Overview of Available Energy Technologies for Rural Development[a]

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Introduction

A discussion of the available energy technologies for rural development is best preceded by a clear statement of the goal for rural energy systems and the associated strategies. If the goal (or objective to be achieved) for ***all*** energy systems is sustainable development, then ***the goal for rural energy systems is that they must be instruments of sustainable rural development***. Rural energy systems, therefore, must advance rural economic growth that is economically efficient, need-oriented and equitable, self-reliant and empowering, and environmentally sound.

The stress on equity means that rural energy systems must first and foremost promote poverty alleviation involving improvement of the living conditions of the poor. Betterment of the life of the rural poor requires an improvement of the Human Development Index (HDI). This improvement of HDI has three crucial dimensions: **equity** based on a marked increase in access of poor to energy services, **empowerment** based on strengthening of endogenous self-reliance, and **environmental soundness**.

For an energy system to be in the interests of the rural poor, it must qualify from three points of view. It must increase the access of the rural poor to affordable, reliable, safe and high quality energy. It must strengthen their self-reliance and empower them. It must improve the quality of their environment (starting with their immediate environment in their households).

Strategies for Rural Energy

The strategies for rural energy systems (i.e., the broad plans to reach the goal or objective) follow from the features of such systems. The specific strategies that would advance the goal of sustainable rural development are:

- the ***reduction of arduous human labour*** (especially the labour of women) for domestic activities and agriculture,
- the ***modernisation of biomass*** as a modern energy source in efficient devices,
- the ***transformation of cooking*** into a safe, healthy and less unpleasant end-use activity,
- the ***provision of safe water*** for domestic requirements,
- the ***electrification of all homes*** (not merely villages),
- the ***provision of energy for income-generating activities*** in households, farms and village industries.

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The strategies listed above pertain to ***what*** rural energy systems should achieve. But, there should also be strategies that pertain to ***how*** these ***products*** should be achieved, i.e., the ***process*** that should be followed.

The standard approach to the establishment of new infrastructures (for example, rural energy systems based on new technologies) is for the government to take the initiative. This approach ends up with the emergence of new government agencies and their bureaucracies. With the growing experience and awareness of the defects of government efforts such as red tape, delays and even corruption, the liberalisation trend has entered the picture.

The market is claimed to be the best solution to the problem of establishing and running economic activities such as the infrastructure. Hence, the slogan: "Leave it to the market!" The market may indeed be an excellent allocator of men, materials and resources, but it does not, however, have a very successful record at looking after equity, the environment, the long-term, and research, development and dissemination of new technologies. Thus, the market may not be an adequate instrument for addressing tasks warranting a low discount rate.

There is, however, a third option, namely, encouraging individual initiative subject to local community control. It has been shown that it is possible to realise "Blessing of the Commons" situations[1] (the converse of the well-known "Tragedy of the Commons") in which the price that an individual/household pays for not preserving the commons far outweighs whatever benefits there might be in ignoring the collective interest. In other words, ***there can be a confluence of self-interest and collective interest*** so that the interest of the commons is automatically advanced when individuals pursue their private interests. Thus, ***individual initiative plus local community control*** is a third option that can be as, if not more, effective than either the government or the market acting alone.

Hence, there are three process strategies for rural energy

- ***individual initiative*** as far as possible through the market
- ***village community*** monitoring and control,
- ***government*** facilitation and enabling support.

Relationship between HDI and Energy

For rural energy systems to play the role of advancing sustainable rural development, the emphasis must be on **energy services --** and not merely on energy consumption (or supply) as an end in itself. The focus has to be on energy services that improve the Human Development Index (HDI) **directly** (cooking, safe water, lighting, transportation, etc.) as well as **indirectly** via employment and income generation (motors, process heat, etc.).

The impact of energy on the HDI depends on the end-uses of energy and on the tasks that energy performs. The direct impact of energy is associated ***inter alia*** with, and is produced by, cooking, supply of safe water, and lighting. The indirect impact of energy is associated with, and is produced by, electric drives [motors, pumps, compressors] and process heat [processing industries].

The role that energy can play in improving the HDI is not just a matter of hope or conjecture. There is an empirical basis to the relationship between HDI and energy (Figure 1a and 1b). Strictly speaking, the relationship must be between energy **services** and HDI. If, however, end-use efficiency is virtually a constant, energy consumption can be taken as a proxy for energy services and the Figures 1a and 1b display the dependence of HDI on energy.

The relationship between HDI and energy has several important implications. The relationship can be considered to consist of ***two regimes*** (Figure 2). In Regime I -- the "elastic region" -- the slope $\delta(HDI)/\delta E$ of the HDI vs E curve is high so that **large** improvements in HDI can be achieved with **small** inputs of energy (small improvements of energy services). Thus, in this regime, the HDI-energy (benefit-cost) ratio is very high. In Regime II -- the "inelastic region"-- the slope $\delta(HDI)/\delta E$ of the HDI vs E curve is small so that even ***large*** inputs of energy (large improvements of energy services) result only in ***marginal*** improvements in HDI, i.e., in this regime, the HDI-energy (benefit-cost) ratio is very low.

Another important implication is that, in the "elastic" Regime I, enhanced energy services lead ***directly*** to the improvement of HDI, i.e., Energy Services à HDI. But, the impact of energy on HDI can also be indirect. Improvements of energy services can yield increased income that can be used to “purchase” HDI improvements. Thus, in the "inelastic Regime II, enhanced energy services can lead ***indirectly*** to the improvement of HDI via income generation, i.e., Energy Services à Increased Income à HDI increase.

In the "elastic" regime, the coupling between HDI and income (used for defraying the operating costs of energy devices) can be reduced. In fact, HDI can even get decoupled from income so that HDI increases can be achieved without income increases. A shift from kerosene lamps to electric lights is an example of the improvement of energy services at operating costs that are the same, or even less than, the costs of using kerosene lamps.

In the "inelastic" Regime II, HDI is coupled to income. But, income-coupled improvement of HDI depends on important conditions being satisfied. The improvement of HDI via income-generation depends on what the income is used for -- HDI improvement? or liquor? or gambling? or conspicuous consumption? These conditions in turn often depend on which gender gets the income – women tend make expenditures that improve the HDI of their families, particularly their children, i.e., they use a much lower discount rate than men use.

Thus, the implication of the "elastic" and "inelastic" regions is that ***the elastic region guarantees direct improvement of HDI whereas improvement of HDI via income depends on what the income is used for. The direct improvement of HDI is therefore a necessary condition for launching an indirect improvement via income.***

Approaches to Poverty alleviation

The relationship between energy and HDI has profound implications for the strategy for alleviating poverty. In the 1970s, the emphasis in poverty alleviation was on direct satisfaction of basic human needs. However, these concerns were swept aside by the wave of liberalisation. It was believed that income generation was the magic wand that would make poverty vanish. Macroeconomic growth became the standard approach to poverty alleviation. Even this did not do the trick for the benefits of economic growth are absorbed far too slowly by the poor. Attention was therefore turned to human capital investment but even this is a slow process. Direct poverty alleviation is a much surer method of improving the HDI instead of indirect route via income generation and human capital formation hoping that the income generated and the human capital utilised will lead to a trickling down of benefits to the poor. The direct improvement of HDI is therefore a necessary condition for launching an indirect improvement via income.

The "elastic" Regime I of the energy-HDI relationship shows that dramatic improvements of the HDI can be achieved with very small investments of energy. In fact, it is possible to get a very rough estimate of the energy cost of an "elastic" improvement of energy services for the poor. Assume that this necessary improvement of energy services in tropical countries consists of (1) safe, clean and efficient cooking with LPG or a LPG-like fuel and (2) home electrification for lighting, space comfort, food preservation and entertainment. The energy required for cooking would be about 2.3 GJ/capita/year or about 73 watts/capita[2]. The electricity for lighting, fans, etc., at twice the consumption of 33 kWh/HH/month of the ordinary connections in Karnataka, would be about 18 watts/capita. This leads to a total of about 91 watts/capita that can be approximated to 100 watts/capita[3]. Thus, ***only about 100 watts/capita is adequate to achieve the dramatic improvement in the quality of life corresponding to safe, clean and efficient cooking with a LPG-like fuel and home electrification for lighting, fans, a small refrigerator and a TV.*** It is worth noting that this 100 watts/capita is only about one-tenth of level required to support a Western Europe living standard with modern energy carriers and energy-efficient technology[4].

Preferences in the Choice of Energy Sources and End-use Devices

Attention must be focussed not only on the supply aspects of the energy system but also on the demand aspects. Rural energy systems must be considered to consist therefore of **whole "fuel" cycles** from energy sources through energy carriers via transmission/transport to distribution to end-users for utilisation in end-use devices to provide energy services. Thus, there must be an emphasis not only on energy **sources** but also on efficient **end-use devices**.

The primary sources of energy are fuels and electricity -- fuels for cooking (stoves) and for process heat (boilers/furnaces/kilns) and electricity for lighting (lamps) and for electric drives (motors, pumps, and compressors). There are also opportunities for cogeneration, i.e., the combined production of heat and power.

The thrust must be on energy sources and devices that are renewable, biomass-based, universally accessible, affordable, reliable, high quality and safe.

Special attention must devoted to sources that are locally available, small-scale, decentralised and renewable, and systems that are amenable to local control and enhance it.

The choice of energy sources (fuels and/or electricity) must be guided by preferences for sources that

- facilitate access by the entire rural population particularly the rural poor through micro-utilities and community-scale systems for compact settlements (high housing density) and home/household systems for isolated homesteads (settlements with low housing density);

- are compatible with high-efficiency end-use devices;

- lend themselves via cogeneration to the production of combined heat and power;

- are decentralised/locally available to strengthen self-reliance and to empower people/communities;

- are renewable to promote environmental soundness.

Access to (and penetration by) home systems is determined by the affordability of the energy source -- costly sources restrict access to the affluent few, and cheap sources facilitate "universal" penetration. Household systems commandeer capital, energy resources and entrepreneurship, and may even pre-empt the establishment and operation of micro-utilities (which increase access by the rural poor).

The following questions are important in the choice of end-use devices. Do they directly improve the HDI? and/or do they generate income that (used constructively) improves HDI? Are they accessible to the rural poor? Do the devices have a low enough first cost and operating cost? or do they have the same/lower operating cost as traditional devices after innovative financing (to convert unacceptable initial costs into affordable operating costs)? Do they benefit women? Are they environmentally sound?

Elitist or Egalitarian Character of Sources and End-use Devices

If rural energy systems have to be instruments of sustainable rural development, the distribution of the benefits of a rural energy technology has to be scrutinised. Equity impact assessment (EIA) statements are important. This obligation to anticipate and examine the distributional or equity implications of a technology is mandatory for those who implement technologies for sustainable development. In contrast, those who pursue technologies, particularly renewable energy technologies (RETS) as ends-in-themselves to advance global environmental objectives, do not have this obligation to consider distributional or equity implications.

Consider the dissemination of photovoltaic solar home systems (PV SHS) in rural India. An analysis (Appendix 1) shows that, given the 1999 costs of four-light 37 watts PV SHS and the income distribution pattern in rural India, only about 7% of the households have the income required for PV SHS even with financing from a bank at 12% interest over a 5-year period. Assuming that only half of those households that can afford PV SHS are prepared to switch to PV SHS, it appears that the market for such systems is restricted to much less than 5% of the richest rural households. The potential penetration is greater with the smaller systems. About 17% of the households have the income to afford the two-light 20 watts SHS, and about 75% of the households can afford the one-light 10 watts SHS.

Since PV SHS are inaccessible to the rural poor, it is tempting to dismiss them as ***elitist*** energy sources/devices. If, however, the purpose of PV SHS is, not merely to improve the quality of life of the households, but to illuminate after-sundown activities that augment income (for example, weaving baskets), then the elitist characterisation may not be applicable. This is because the income generated under illumination by the PV SHS more than pays for the investment on the light.

Another reason for cautioning against hasty judgements about the elitist or egalitarian character of sources and devices derives from the well-known fact that technological advances and organisational learning can bring about major cost reductions in the case of emerging not-yet-mature technologies. The point is well illustrated by the declining trend in the cost of PV modules. This means that decisions must be made on the basis of future costs, rather than present costs that are bound to decline. The implication is that declining costs can erode the elitist character of sources and end-use devices and strengthen their egalitarian character.

If, however, particular sources and end-use devices are elitist, then they will (a) bypass the rural poor, (b) fail to alleviate poverty, (c) make a negligible contribution to energy system and (d) hardly mitigate negative environmental impacts. They can, however, offer a small high-profit market for profit-making enterprises.

The skewed distribution of the benefits of some technologies leads to some important questions such as the following. Do elitist sources/devices pre-empt the possibility of dissemination of affordable sources/devices for rural poor? Do they hijack capital that would otherwise be used for poverty alleviation? Do they divert resources that would otherwise be used for the rural poor, for example, do household-size biogas plants use up the dung that could be used by more cost-effective community-scale plant? Is there a level playing field for elitist sources/devices and devices for rural poor? Are banks and financial institutions biased towards elitist sources/devices?

Financing of Rural Energy Technologies

A widely held, but erroneous, belief is that, without subsidies, the poor cannot afford priced basic services[5]. The fact of the matter is that the poor are currently paying for these services – food, water, lighting, etc. – either with money or with their labour time. So the question is whether the poor will decide to opt for an alternative way of obtaining the service in preference to their current option. Even when they are getting a service "free", i.e., without financial cost, they devote their labour time for which there may be other more pleasant and/or lucrative options. Thus, they may even choose to pay for a service that they normally get "free". For example, rural households have preferred to pay for priced safe water in preference to "free" water from unsafe sources.

The implication is that, for most services, even the poorest rural households can afford to make some payments commensurate with what they are currently spending. And if they are currently getting something "free", there are opportunity costs associated with the time they spend to obtain the service. The real or opportunity costs of traditional practices are therefore an important benchmark because invariably they define the maximum amount that the household is willing to spend. Thus, the operating costs of traditional devices (e.g., kerosene lamps) are a sort of upper bound for the costs of an alternative technology. From this point of view, it appears that the problem arises more with the capital costs of new technological options than with their operating costs. Hence, innovating financing can play a major role. Loans (not necessarily soft loans), leasing, etc. can convert unacceptably high initial capital costs into manageable affordable operating costs.

In the case of energy, the window of technological opportunity is upper-bounded by the maximum possible household expenditure on energy (say 15%). But, (after a favourable financing scheme), the operating costs of proposed (improved) devices (e.g., electric fluorescent lights) can be even lower than the operating costs of traditional devices (kerosene lamps). Technology, therefore, can widen the window of opportunity.

The conversion of capital costs into affordable operating costs requires investments from financial institutions. Fortunately, there are financial institutions/banks/donors that have the capacity to provide the financial inputs for innovative financing. With their backing, rural banks must provide loans for purchase of energy efficient devices (stoves, lamps, drives, boilers/ furnaces/ kilns, etc) to improve HDI directly and indirectly via income generation. They must also implement schemes for the leasing/financing of energy-efficient devices so that unacceptably high first-costs become acceptable operating costs. However, many of the new tasks are ones to which they are not accustomed and therefore they have to go through a learning process.

New energy enterprise(s) may also have to be established if existing institutions such as local-level bodies cannot discharge the new responsibilities. The new energy enterprise(s) must tackle the challenges of marketing of non-conventional energy sources and/or energy efficient devices. New institutional arrangements may also be required. For example, concessions may have to be allotted to enterprises to deliver services to households in a specific region with an obligation to serve even the poorest households. Joint ventures may have to be established to set up decentralised/ renewable energy systems compatible with high-efficiency devices accessible to the rural poor. It may also be necessary to establish and develop micro-utilities (particularly those run by women) and to commercialise decentralised/renewable energy sources and energy efficient devices.

Time Horizon for Technological Options

The identification of technological options for sources/devices depends very much on the time horizon. Unfortunately, two extreme trends can be observed. Grassroots rural development workers are preoccupied with the immediate problems of the people with whom they work directly. As a result, they tend to choose technological options that are available straightaway off-the-shelf. They use a very high discount rate for their technological decisions being totally preoccupied with the present. In contrast, technical experts are excited by technological possibilities. They talk of futuristic solutions as if they are already valid. Being totally preoccupied with the distant future, they use a very low discount rate for their technological decisions. Thus, the grassroots rural development workers are moved by real human beings and restrict themselves to "Band-Aid" or Quick-Fix remedies forgetting about ultimate sustainable solutions. In contrast, technologists are sometimes enamoured with technological innovations even though these will take quite considerable time to become realities. They are little concerned with the fact that, while waiting for the pie in the sky, people are condemned to remain in their present misery.

Obviously, an either-or approach must be avoided. Starting from the present technology (the initial condition), there is a necessity of three types of technology for each energy-utilising task. A near-term technology should lead to immediate improvement compared to the present situation. A medium-term technology to achieve a dramatic advance should be available in five to ten years. And a long-term technology should prevail after say 20 to 30 years and provide an ideal sustainable solution. Ideally, the technologies for the near, medium- and long-terms should be forward compatible so that the technology at any one stage should be upgradable to the better version. And in planning efforts, it is wise to have a balanced portfolio with a combination of near-, medium- and long-term technologies. Guarantees of near-term improvements before the next election will win over political decision-makers and ensure that they support long-term technologies.

It is implicit that the technologies for the near, medium- and long-terms are the most appropriate or "best" technologies for each period selected by a "natural selection" process of competition. In other words, one is thinking of a transition from the most appropriate technology for the near term to the "best" technology for the medium term and then to the "best" technology for the long term. Implicit in this approach is the concept of technological leapfrogging according to which the historical path of technological evolution is replaced by leapfrogging to the "best" technology for the next period. This technological leapfrogging approach is fundamentally different from the so-called "energy ladder" approach according to which there is a climb from the technology corresponding to one step of the ladder to that corresponding to the next higher step. For example, in the case of cooking, the climb (with increasing income) is from fuelwood to charcoal to kerosene to LPG/electricity. But the energy ladder is a description of the past and present behaviour of consumers. In contrast, technological leapfrogging is a normative prescription of future behaviour. So, the recommendation is that rural areas do not replicate the energy ladder behaviour of the past and present but adopt a technological leapfrogging approach.

Specific Technological Options

The present emphasis with regard to electricity as a convenient energy carrier is on grid electricity. However, due to the problems of supplying grid electricity to small and scattered loads, the attraction of decentralised generation of electricity is increasing. Where appropriate, decentralised generation from the intermittent sources of wind and/or small hydel, solar photovoltaics and solar-thermal have roles to play. The exciting developments are the availability of ~100 kW micro-turbines and ~ 10 MW biomass integrated gasifier combined cycle (IGCC) turbines. Biomass-based generation of fuels to run fuel cells is an attractive long-term option particularly because there are possibilities of generating surplus base-load power that can be exported from rural areas to urban metropolises.

At present, the predominant fuel in rural areas is biomass, particularly fuelwood and agricultural crop residues. A switch to stoves and furnaces fuelled with biogas, producer gas, natural gas and LPG is an obvious next step. But, modern LPG-like fuels derived from biomass, so-called biofuels, syngas in general and dimethyl ether (DME) in particular, may be the medium- and long-term answer.

It is important not to be locked into thinking separately about electricity generation and heating. The co-generation of electricity and process heat is an attractive proposition that is well known particularly when the utilisation of the heat can be achieved close to the device generating electricity. Decentralised electricity generation facilitates this combined production of heat and power. It is even possible to go one step further with so-called "tri-generation" systems that combine the production of heat, power and liquid fuels (synthetic LPG) in Fischer-Tropsch reactors and biomass integrated gasifier (≈ 10 MW) combined cycle (IGCC) turbines[6].

In the case of cooking, the perspective should be to go from the present inefficient, unhealthy stoves using arduously gathered fuelwood through improved woodstoves to gaseous-fuelled stoves to clean, efficient and convenient stoves operating on electricity or on gaseous biomass-based biofuels. Catalytic burners may also have a place.

The provision of safe water is a crucial task that yields an enormous payoff in terms of improved health. But, it invariably requires inputs of energy to go from surface water (often contaminated) to "safe" ground water lifted from tubewells to filtered or UV filtration or treated water to safe piped water.

With roughly 60-70% of rural households being without electricity connections and therefore forced to depend on lamps burning plant oils or kerosene, the way forward is electric incandescent bulbs that are replaced as rapidly as possible with fluorescent tubelights and compact fluorescent lamps.

Radical improvements in the quality of life often depend on replacing human and animal power with motive power based on electric motors and engines driven by the combustion of fuels. Today, fossil fuels are conventional sources for engines but prime movers running on biomass-derived fuels and hydrogen are the future. In parallel, motors with much greater efficiency should be implemented.

The plight of women is very much connected to their being forced to put in enormous amounts of arduous physical labour performing various household chores. A key objective of rural energy must therefore involve the reduction of this manual labour with appliances. The advance can then be from simple electrical appliances to efficient appliances and super-efficient appliances.

Rural industries such as pottery and metalworking are currently based on process heat derived from fuelwood and/or other biomass sources such as sugarcane bagasse. Future developments have to be based on electric furnaces, cogenerated heat, producer gas and natural gas fuelled furnaces, and solar thermal and induction furnaces. The long-term future will perhaps belong to furnaces based on biomass-derived fuels.

Rural transport particularly within villages and from house to farm and vice versa is today based overwhelmingly on animal-drawn vehicles and human-powered bicycles. Mechanisation, however, is making inroads with vehicles fuelled with petroleum products gasoline/motor spirit and diesel. Natural-gas-fuelled vehicles are bound to play a part. Over the medium-term, however, vehicles can be run on biomass-derived fuels such as producer gas and/or methanol and/or ethanol and over the long-term, fuel-cell-driven vehicles are the option.

The technological sources and devices for the near-, medium- and long-term are summarised in the Table 1.

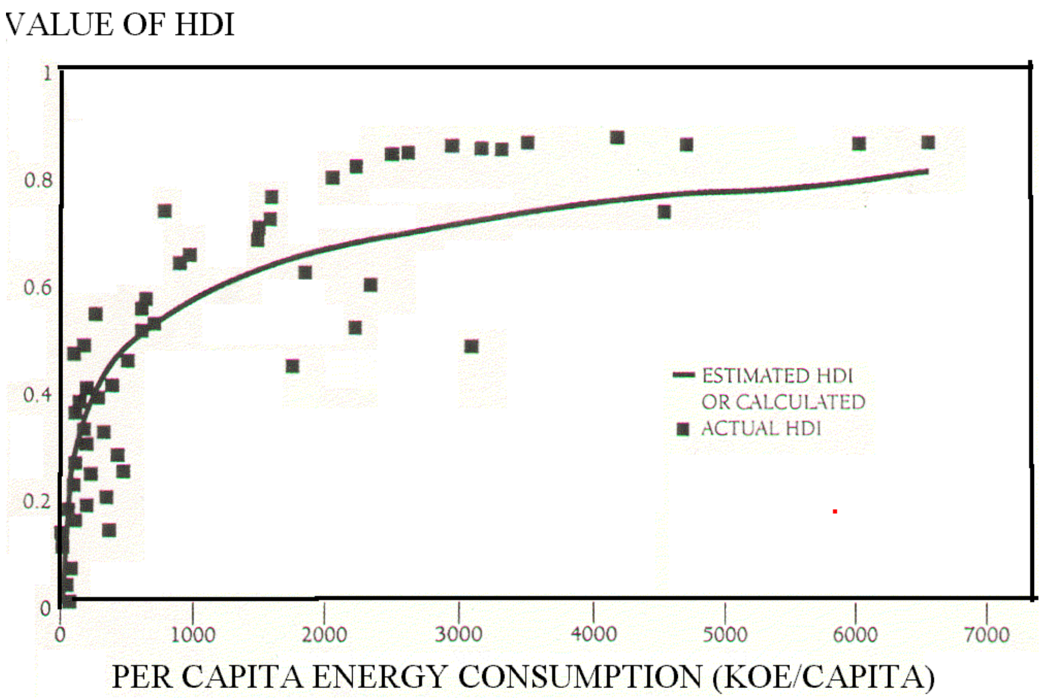
General Implications of Rural Energy Strategies and Policies

If rural energy strategies are oriented towards the goal of sustainable rural development in the manner outlined above, they will have implications for other pressing social problems. Above all, they will result in a betterment of the quality of life and the HDI. They will advance poverty alleviation in a direct way. In addition, they will dramatically improve the position of women. The life of children will also be improved. The rural environment and the health of rural inhabitants will take a turn for the better. In the long run, there will be a positive impact on population growth. Thus, a focus on rural energy will have a synergistic effect on an array of major social problems.

Table 1: Sources and Devices for the Near-, Medium- and Long-term

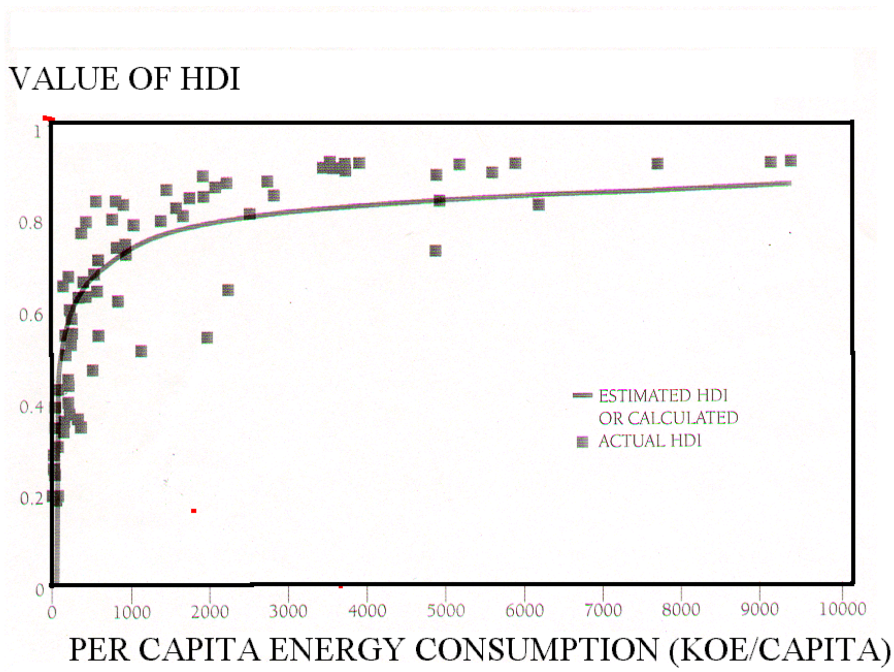
SOURCE	PRESENT	NEAR TERM	MEDIUM TERM	LONG TERM
Electricity	Grid or no electricity	Biomass-based generation Internal combustion engines coupled to generators	Biomass-based generation through Micro-turbines and Integrated Gasifier Combined cycle turbines PV/Wind/ Small Hydel /Solar Thermal	Fuel Cells for baseload power
Fuels	Wood/ Charcoal/ Dung/Crop Residues	NG/LPG/ Producer Gas/ Biogas	LPG/Biofuels/ Syngas/DME	Biofuels
Co-gene-ration (Combined Heat and Power)		Internal combustion engines Turbines	Micro-turbines and Integrated Gasifier Combined cycle turbines	
TASK	PRESENT	NEAR TERM	MEDIUM TERM	LONG TERM
Cooking	Woodstoves	Improved Woodstoves/ LPG Stoves	LPG/Biogas/ Producer Gas/ NG/DME Stoves	Gaseous biofuelled stoves/ Electric Stoves/ Catalytic burners
Safe Water	Surface/ Tubewell Water	Filtered/ Treated Water/UV filtration	Safe piped/ treated water/ (De)centralised water treatment	Ultra Safe piped/treated water
Lighting	Oil/ Kerosene Lamps	Electric Lights	Fluorescent/ Compact Fluorescent Lamps	Fluorescent/ Compact Fluorescent Lamps
Motive Power	Human/ Animal powered devices	IC Engines/ Electric motors	Biofuelled prime movers Improved motors	Biofuelled prime movers Improved motors Fuel cells
Appliances	--	Electric Appliances	Efficient appliances	Super-efficient appliances
Process Heat	Wood/ Biomass	Electric Furnaces/ Cogeneration/Producer gas/ NG-fueled Solar Thermal furnaces	Induction Furnaces Biomass-fuelled Solar Thermal	Biofuels/ Solar
Transport	Animal-drawn vehicles/human-powered bicycles	Petroleum/ NG-fuelled Vehicles	Biomass-fuelled vehicles	Fuel-cell driven vehicles

Thanks are due to Robert Williams for help in the finalisation of this table.



Note: Data for 100 developed and developing countries.
Source: Caluculations by Carlos Suarez based on data in United Nations Development Program,

Figure 1a: Relationship Between HDI and Per Capita Energy Consumption (1960-1965)



Note: Data for 100 developed and developing countries
Source: Calculations by Carlos Suarez based on data in United Nations Development Program,

Figure 1b: Relationship Between HDI and Per Capita Energy Consumption(1991-1992)

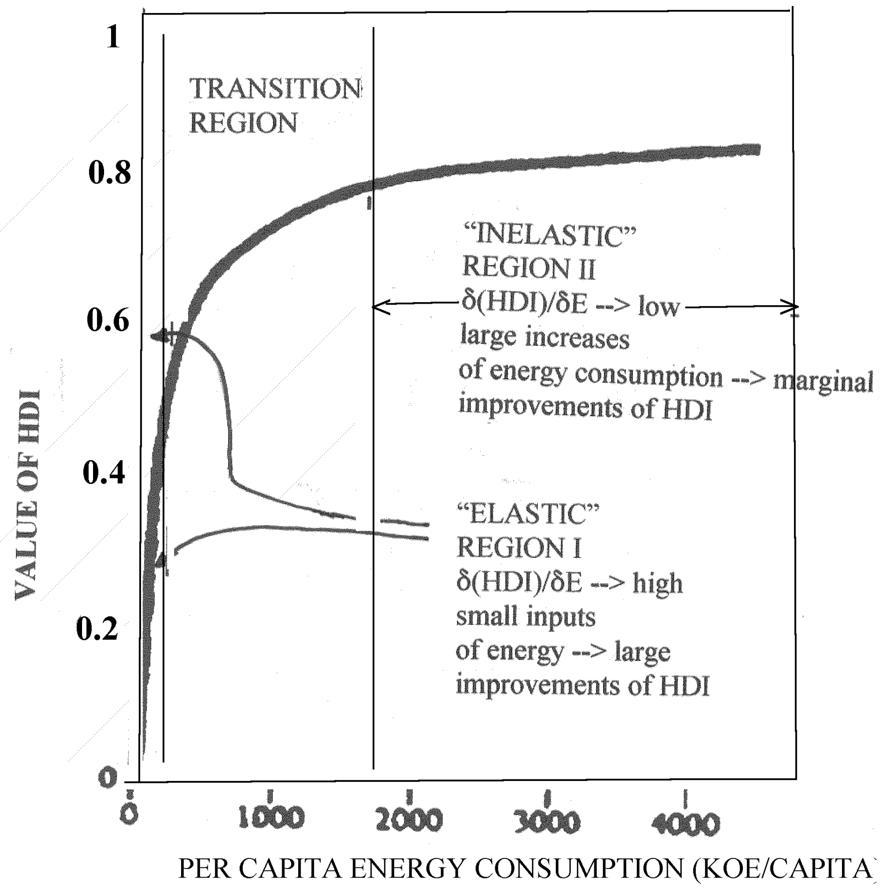


Figure 2: "Elastic" & "Inelastic" Regions of HDI Vs Energy Consumption

Appendix 1: Dissemination of photovoltaic solar home systems (PV SHS) in rural India.

India's population according to the 1991 census was 846 millions. The rural population was 74.34% or 623 millions which at 5.5 persons per household corresponds to 114 million households. 69% of these households, i.e., 78.6 million households, were un-electrified. The initial cost of a four-light 37 watts PV SHS[7] in 1999 was about $ 430 (Rs 18,500 @ Rs 43/$) for which financing from a bank could be obtained at 12% interest over a 5-year period. This corresponded, after a down payment of 15% ($ 64.50), to a household expenditure of $ 101.45 (Rs.4,362) per year or $8.45 (Rs.364) per month. On average, energy accounts for about 7.5% of the expenditure of a household. If, to be liberal, this is doubled, it means that 15% of its monthly expenditure is the upper limit to what a household can spend on energy. The monthly expenditure on a PV SHS of $ 8.45 per month translates at 15% to a household income of $56.36 (Rs.2,423) per month. The income distribution pattern in India is such that only about 7% of the households have this income required to afford PV SHS. Assuming that only half of those households that can afford PV SHS are prepared to switch to PV SHS, it appears that much less than 5% of the richest rural households constitute the market for such systems.

The potential penetration is greater with the smaller systems. The two-light 20 watts SHS costs about $ 267.50 (Rs.11,500) and can be obtained with the same financing terms as the four-light system. This cheaper system implies $ 40.12 (Rs.1,725) down payment and $ 5.26 (Rs.226) per month requiring an income of about $35.00 (Rs.1,506) per month available to about 17% of the households. The one-light 10 watts SHS costs about $ 128.00 (Rs.5,500) and implies (with the same financing terms) about $19.20 (Rs.825) down payment and about $2.50 (Rs.108) per month requiring an income of about $16.75 (Rs.720) per month available to about 75% of the households.

It follows that the two- and four-light systems can only be afforded by the richest rural sections constituting 17 and 7% (respectively) of the population.[8] Even the cheapest one-light PV SHS is beyond the means of the poorest 25% of the rural population.

Since PV SHS are inaccessible to the rural poor, the question arises: are they ***elitist*** energy sources/devices? If the purpose of PV SHS is, not merely to improve the quality of life of the household, but to illuminate activities that augment income, then the elitist characterisation may not be applicable. To illustrate[9], suppose that a one-light PV SHS permits a tribal household to weave two extra baskets per evening to earn $0.12 (Rs.5) per basket and therefore (after paying for materials) about $5.80 (Rs.250) per month. Then the income generated by the PV SHS more than pays for the investment on the light. A similar case is that of a mobile vegetable vendor who can have two extra hours of sales. Thus, there are non-elitist ***niche*** markets for PV SHS.

End-notes and References

1 A.K.N. Reddy, "Blessing of the Commons", **Energy for Sustainable Development, Volume II**, No. 1, pp 48-50, May 1995

2 Watts/capita is an abbreviation for Watt years/(capita year).

3 This number is in broad agreement with the estimate of Robert Williams (in his personal communication to Gary Nakarado of the UN Foundation) of slightly more than 100 watts/capita consisting of 87 watts/capita for cooking with clean LPG, 3.75 watts/capita for five CFLs for lighting, 3.13 watts/capita for a colour TV and 13.65 watts/capita for a refrigerator.

4 J. Goldemberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, "Basic Needs and much more with 1 kW per capita", **Ambio, Volume 14,** No. 4-5, pp 190-200 (1985)

5 Actually, subsidies granted in the name of the poor often end up going to the better off. For example, free electricity to rural areas goes primarily to farmers rich enough to own an electric pumps for pumping irrigation water.

6 E.D. Larson and Jin Halming "A Preliminary Assessment of Biomass Conversion to Fischer-Tropsch Cooking Fuels for Rural China", **Proceedings of the Fourth Biomass Conference of the Americas**, Oakland, CA, 29 August-2 September 1999.

7 The SELCO four-light 37 watts SHS costs Rs.18,500 and after 15% down payment can be financed with a Grameen-type bank loan of 12% for 5 years.

8 The restriction of penetration to the richest sections of the rural population is observed even in the case of the Grameen Shakti programme of the Grameen Bank of Bangladesh which is world famous for its success in microcredit to the poor. Bangladesh's projected population for 1996 was 123.6 millions. The rural population was 79.9% or 98.76 millions which at 5.6 persons per household corresponds to 17.64 million households. 86% of these households, i.e., 15.17 million households, were un-electrified. The initial cost of a PV SHS is Taka 9,200 (Taka 45.5 ≈ $ 1 US) for which Grameen intends to provide financing at 8% interest over a 2-year period after a 25% down payment. This corresponds to a household expenditure of Taka 3,867 per year or Taka 323 per month. On average, a household spends about 5.47% of its expenditure on energy. If, to be liberal, this is doubled, it means that 10.94% of its monthly expenditure is the upper limit to what a household can spend on energy. The monthly expenditure on a PV SHS of Taka 323 per month translates at 10.94 to a household income of Taka 2,952 per month. The income distribution pattern in Bangladesh is such that about 46.8% of the households have this income required to afford PV SHS. Assuming that only half of those households that can afford PV SHS are prepared to switch to PV SHS, it appears that only 23.4% of the richest rural households constitute the market for such systems in Bangladesh.

9 Thanks are due to Dr. Harish Hande, SELCO, for these real-life examples.