High Technology for Sustainable Development of Rural Poor[A]

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Introduction

There are 3 billion people in the world who earn less than $2/day. With increased access to TV and other mass media, they aspire to an "affluent life style" which is mostly dictated and defined by Western media. As we all know, this life style is unsustainable yet it provides the role model and living standard towards which the developing world aspires. However, for the world's sustainablity this life style has to change. Becoming spiritual will help us do that.

Spirituality is the state of mind that helps us to understand that Truth is beyond the barriers of worldliness, caste, creed, race or geographical boundaries[1]. Spirituality connects us to Universal Consciousness and gives a certain perspective in and towards life. As a person progresses on the path of spirituality, his or her priorities in life change. The focus of life shifts more towards getting personal happiness through mental peace and less on material needs and desires and hence more towards sustainability.

Spirituality also helps us become more secure. Increased internal security helps in reducing greed. When each one of us become less greedy then the world will become more sustainable. Sustainability should therefore be practised by each of us in our daily life. Thus we should try to conserve energy and be more frugal with the resources we use.

We however cannot impose it in a democratic society. Nevertheless, we need to talk, cajole, educate and generate spiritual awareness in young people in different fora, schools and colleges. It is a long process but it will have its effect. All of us have to be actively involved in this process, especially because of the tremendous onslaught by big companies, corporations and advertising media on people's sensibilities, exhorting them to buy more and more goods, to drive bigger cars, to consume more of the earth's resources.

The 3 billion poor nevertheless cannot wait for the rest of the world to become spiritual and use fewer resources. They need the basic necessities of life right now and want to improve their life style. Thus, greed reduction in West and technology development for poor people should take place simultaneously.

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What needs to be done?

Development and deployment of technologies specifically designed for the 2-3 billion rural poor can help improve their lifestyles and livelihoods while bringing them in mainstream development process. Technology intervention will also help in rural employment generation. Thus the North, from where most of the new technologies originate, should encourage rural technology development and its availability on very soft terms for e.g. make freely available drug recipes, charge very little for technologies, etc.

Most of the technology efforts in past for providing basic facilities to rural areas have been based on a "tinkering" approach, meaning a small adjustment here and there, and using "low" or appropriate technology. This approach, which has been mostly used by aid agencies, normally resulted in incremental changes like development of improved cook-stoves or better bullock carts. Tinkering, however, has barely made a dent in the quality of life of poor people. And often, the introductions of these technologies brought other problems such as increased workloads for women.

I believe that sophisticated – or "high" – technology is needed to convert efficiently the locally available resources and materials into useful products. This is the hallmark of evolution where natural systems evolve into very efficient materials and energy converters. In this process, size reduction and sophistication of system takes place[2]. Some of our designs and technologies are following the size reduction route, for example, computer chips, cellphones, power plants, etc. Technology developers should follow this strategy in developing rural technologies. In fact, much more sophisticated thought and high technology is required for solving rural problems since the materials and energy resources available in these areas are fewer and often only available in "dilute forms". The strategy of high technology should be used in poor areas of the world to allow maximum energy and materials to be extracted for useful end products.

Strategy for Sustainable Development

Three technology areas need to be given priority for rural areas :

1. Provision of clean cooking fuel and stoves.
2. Provision of adequate lighting.
3. Availability of clean drinking water.

Cooking and lighting constitutes ~ 75% of total energy used by rural households in India[3]. Similar numbers are also applicable in other rural areas of the world. Together with the provision of clean water, the total energy used from locally available renewable resources becomes quite large.

Provision of adequate lighting and clean cooking fuel and drinking water are the fundamental needs of mankind. Their availability in rural areas can go a long way in improving the quality of life and livelihoods for nearly 3/5th of mankind and in bringing them into mainstream of development process.

The engine of rural development has however to be fueled by locally produced energy. Thus efficient biomass, solar and wind technologies need to be developed to provide the quality product to satisfy the basic needs. This will help in improving environment through use of renewables, reduce pressure on fossil fuels and provide tremendous economic benefits to rural areas. Since renewable sources provide low-grade energies hence very efficient energy converters are needed to provide useful end products. Emerging high technology areas like biotechnology and nanotechnology can provide such convertors.

Efficient Cooking Systems

There are estimates that around 1.6 million deaths per year take place because of indoor air pollution caused by biomass cook stoves[4]. Gaseous and liquid fuels from locally available biomass can provide safe and convenient cooking energy. One such gaseous fuel is biogas. Biogas has been used extensively in rural areas of the world and is produced very inefficiently in fixed and floating dome systems, requiring considerable amount of cowdung and other nitrogenous material. It is therefore not suitable for a household with less than 3-4 cattle. Besides there are problems of gas production during winter and improper mixing of inputs like biomass, night soil, cowdung, etc. Biogas which is a mixture of methane and carbon dioxide cannot be liquefied and requires very high pressure (> 100 atmospheres) to compress it so that it can be used over extended periods.

Thus R&D is necessary in two areas. One is the development of extremely efficient biogas reactors so that the production/unit of biomass inputs could be maximized. Genetically engineered microbes can substantially increase gas production efficiency. The second area is the development of appropriate storage materials, which could store biogas at medium pressures.

Recent experiments show that biogas can be stored at medium pressures (< 40 atmospheres) in hydrates, porous carbon and porous organic structures similar to those used in hydrogen storage[3]. Thus a scenario can be thought of whereby micro-utility companies can be set up in rural areas which will buy locally available raw materials like cowdung, biomass etc. and will use them in a very high tech biogas reactor to efficiently generate biogas. This gas can then be stored in small cylinders lined with gas absorbent structures and can be transported to households like the present LPG cylinders. This will revolutionize the cooking system in rural areas. Optimization of biogas production from a reactor requires sophisticated electronics-based controls and bio-chemical engineering technology. A small utility can afford to do it whereas for a household it might be too costly.

Similarly ethanol, biodiesel and pyrolysis oil from locally available biomass resources can provide clean cooking fuel. NARI has developed a high tech stove running on low concentration ethanol/water (50% and above) mixture[5]. This safe mixture can be easily distilled in rural areas and can provide clean cooking fuel. Breeding techniques for crops and using genetically modified bacteria for fermentation can further help in increasing the yields of these fuels from the biomass resources so that less land is utilized for energy producing crops. Liquid fuel production from biomass will also help create rural wealth and employment through the creation of possibilities.

NARI ethanol stove

There is however a need to develop stoves running on biodiesel and pyrolysis oil. Because of high viscosity and soot forming ability of these fuels, very sophisticated combustion science and technology is required for developing such stoves. Production of blue flame in such stoves will also help in developing combustors for liquid based lighting purposes.

Lighting systems

a) Liquid Fuel based Lighting

It can safely be said that the history of present civilization is the history of lighting. Adequate lighting (50-100 lux) should therefore be a part of minimum needs program of any government for its people[3]. Presently mankind knows two methods to produce light. Once is via thermal route where the fuel (like kerosene or oil) is used to produce an incandescent flame and the other is effected by electricity.

For rural lighting technology there is a need to again look closely at the liquid fuel lighting systems. One of the best system still in use is a pressurized mantle lamp where the combustion of kerogas lights up the rare earth oxide mantles. Recently NARI has developed an extremely efficient multifuel lantern called Noorie which runs on kerosene, diesel and with slight modification on ethanol[6]. This lantern produces light equivalent to that from a 100 W bulb and also doubles up as a cooking device. The light production is by heating of thermoluminescent (T/L) mantles by kerogas.

Noorie lantern with cooking arrangement

The thermoluminescent mantles in these lanterns have not changed since Welsbach developed them in Germany in late 1880's. They are basically a mixture of 99% thorium oxide and 1% cerium oxide (called thoria mixture) and have very low light efficiency (called efficacy). Thus the efficacy of these mantles is ~ 2-3 lumens per watt (lm/W), whereas that of light bulb is ~ 10-15 lm/W. The efficacy of compact fluorescent lamps (CFL) is however 50-70 lm/W [4].

With the present level of materials technology and use of nanotechnology, it should be possible to develop new materials for T/L mantles, which will use less of thoria mixture and also increase their efficacy. It is quite possible to match the efficacy of light bulb by this strategy. This can make liquid fuel lighting superior to electric lighting in terms of overall power plant-to-light efficiency. Presently the effective overall power plant-to-light efficiency for fluorescent lamps is ~ 14 lm/W. This low number results because of losses in producing power from fossil fuels and transmitting it through utility lines. Thus with thermal power plant efficiency of 30%, transmission and distribution (T&D) losses of 20% and fluorescent lamp efficacy of 60 lm/W the final efficacy becomes low. Thus a liquid fuel lamp running on locally made fuels like ethanol, biodiesel or pyrolysis oil with efficient T/L mantles can be an excellent distributed light source for rural areas.

Research is also needed in developing better substrates for mantles. Presently the mantles are made of silk cloth and after firing them, a very thin and fragile ash substrate remains. This breaks very often and consequently the mantles have to be replaced frequently which increases the running cost of such lanterns. Thus there is a need to develop stronger and more durable materials such as those based on ceramics and carbon-carbon composites. With such mantles the liquid-based lighting with improved lanterns like Noorie can become very rugged besides being efficient.

One of the most efficient lighting systems in the world is bioluminescence of firefly where chemical energy is converted directly into light. Estimates are that its lighting efficiency is around 85-90%, compared to that of a light bulb which is 7-10% [4]. R&D should be done in trying to duplicate this mechanism. The ultimate lighting system can be thought of as a solar powered unit producing luciferase enzyme and luciferin (the two chemicals used in bioluminescence of firefly) from a biomass resource and then using them at night to produce light. It is an utopian dream but will be the ultimate in a distributed light source.

b) Decentralized electricity based lighting

With unavailability of grid electricity for majority of rural areas, large amount of R&D world over is also being conducted in developing distributed or decentralized sources of electricity. They range from 5-10 kW to 10 MW capacity. This includes biomass based 10-20 MW power plants, gasifier-based systems and very innovative technologies like space age steam engine, gas powered 20-30 kW microturbine, etc. Distributed electricity sources running on locally available biomass resources can also effectively provide light for rural areas.

For individual household level R&D in three micro technologies for producing electricity need mention. One is the development of human muscle-powered lighting system; second is thermoelectric devices for light and third is nanoengines.

c) Micro technologies for Lighting

Recent advances in lightweight and highly efficient permanent magnet DC (PMDC) motors have made it possible to produce small amount of electricity via human power. This electricity together with rechargeable batteries can power a light emitting diodes (LED) system for lighting. Among all light-producing devices, LEDs are some of the most efficient and long lasting. Freeplay in Europe and Light the World in Canada have pioneered this system[4]. Presently these systems are very expensive (US $50 for a handheld flashlight). Hence R&D is required in essentially three areas namely: development of very efficient and lightweight PMDC motors (40-50 W), development of efficient capacitors with suitable electronics as a substitute for batteries, and development of cheap LED units. A bicycle-powered unit in which the members of a household can take turns to charge the battery, which will give 3-4 h of light, will be a great boon for rural areas. This may be akin to Mahatma Gandhi's charkha (spinning wheel) except that it will produce electricity instead of spinning cotton and in Gandhian analogy may help in sustainable development.

Similarly majority of rural households use primitive biomass cookstoves for cooking. The stoves are inefficient and smoky with about 10-15% cooking efficiency. An extremely efficient thermoelectric device attached to the stove can produce 50-60 W of DC power. This power can be stored in suitable high efficiency batteries for lighting. At the same time part of the power can also be used to run a small fan for the cookstoves. Recent biomass cookstove designs have shown that air draft powered by a 5 W fan can double the efficiencies of these stoves. A small fan can help the combustion process thereby reducing the particulate emission's from wood stoves.

Recent developments in nanotechnology and new materials have also shown that very efficient thermoelectric elements and thermionic devices can be developed[8]. Some of these thermoelectric elements have been able to break the ZT barrier of 1 and have reached a figure of 2.4. ZT is a figure of merit which shows how good the device is in converting heat to electricity. The higher the ZT, the more efficient is the device. Similarly nanotechnology has been used in making an efficient thermionic device for power generation.

A penny size nanoengine running on biomass derived fuel like ethanol and capable of producing 10-15 W power can power LED lamps and can revolutionize the distributed rural lighting. These engines are being developed for defense applications and as mobile phone power devices[9]. Such a compact system will bypass the bulky and costly battery technology since the liquid fuel itself will store the energy.

Clean drinking water

In the field of clean water production, nanoparticles based filters are helping to purify water. Similarly another simple method has proved to be effective. Thus water filled plastic bottles kept in the sun can heat the water to more than 70^0C killing majority of harmful bacteria. However if these bottles are also coated with a cost effective nanobased photocatalyst then the system can become even more useful since sun's UV radiation via catalyst can kill all the harmful bacteria.

For rural areas, a micro-utility which can produce both power (~ 100-500 kW) and clean water would be a great boon. This utility company can produce power through renewables powering an internal combustion engine and the heat from flue gases of the engine can be used to produce clean water either through distillation or simply through boiling it[10]. This will help in increasing tremendously the power plant efficiency. The utility can also access water resources by rainwater harvesting techniques.

Conclusions

The outlined strategy can help improve the quality of life of rural poor. It will have other benefits :

1. The use of renewables will help in improving local and ultimately global environment.
2. Fossil fuels will be conserved. These can then be used as raw material for chemicals and value added products. Using less fossil fuels might help reduce world conflict since the pressure on fossil fuels from emerging economics like India and China could be lessened. It is therefore in the interest of the North to provide the latest energy technologies to developing world at very soft terms.
3. Electricity and liquid fuel production from biomass would increase rural wealth and generate employment. Preliminary economic analysis shows that in India alone this could be a $ 6 billion/year industry.
4. New technologies will create huge market for technology providers.
5. Providing clean fuels, light and clean water will help bring the 3 billion people into the mainstream of progress.

To my mind the highest spiritual work for mankind is to help poor people improve their quality of life. As engineers and scientists we can do it by providing right-sized technologies at the right "price" to the poor. It is a doable goal. What is needed is the direction and will of leaders both in North and South to make the life of poor people better.

Finally, it should be pointed out that rural population of the world is much more spiritual than those in developed countries. They have the great strength of being satisfied with few material comforts. Thus I believe that the provision of high technology for meeting the basic needs of rural poor together with their spiritual strength may provide a new model of sustainable development and in the process may teach North a lesson or two in sustainability.

References

1. Rajvanshi, A. K., **Nature of Human Thought**, Published by NARI, India. August 2005, pg. 66.
2. Ref. 1, pg. 65.
3. Rajvanshi, A. K., "R&D strategy for lighting and cooking energy for rural households", Curr. Sci., 2003, **85**, 437-443.
4. Smoke-the killer in the kitchen. ITDG report. www.itdg.org/html/smoke/smoke_report_1.htm.
5. Rajvanshi, A. K., S. M. Patil and Y. H. Shaikh, "Development of Stove Running on Low Concentration Ethanol Stove", http://nariphaltan.virtualave.net/ethstove.pdf.
6. Rajvanshi, A. K., "Improved lantern for rural areas". http://nariphaltan.virtualave.net/ lantern.htm.
7. Rajvanshi, A. K., "New Candoluminescent materials for kerosene lanterns for rural areas". Final project report (unpublished) to DST, New Delhi, March 1998.
8. Venkatasubramanian R. et. al. "Thin-film thermoelectric devices with high room-temperature figures of merit". *Nature*, 2001, **413**, 597-602.
9. Freedom, D. H., "Power on a Chip". *Technology Review*, 2004, **107** (9), 48-53.
10. Rajvanshi, A. K., "Electricity and water revolution for rural areas", http://nariphaltan. virtualave.net/EW.pdf.

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