Energy for rural sector

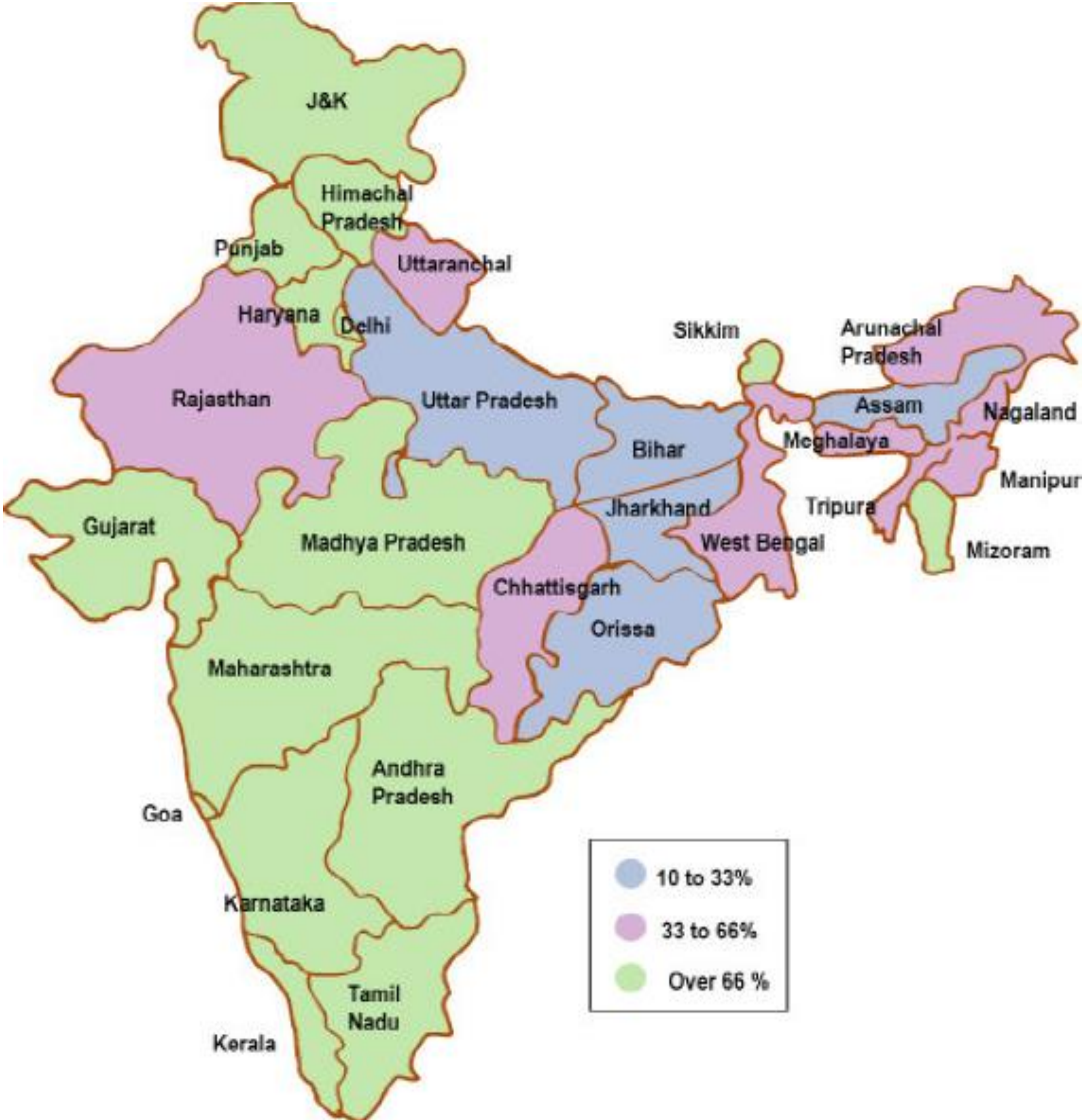
- Electricity – lighting, fan, refrigerator, water pumping for drinking water and irrigation, cottage industry, if any
- Heat – cooking, bath water heating, cottage industry

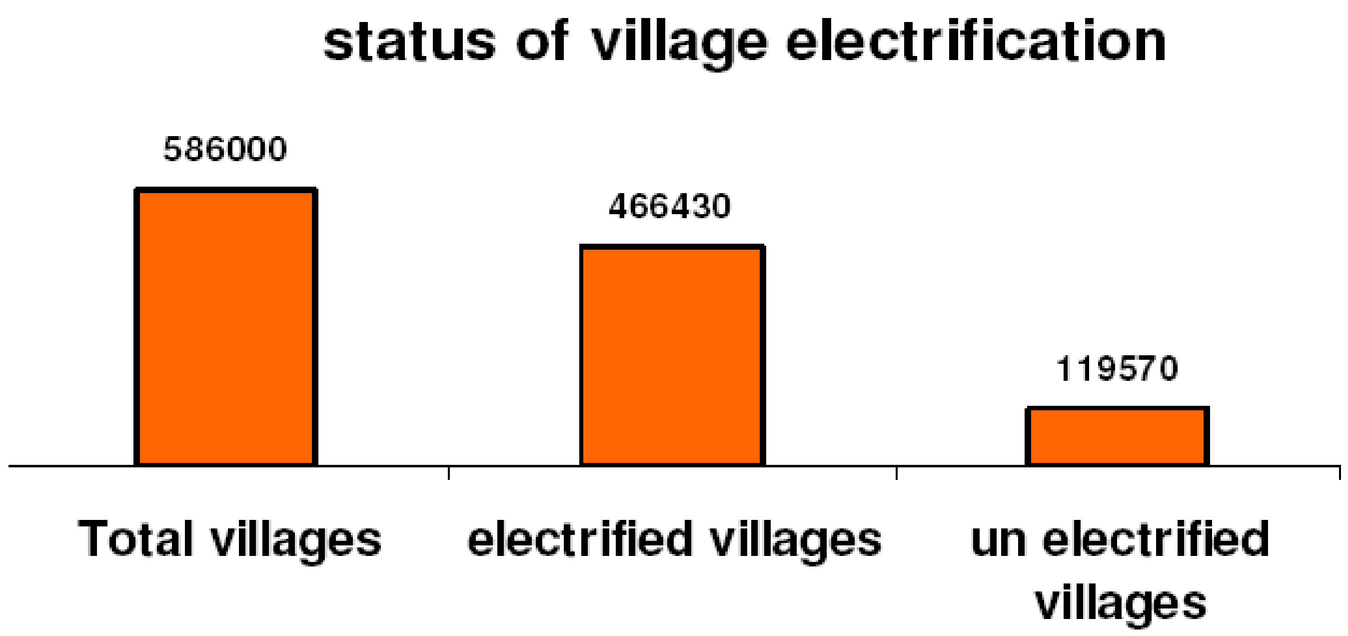
Small Business Forum, IKST-CST

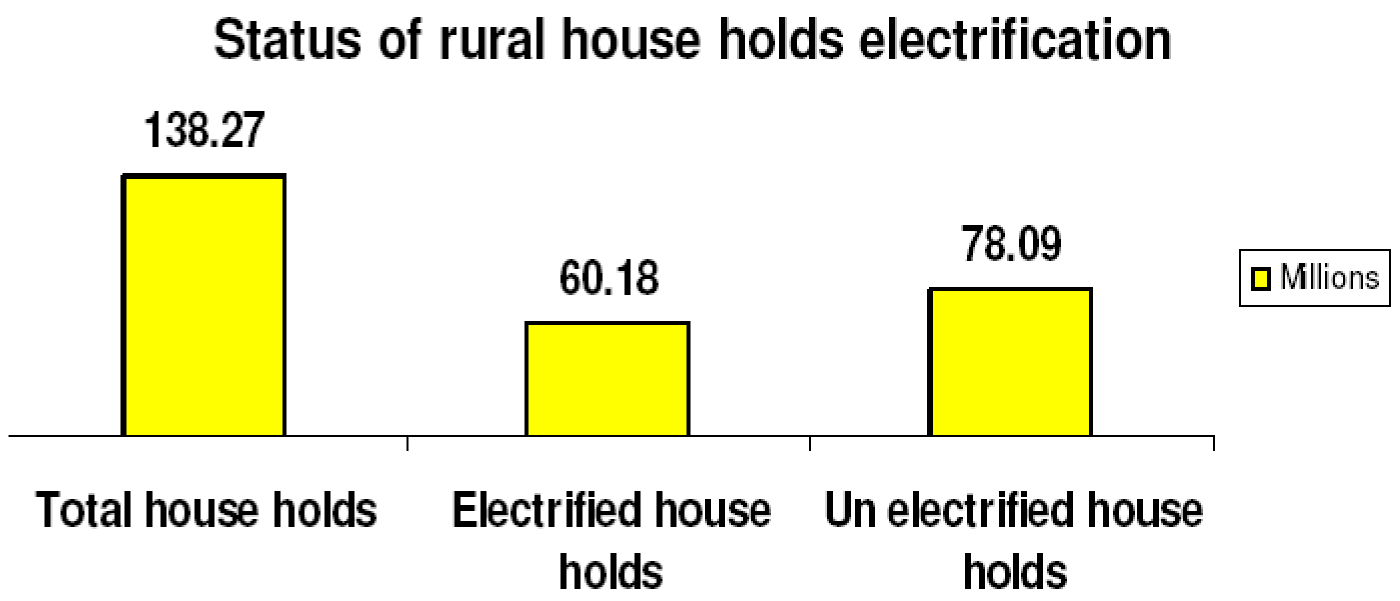
H S Mukunda,
CGPL, Aerospace Engg Dept, IISc, Bangalore
http://cgpl.iisc.ernet.in

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

Electricity for homes

- Over 75 % households and 100,000 villages are without electricity in India.
- Grid electricity has not been able to achieve the outreach (for several reasons)
- Similar is the situation in several other developing regions of the world. In particular, the large number of hamlets and villages in the inhabited islands get their electricity supply for the quality of life and some minimal productive activities from D-G sets. This electricity is very expensive (~25 US cents/kWh)
- Distributed electricity generation or small IPPs are the answer, a subject encouragingly discussed in many parts of the world.
- The minimum-most need is ~200 W max and about 50 W min over 18 hours a day every family. Over the rest, the demand drops to a quarter/fifth this value
- Quite often, SPV is considered an alternative for providing lighting, particularly for school going examination beset children – for several hours at night.

Issues with Grid Electricity

1. Grid electricity is State controlled, largely. The State has the right to pick and choose to give free electricity to whom-so-ever they think should be so rewarded, *even if they know that nothing ever comes free*. This feature has been practiced for varying periods of seven to ten years in different states across India.
2. This has led to many ills
   a. The state utilities have become nearly bankrupt and/or do not have resources to modernize the generation-distribution network. *Changes are taking place, but at too slow a pace.*
   b. To partly overcome these issues, they restore rural electric supply only during nights. *Rural folk have resented this over a time.*
   c. This has led also to indiscriminate ground water pumping to an extent that the water table has gone down over large tracts.

Alternates - 1

Can one perform generation at 250 kWe to 1 MWe and distribution over a single or a group of villages/hamlets with additional facility to grid up-linking and third party sales after meeting the requirements of the villages?

Ans: Yes, of course. One can implement such projects at the lowest investment cost with biomass gasification based ideas.

But most plans do not separate the generation from distribution and tariff collection. If the state distribution can take responsibility *to pay for the power generation at reasonable rates* and also ensure fair practice of meeting the demands of the villagers, things will succeed.

Are there success stories? ……..

Alternatives – 1 (contd)

There are no complete success stories to speak about.

- In a major project that got initiated due to the work of academics of ASTRA (present CST), Bio Energy for Rural India undertook to set up up-to 1 MWe biomass gasification based power packs.
- Due to a variety of governmental decisions, the situation was brought to a stage that a perception got created that "gasifiers won't work" When it was brought to their attention that these are working well in private sector, they said: "gasifiers won't work in public sector"
- It took a clear 1000 hour continuous run (plus another 1500 hours) to demonstrate that gasifiers indeed work – provided the systems are dealt with due respect that they need. Commercial demonstrations in such projects are yet to be done.

Perhaps, we may have to go some way before the gasification systems are accepted by the society despite their dire need. …….Dire need?

Dire need?

- Large number of villages, particularly in the northern belt still suffer lack of electricity.
- Much business in the evenings and nights goes on with diesel electricity that is both expensive and highly polluting.
- Desperation is writ on most people for the lack of quality-of-life electricity.
- Telecom sector that has a large number of towers almost always has a D-G set that appears to operate for over 3000 hours a year in a large number of areas. The power level is ~ 2 – 5 kWe.
- Can something be done by combining a better paying client (the telecom operator) and the villages who also may pay lower tariffs to construct commercially meaningful power packages?
- Current efforts have yet to see a good investor.

Alternative - 2

- Grid at hundreds of to thousands of MWe and min-grid options (0.25 to 1 MWe) must be allowed to play their role whenever and whereever they can play.

  [Why limit the mini-grid option to 1 MWe?

  Note that the most economic option is only the biomass gasifier based system. This demands about 7500 to 8000 tonnes of dry biomass per year. The collection radius and delivery over 1000 – 1500 hectares (10 to 15 sq km) will become economically limiting]

- Can one develop a single family power pack of 200 W, 500 W and allow it to be bought by as many families as can afford?

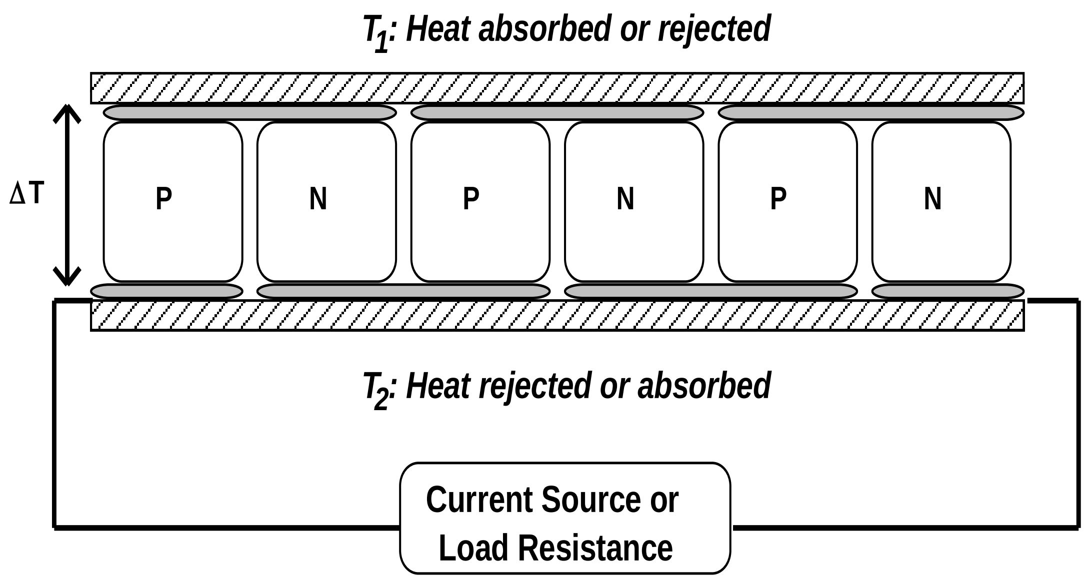
  Ans: Yes,

  a: Solar photovoltaic cell based power packs – available at typically 200 -300 Rs per peak W. This translates to > 1000 Rs./average W.

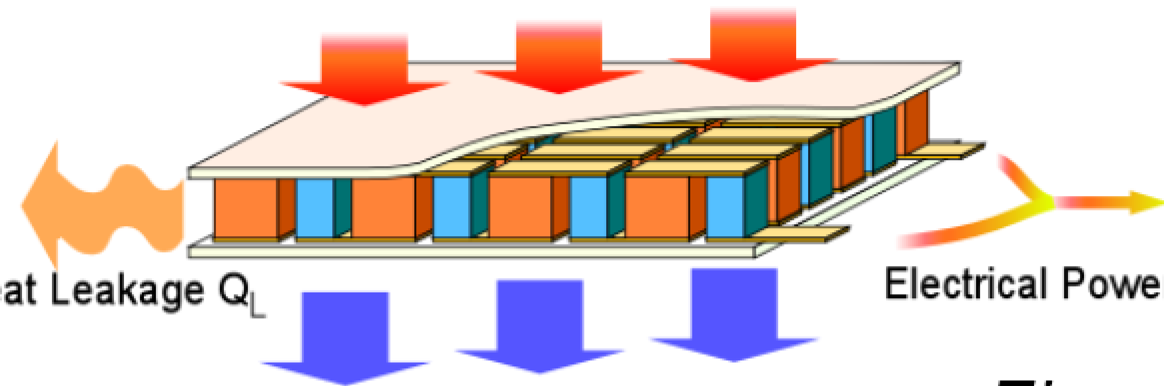
  b: Can "New" technologies like thermo-electric power can be engineered today…….?

Thermoelectric power?

- Thermoelectric devices are based on two transport phenomena: the Seebeck effect for power generation.
- If a steady temperature gradient is applied along a conducting sample, the initially uniform charge carriers distribution is disturbed as the free carriers located at the high temperature end diffuse to the low temperature end. This results in the generation of a back emf which opposes any further diffusion current. The open circuit voltage when no current flows is the Seebeck voltage. (Thermocouple effect)



Thermoelectrics for Waste Heat Recovery



Efficiency:

$$\varepsilon = \frac{T_H - T_C}{T_H} \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_C}{T_H}}$$

Figure of Merit:

$$ZT = S^2 T/\kappa_T \rho$$

S = *Seebeck Coefficient (Thermoelectric Power)*

κ_T = *Thermal Conductivity*

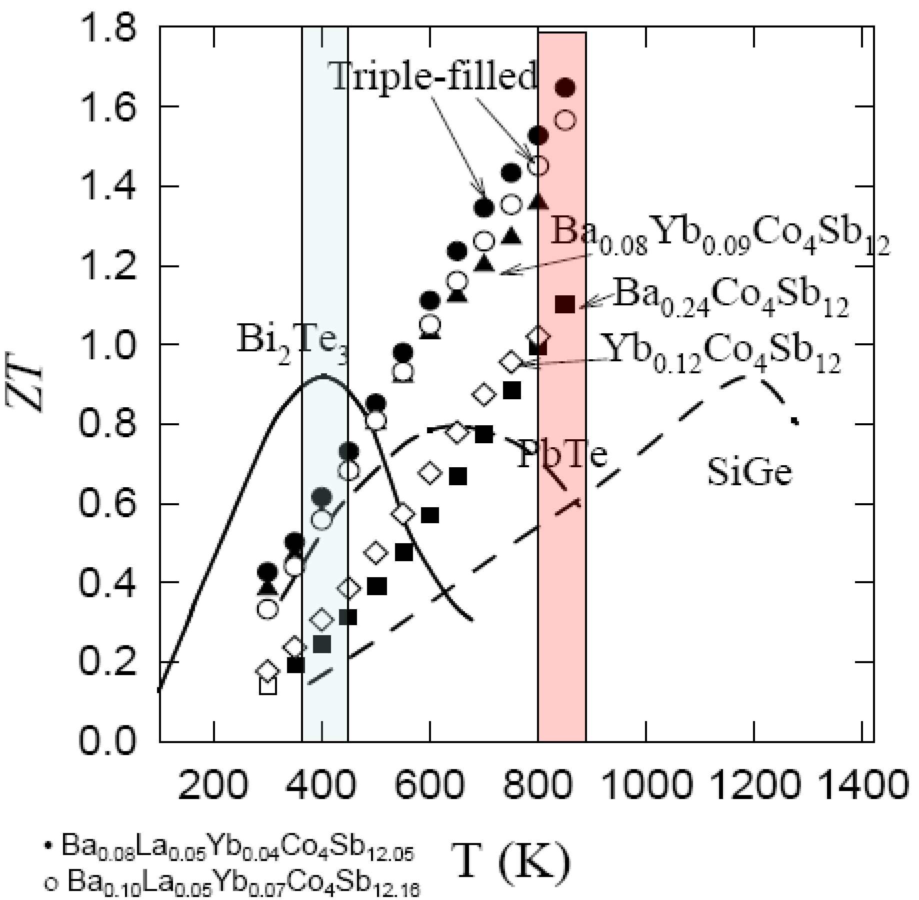
ρ = *Electrical Resistivity*

Maximizing ZT ?

Insulators: *S* can be very high, but electrical resistance is very high $\Rightarrow$ *ZT* too small.

Metals: Electrical resistance very low, but *S* is very low, and thermal conductivity is too high $\Rightarrow$ *ZT* too small

Semiconductors: Can find materials with adequate *S*, acceptable resistance that can be tuned by doping, and low thermal conductivity. Optimized material properties can give large *ZT*.



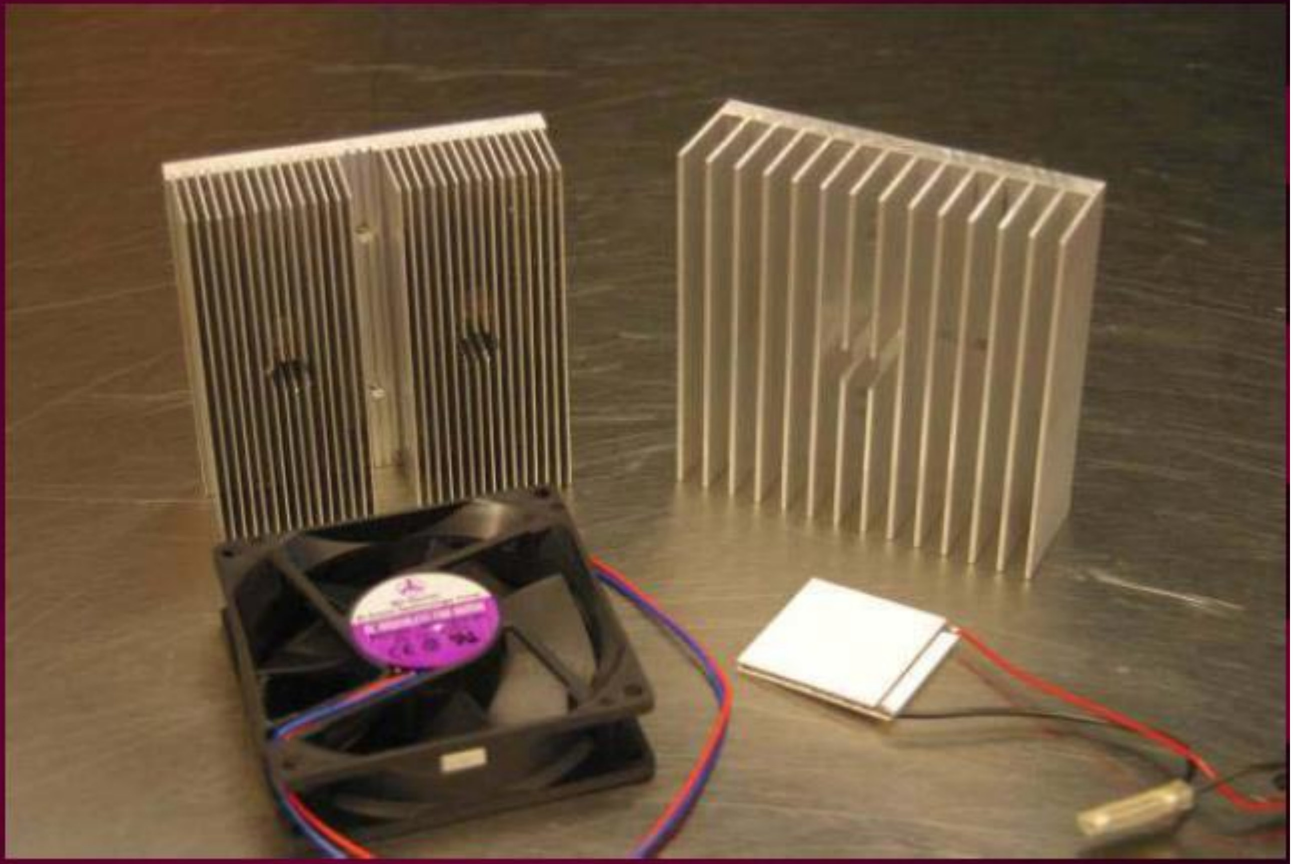
X. Shi, et al. Appl. Phys. Lett. **92**, 182101 (2008).
X. Shi, et al, Electronic Materials 38, 930 (2009).

Bismuth Telluride appears an optimum material at present.

System Components

A thermoelectric generator requires the following components:

- Hot sink
- Module
- Cold sink
- Cooling fan (Optional)
- Power circuit



Module Selection

A high temperature bismuth telluride module has been selected due to its high efficiency and high operating temperature

4% efficiency

5.9 Watts @ max power

$10 in large quantity (10,000+)

Thus,

- In a SPV, there is distinction between peak power and average power (about one-quarter of the peak). It costs Rs. 200 - 300 per peak W.
- In a TEG, there is no distinction between peak and average power. It can always be power on demand. It costs about Rs. 150 per W.
- When combined with cooking, the overall efficiency composed of electricity and heat becomes respectable.
- Therefore, much can be done by developing TEG power using advanced stoves (discussed later).

On to meeting needs of heat

Domestic cooking, Community or large scale cooking

Low emission, high efficiency

biomass stoves with control on power with suitable “standard” fuel supply at affordable cost

Costs of the device as well as fuel should be most affordable for domestic applications. These get relaxed with larger capacity systems.

What is the current status of solid bio-fuel use in the country?

……..

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

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 %

The total biomass use is 400+ mmt. This is comparable to coal use for power generation. We must raise the end use efficiency of solid bio-fuels.

The crucial points

- Biomass needs to be made a *main-stream fuel* as much as kerosene by improving the quality in terms of *shape, size and moisture content* the significant variation in all of which is contributing to poor performance as a cooking fuel.
- It is far more important that we should attempt to improve the efficiency of the use of agro-residues because:
  - It is definitely renewable (something not always true of fuel wood)
  - Using it for cooking will preserve fuel wood for better uses.
  - In doing so, design must cut down emissions at generation point rather than transferring it out of the work place (this reduces both indoor and outdoor air pollution)
  - Two approaches are …….

REDS – Gasifier Stove Tec transferred to BP, India and FEPL, Pune

Fuel for stoves

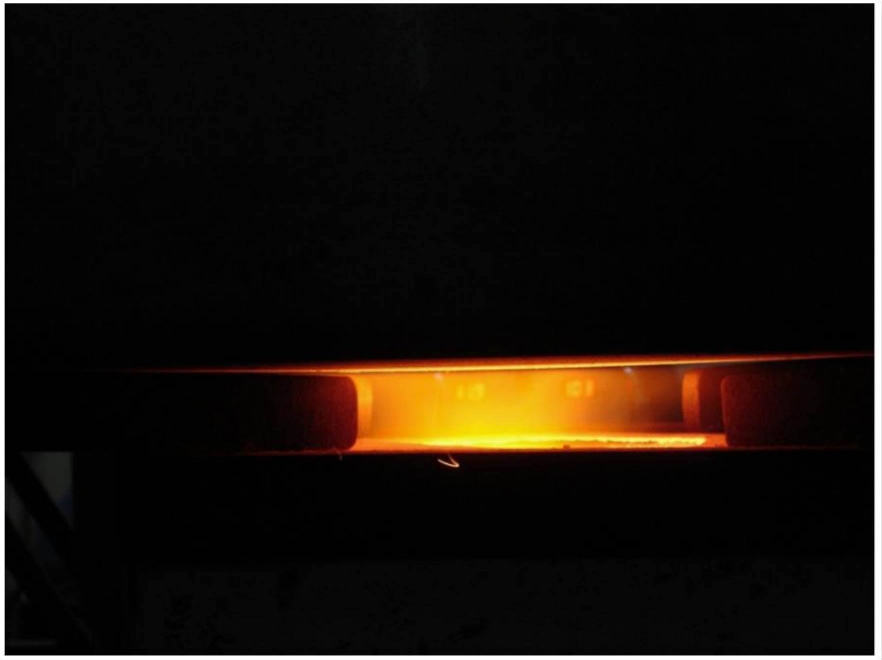
Agro-residues like bagasse, ground-nut shell, rice bran, sugarcane trash, sawdust, some oils like Sal/Mohua/saf-flower wastes or others available around the industry in proportions that lead to 10 ± 2 % ash and 6 to 8 % moisture.

Delivered cost of the raw fuels increased from Rs. 2 to 5 over several years. This led the cost of the prepared pellets to increase from Rs. 5 to Rs. 8 and it is now Rs. 12 per kg. At this cost, domestic stoves will not be economical compared to LPG. People have gone back to traditional biomass stoves.

Currently, small machines for pelleting are being manufactured by FEPL (at Rs 3 lakhs per machine for 50 to 75 kg/h output). These can be used to produce pellets in a distributed manner at a conversion cost of Rs. 1.50 – 2.00 per kg. The final production cost will work out at Rs. 3.50 to 4.00 per kg.

This will enable much broader penetration of stoves.

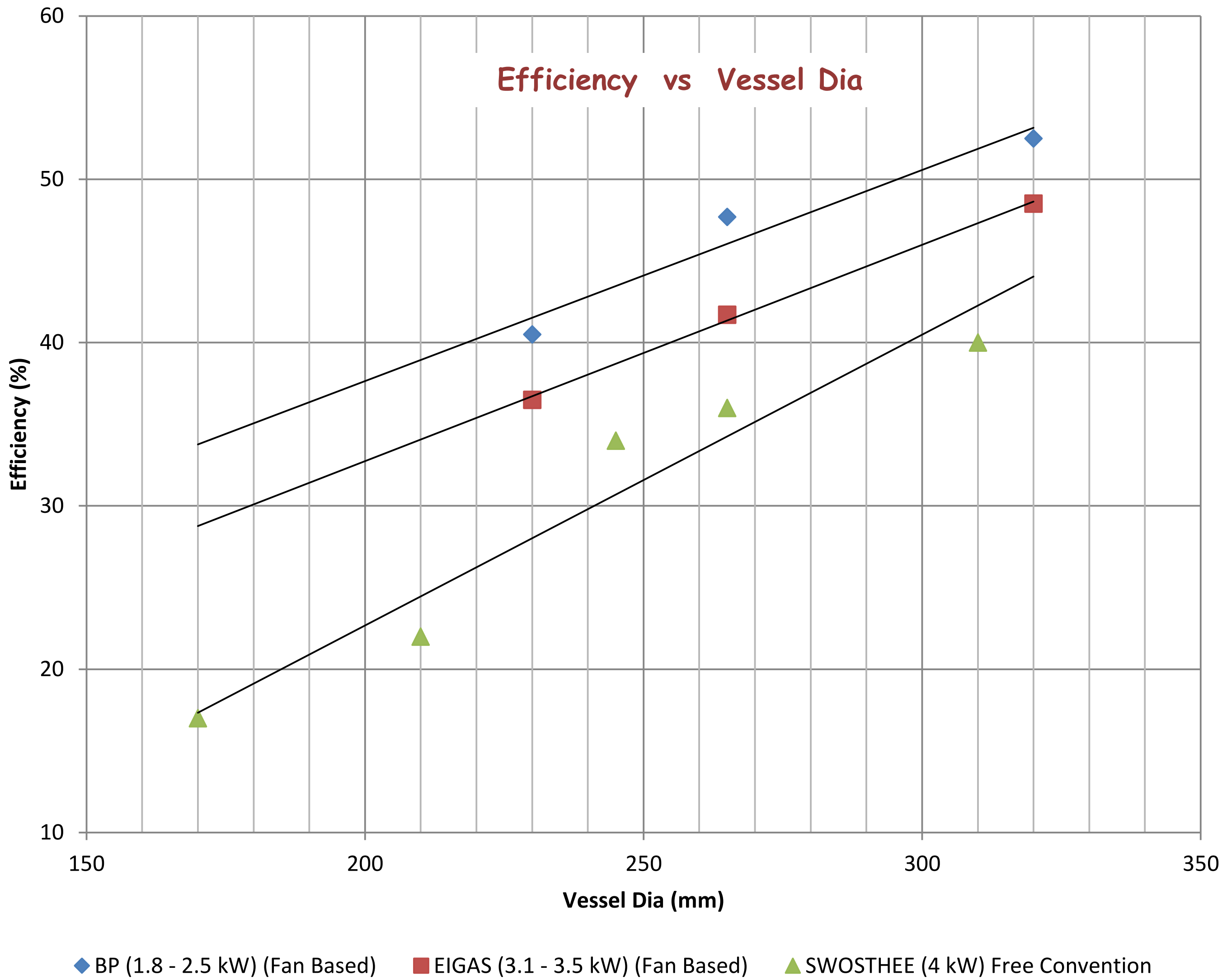
Fire wood or mixed fuel based stoves of high efficiency – EIGAS stoves



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 %

Can use solid agro-residues like coconut shell, corncobs, bamboo, firewood, chopped stalks of many crops

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



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

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**

Further,

Can we combine the high efficiency stove and thermoelectric power generators to get both electricity and heat?

An industry, TEG-Power sells a variety of TEG systems and the cost of 3 USD per W. The peak temperature is about 325 °C. It is possible to get cooking heat between 1000 °C up to 300 °C and then electricity from this device. One would get 50 W from a stove of 3 kWth (0.75 kg/h combustion system, 45 % heat extracted for cooking and the rest 1.65 kWth available for electricity conversion; assuming 1.3 kWth treated converted to electricity at 4 % efficiency)

These need to be yet demonstrated in practice.

Summary

- All options for electricity generation – grid, mini-grid and stand alone approach and distribution should be considered for development and commercial implementation.
- New ideas for small power generation have value for both rural and urban sectors.
- Solid bio-fuel based heat demand in rural sector is substantive in magnitude compared to coal for power generation.
- It has received little attention from those who should be concerned most – planners and administrators.
- The urgency of this demand keeps growing with time, due the increased inaccessibility of “clean” fossil sources, like LPG and in part, to the population increase.
- There is role for scientists, NGOs and administrators to resolve the issues.

…….Thank you