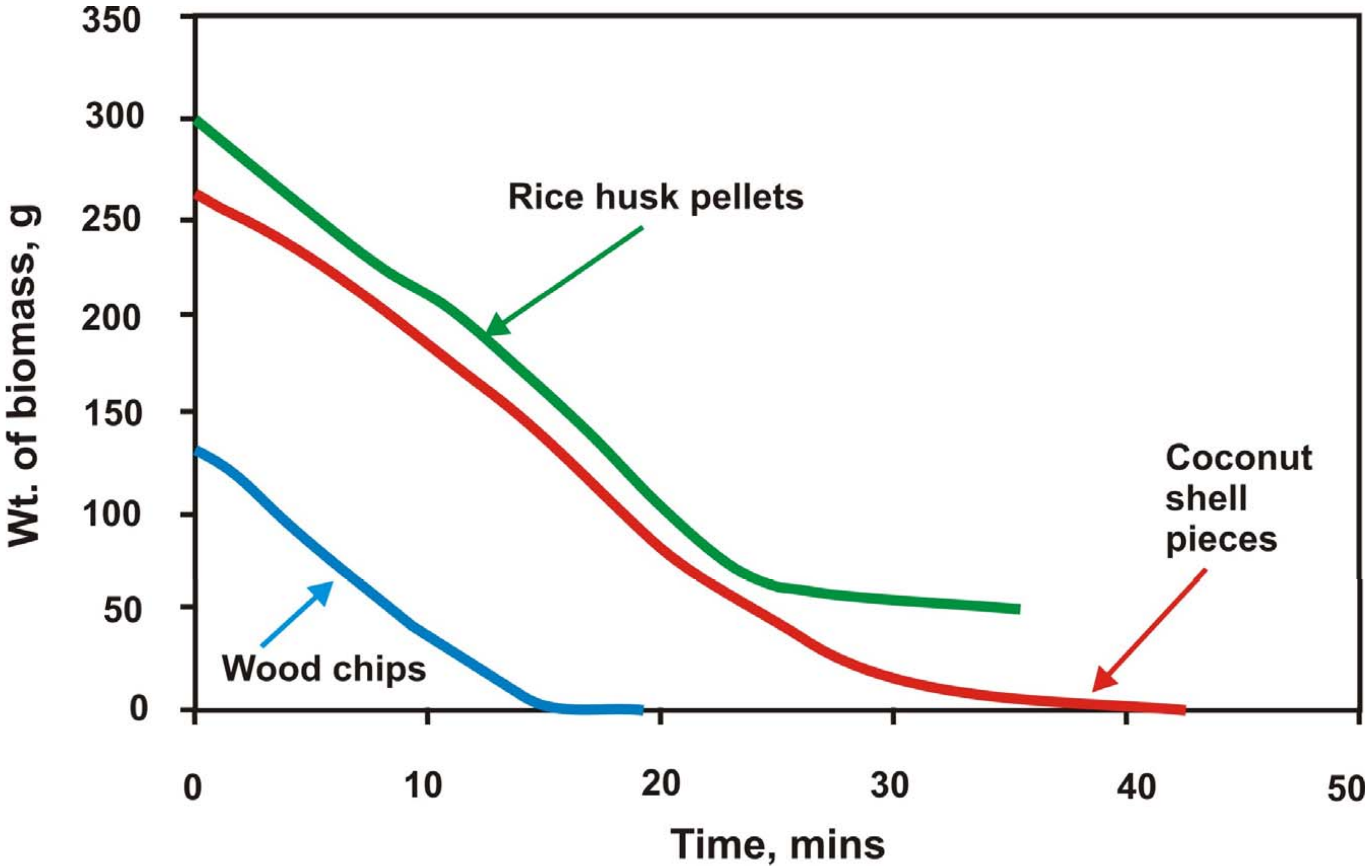
Fuel is in the form of pellets – 8 to 10 mm dia and 30 to 50 mm long

Air from the bottom – primary air – produces combustible gas over the solid fuel bed

Air at the top region – secondary air – burns up the gas at near stoichiometric proportions

Power variation in a gasifier stove.

(mass loss varies linearly – power is nearly constant)



Why is the power nearly constant in gasifier mode?

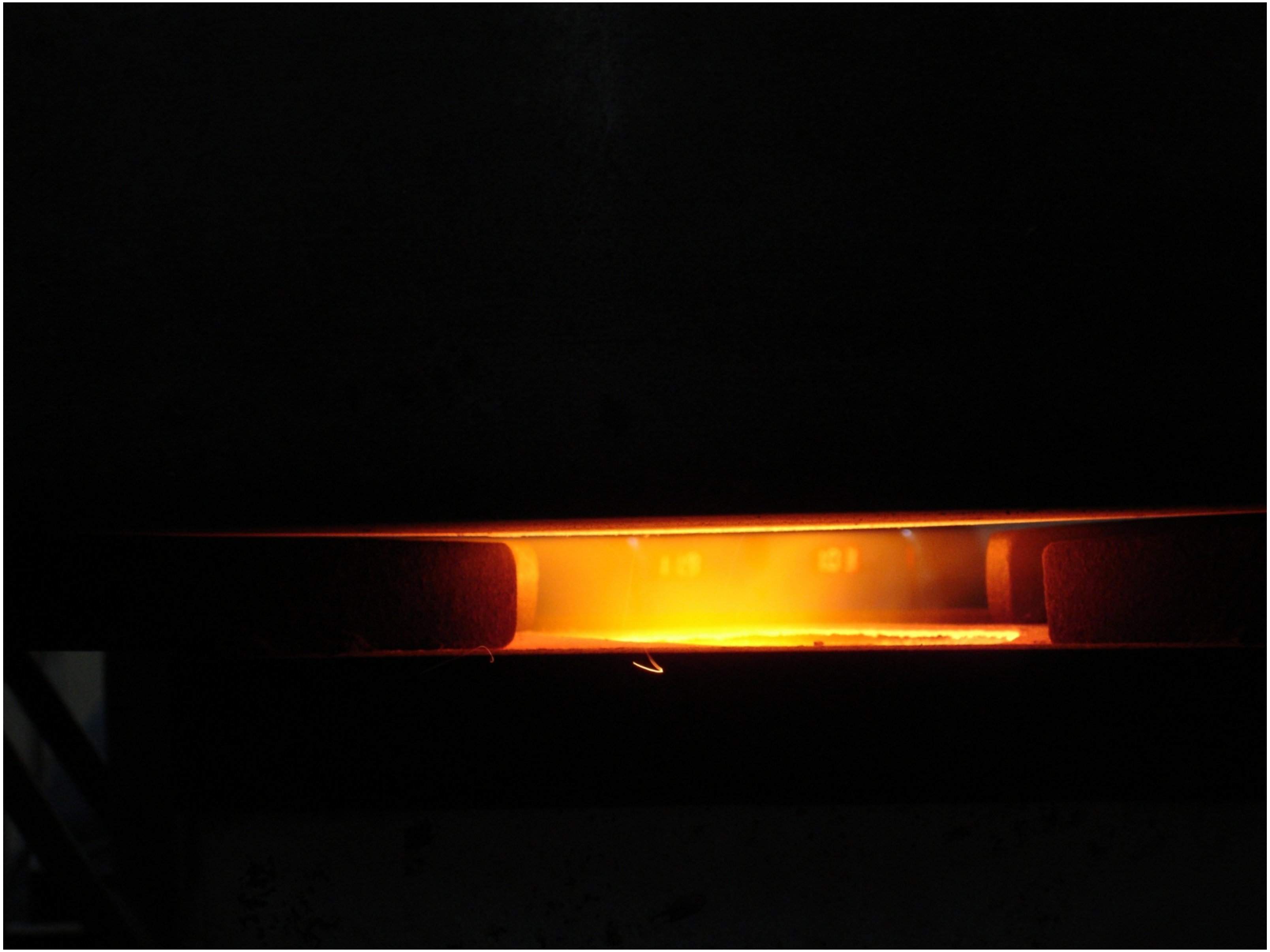
- In the gasification process, excess carbon is always present in the form of charcoal.
- Only that amount of carbon that is required to cause the reduction reactions is consumed.
- The propagation of the thermal profile against the flow of air occurs at a rate to reach equilibrium composition or conversion.
- With the use of sizes of biomass not widely different, the amount of biomass covered by the thermal profile is also nearly same.
- This keeps the consumption rate constant.

Another approach

- Principle – Ejector induced gasification based stoves – continuous fuel feed – can deal with firewood
- An ejector induces an air current below it. This is made use of to draw air through a fuel bed horizontally located
- The use of partial blockage helps the gasification process.
- The char bed on the grate allows gasification process to be completed.
- Controlled air flow through the grate from the bottom section helps char conversion and maintain a high temperature in the fuel preparation zone


WEIGHT kg
6.322
Essae
12.0 V
0.10 A


EIGAS-10
INDIAN INSTITUTE OF SCIENCE
ABETS, CGPL

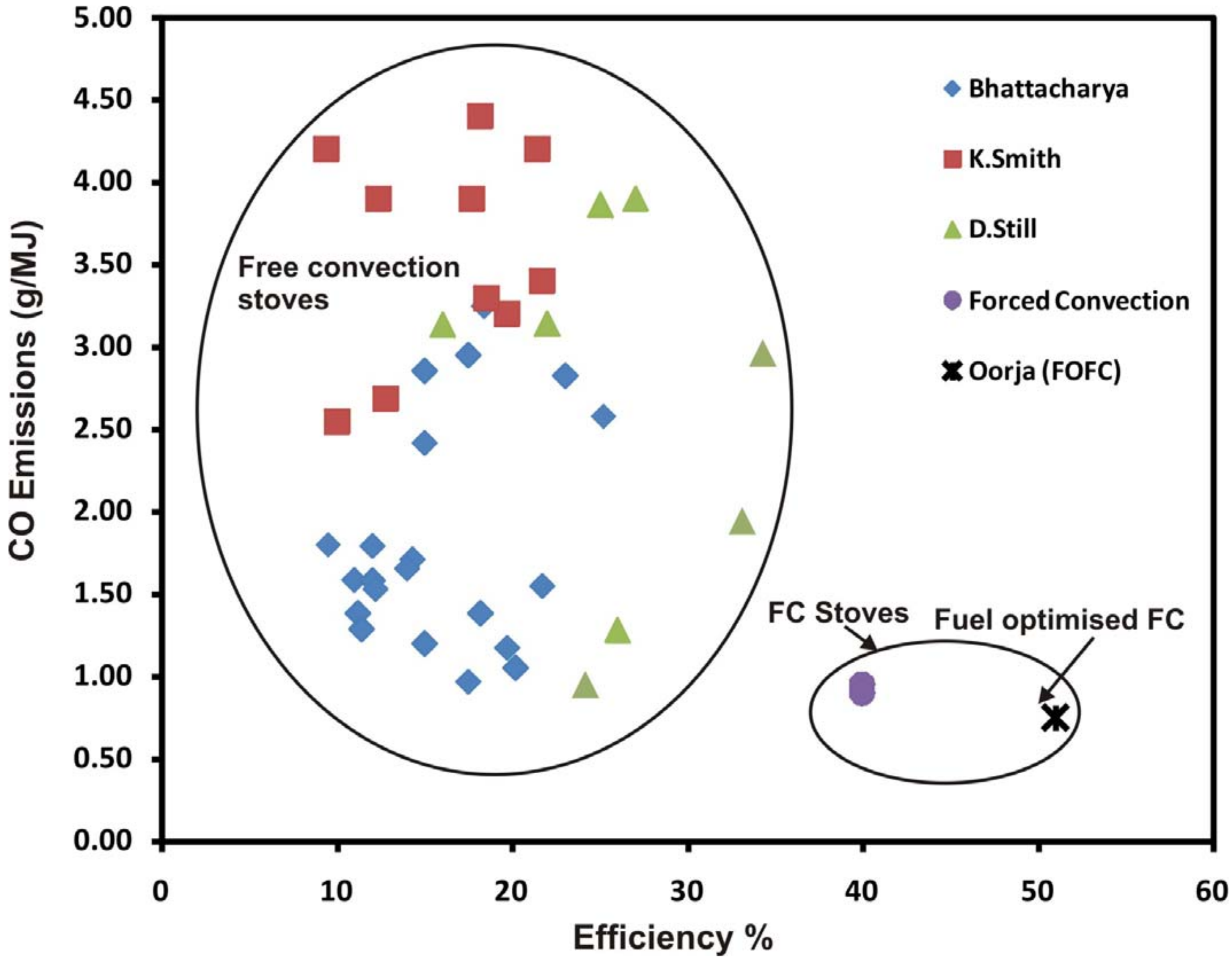


10 kg/h stove functioning at optimum conditions

EIGAS stove at 30 kg/h (120 kWth)
It runs on 2 x 12 V x 1 amp two stage fans

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**



Increase in efficiency appears synonymous with reduced emissions
This is the idea of HELE (High Efficiency Low Emission) design

Environmental-international issues

E-I issues

- Indoor air pollution (avoided by Chimney based stoves)
- Indoor and environmental pollution (avoided only by fan based designs)
- Biomass as an aid to reduce Green House Gas emission
- Black carbon and GHG emission – stoves, large scale biomass burning

Biomass as an aid to reduce GHG

- GHG emissions are very significant from fossil fuels – largely controlled by fossil fuels – transportation and coal based power generation.
- Solutions for power generation – using CO_2 from exhaust gases to produce industrial products (cheap) or storing it underground, etc.
- Co-firing with biomass in coal power stations is one route.
- Solutions for transportation are sought in liquid bio-fuels.
- We need to remember that this route leads to 70 to 80 % solid residues.

Biomass as an aid to reduce GHG

- Biomass is intrinsically C +/neutral/- depending on (usage – storage). Growing biomass reduces GHG through absorption of $CO_{2.}$
- Simply growing biomass is inadequate. CO_2 absorption rate is higher during growth. Harvesting, efficient usage for energy would be a meaningful route.
- Better carbon sequestration is sought by incorporating the residual char (Bio-char) into the soil with benefits – GHG reduction and nutrient conservation.
- Extensive practice is argued to lead to a definitive C negative solution in the most economical manner

Black carbon issue?

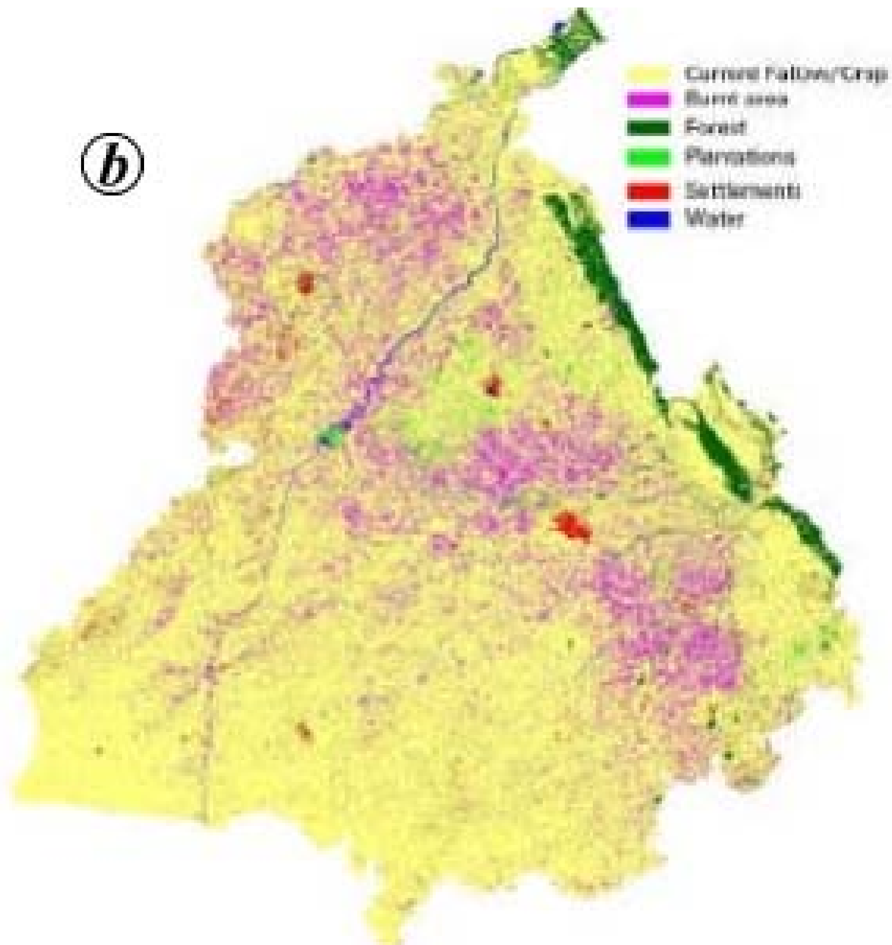
Soot is an amorphous-shaped particle emitted into the air during fossil-fuel combustion, bio-fuel combustion, and biomass burning.

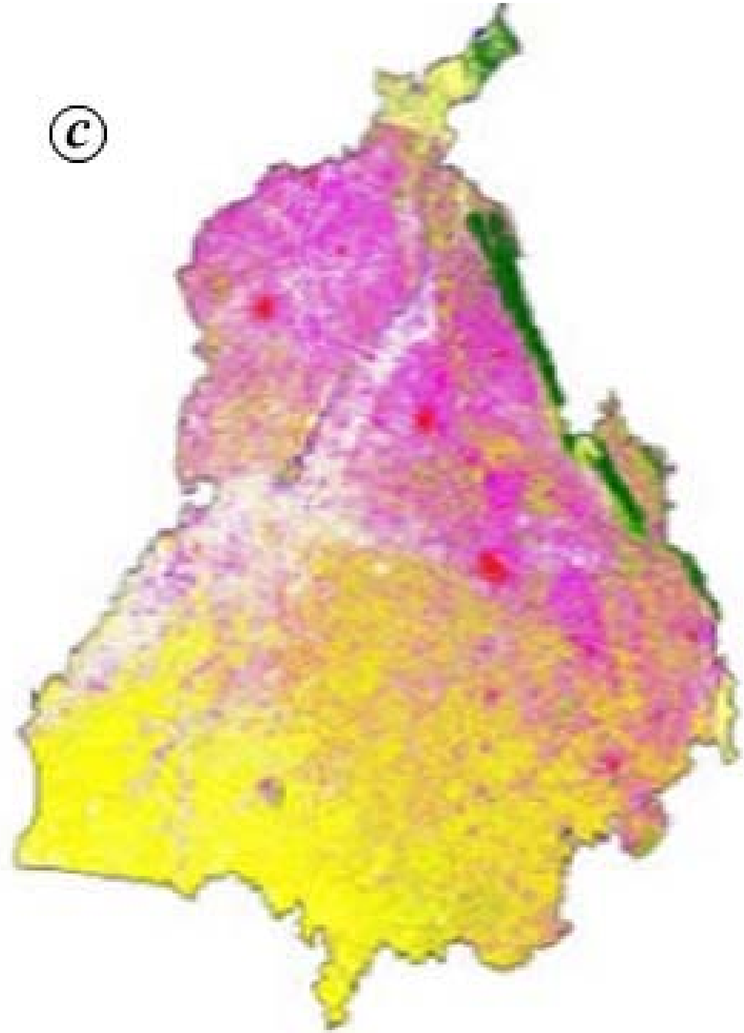
Soot particles contain black carbon, organic carbon, and smaller amounts of sulfur and other chemicals.

Soot from diesel combustion usually appear black because it contain a high fraction of black carbon, which absorbs all colors of visible light, preventing such light from reaching our eyes.

Soot from bio-fuel burning is brownish because it contains a higher ratio of organic carbon to black carbon than diesel soot, and organic carbon absorbs short light wavelengths preferentially, appearing brown.

…. Called therefore Brown cloud problem… (an Indian Scientist, V Ramanathan at Scripps institution of Oceanography is involved in this subject as well. An UNEP document An integrated assessment of black carbon and tropospheric ozone, UNEP/GC/INF/20)





Wheat field burning after harvest
Punjab – 5500 km^2 May 2005

Rice field burning after harvest
Punjab – 12,600 km^2 Oct 2005

From an NRSA paper, Current Science, June 2006

Table 1. Top-of-the-atmosphere global direct radiative forcing by anthropogenic gases and particulate black carbon.

	Global direct radiative forcing (W/m^2)	Percent of total
Carbon dioxide	+1.66	48
Methane	+0.48	14
Nitrous oxide	+0.16	4.6
Halocarbons	+0.34	9.7
CFCs*	+0.268	
HCFCs*	+0.039	
HFCs+PFCs+SF_6	+0.017	
Ozone (tropospheric and stratospheric)*	+0.30	8.6
Total gases	+2.94	84
Anthropogenic black carbon*	+0.55	16
Total gases + black carbon	3.49	100

Soot particles also differ from greenhouse gases in that soot particles have relatively short lifetimes in the atmosphere of around one to four weeks. Greenhouse gases have long lifetimes (e.g., 30-43 years for carbon dioxide[20,21] and 8-12 years for methane). The lifetime of a chemical is the time required for the chemical's concentration to decay to about 37% its original value.

Way-forward

- There are a number of issues both intrinsic and externally imposed on energy and environment.
- Increasing efficiencies, avoiding arbitrary burning and getting fuels from wastes all contribute to reducing the emissions internal and environmental while meeting energy needs.
- Beyond rhetoric and posturing, greater recognition and understanding are required to deal with substantive issues
- Mainstreaming biomass as a fuel of significance is one of the very important aspects. Awareness and education are central to this approach.
- Education whose purpose is understanding of fundamentals of bio-energy is central to the way-forward.

…………Thanks