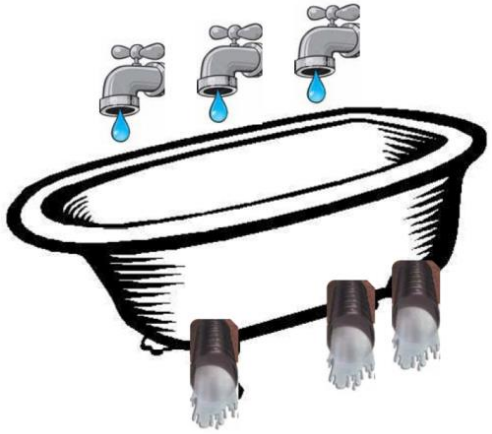
Biofuels – liquid and solid - Energy for future

- Background and details
- The World energy scenario today and in future
- Principal issues and way forward on liquid biofuels, cooking energy, and distributed electricity generation
- The final possible solution – biomass-hydro-wind-SPV combination



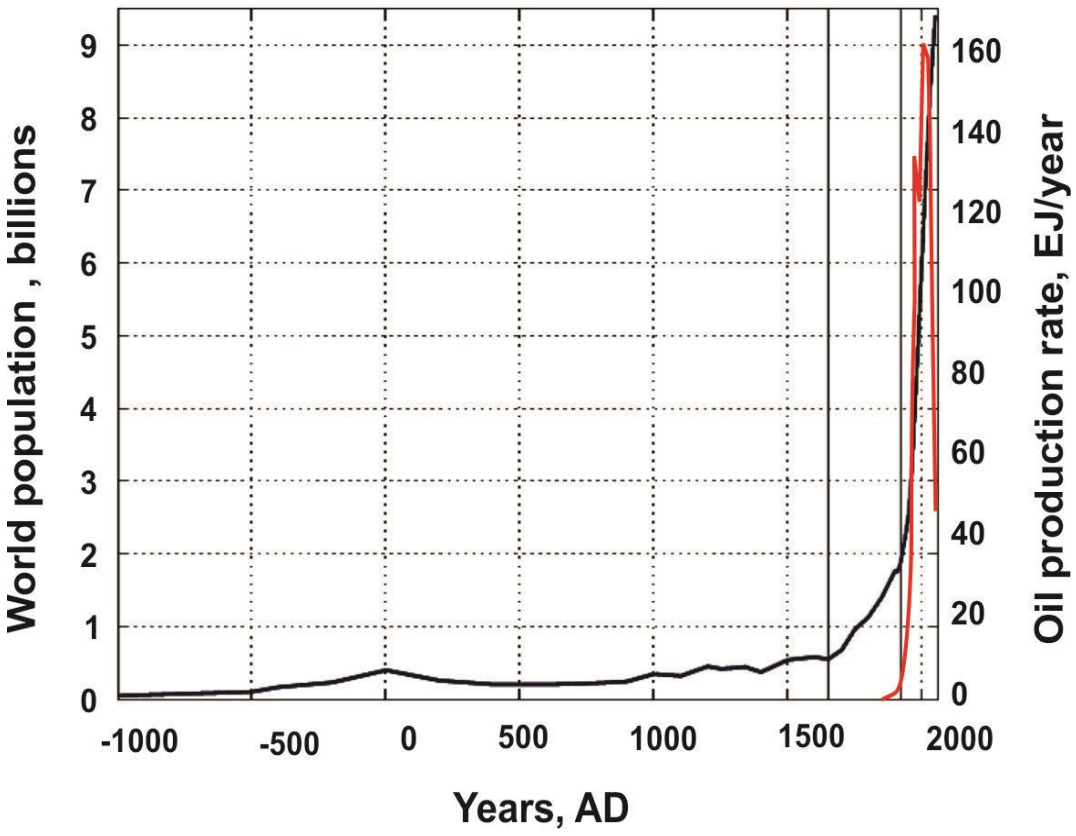
This is not a bathtub.

H. S. Mukunda

August 03, 2013, IISc-JU

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

From the last 3000 years…

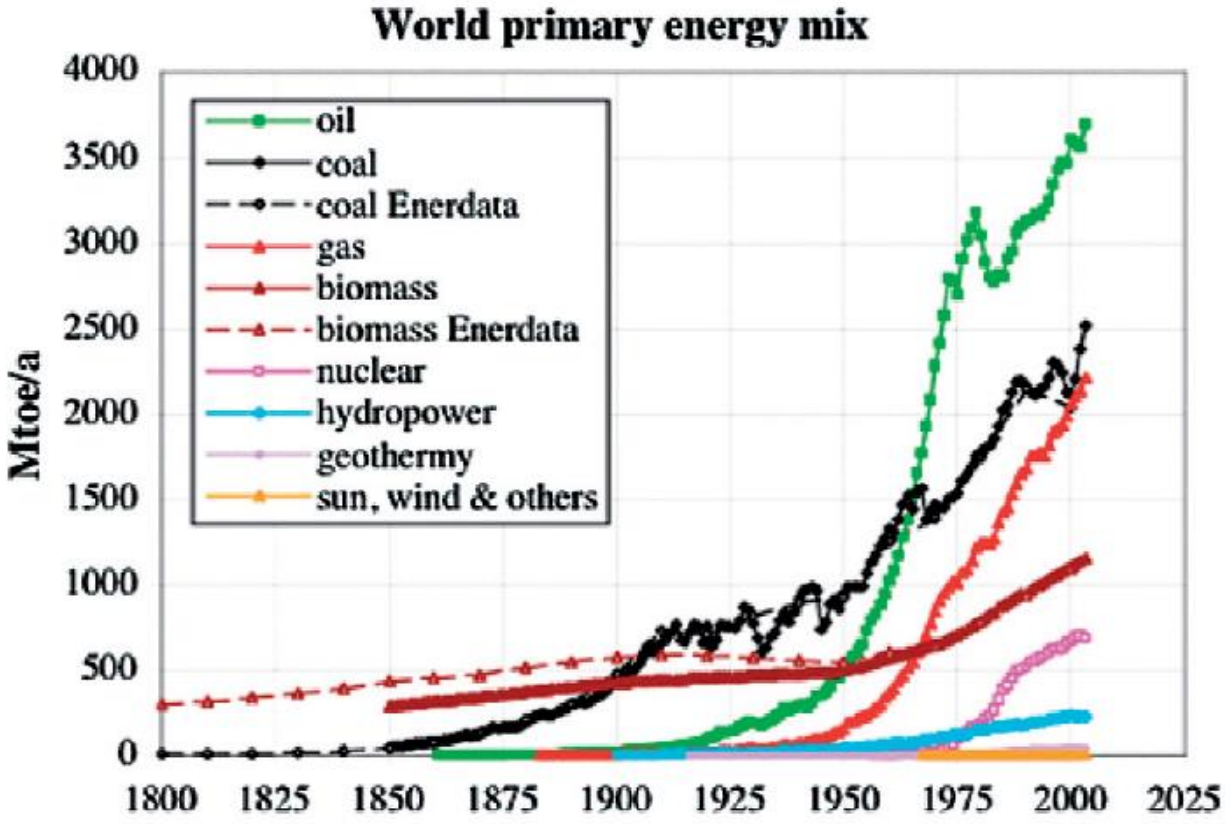


World population and World oil production over 3000 years that must have constituted about 60 to 70 human cycles; science also helped battle diseases that limited the longevity of human life and ensured population increase; **human civilization has been functioning without oil for over 2800 years; having discovered oil, it has produced and consumed so much that arguments about anything being left for use for the next generation loom large (drawn from Patzek, 2008)**

On richness/poverty of countries and so….

- One strong measure (not the only one, though) of a country's richness and economy is based on how much oil it has or its poverty measured by how much oil it has to import.
- Buying oil from international sources was considered a profession worthy of pursuit for the oil companies till about 2005. Oil ruled at less than 30 USD per barrel and this could be afforded by the economies *even if the population grumbled once in a while*.
- But the roller-coaster variations in the last seven years to levels of 140 USD per barrel and settling down to no less than 60 USD per barrel have woken up some countries (not India yet) to think of ways of mitigating the economic hardship.
- A further factor that has made international headlines is the aspect of climate change due to excessive emission of green house gases like carbon dioxide and methane.
- The implication of this development is that in future renewable energy sources must be brought to centre-stage. No rich nation wants to agree to this since the reduction in quality of life would be substantial as these directly impinge on their existence.
- In view of all these, it is better to deal with economy based decision making.
- And those who have to import to procure oil need to think indigenously and preferably, ingeniously. This unfortunately is not happening despite good examples from some countries.

The World energy mix



The range of primary energy sources and the magnitude of use over the 200 years over which most energy sources have been produced and utilized in the world (drawn from Hall et al, 2008)

World primary energy mix in million tonnes oil equivalent (mtoe)

Fuel \ Year	2004 mtoe	2010 mtoe	2015 mtoe	2050 mtoe	2050 EJ
Coal	2773	3354	3666	4000	160
Oil	3940	4366	4750	5000	200
Gas	2302	2686	3017	3500	140
Nuclear	714	775	810	1000	40
Hydro	242	280	317	500	20
Biomass and waste	1176	1283	1375	3500	140
Other renewables	57	99	136	1500	60
Total	**11204**	**12842**	**14071**	**22050**	**760**

The amount of energy used over the World in 2010 is 13000 mtoe = 520 EJ = 520 x 10^{18} J

Coal is largely used in power generation, nearly 95 % of it in standard steam cycle.

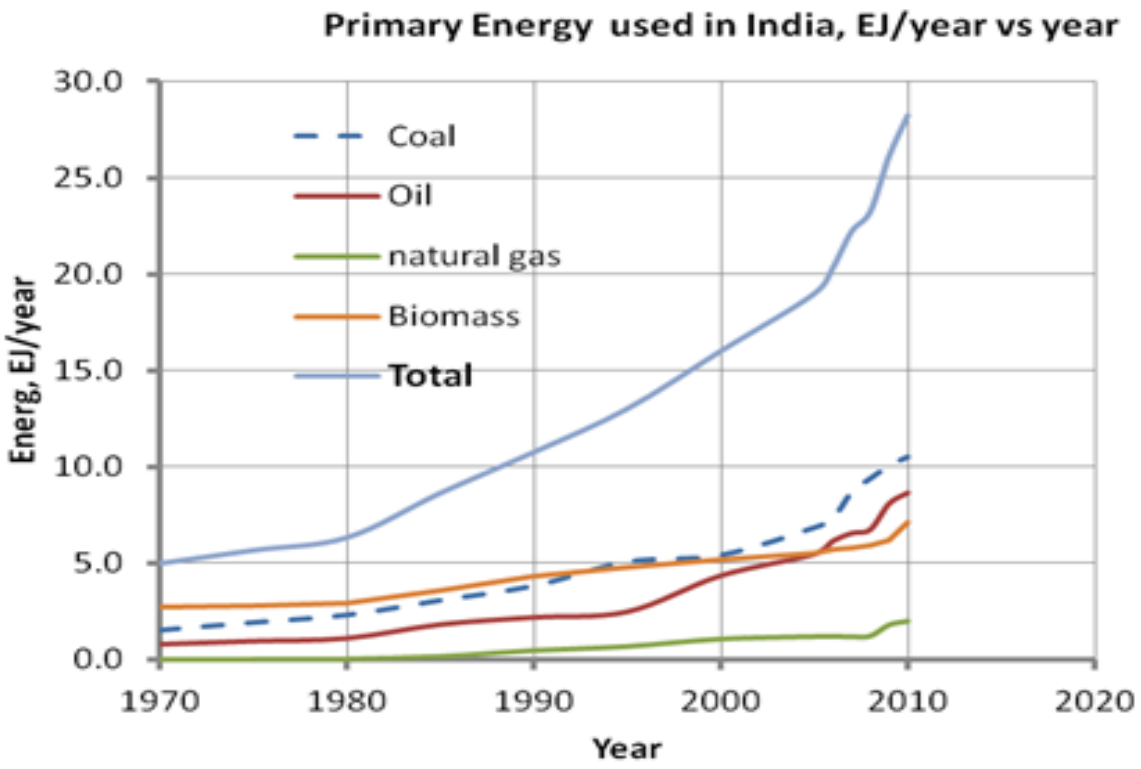
The break-up oil in terms of gasoline, diesel and fuel oil is important.

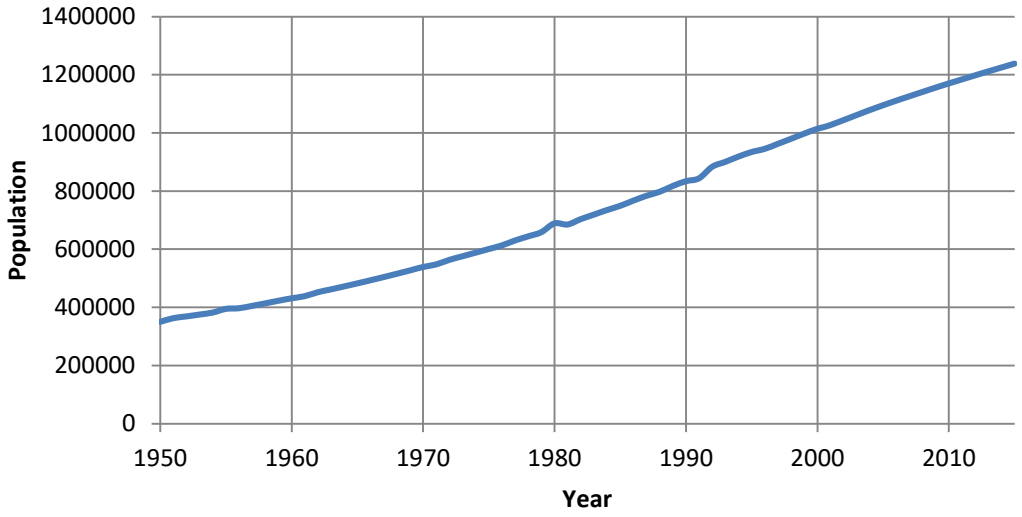
About 900 mta (million tonnes per annum) of gasoline, 1800 mta of diesel and 600 mta of fuel oil are consumed by the World.

Natural gas is used for stationary power generation, as domestic fuel for cooking and in some countries as fuel in city transportation due to its cleaner combustion features.

A remarkable feature is that biomass occupies a visibly important feature.

Biomass use is significant across the World





Total Indian consumption is about 4 % of the World consumption

Coal – 600 mmt

Biomass – 450 mmt

High speed diesel (HSD) - 78 mmt

Gasoline - 26 mmt

Fuel oil (furnace oil) - 20.5 mmt

Naphtha - 17.5 mmt,

Aviation turbine fuel - 9.6 mmt,

Kerosene - 7.7 mmt,

LPG - 7.5 mmt,

Other distillates - 15 mmt.

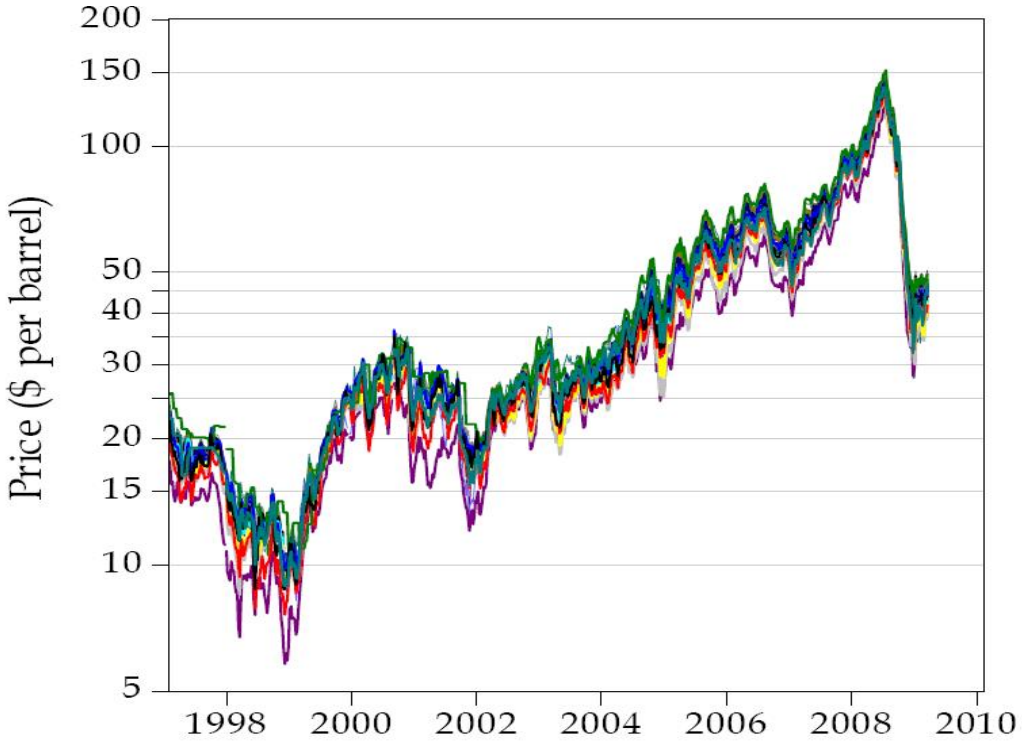
Note that biomass comparable to coal but used most inefficiently. Needs scientific, industrial and policy inputs to make its use efficient and reduce emissions from its use.

The issues

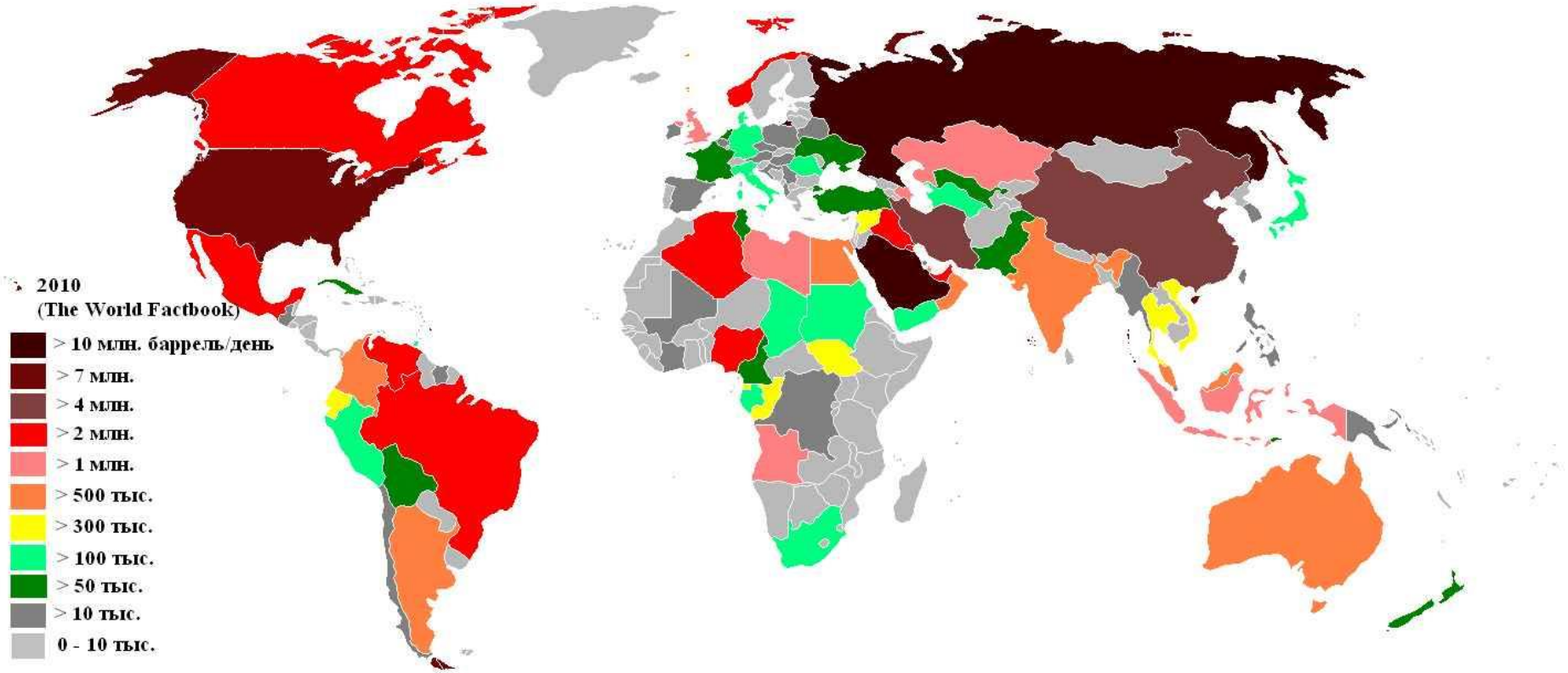
The oil problem

Rural cooking energy problem

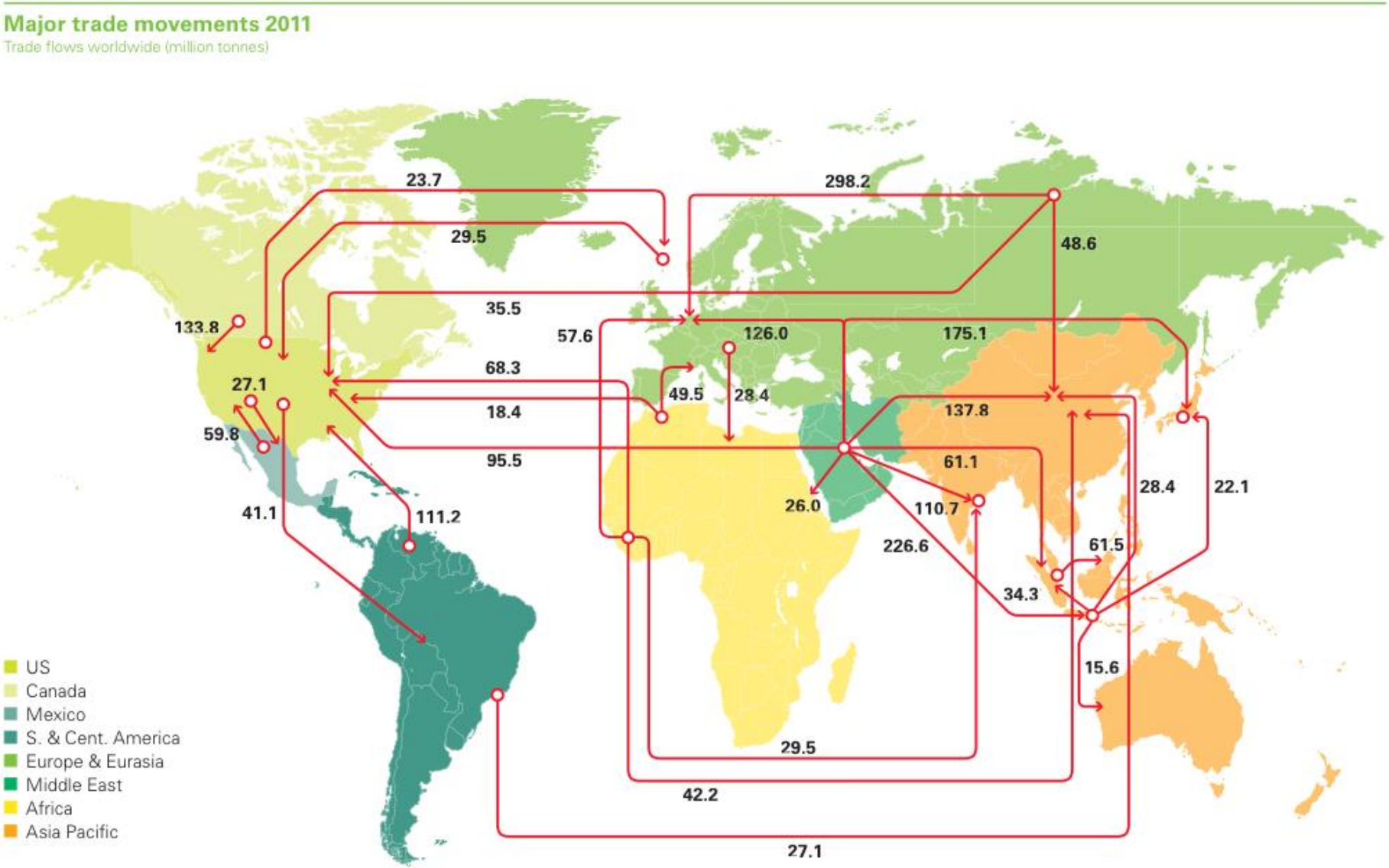
Rural electricity availability problem



The oil issue…production across the World



Major trade in oil – mmt, 2011



The Indian oil problem and similarly of others as well

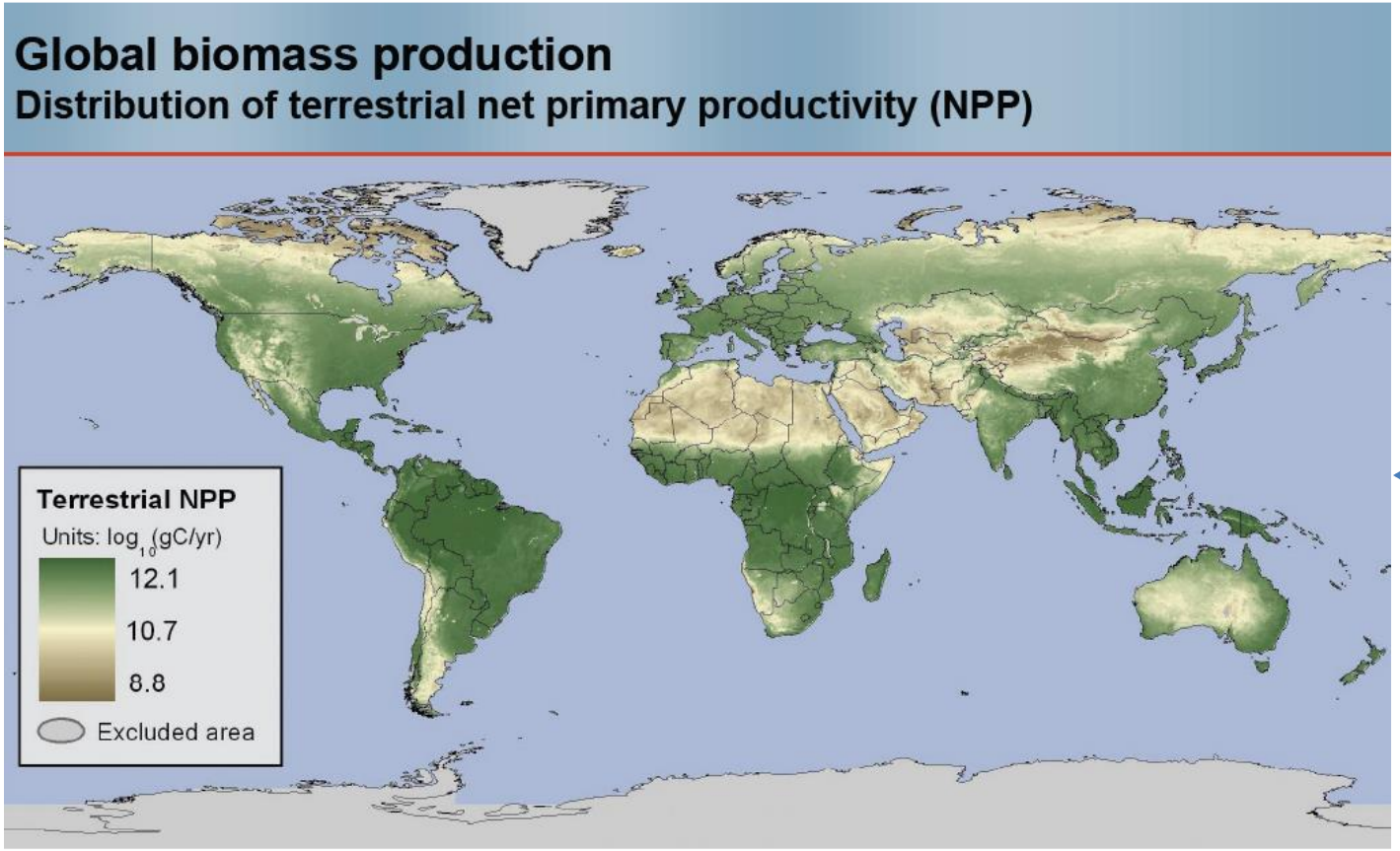
- In 2010-2011, India produced about 38 mmt crude internally and imported 164 mmt. As higher economic growth rate is demanded, the demand for oil increases. The internal production increases marginally. **Hence imports keep increasing.**

- A recent statement on oil imports of India by the oil minister Sri. S. Jaipal Reddy who indicated "India's oil import bill leaped 40 per cent to a record **$140 billion (Rs. 720,000 crore)** in 2011-12 as high oil prices shaved off much of the nation's GDP growth rate". That 10 years ago, it was just **$20 billion (Rs. 100,000 crores)** shows the enormity of the problem.

- The situation is similar in a number of countries in Africa and several other developing countries in the Americas.

Any way out of the problem?

One complementary approach is to grow biomass of the right kind on land that is not competitive by giving it to profit making industries with suitable long term fiscal incentives. The questions are: Is there enough land? What is the right biomass?



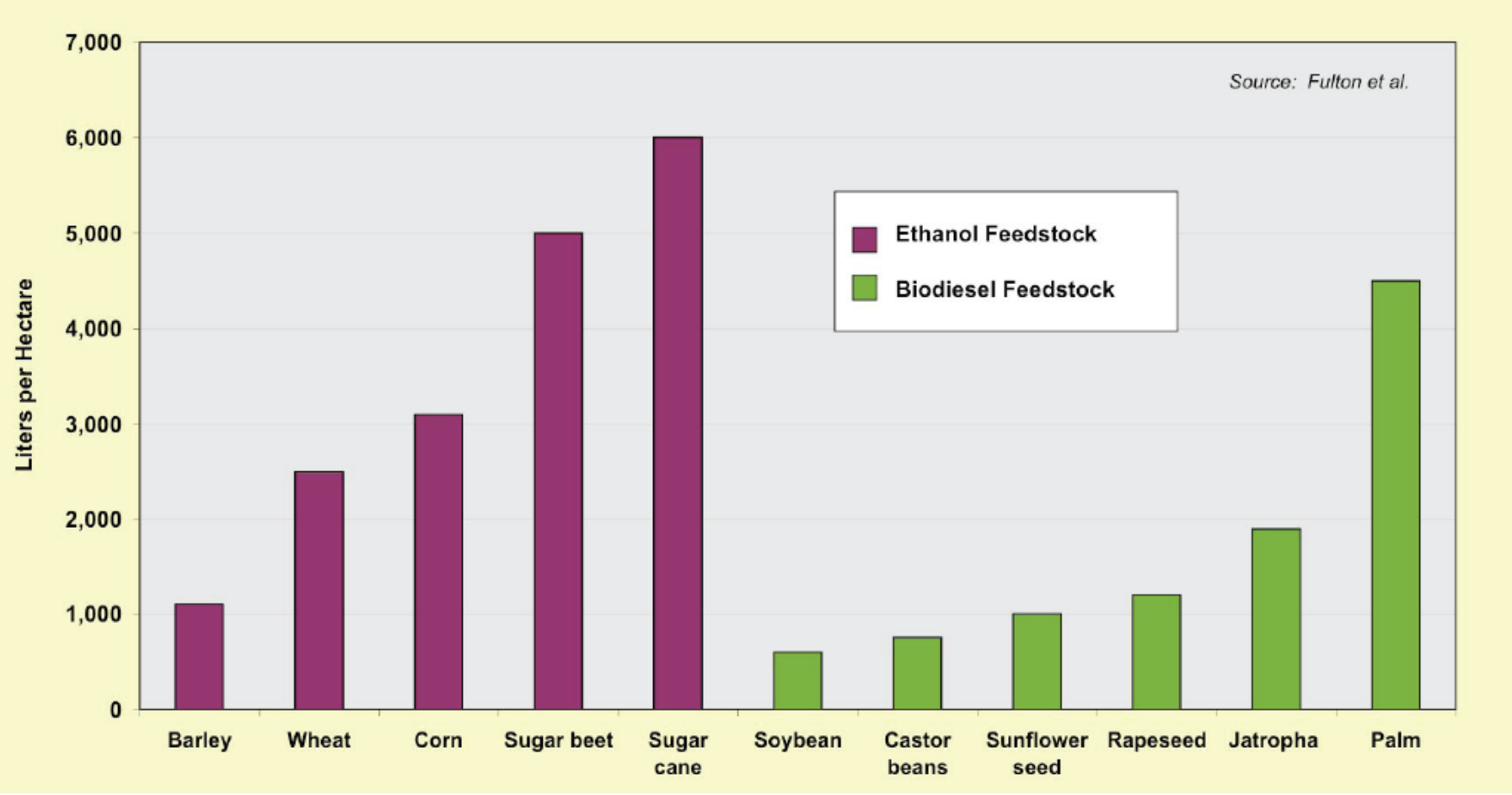
Equator

The land available for plant culture beyond agriculture is about 13 million-km^2

What are the issues and what do we grow?

- It is important to avoid land currently used as agricultural land to avoid societal conflicts.
- In non-agricultural land using appropriate investments create conditions for growing high productivity oil supporting biomass.
- We need to find replacements of high speed diesel to support long distance heavy vehicle transport and ethanol for light motor vehicle transport.
- To replace high speed diesel, one can use plant oils such as Jatropha curcus, coconut oil, palm oil and similar other oils. To replace gasoline, one can use ethanol.
- Excellent examples of exploitation of both are found in other countries.
- Brazil is a leader in ethanol production from the past fifty years. They have also produced fuel-flex vehicles that operate on 0 – 100 % ethanol-gasoline mix
- Malaysia and Indonesia are leaders in Oil palm cultivation and their economy depends strongly on oil palm production. Germany is a leader in Rapeseed oil. Brazil has recently moved into oil palm space.
- **Since any bio-based output has both food and fuel opportunities, produce more food than required for use as fuel to prevent food vs. fuel conflict.**

Liquid fuel output per hectare for different species



Sugarcane as a replacement for ethanol and palm oil as replacement for diesel are the high productivity possibilities.

Currently and in future…

- We need to meet the 120 million tonnes of sugar demand over the World. Sugarcane production is 70 t/ha/yr. 10 % is sugar production. Thus, at 7 t/ha/yr of sugar produced, the land area required is about 20 mha all over the World.
- The sugar production of India -- the world's largest consumer of the sweetener -- has reached 34 mmt in 2011 over 4.8 mha.
- If, in addition, we need to produce the energy equivalent of 800 mty of gasoline, the amount of alcohol to be produced would be 1200 mty. At 5 t/h/y of alcohol production, one would need 240 mha of sugarcane production.
- **Thus a total of 260 mha (2.6 m-km^2)of land in the tropical region is what is required to meet the demand of light motor vehicles.**

Biodiesel

- It is established through agronomic research, field development and actual practice that the yield of palm oil over large areas) is 4.5 t/ha/yr. Thus, the production of 2000 million tonnes per year of biodiesel using oil palm requires a land area of 450 mha (4.5 million-km^2).
- Thus the total land area required is 710 mha (7.1 m-km^2) for taking care of liquid fuels.
- The world consumption of edible oils is 140 million tonnes. The consumption consists of several oils based on palm, soyabeen, rapeseed, and peanut largely.
- The land required for edible oil production can be calculated based on the average productivity of 2 t/ha/yr as 70 million hectares.
- Thus the total land area required is 780 mha for taking care of edible oils and liquid fuels.
- **We can allow for 1000 mha (10 m-km^2) for producing food and liquid fuels for the entire world.**

Land availability

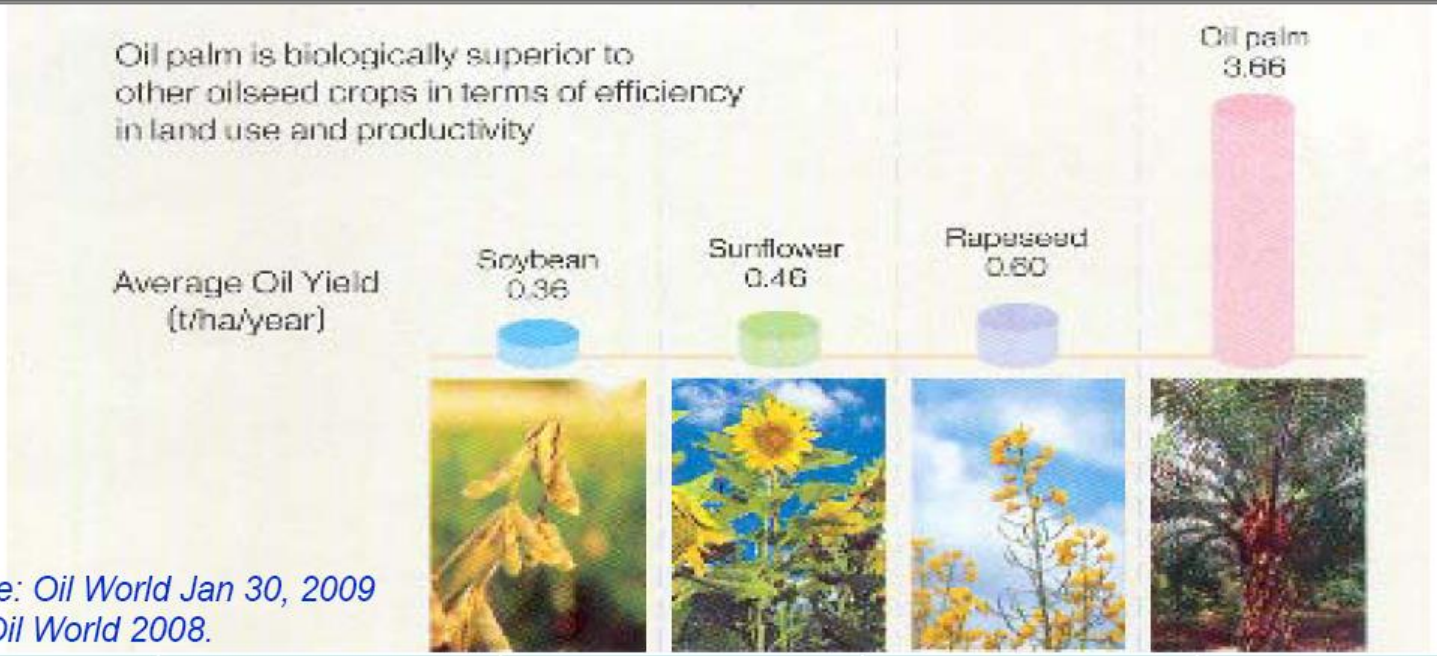
- The total land area of the World of 149 million-km^2.
- The data shows that over the world, the agricultural land is 48 m-km^2 and arable land is 13 m-km^2.
- Most of developed part of Europe has used 30 to 35 % of the land for agriculture.
- The whole of sub-Saharan Africa has 26 m-km^2 with cropped area of 6 m-km^2. Forest area is 5 m-km^2. permanent pasture is 9 m-km^2. Australia has at least 1 m-km^2 area available for plant culture.
- India for instance uses 45 % of the land area for agriculture.
- Yet, India has 10 % land that is culturable and has remained wasteland (or wasted land, 30 mha (0.3 m-km^2).
- Thus these magnitudes are indeed large.
- Thus world seems to have reasonable amount of land for growing oil bearing trees if it is driven to a stage when global societal consciousness is seized of the total problem.

What has palm oil production done to Malaysia?

Selected slides from the presentation made by Malaysia to

USITC, 2010, www.americanpalmoil.com/pdf/USITCpre-PublicHearing-V2.pdf

Oil Palm – the most productive oil crop



Source: Oil World Jan 30, 2009 and Oil World 2008.

Oil Crop	Production (million t)	% of total production	Total area (million ha)	% of total Area
Oil palm	**42.99**	**33.58**	**10.50**	**4.74**
Soya bean	**36.87**	**28.80**	**94.25**	**42.50**
Rapeseed	**19.82**	**15.48**	**27.15**	**12.25**
Sunflower	**10.80**	**8.52**	**24.09**	**10.87**

Major Vegetable oil production: 128 Mn T

Feedstock for biodiesel in Malaysia

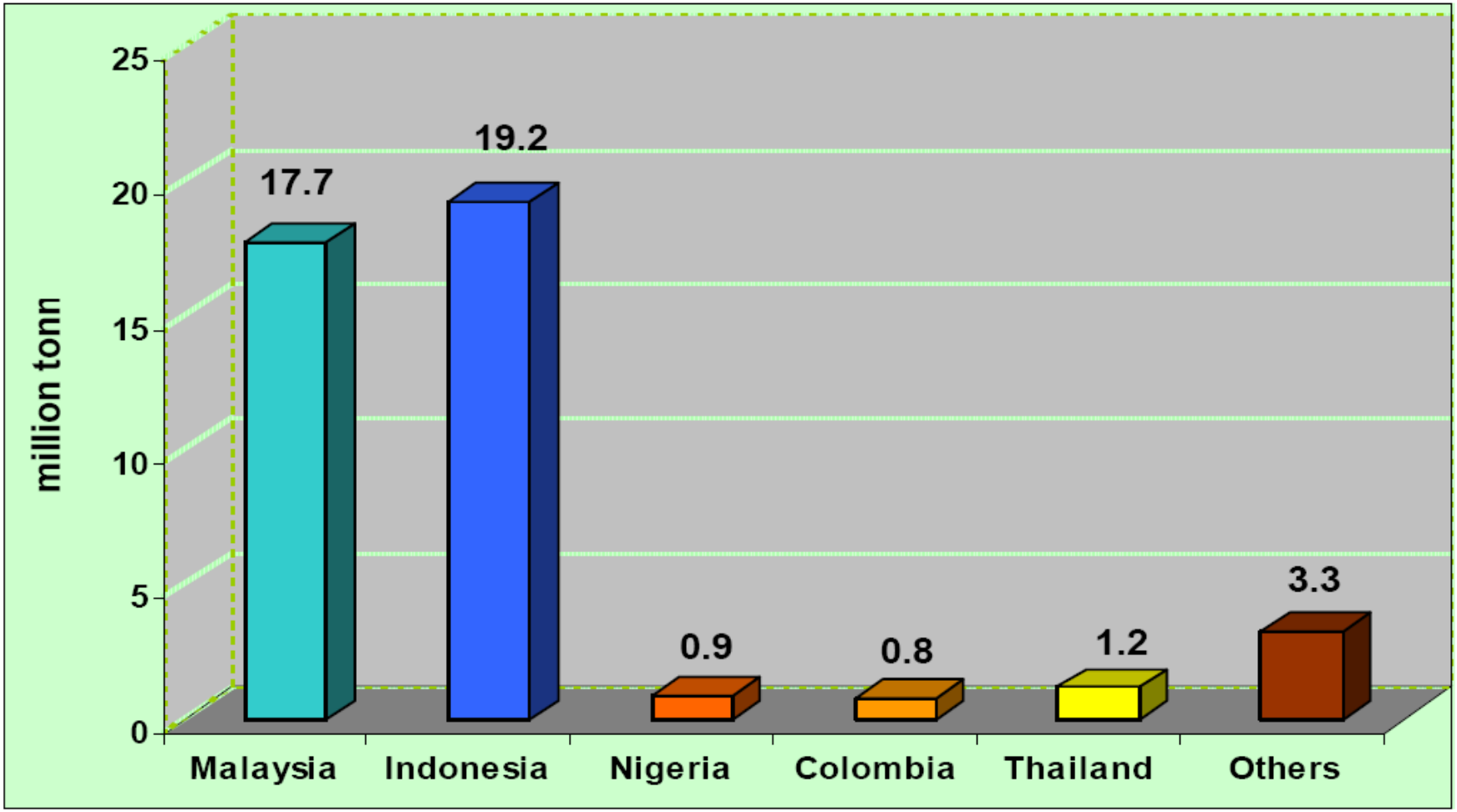
Fresh Fruit Bunch

Crude palm oil, RBD Palm oil, palm olein and palm stearin

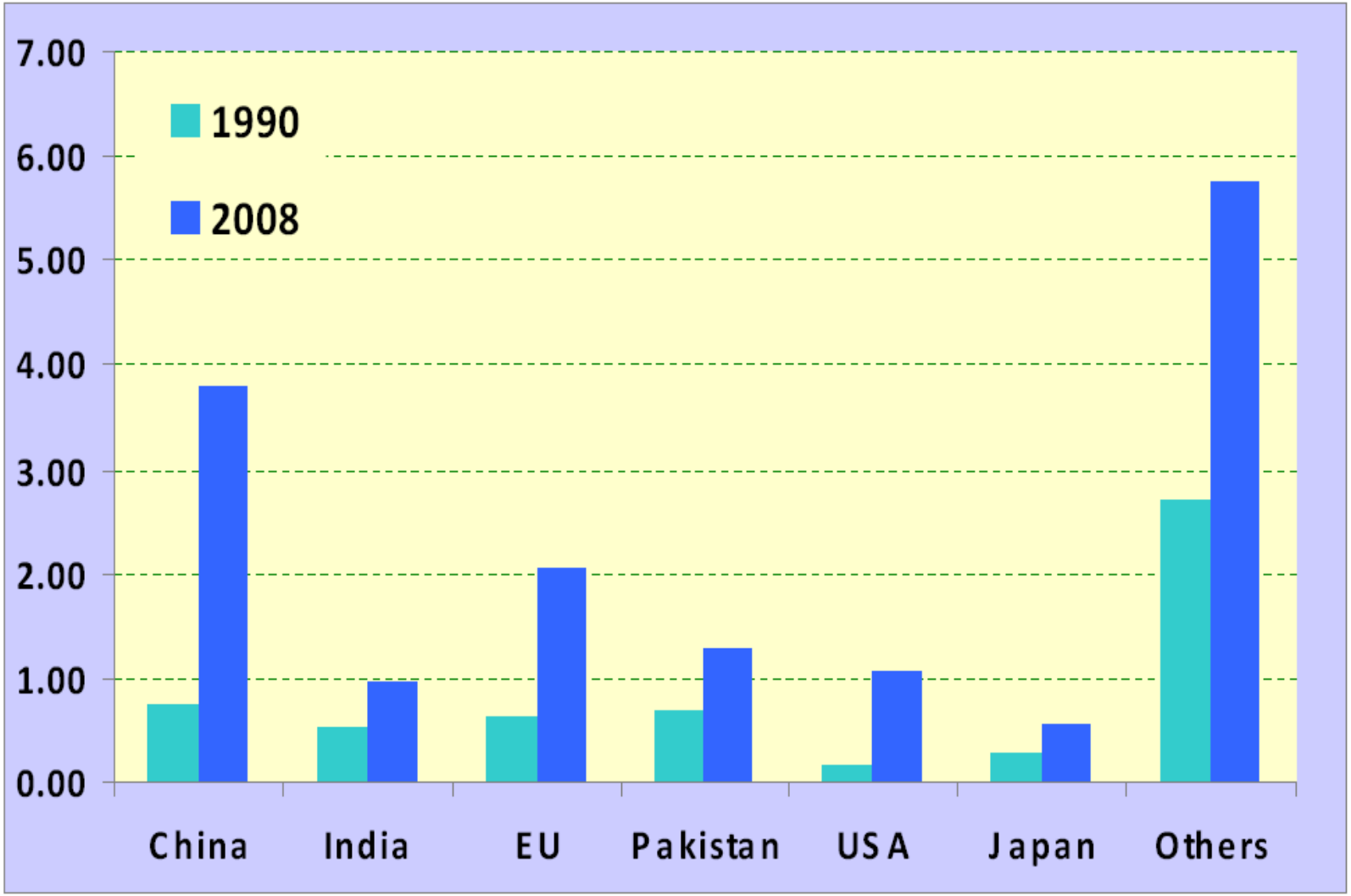
Used Frying Oil

Spent Bleaching Earth (SBE)

Comparison between Malaysia & Other Palm Oil Producers in 2008



Major Importers of Malaysian Palm Oil
(million tones)



Importance of oil palm to Malaysia

Year	Palm oil export value (RM/USD billion)	Export value of all commodities (RM/USD billion)	% of palm contribution in the overall export
1980	2.89 (0.80)	48.80 (13.56)	6.0 %
1990	5.50 (1.53)	20.70 (5.75)	26.6 %
2000	14.94 (4.20)	42.72 (11.87)	35.0 %
2007	45.61 (12.7)	89.60 (24.89)	50.9 %
2008	65.20 (18.1)	112.43 (31.23)	★ 57.6 %

1 USD ~ 3.6 RM

The oil palm industry : a major source of employment

Eradicated poverty and narrowed income gap between town and rural folk

Created rural townships where workers reside and enjoy good quality of life

Contributed to social security and peace

Reduced migration of labor force from rural areas to urban areas

Year	Area (ha)	People Employed (person)
1980	1,203,306	92,352
1990	2,029,464	115,285
2000	3,376,664	251,039
2007	4,304,913	420,000
2008	4,480,000	570,000

A total of 1.5 million in the sector; In Malaysia, the labor per hectare is 0.3; In India it is 2.5 Equivalent Indian job creation over 30 mha is 75 million.

http://www.nationmaster.com/graph/agr_wor_per_hec-agriculture-workers-per-hectare

Strengths of Plantation

- At a time when the flow of people from the countryside into the cities is creating major problems in Third World, the Plantation Industry provides contra-cyclical jobs in the heart of the countryside;
  - ✓ not only jobs for agricultural workers but also for skilled mechanics, fitters, laboratory workers, factory operators, drivers, office staff, secretaries and Managers.

- **The oil palm plantation industry is one of the few examples of an agricultural development in the Third World which, without any Government subsidies, can successfully compete with the highly protected farmers in the G7 countries.**

Using new variety of palm oil - High Yielding Materials

	CPO Yield tonnes/hectare/year)
Biological Potential of Oil Palm	18
National Average for Malaysia	4
Best Managed Oil Palm Plantation	8
New Varieties of Oil Palm	10

Is it not sufficient indication for India to move from 0.8 tonnes/ha/yr of Jatropha Grown in small area (10,000 ha class) to high productivity oil palm in large areas Following the experience of Malaysia/Indonesia so that the most important element namely, land area is minimized to grow what is required?

To produce 100 mmt of diesel varieties we would need as of now, 25 mha and when R & D improves in India as well, it could reduce to 17 mha.

The Brazilian approach towards ethanol to replace gasoline and palm oil + soybean oil to replace diesel

Renewable oil Policy – The Brazilian Program

- Petrobraz, the government company was mandated to spearhead research, development and commercialize the production and distribution of renewable liquid fuels, ethyl alcohol and biodiesel.
- Alcohol program – ambitious program lauched by the Brazilan government in the seventies; Gained momentum in the eighties; Faced some problems in the nineties
- The new technology Flex Fuel and the oil prices opened a new perspective for Brazilian domestic market; 7 million cars in 2012
- Biodiesel Program lauched December 2004 aiming to add 2% of biodiesel to diesel oil
- Procedures to incentivise the production: Tax incentives and social labeling – Just companies that have this seal can participate in the supply, etc

Moving on to

Issues of rural cooking problems

(technical and fuel availability)

Societies wish to survive first – Water, food grains and cooking energy are the fundamental needs

Then, they need electricity next for enhancing productivity

Then they wish to have quality of life electricity.

Size of the problem

- Roughly a third of the World population today uses biomass for cooking that turns to be the more essential need than the quality-of-life enhancing electricity. This amounts to 550 million households across the World!

- In India alone, about hundred and twenty million households (120 mhh) depend on biomass or the variants (like cowdung) for cooking

- Many countries produce charcoal as a cottage industry to produce fuel for cooking. A large part of Indo-china culture Believes in charcoal as the fuel for cooking and whole forests are brought down for this purpose –

- Cambodia is a leading example that uses effectively 12 kg biomass to for cooking a meal with 2 kg charcoal when even 2 kg biomass will do!

Figure 15.1: Share of Traditional Biomass in Residential Consumption by Country

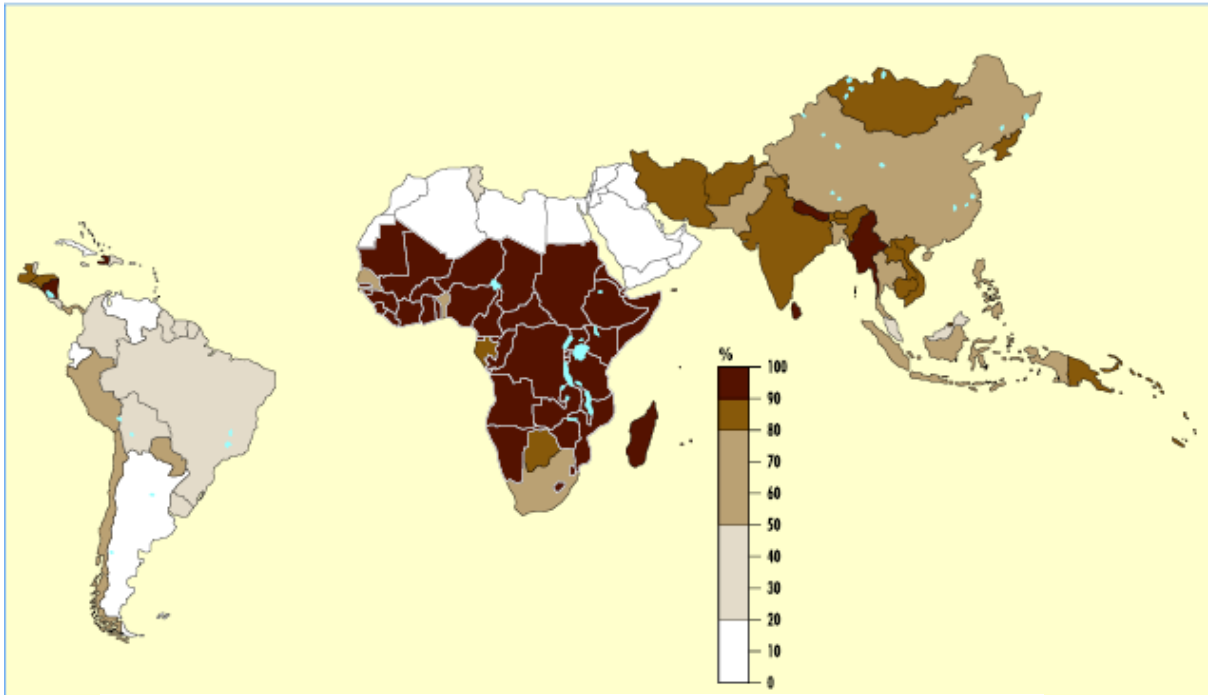
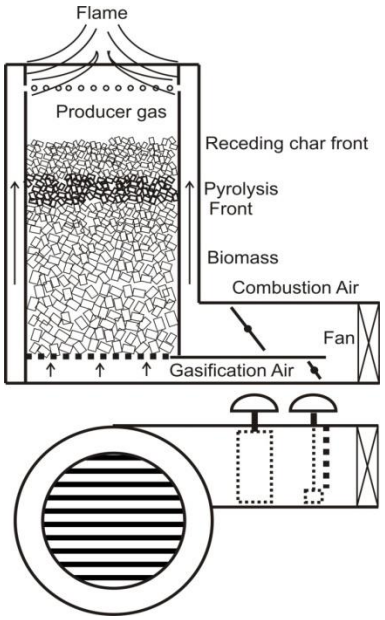


Table 15.1: People Relying on Biomass Resources as their Primary Fuel for Cooking, 2004

	Total population		Rural		Urban	
	%	million	%	million	%	million
Sub-Saharan Africa	76	575	93	413	58	162
North Africa	3	4	6	4	0.2	0.2
India	69	740	87	663	25	77
China	37	480	55	428	10	52
Indonesia	72	156	95	110	45	46
Rest of Asia	65	489	93	455	35	92
Brazil	13	23	53	16	5	8
Rest of Latin America	23	60	62	59	9	25
Total	**52**	**2 528**	**83**	**2 147**	**23**	**461**

Sources: IEA analysis based on the latest available national census and survey data, including the 2001 Population and Household Census of Botswana; the 2003 Demographic and Health Survey of Nigeria; the National Bureau of Statistics of Tanzania, 2000/01; the 2001 Census of India; Energy Statistics for Indonesia, 2006; the Bangladesh Bureau of Statistics, 2005; the National Statistical Office Thailand, 2000; ORC Macro (2006); WHO (2006).

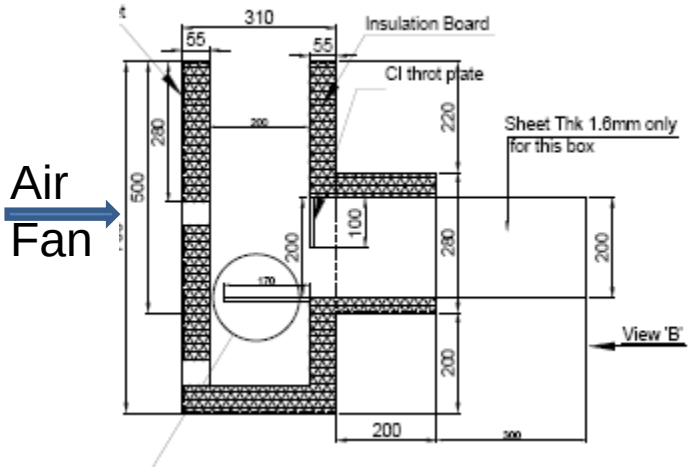
New methods for Domestic cooking/heating needs



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.

Another approach - EIGAS



Principle – Ejector induced gasification based stoves – continuous fuel feed – **can deal with firewood**

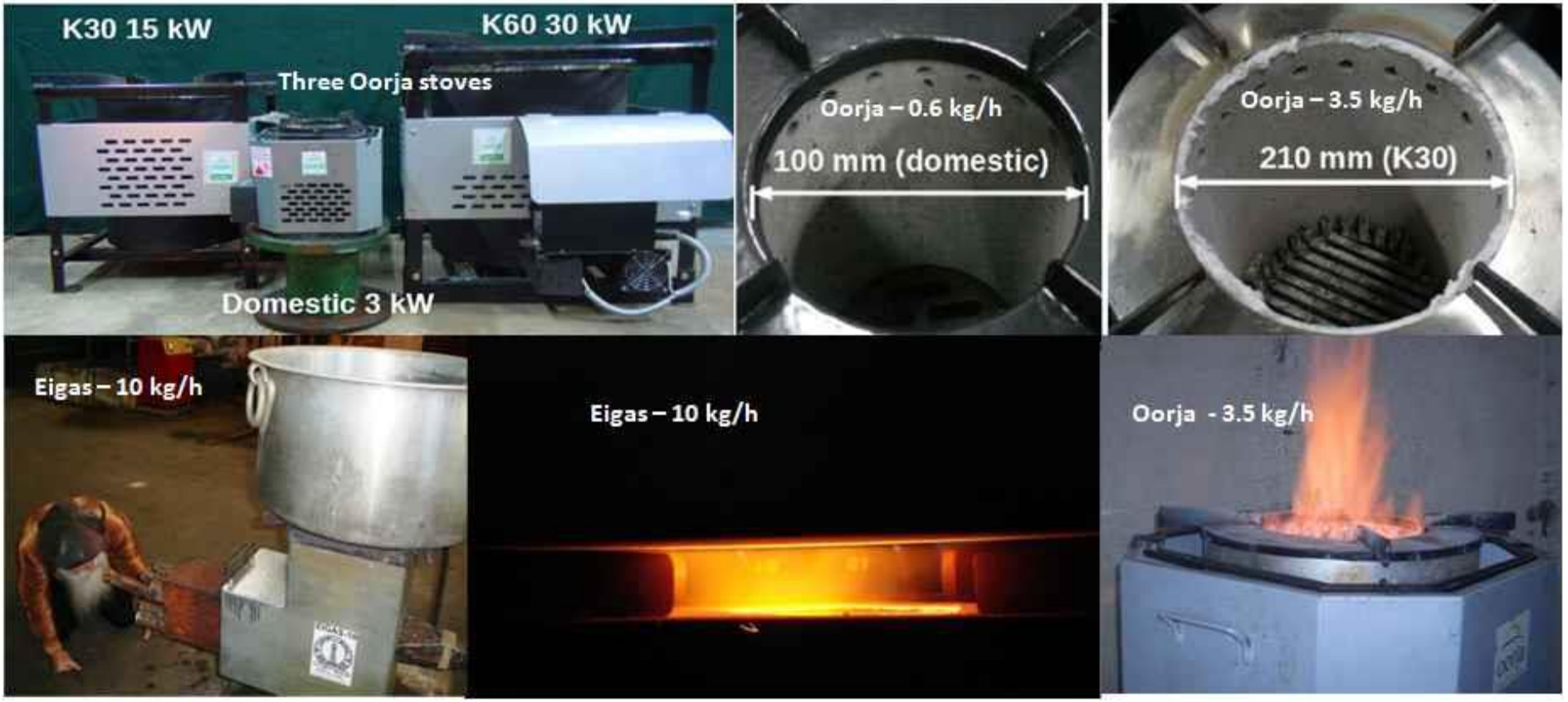
An ejector induces an air that draws air through a fuel bed horizontally located

The use of partial blockage helps the gasification process.

The char bed on the grate allows gasification process to be completed.

This has been industrialized at various capacities and will enter the market.

Currently, additional research on this class of configurations are underway at CDM, JU



Various industrialized modern fan based HELE biomass stove designs realized by industries and used in practice

Achieved: 2 x 0.6 kg = 1.2 kg pellet fuel using agro-residues or fuel wood for cooking

Efficiency = 55 % (water boiling efficiency) = 80 % more than three-stone fire stove

Emissions – see next…

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**

What about solid fuel availability?

- When oil seeds/fruits including oil palm are processed, it is only about 30 % that leads to oil. The rest will be solid waste. Part of this may go as fodder and the rest for energy purposes. Every such plantation also produces other solid wastes to the extent of up to 4 sun-dry t/h/y.
- The net effect is that about 2000 mta of solid waste is available for energy conversion purposes.
- These wastes (and classified urban wastes) can be and should be converted into solid fuels – in the form sized material and pellets and briquettes with *controlled quality* - size, shape, density and ash content declared - for use in domestic stoves and industrial operations for heat and electricity generation.
- Unless fuel is costed, *it will be wasted most usually* – or used rather inefficiently without real concern for wastage.
- This may pose problem for finders-keepers idea of a rural situation. But then quality cannot be expected unless society pays for it.

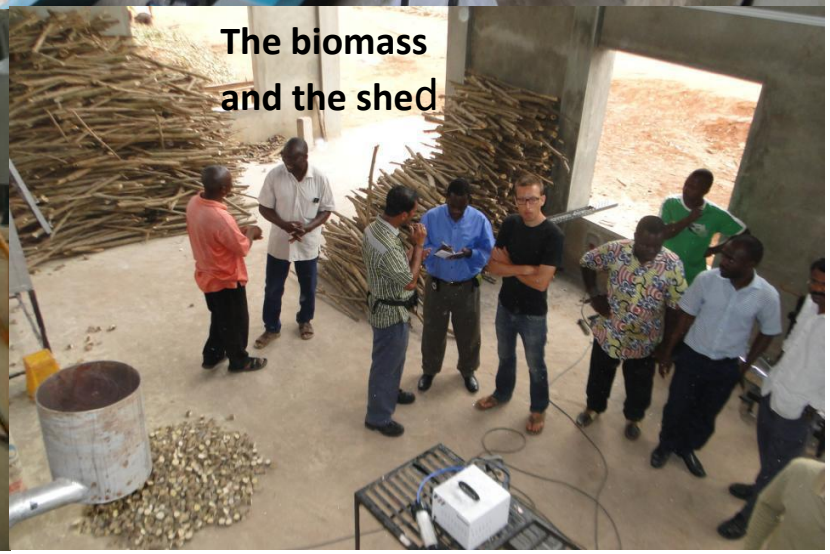
Renewable electricity - The options and features

- Wind - much enthusiasm all over the World, including India – an intermittent source - valid at reasonable and large power levels - useful for grid linking – PLF ~ 25 % (15000 MWe in India, 2011)
- Solar – again, far more enthusiasm all over the World, including India – an intermittent source – can be generated PLF ~ 25 % (40 MWe in India)
- If these become smaller fraction of conventional power, grid linking helps usage very well. If stand-alone wind and or solar has to be the main supply, one needs to find ways of storage – usually battery or fuel cell. This is expensive and other methods are far more inefficient.
- Hydro power – large and small have a plant load factor of 70 to 75 %. It is also possible that major failure of rains causes serious loss of hydro power – Several countries have experienced it – Brazil, some states in India. (small hydro ~ 3300 MWe in India)
- Biomass and waste to energy are base load power sources as long as the use is limited to or less than production. These can form 24 x 7 option much like coal. Realization of this feature is still to sink into the total systems. (3000 MWe in India)

Biomass electricity

- If domestic applications are to be serviced for quality-of-life electricity at 50 to 200 W capacity, SPV is the only option at this time.
- If a village has to be serviced with electricity for Q-o-L demand as well small industry requirement, biomass option at 10 to 100 kWe is the most appropriate economic option.
- Biomass has a lower density and its growth is widely distributed.
- For economic transportation, It is better to use the biomass in power plants of a maximum of 2 MWe class (that requires 15000 tonnes per year) rather than 20 MWe (0.15 million tonnes per year). The latter is economically and environmentally unsustainable in India and countries with small land holdings.
- Economically operating power plants at power levels of 25 kWe are possible.

600 tonnes of coconut shell being stored on the industrial site and a 1500 kWe reciprocating engine systems with 1700 kg/h gasification system (IISc design)



The biomass gasification – reciprocating engine based power generation system of 25 kWe capacity (consuming about 30 kg/h dry cut biomass) deployed in a village Songhai in Benin, Africa (the technology provider IISc, Bangalore); left – gasifier, middle – 25 kWe producer gas based spark ignited engine and right: biomass store and the gasification plant area with technicians from IISc and others from Benin and Nigeria undergoing training on operations and maintenance of the system

Finally, Is the living on the planet energy-sustainable?

Yes, if we

Regulate the population; Look for fulfilling needs

not very much more – slow down

Care and conserve where we can; Increase end use efficiency and reduce emissions thereby.

Grow more and appropriate biomass to help support liquid fuels for transportation and other objectives as economically as feasible.

Residual solid bio-fuels are those that can be depended upon for cooking heat and economic distributed electricity generation.

Finally, biomass for liquid fuels, biomass-hydro for base load management and wind-SPV as intermittent power generators feeding into grid appears to be a conceptually meaningful solution for meeting energy needs of the future.

.....Thank you