Biomass based energy - IISc and India

- The fourth source syndrome
- Technologies developed and transferred
- What these technologies are
- Science in step with technology
- The national scene on energy, briefly
- The national problems and a way out..

H S Mukunda

Advisor, ABETS, CGPL, AeS engg, IISc

http://cgpl.iisc.ernet.in

The fourth source syndrome

Whenever alternate energy is talked about, the four sources discussed are

1. Solar photovoltaic
2. Wind
3. Hydro, and as an after-thought,
4. Biomass is brought up.

This is done, by not recognizing the fact that biomass provides for food, fiber, fuel – solid and liquid and chemicals in a reasonable and affordable way, something other sources cannot even come near.

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 look at the work on *biomass* that one lab in IISc (CGPL) has been engaged in.

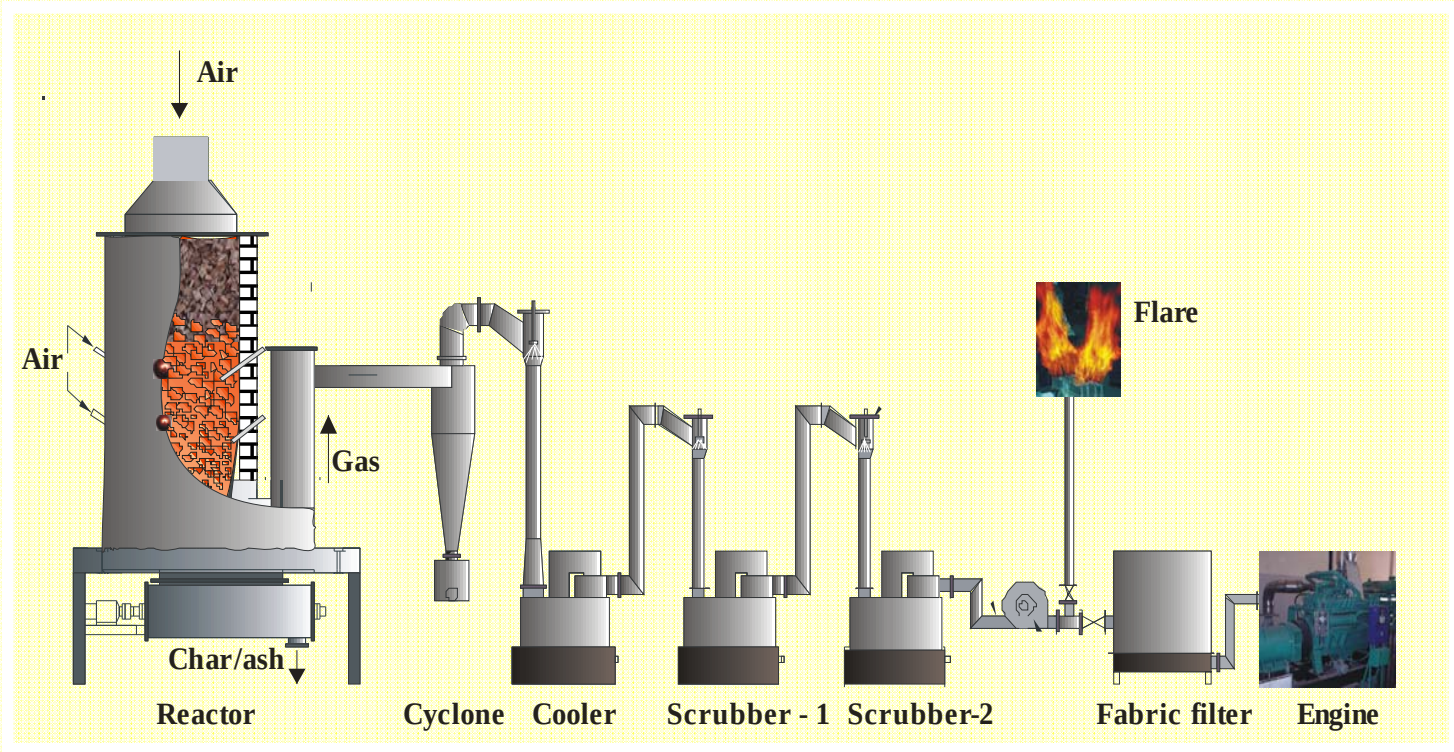
Even here, *only that* which may have *the largest impact on the national economy and quality of life of a common man* (rural/urban) will be addressed

The Technologies from ABETS, CGPL, IISc

Technology	Output	Capacity	Licensed?	No. systems
Biomass gasification Input: Solid biomass and air Output: producer gas and charcoal	Producer gas for heat, charcoal (~5%)	10 to 1000 kg/h	8 (India, Japan, Brazil, Switzerland)	~ 100, 1 to 1500 kg/h + 25 kW to 5 MWe
	producer gas for electricity	10 to 1000 kWe		
	charcoal (~33%) and heat	~ 700 kg/h	1	1
H_2S removal from biogas (digester gas)	Sweetened gas and Sulfur and electricity	10 to 10000 m^3/h	1	4
Precipitated silica from rice husk ash	Precipitated Silica of various grades	1 to 10 t/day	1	Pilot plant
Gasification based combustion devices	Industrial heat	5 to 10 kg/h	1	15
	Domestic heat	1 kg/h	1	400,000

All the technologies are IP protected in India and some appropriate countries

Open Top downdraft re-burn Gasifier (IISc design) for electricity



Ceramic reactor to withstand high temp oxidizing and reducing environment; bottom screw system meant for ash extraction (high ash biomass)

Generation of activated carbon with surface area of 450 to 550 m^2/g in the bottom section (600 to 800 °C)

Cooling and cleaning train to get dry gas at (P + T) < 5 ppm

Gas composition: 20 % each of CO and H_2, ~ 1 % CH_4, 10 % CO_2 and rest N_2

(Note that CO burns slowly, H_2 burns very fast)

…Its characteristics…

- System can run on 24 x 7 basis for > 7000 hours/year.
- It takes ~ 1 kg/kWh of sundry biomass of < 2 % ash (for instance coconut shell and wood have < 1 % ash, rice husk 20 % ash). This means one needs ~7000 t dry biomass at 1 MWe level
- Package costs Rs. 5.0 – 5.5 crores/MWe at ~ 1 MWe and costs Rs. ~ 6.5 crores/MWe at 100 kWe
- The O & M costs are Rs. 1.00 at 1 MWe and Rs.1.50 at 100 kWe if the plant is operated for > 6000 hours
- The energy generation cost is biomass cost/kg + Rs. 1.00 to 1.50. Typically at Rs. 1.50 per kg, the energy generation cost is Rs. 2.50 at 1 MWe level (+ finance cost of Rs. ~ 0.50/kWh)
- These are data from plants installed and run ~ 50 electrical systems from 20 kWe to 1500 kWe

Progressing technology…

- The process was understood in essential aspects by 1986
- The influence of moisture in biomass and process parameters on gasification efficiency (energy in gas as a ratio with input biomass energy) and cleanliness of the gas were understood in terms aero-thermo-chemical aspects.
- Minimizing tar and particulates in the gas stream from the system with minimum system complexity required inputs from fluid flows and some ideas of physics.
- Char and ash extraction strategies for higher ash containing fuels needed modeling and testing at smaller scale.
- Establishing long life in a zone with oxidative and reducing atmospheres at high temperature (~1200 C) required integration of ceramic materials technology

Armed with these the technology progressed from 1986 to near full maturity around 2002 and from then on incremental advances are taking place in specific elements based of field experience which is now close to 150,000 operating hours (over all plants)

1KgPH DINJAM PLANT

System cost~ 150000 Rs/kWe

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)

Performance of gasification systems as IPPs

SYSTEM	ESTBLD	CAPACITY	FUEL	HRS PER YEAR (OPERATD)	PLANT AVAI-LABILE?
ARASHI HI-TECH BIOPOWER	2002 (D-F) 2004 (GAS)	1 MWe	Julifora Prosopis, Coconut shell	6500	>85 %
HINDUSTAN PENCILS	2003 (D-F) 2005 (GAS)	200 kWe	Sawdust briquette	5500	> 95%
TANFAC	2003	1100 kg/hr	Juliflora Prosopis, Forest waste	7500	>95%
TAHAFET	2001	300 kg/hr	Juliflora Prosopis	7000	>95%
CRUMB RUBBER (1)	2002	80 kg/hr	Wood, Coconut shell	7000	>97%

All these needed science inputs…because

1. Biomass is taken to be widely understood for several thousand years (Vedic times, at least)
2. While it is understood by all that a diesel or gasoline vehicle can run only on diesel or gasoline, it is not understood that biomass should also be prepared for it to give performance.
3. Really speaking, it is the least understood and certainly poorly compared to fossil fuels, even by international standards
4. Look at the way smoke pervades a Yāga shāla and arguments in favor.
5. European gasifier builders have *always* wanted to work with as received biomass for energy purposes little knowing that they will need to pay *double tax* – to heat up the moisture to combustion temperatures and lower the peak temperatures that they really want to increase

On the Science aspects….

Gasifier-related	Producer gas engine
• Experiments on wood spheres and briquettes in air • Experiments on wood char spheres in an atmosphere of CO_2 and H_2O at high temperatures (to get conversion rates to gas) • Experiments on reactors to determine the flame propagation rates in a packed fuel bed – char as well as biomass • Reactive flow modeling – simple and computational on all of the above experiments	• Experiments on the combustion process inside producer gas based small engines • Simple and full scale computational (reactive flow) of engine processes • Performance of several engines – Cummins, Jenbacher, MWM, etc

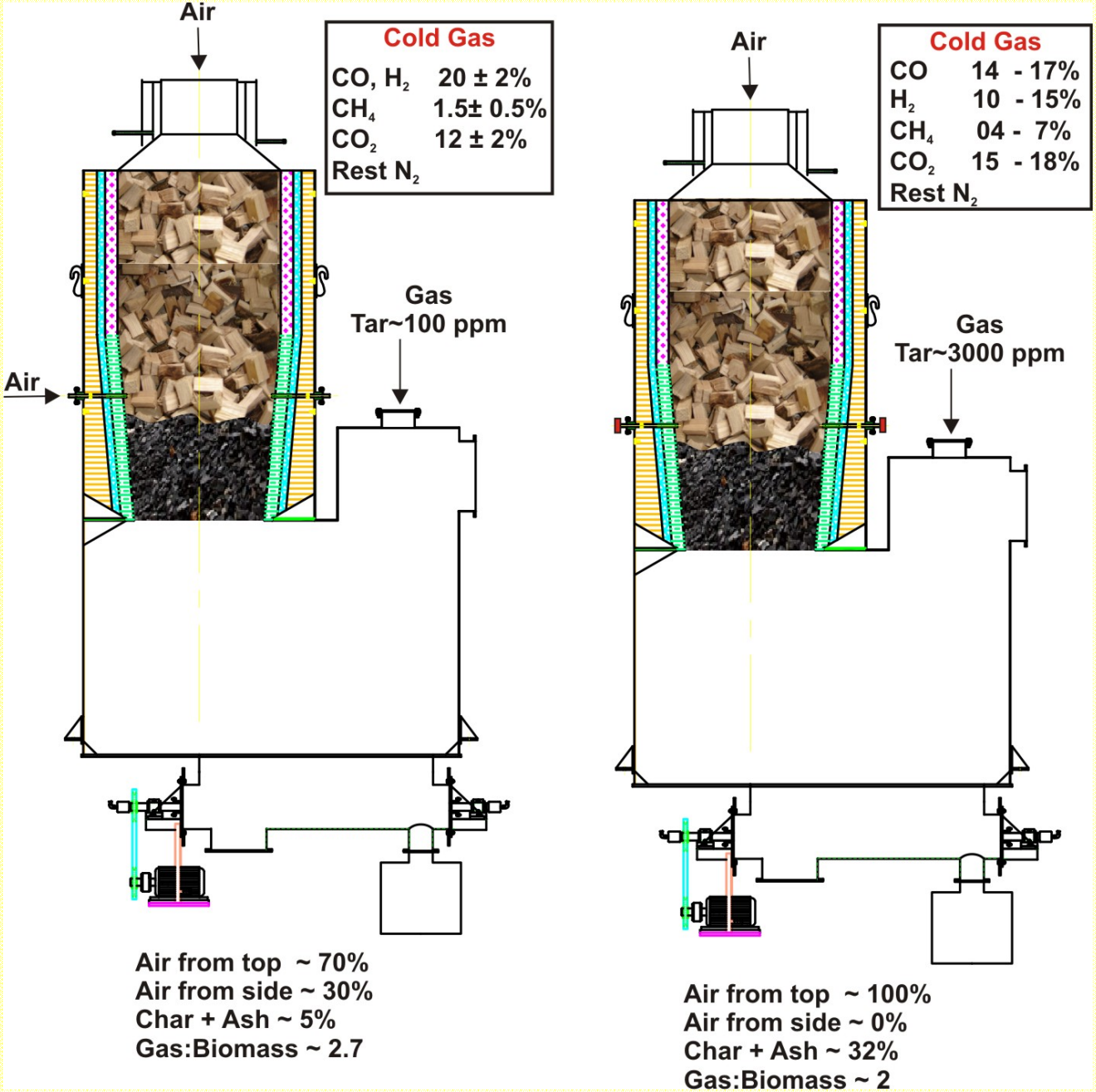
Outputs

20 Journal publications, 2 Ph. D theses (IISc), 50 B E projects, 6 Chapters in books, 10 Conference presentations, Renewed visits of ten technical teams from Europe

Variants of the gasification system

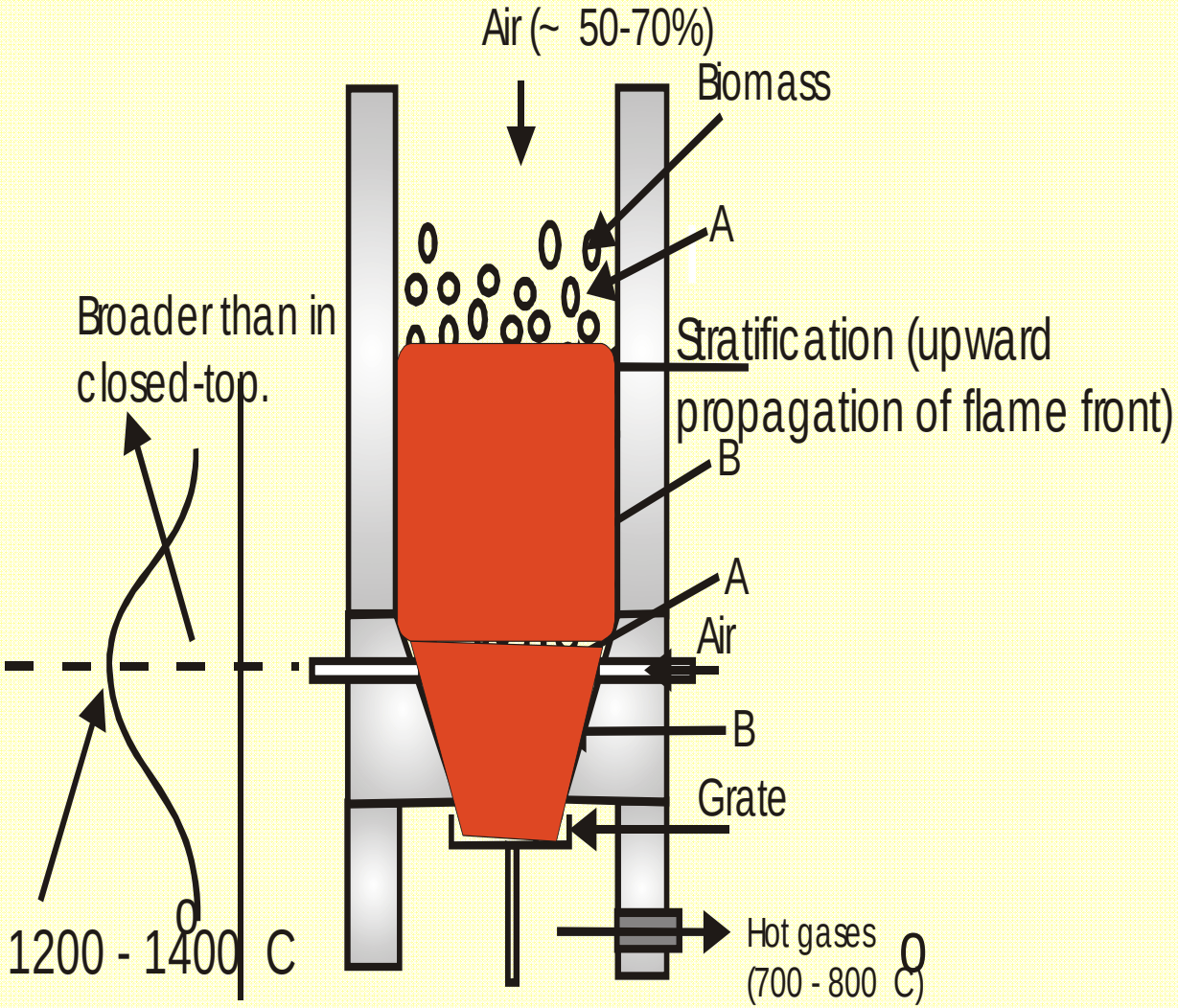
System	Achieves what
Twin/Shared air entry from top and sides	High quality gas, operation with finer size biomass like coconut shell, briquettes of urban solid waste with control on mud, sand, etc– 5 % dry ash extraction with char of 500 m^2/g surface area , Conversion eff. ~ 85 % (hot), 80 % (cold)
Side air entry closed, air entry only from top	~ 32 % char extraction of 400 to 450 Iodine no. (partly activated char) and energetic gas – Conversion efficiency ~ 85 %
Reversed reactor and local combustion (REDS – REverse Downdraft Stove)	A stove design for fixed amount of biomass - domestic stoves and specific industrial stoves to use wastes – water boiling efficiency ~ 50 % and ultra-low emissions of CO and particulates High density quality controlled fuel pellets from agro-residues
Horizontal gasifier and vertical combustor	A stove design for continuous operations for firewood, and other biomass. Water boiling efficiency ~ 50 % and low emissions of CO and particulates

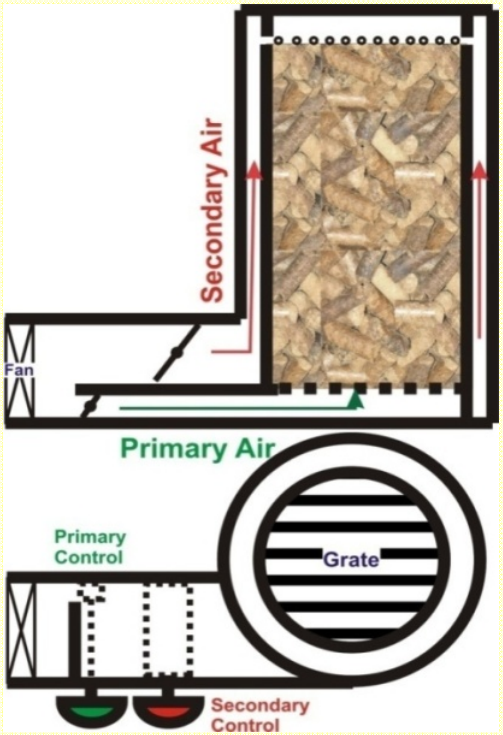
Gasifier operation for electricity application



Gasifier operation for charcoal production

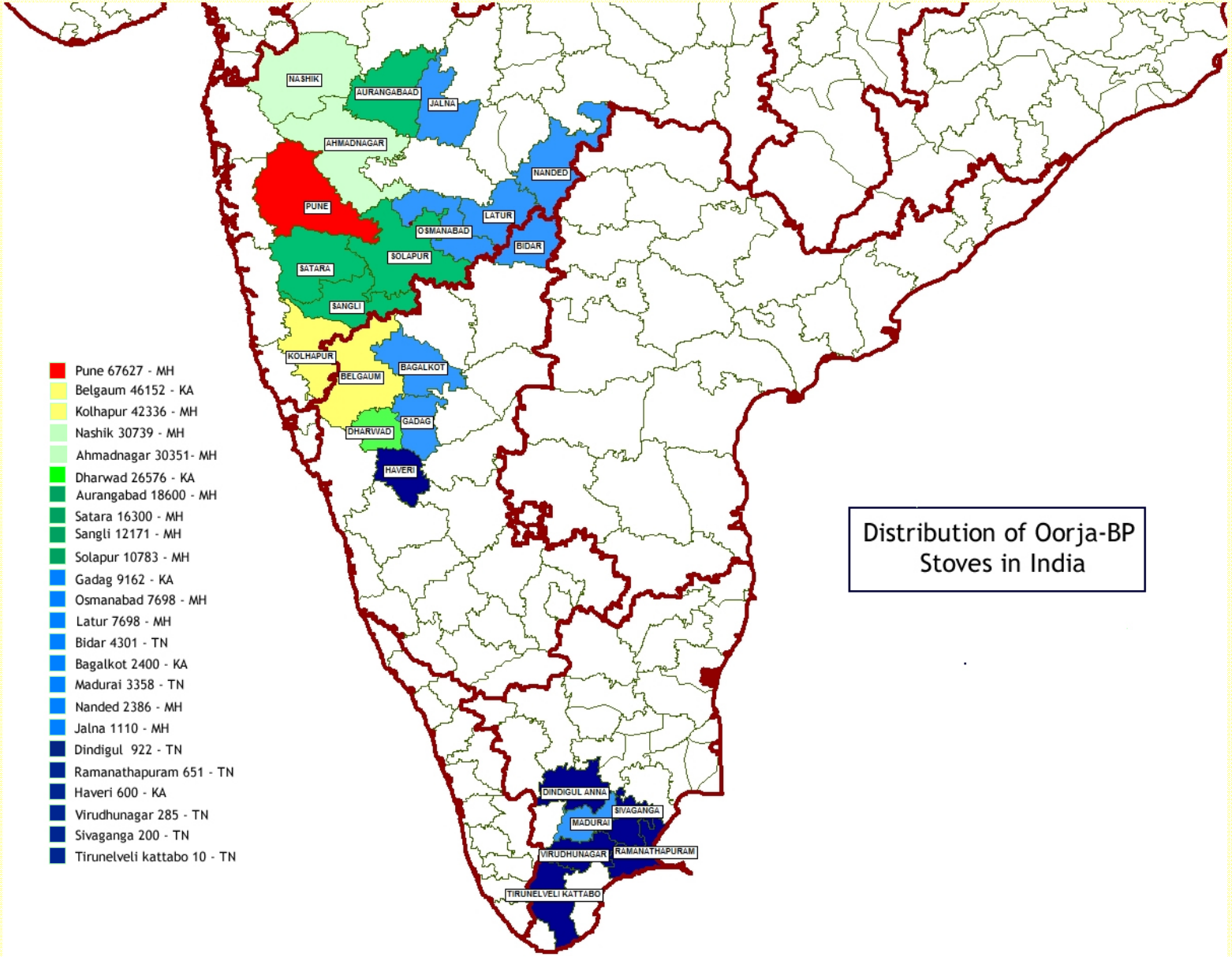
Domestic heat? – Reverse the downdraft gasifier



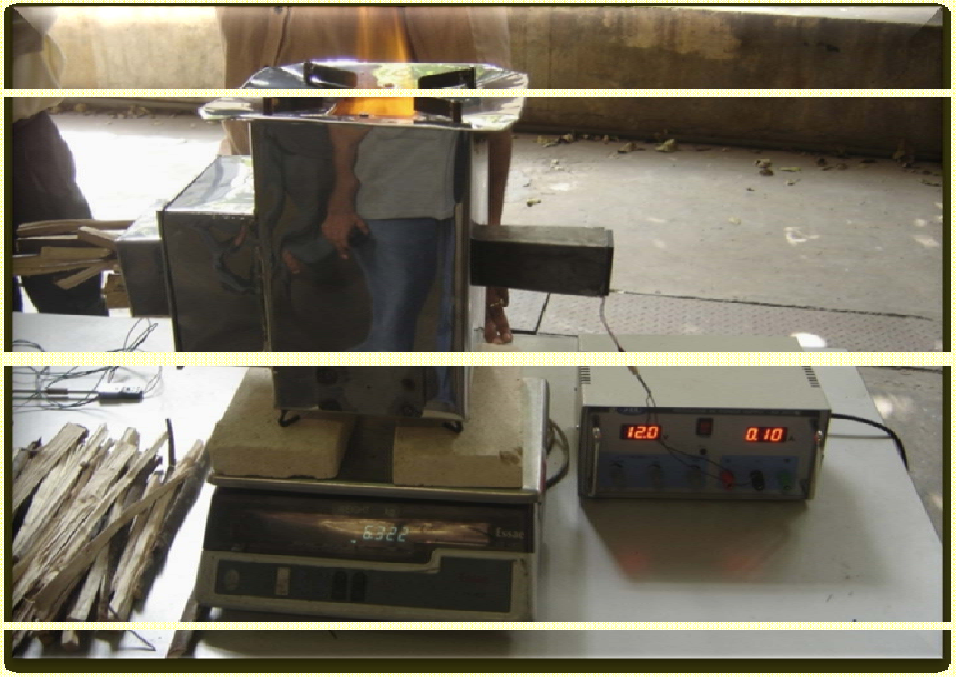


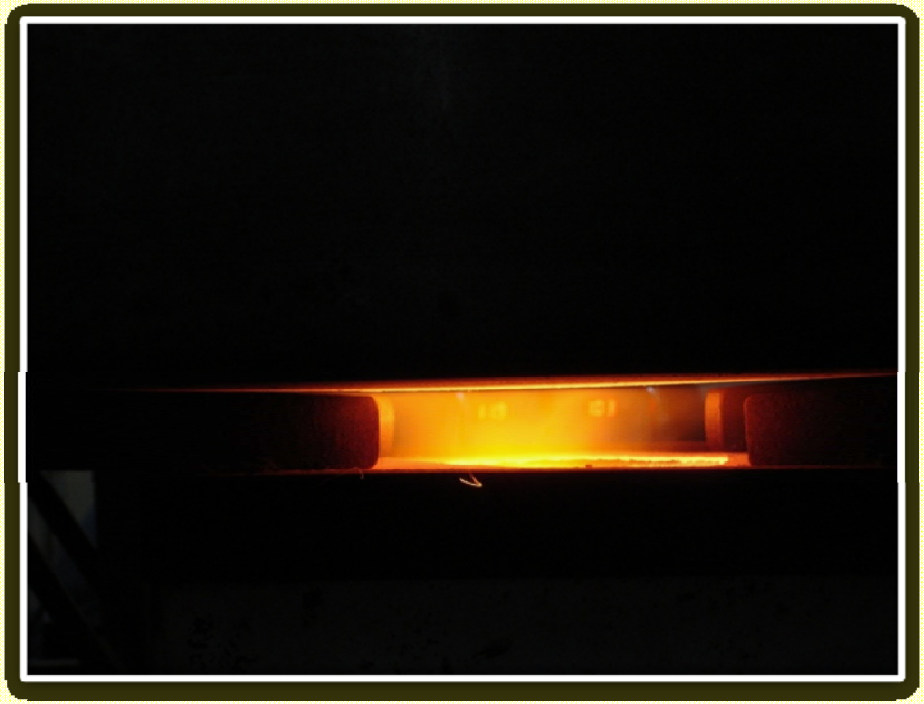
Close the side air nozzles; invert the gasifier

REDS – Gasifier Stove Tech transferred to BP, India



BP, India has commercialized and marketed 400,000 stoves





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 %

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

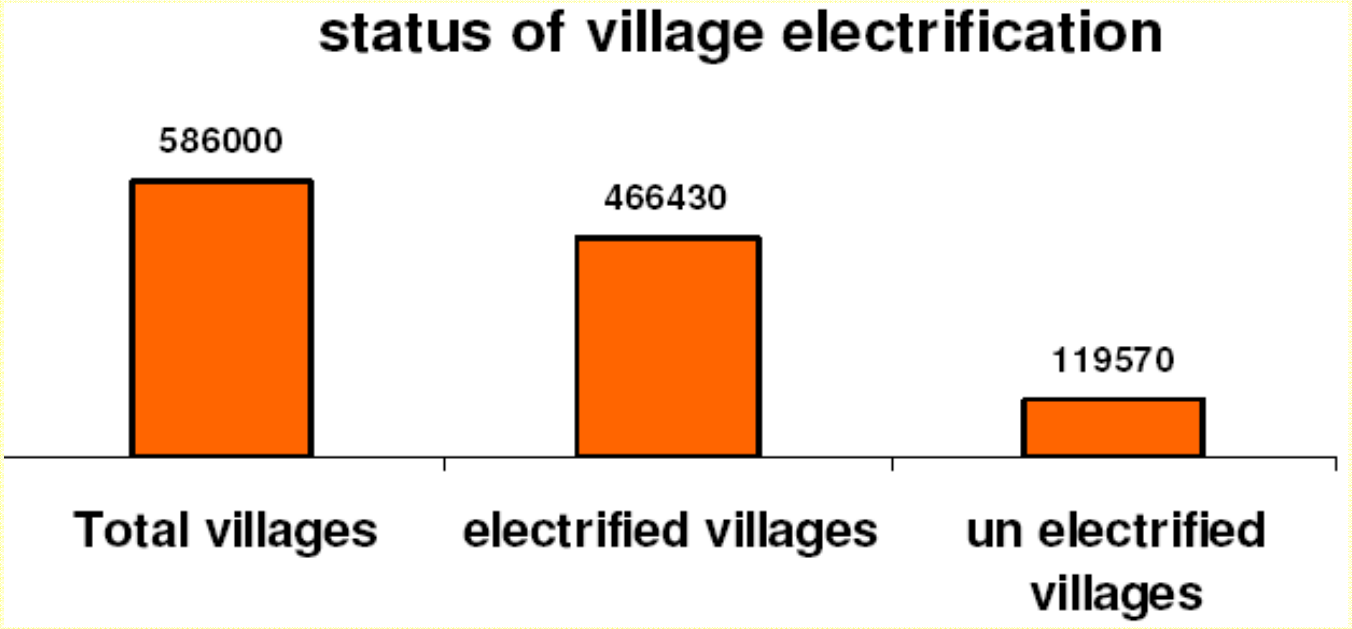
The National scene on energy,

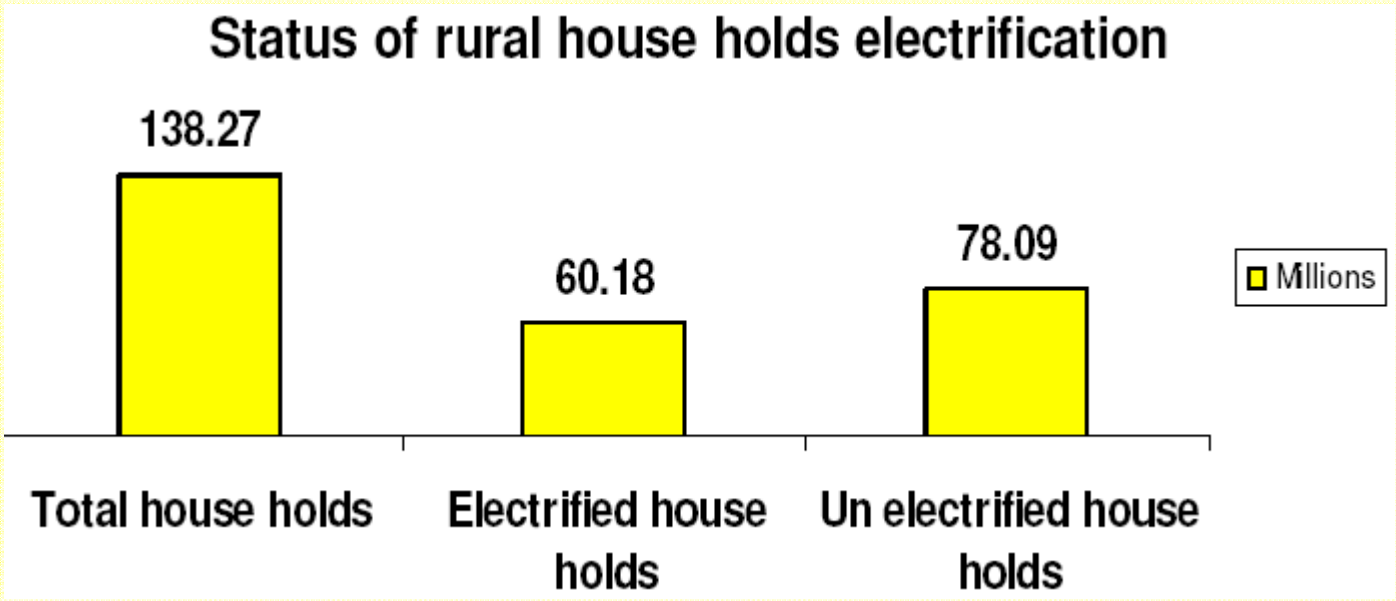
1. Electricity
2. Domestic cooking fuel
3. Transport fuel

….briefly

Statistics of Mwe installed apart, we look at

% People having access to electricity across the country


status of village electrification
586000
466430
119570
Total villages
electrified villages
un electrified villages


Status of rural house holds electrification
138.27
60.18
78.09
Millions
Total house holds
Electrified house holds
Un electrified house holds

Fuel usage over rural and urban households (HH) 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

The oil/gas sector

Derivative from crude oil	Amount mmt/yr	Nature of use
High speed diesel	40	Heavy vehicle transport
Furnace Oil/LSHS	14	Stationary power generation Combustion in furnaces
Naphtha/NG 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 Rural lighting/Domestic cooking/power
Total	31	Domestic / transport /stationary power

Our oil import bill ~ 30 billion dollars (~150,000 crore Rs)
Replacing Diesel has the greatest benefit to the economy

The national problems

1. Our national fuel related economy is fragile – depends on oil import enormously (OPEC can create misery to us simply!)
2. In the last ten years we have added to inequality in the quality of life in the country *rich have become richer*, poor have remained poor with inaccessibility to minimum services
3. This condition when it reaches beyond a stage can lead to societal instability, for large number of people have nothing to loose and some lot to loose (examples from history are abound – Tsarist Soviet Union).

And a way out?

For this purpose, let us take stock of our biofuel resources

Biofuels and wastes?

- Some seeds give oil that can replace diesel – Palms produce 5 t oil/Ha; Jatropha, Pongemia 1 t oil/Ha (Note the wide variation in oil productivity . Industries may get motivated to work for the higher productivity through biotechnology options)
- Oils constitute 30 to 40 % seeds. Other wastes are solid and constitute about 5 to 7 t/Ha dry matter including tree droppings.
- Culturable waste land area in India is 33 million Ha (NRSA document for MRD, GoI, 2005)
- Other solid wastes – plantation, agricultural constitute 250+ million t /year of solid biomass and urban solid waste of 40000+ tonnes per day (as a reference, the solid bio-fuel used for cooking in the country is ~200 million tonnes/year)

Bio-wastes….

- 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.

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

So, what is it that should be done…

- There is need for a national recognition of the problems and sources of solution within the country, *much like the way Obama has done recently for energy for the USA*
- What did Obama say to his nation on energy…

  Reduce dependence on foreign oil…15 billion USD per year to create new energy technologies – solar, wind, biofuels – and plug-in hybrid cars with new battery technologies…clean coal technologies with carbon sequestration…

- Occasionally we also claim we are doing something in these areas. But what we have done till now is just scratching the surface with knee-jerk reactions, disparate attempts that will produce results that will be adequate for breast-beating and nothing else. Can we expect some time a leader to have a clarity comparable to Obama? Or is it too much?

So, what is it that should be done…

- *Like Brazil*, Indian oil (w/ or w/o ONGC) should be the lead commercial entity that owns up and drives the bio-oil production process and its profit margins must include bio-oil.
- Make use of modern technologies for *distributed power generation* and cooking devices along with *solid bio-wastes* from *tree culture and oil extraction industry* to allow production of fuel for electricity and cooking.
- There are many actions that private industry can easily deal with, but the pathway through policy and schemes for using waste-land must be undertaken by the Government.
- What is being asked is a just Public-Private Partnership arrangement with due roles for each – not lots of investment money that was also talked of in Obama's speech. Even this needs lots of energy to kick-off…

What have you heard?

1. Making available electricity and clean domestic cooking solutions for a minimum quality of life for large population are large problems of our country.
2. IISc has developed technical solutions that have been field tested for reasonable time.
3. Oil-for-transport is another serious economic issue involving import of crude.
4. It is possible to combine these aspects into a solution package that makes our country rich, deprived rural segment have much better quality of life using commercial strategies
5. Getting things going through a public-private partnership with little Governmental financial investments is possible provided all concerned agree on the strategies.
6. *And some statements of exasperation* ..... Thank you