4 Energy Technologies and Policies for Rural Development*

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If the goal to be achieved by *any* energy system 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 and improved living conditions for the poor, as measured by the Human Development Index (HDI). The HDI measures a country's achievements in three aspects of human development: longevity, knowledge, and a decent standard of living. Improving these aspects of human development, and therefore the HDI, has three crucial dimensions: *equity* based on a marked increase in access of poor to energy services, *empowerment* based on strengthened endogenous self-reliance, and *environmental soundness*. Thus for an energy system to be in the interests of the rural poor, it must:

- Increase their access to affordable, reliable, safe, and high-quality energy.
- Strengthen their self-reliance and empower them.

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- Improve the quality of their environment (starting with the 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) include the following:

- 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.

These strategies 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., to the *process* that should be followed. There are three process strategies for rural energy:

- Government facilitation and enabling support.
- Individual initiative as far as possible through the market.
- Village community monitoring and control.

The standard approach to the establishment of new infrastructures (for example, rural energy systems based on new technologies) has been for governments to take the initiative. This approach often ends up with the emergence of new government agencies and accompanying bureaucracies that may be plagued by red tape, delays, or even corruption. The result has been the more recent trend toward liberalisation.

Many claim that the market is 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 do an excellent job of allocating men, materials, and resources; it does not, however, have a very successful record at safeguarding equity, the environment, the long-term, or research, development, and dissemination of new technologies. The market is thus not an adequate instrument for addressing tasks characterised by a low discount rate; it will have to be assisted by the State.

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 costs that an individual/household experiences 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.

The Relationship between HDI and Energy

For rural energy systems to advance sustainable rural development, the emphasis must be on *energy services* – 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 *directly* (cooking, safe water, lighting, transportation, etc.) as well as *indirectly* via employment and income generation (motors, process heat, etc.).

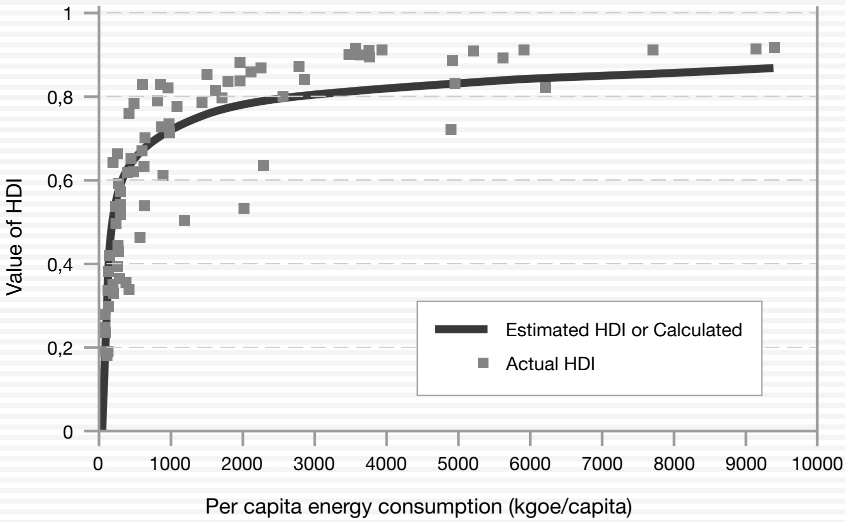
The impact of energy on the HDI depends on the end-uses of energy and on the tasks that energy performs. The direct impact of energy is associated *inter alia* with, and is produced by, cooking, supply of safe water, and lighting. The indirect impact of energy is associated with, and is produced by,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

The role that energy can play in improving the HDI is not merely a matter of hope or conjecture. There is an empirical basis to the relationship between HDI and energy. Strictly speaking, the relationship must be between energy *services* and HDI. However, if end-use efficiency is virtually constant, energy *consumption* can serve as a proxy for energy services (Figure 4-1).

The relationship between HDI and energy has several important implications. The relationship can be considered to consist of *two regions* (Figure 4-2). The figures shows that in region I – the 'elastic region' – the slope $\delta(\text{HDI})/\delta E$ of the HDI vs E curve is high; *large* improvements in HDI can be achieved with *small* inputs of energy (small improvements of energy services), making the HDI-energy (benefit-cost) ratio very high. In region II – the 'inelastic region' – the slope $\delta(\text{HDI})/\delta E$ of the HDI vs E curve is low; even *large* inputs of energy (large improvements of energy services) result only in *marginal* improvements in HDI, i.e., the HDI-energy (benefit-cost) ratio is very low.

In the 'elastic' region I, enhanced energy services lead *directly* to the improvement of 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' region II, enhanced energy services can lead *indirectly* to the improvement of HDI via income generation. In the 'elastic' region I,

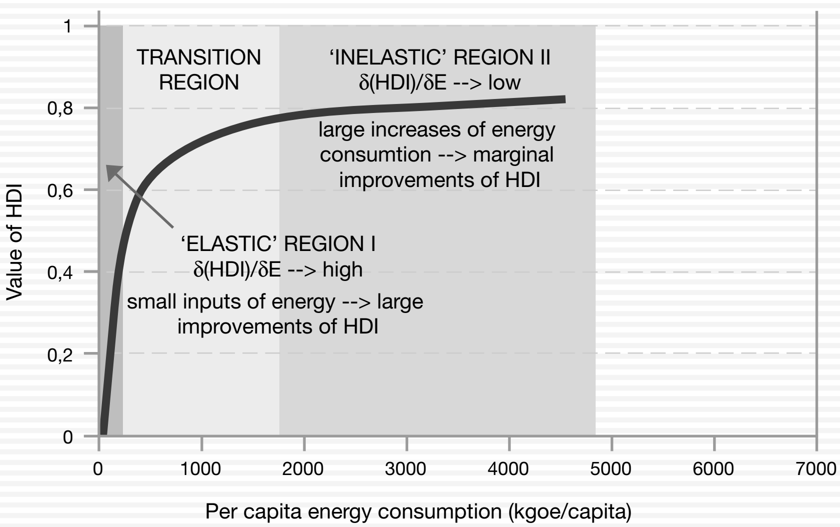
FIGURE 4-1: RELATIONSHIP BETWEEN HDI AND PER CAPITA ENERGY CONSUMPTION (1991–1992)



Note: Data for 100 developed and developing countries.

Source: Calculations by Carlos Suarez based on data in United Nations Development Program.

FIGURE 4-2: 'ELASTIC' & 'INELASTIC' REGIONS OF HDI VS ENERGY CONSUMPTION



the coupling between HDI and income (used to defray 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 improvements in energy services at operating costs comparable to, or even less than, the costs of using kerosene lamps.

In the 'inelastic' region 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. Is it used for HDI improvement? For liquor? Gambling? Conspicuous consumption? This in turn often depends on which gender gets the income – women tend towards 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 in the elastic region increased energy services guarantee direct improvement of HDI, whereas improvement of HDI via income depends on what the income is used for.

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. However, this did not work because the benefits of economic growth are absorbed far too slowly by the poor. Attention was then turned to human capital investment, but even this is a slow process. Direct poverty alleviation is a much surer method of improving the HDI than the indirect route of income generation and human capital formation in the hope 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 a necessary condition for launching an indirect improvement via income.

The 'elastic' region of the energy-HDI relationship shows that dramatic improvements in 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 a) safe, clean, and efficient cooking with liquefied petroleum gas (LPG) or a LPG-like fuel and b) home electrification for lighting, space comfort, food preservation, and entertainment. The energy required for cooking would be about 2.3 gigajoule per capita per year, or about 73 watts/capita[a]. The electricity for lighting, fans, etc., at twice the consumption of 33 kilowatt hours per household per month currently found in Karnataka State, South India,

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[a] Watts/capita is an abbreviation for watt years/(capita year).

would be about 18 watts/capita. This leads to a total of 91 watts/capita that can be approximated to about 100 watts/capita[b]. Thus, *as little as 100 watts/capita is adequate to achieve a dramatic revolution in 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 television*. This 100 watts/capita is only about one tenth of the level required to support a western European living standard with modern energy carriers and energy-efficient technology.[2]

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 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. 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 be devoted to sources that are locally available, small scale, decentralised, and renewable, and systems that are amenable to and enhance local control.

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

- Give the entire rural population, but particularly the rural poor, access through micro-utilities and community-scale systems for high-density settlements and through home/household systems for individual homesteads in settlements with low housing density.
- Are compatible with high-efficiency end-use devices.
- Lend themselves to cogeneration (i.e., the combined production of heat and power).
- Are decentralised/locally available to strengthen self-reliance and to empower people/communities.
- Are renewable and promote environmental soundness.

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[b] This number is in broad agreement with the estimate of Robert Williams (Princeton University, personal communication) 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 television, and 13.65 watts/capita for a refrigerator.

Access to (and penetration by) individual homes 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 subsequent establishment and operation of micro-utilities (that increase access by the rural poor).

The following questions are therefore important in the choice of end-use devices. Do they directly improve the HDI? 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, how a rural energy technology distributes benefits must be scrutinised. Equity impact assessment (EqIA) statements are important. Those implementing technologies with a goal of sustainable development have an obligation to anticipate and examine the distributional or equity implications of the technology they are promoting. 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 SHSs) in rural India. An analysis of the 1999 costs of four-light, 37-watt photovoltaic home systems and the income distribution pattern in rural India shows that only about 7 percent of households have the income required for such systems. Assuming that only half of households that can afford the PV SHS are prepared to switch, it appears that the market for such systems is restricted to much less than the richest 5 percent of rural households. Smaller systems have much greater potential for penetration. About 17 percent of households have the income to afford two-light, 20-watts systems, and about 75 percent of households can afford one-light, 10-watt systems. (see Annex A)

Since PV SHSs are inaccessible to the rural poor, it is tempting to dismiss them as *elitist* energy sources/devices. However, if the purpose of a PV SHS is not merely to improve the quality of life of the household, but to illuminate after-sundown activities that augment income (for example, weaving baskets), then the elitist characterisation may not apply. The income generated under illumination by the PV SHS can more than pay for the investment in the light.

Another reason not to engage in hasty judgements about the elitist or egalitarian character of energy sources and devices is that technological advances and organisational learning can bring about major cost reductions in the cost of emerging, not-yet-mature technologies – a point 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. Declining costs can erode the elitist character of sources and end-use devices and strengthen their egalitarian character.

If 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 systems 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 important questions such as the following. Do elitist sources/devices pre-empt the possibility of dissemination of affordable sources/devices for the 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 a more cost-effective community-scale plant? Is there a level playing field for elitist sources/devices and sources/devices for the rural poor? Are banks and financial institutions biased towards elitist sources/devices?

Financing Rural Energy Technologies

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

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 for 'free', there are opportunity costs associated with the time they spend to obtain the service. The real or opportunity costs of traditional practices are an important benchmark because they invariably 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. The cost problems associated with a new technology stem from the capital costs of acquiring it rather than from the operating costs. Hence, innovative 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.

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[c] Actually, subsidies granted in the name of the poor in India often end up going to the better off. For example, free electricity to rural areas goes primarily to farmers who are rich enough to own an electric pump for pumping irrigation water.

In the case of energy, the technological opportunity is upper-bounded by the maximum possible household expenditure on energy (say 15 percent). After a favourable financing scheme, the operating costs of the 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.

Converting 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. Their backing enables rural banks to provide loans for purchase or lease of energy-efficient devices (stoves, lamps, drives, boilers/furnaces/kilns, etc.) to improve HDI directly as well as indirectly via income generation. However, rural banks may not be accustomed to developing programs to help turn capital costs into operating costs, and may have to go through a learning process.

Similarly, local-level implementing agencies/bodies may not have the expertise or capacity to discharge their new responsibilities, making new energy enterprises necessary. These new energy enterprises must tackle the challenges of marketing 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: The Near, Medium, and Long Term

Identification of technological options for energy sources and devices depends very much on the time horizon. Unfortunately, two extreme trends can be observed. Because grassroots rural development workers are preoccupied with the immediate problems of the people with whom they work directly, they tend to choose technological options that are available right off-the-shelf. Totally preoccupied with the present, they tend to use a very high discount rate for their technological decisions. In contrast, technical experts are excited by technological possibilities, and talk about 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 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. Technologists – enamoured with technological innovations even though they may take a long time to become realities – are little concerned that people remain in their current misery while they are waiting for the promised ideal technology.

Obviously, an either-or approach must be avoided. Starting from the present technology (the initial condition), three types of technology are needed 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 twenty to thirty years and provide an ideal sustainable solution. The technologies for the near, medium, and long terms should be forward compatible so that the technology at any one stage can be upgraded to the better version. 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.

Clearly, the technologies for the near, medium, and long terms should be the most appropriate or best technologies for each period and should be chosen through a 'natural selection' process of competition. In other words, there should be a transition from the most appropriate technology for the near term to the 'best' technology available in the medium term, and then to the 'best' technology for the long term. This process should involve technological leapfrogging, i.e., 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', 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 concept describes past and present behaviour of consumers. In contrast, technological leapfrogging is a normative prescription for future behaviour. The recommendation here is that rural areas not replicate the energy ladder behaviour of the past and present but adopt a technological leapfrogging approach. In Brazil, the introduction of LPG almost completely eliminated the use of fuelwood for cooking (Box 4-1).

Specific Technology Options

The current 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, decentralised generation of electricity is increasingly attractive. Where appropriate, decentralised generation from the intermittent sources of wind and/or small hydro, solar photovoltaics, and solar-thermal sources all have roles to play. The exciting developments are the availability of ~100 kilowatt micro-turbines and ~ 10 megawatt biomass-integrated gasifier combined cycle (IGCC) turbines.

Biomass-based generation of fuels to run fuel cells is an attractive long-term option, particularly because it may be possible to generate 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

Box 4-1
Liquefied Petroleum Gas in Brazil

Liquefied petroleum gas (LPG) was introduced in Brazil in 1937, when a private entrepreneur started to sell bottles from a stock of a few thousand made available by a German company. In order to promote the use of the new fuel, this private entrepreneur also marketed cooking stoves. After World War II, the business expanded and several multinationals began to import LPG in special ships and bottle it locally. In 1955, PETROBRAS, the national oil company, gained a monopoly of production and imports of LPG. From 1975 on, PETROBAS subsidised LPG through higher gasoline and diesel prices, and the market expanded extraordinarily. While international prices of LPG were US$400 dollars per ton (or higher), prices in Brazil where kept to around US$200 per ton, benefiting millions of people.

In 1999, 97.4 percent of all households in Brazil were equipped with LPG stoves. Approximately 6.5 million 13-kilogram bottles were sold every month, generating 300,000 jobs. Ten thousand trucks were used for distribution. Total consumption was 6.8 million tons per year, of which 2.8 million were imported.

The introduction of LPG for cooking purposes in Brazil has almost completely eliminated the use of fuelwood for cooking. One can estimate that this shift in fuels has avoided the deforestation of one million hectares of forest per year.

Among developing countries, Brazil ranks seventh in per capita consumption of LPG, at approximately 40 kg/capita/year. China, India, Indonesia, and Pakistan consume less than 10 kg/capita/year. In Africa, with the exception of Tunisia and Algeria, average consumption is less than 1 kg/capita/year.

residues. A switch to stoves and furnaces fueled 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 cogeneration of electricity and process heat is a well-known, attractive option, particularly when heat can be utilised close to the equipment generating the 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 IGCC turbines (≈ 10 MW).[3]

In the case of cooking, the transition must be made from today's inefficient, unhealthy stoves using arduously gathered fuelwood, first to improved woodstoves, then to gas-fueled stoves, and then to clean, efficient, 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 to 70 percent of rural households having no 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 in the future motive power will come primarily from biomass-derived fuels and hydrogen. At the same time, much more efficient motors should be installed.

The plight of women is very much connected with the enormous amounts of arduous physical labour required for basic household chores. A key objective of rural energy must involve reducing the amount and the difficulty of this work. Immediate to long-term improvements can come first from simple electrical appliances and then progress to efficient and then super-efficient appliances. Box 4-2 shows one way in which women are both providing energy services and benefiting from increased incomes.

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-fueled 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 fueled with petroleum products such as gasoline and diesel. Natural-gas-fueled vehicles are bound to play a part as well. Over the medium term, vehicles can be run on biomass-derived fuels such as producer gas, 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 Table 4-1.

Box 4-2
The Multifunctional Platform Approach: Creating Opportunities for Growth and Empowerment of the Poor

The multifunctional platform project, implemented by UNDP and the United Nations Industrial Development Organisation (UNIDO) in Mali and at a pilot stage in Senegal, Burkina Faso, and Guinea, seeks to reduce rural poverty in general and that of rural women in particular, while creating income-generating opportunities through provision of affordable energy services. To date, about 220 platforms are operational in Mali, where the project intends to install platforms in 450 villages serving about 10 percent of the rural population.

The multifunctional platform has a simple diesel engine that can power different tools, such as a cereal mill, husker, and/or battery charger. The engine can also generate electricity for lighting and refrigeration and to pump water. The advantages of the engine are its simplicity and multiple uses. With its many functions, it can be used for a variety of services that can generate incomes for the group operating the platform. Because it is a very simple machine, its installation and maintenance can all be handled by local artisans and spare parts are readily available across West Africa.

Installation of a platform is demand-driven. A duly registered women´s association has to request it, with the active support of the village community. But before a platform is installed, a social, economic, and technical feasibility study is undertaken that provides the women's association as well as the whole community with information to make an informed purchasing decision, identifies potential partners, and establishes base line indicators against which platform results as well as development impacts at the village level can be monitored. After initial literacy training, the association elects a Women Management Committee, whose members are then trained in managerial and entrepreneurial skills to ensure the technical and economic viability of the platform.

At an estimated cost of US$4,000 for engine, rice de-huller, stone mill, battery charger, and housing for the platform, the platform is comparatively cheap to buy, install, maintain, and replace. Between 40 and 50 percent of the cost is financed by the women's association, often with financial support from the rest of the community; a one-time subsidy of approximately US$2,500 is provided by the project. The project informs beneficiaries of existing financial and management support facilities and facilitates access to credit in order to finance the platform. Depreciation and variable costs (maintenance, salaries of female operators, etc.) are borne entirely by the Women Management Committee. Village case studies clearly indicate that the platform has positive cash flows from the first day after installation.

In each village, around 800 clients – mostly women – buy energy services from the platform, and studies show strikingly positive impacts. In Mali, for example, the project increased annual income per participating woman from about US$40 to US$100 and freed up two to six hours of her time per day (depending on the services of the platform). The 'invisible' time and energy spent on repetitive and tedious work is made visible as women re-organise their allocation of time and as they gain social as well as economic recognition for the work they do. The introduction of a platform in a village has also resulted in higher levels of schooling for girls.

The Challenges of Scaling Up

The experiences of the project show that multifunctional platforms can serve as a basic rural infrastructure to develop the rural economy and to mobilise necessary local capital, with limited assistance from outside.

In order to replicate the platform approach, appropriate measures should focus on establishing conditions for small and informal enterprises to be an engine for growth and rural development. Creating such conditions is an involved process and poses a significant challenge for scale-up. Often, there is no clear policy and institutional framework for decentralised energy management for rural areas. As such, strengthened coordination among public institutions at both central and decentralised levels is needed to integrate the platform approach into existing public and private institutions. Expansion of a decentralised approach depends upon local rural industrial markets, which are narrow, and the rural technical skill to develop and implement a well-designed market strategy, which is very weak. Addressing the capacity development needs of rural communities and rural entrepreneurs must be an essential component of policy measures to promote the platform approach.

As the Malian experience has shown, linking micro-scale experiences with policy formulation at the macro level presents yet another challenge. How a focus on the users of energy services for multiple ends can be a practical engine of synergy for cross-sectoral policy coordination is poorly understood and advocated. For example, macroeconomic analyses that make the link between poverty reduction and economic growth do not sufficiently count and analyse data on the informal sector. Thus the significant prospects that poor people, particularly rural women, represent for growth and poverty reduction tend to get missed. Platform initiatives can be an effective mechanism to collect and analyse social and economic data at the village level that can be aggregated to make their collective contributions to the national economy more visible. An intervention like the multifunctional platform can create ways to connect a well-designed community level intervention to the formulation of national policy and strategies, such as poverty reduction strategies, which reflect concerns of the poor. This is an important step for scaling-up rural energy development.

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Sources: Brew-Hammond, A., and A. Croles-Rees, *Multifunctional Platforms in Africa: A Forward-looking Review* (New York: UNDP, 2001); and Burn, N., M. Takada, and L. Coche, *Concept Paper for the Expanded MFP Project in Africa* (New York: UNDP and UNIDO, 2000).

TABLE 4-1: ENERGY 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 (IGCC) PV/Wind/Small hydro/Solar Thermal	Fuel cells for baseload power
Fuels	Wood/Charcoal/ Dung/Crop residues	NG/LPG/ Producer Gas/ Biogas	LPG/Biofuels/ Syngas/DME	Biofuels
Cogeneration (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 biofueled 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	Internal combustion engines/ Electric motors	Biofueled prime movers/ Improved motors	Biofueled prime movers/ Improved motors/ Fuel Cells
Appliances		Electric appliances	Efficient appliances	Super-efficient appliances
Process Heat	Wood/Biomass	Electric furnaces/ Cogeneration/ Producer gas/ Natural-gas-fueled or Solar thermal furnaces	Induction furnaces/ Biomass-fueled or Solar thermal furnaces	Biofuels/Solar thermal furnaces
Transport	Animal-drawn vehicles/Human-powered bicycles	Petroleum/ Natural gas-fueled vehicles	Biomass-fueled vehicles	Fuel-cell driven vehicles

Note: Thanks are due to Robert Williams for help in the finalising this table.

Policies that Promote Rural Energy Strategies

Policies to implement the strategies outlined are needed in the following areas.

- A fundamentally important issue concerns the choice of technology. In a command-and-control set-up, technologies are chosen in a top-down manner by government. In effect, this means that the choice is made by bureaucrats. Unfortunately, such choices are often notoriously defective. One has only to recall the breeder reactor programmes of the United States, France, and Japan, or the Super Sonic Transport (SST) plane. The other option is to allow the market to make the choice through a process of competition. Though the market option is attractive, it is only effective when there is a level playing field for the various contending technologies. This means that deliberate policies are needed to ensure that there is a *level playing field for centralised supply and decentralised village-level supply and for supply expansion and end-use efficiency improvement*. The problem is that yet-to-mature emerging rural energy technologies must not be compared on the basis of their current costs with mature conventional technologies. The place of emerging technologies must be determined on the basis of their future costs resulting from technological advances and organisational learning.

- Policies must promote *household-level supply* of energy when the cost of a household-level system is less than the per-household cost of a community system plus the distribution cost. They must advance community-based supply of energy sources when the cost of sources for N households (i.e., the cost of generation) plus the cost of the distribution network is less (i.e., more cost-effective) than the cost of N household-level sources. But there should also be policies to encourage *'centralised' multi-community supply* of energy sources if the generation plus distribution is more cost-effective than community-level sources.

- Policies are required to promote *integrated resource planning* in order to identify least-cost mixes of sources and associated devices.

- Notwithstanding the importance of the cost criterion for the choice of technology, there are other crucial sustainable development criteria as well. In particular, a technology has to be accepted by society for it to be socially sustainable. This means that there has to be social participation in the choice of technology. Special policies are required to ensure that the *process of technology choice is transparent and democratic*. In this process, whatever criteria can be quantified must be quantified. And criteria that cannot be quantified today should, as an interim measure, be represented with traffic-light colours – green for 'acceptable', red for 'not acceptable', and amber for 'uncertain' – while setting in motion a process to develop a method of quantifying the criteria.[4]

- Policies are needed to promote the development and dissemination of technologies that improve HDI directly (cooking, safe water, home electrification for lighting, space conditioning for comfort, etc.) as well as technologies that improve HDI indirectly via income generation (stationary and mobile motive power, process heating, etc.).

- Policies are necessary *for near-term, medium-term, and long-term time-horizons*. Most urgent is the development and dissemination of technologies that will immediately improve energy services in order to provide a better quality of life for the rural poor.

- Most rural energy technologies (stoves, windmills, biogas plants, wood gasifiers, etc.) have evolved through several generations. The first generation of unsuccessful devices was often the result of the enthusiasm of unqualified amateurs. The second generation of successful prototypes emerged from the creative efforts of competent technologists. The third generation involved the conversion of prototypes into products in the economy, i.e., commercialisation for large-scale dissemination. This third generation required management inputs. Hence, for each rural energy system, for example, producer-gas-based electricity generation, it is vital to have an entire *implementation package of hardware plus 'software'*.[d] Such packages must consist of the technology, economics, financing, management, training, institutions, etc., necessary for the dissemination of that system. Unfortunately, far too often, crucial elements (for example, institutional requirements) are missing in the dissemination programmes, leading to failures. Hence, policies to encourage the preparation of implementation packages are imperative.

- Unlike conventional energy sources/end-use technologies, most new rural energy technologies are in the process of maturing. In particular, their costs are declining because of technological advances and organisational learning. Hence, it is important to have policies that actively promote *technological advances and organisational learning*.

- If they are used as a policy instrument, *subsidies must be time-bound* with a sunset clause and they must promote technological advances and organisational learning. Above all, subsidies must not be a permanent crutch inhibiting the advancement of the technology.[e]

- The establishment and operation of rural energy systems should lead to *local capacity building* in the matter of hardware (technology) and 'software' (particularly management). Policies must be put in place to promote such local capacity building at the rural level, and special attention must be given

[d] 'Software' refers to the instructions, procedures, knowledge, etc., necessary to utilise the hardware.
[e] The consensus particularly among solar water heater manufacturers in India is that the subsidies provided by the Ministry of Non-Conventional Energy Sources hindered the development of solar water heaters and in particular interfered with cost reduction. Fortunately, these subsidies have been withdrawn.

to operation and maintenance know-how as distinct from construction and design know-how.

- It is vital that policies include a *key role for women* as users, operators, and entrepreneurs in rural energy systems.

- Policies that enable and ensure *people's participation* (in particular for the supply of resources and payment for services) as households and/or as a community are imperative.

- Policies are crucial to arrange/enable *financing* (through leasing, loans, etc.) for households and communities so that unacceptably high initial capital costs are converted into manageable operating costs.

- Policies are needed to encourage and support effective, democratic, and transparent *institutional arrangements at the rural level* to monitor energy systems and maintain clear, transparent records and accounts.

- In view of the shortcomings of government implementation, the strengths of entrepreneurship and the market mechanism as well as the advantages of local community action have to be exploited for operations independent of the government. Nevertheless, government involvement in rural energy systems is essential to provide an enabling environment. Above all, parallel operations by government must not compete with rural energy systems.[f] Thus policies to ensure *synergistic government support* for individual and/or community operation of rural energy systems are vital.

- Policies are required to promote the *establishment of new energy enterprise(s)* if existing institutions such as local-level bodies cannot discharge the new responsibilities. Policies must also encourage financial institutions/banks/donors to take on new tasks.

Rural Energy and Improved Quality of Life

If rural energy strategies are oriented towards the goal of sustainable rural development in the manner outlined above, and the associated policies are implemented successfully, they will have implications for other pressing social problems. Above all, they will result in improved quality of life and HDI. They will help to alleviate poverty, and 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.

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[f] Just when Rural Energy and Water Supply Utilities (REWSUs) in Karnataka State in South India were establishing and operating drinking water schemes based on households paying for piped water to homes, the Karnataka government started implementing a World Bank-financed rural water supply scheme to supply 'free' water in an obviously unsustainable manner.

Conclusions

Strategies for rural energy that would advance the goal of sustainable rural development are the reduction of arduous human labour, the modernisation of biomass, the transformation of cooking, the provision of safe water for domestic requirements, the electrification of all homes, and the provision of energy for income-generating activities.

Dramatic improvements in the quality of life (safe, clean, and efficient cooking and home electrification) can be achieved with very small investments of energy of about 100 watts/capita.

The real or opportunity costs of traditional practices are an important benchmark because invariably they define the maximum amount that the household is willing to spend. Thus, the operating costs of traditional devices are a sort of upper bound for the costs of an alternative technology. The window of technological opportunity is upper-bounded by the maximum possible household expenditure on energy, but technological advances can widen the window of opportunity.

The conversion of capital costs into affordable operating costs requires investments from financial institutions. However, many of the new tasks are ones to which these institutions are not accustomed and therefore they may have to go through a learning process. New energy enterprise(s) may also have to be developed and established if existing institutions such as local-level bodies cannot discharge the new responsibilities.

The identification of technological options for sources/devices depends very much on the time horizon. 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, a medium-term technology, and a long-term technology that should provide an ideal sustainable solution.

Instead of rural areas replicating the energy ladder behaviour of the past and present, they must adopt an approach of technological leapfrogging (a normative prescription of future behaviour) to the 'best' technology for the next period.

To implement rural energy strategies, it is necessary to have policies to ensure that there is a level playing field for centralised supply and decentralised village-level supply and for supply expansion and end-use efficiency improvement so that the market can make the choice through a process of competition; to promote household-level supply, community-based supply of energy sources, and 'centralised' multi-community supply of sources (whichever is appropriate); to promote integrated resource planning in order to identify least-cost mixes of sources and associated devices; to ensure that the process of technology choice is transparent and democratic; to develop and disseminate technologies for direct HDI improvement and indirect HDI improvement via income generation and for the immediate-term, medium-term, and long-term time-horizons; to develop hardware plus 'software' implementation packages for rural energy systems; to promote technological advances and organisational learning; to ensure that subsidies are not a permanent crutch inhibiting the advancement of the technology; to lead to local capacity building in the matter of hardware (technology) and 'software' (particularly management); to include a key role for women as users, operators, and entrepreneurs in rural energy systems; to enable and ensure people´s participation as households and/or as a community; to arrange/enable financing for households and communities; to lead to democratic and transparent institutional arrangements at the rural level to monitor rural energy systems; to ensure synergistic government support for individual and/or community operation of rural energy systems; to promote new energy enterprise(s) to be established if existing institutions such as local-level bodies cannot discharge the new responsibilities, and to encourage financial institutions/banks/donors have to take on new tasks.

Annex A
Dissemination of Photovoltaic Solar Home Systems in Rural India

India's population according to the 1991 census was 846 million. The rural population was 74.3 percent, or 623 million, which at 5.5 persons per household corresponds to 114 million households. Of these households, 69 percent, or 78.6 million, were not electrified. The initial cost of a four-light, 37-watts photovoltaic solar home system (PV SHS) in 1999 was about US$430 (Rs 18,500 @ Rs 43/US$), for which financing from a bank could be obtained at 12 percent interest over a five-year period. This corresponded, after a down payment of 15 percent (US$64.50), to a household expenditure of US$101.45 (Rs 4,362) per year or US$8.45 (Rs 364) per month.

On average, energy accounts for about 7.5 percent of household expenditures. On the (probably overly optimistic) assumption that this could be doubled, then 15 percent of monthly household expenditures is the upper limit to what a household can spend on energy. The monthly cost of US$8.45 for a PV SHS translates, at 15 percent, to a required household income of US$56.36 (Rs 2,423) per month. The income distribution pattern in India is such that only about 7 percent of households have this level of income to afford a PV SHS. Assuming that only half of households that can afford a PV SHS are prepared to switch to purchase one, much less than 5 percent of rural households constitute the market for such systems.

The potential penetration is greater with the smaller systems. The two-light, 20-watt PV SHS costs about US$267.50 (Rs 11,500) and can be obtained with the same financing terms as the four-light system. This would involve a down payment of

US$40.12 (Rs 1,725) and monthly payments of US$5.26 (Rs.226), requiring an income of about US$35.00 (Rs.1,506) per month – available to about 17 percent of the households. The one-light, 10-watts PV SHS costs about US$128.00 (Rs.5,500) and implies (with the same financing terms) a down payment of about US$19.20 (Rs.825) and monthly payments of about US$2.50 (Rs.108), requiring a monthly income of about US$16.75 (Rs.720) – available to about 75 percent of households.

Thus the two- and four-light systems can only be afforded by the richest rural households, constituting 17 and 7 percent of the population, respectively.[g] Even the cheapest one-light PV SHS is beyond the means of the poorest 25 percent of the rural population.

Since PV SHSs 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. For example, a one-light PV SHS might permit a tribal household to weave two extra baskets per evening, earning US$0.12 (Rs.5) per basket and therefore (after paying for materials) about US$5.80 (Rs.250) per month; the income generated by the PV SHS would more than pay for the investment in the light. Similarly, light might give a mobile vegetable vendor two extra hours of sales and thus increased income. These examples show that there are non-elitist niche markets for PV SHS.[5]

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[g] The factors limiting penetration of PV SHS systems to the richest segments of the population can be found even in the lending programmes of the Grameen Bank of Bangladesh, which is world famous for its success in extending micro-credit to the poor. Bangladesh's projected population for 1996 was 123.6 millions. The rural population was 79.9 percent, or 98.8 million people, which at 5.6 persons per household corresponds to 17.6 million households. Of these households, 86 percent, i.e., 15.2 million households, were not electrified. The initial cost of a PV SHS is Taka 9,200 (Taka 45.5 ≈ US$1), for which Grameen intends to provide financing at 8 percent interest over a two-year period after a 25 percent 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 5.5 percent of its expenditure on energy. If, to be liberal, this is doubled, then 10.9 percent 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 10.9 to a household income of Taka 2,952 per month. About 46.8 percent of households in Bangladesh have the income required to afford a PV SHS. Assuming that only half of those households that can afford it are prepared to switch to PV SHS, it appears that less than a quarter (23.4 percent) of rural households constitute the market for such systems in Bangladesh.

For Further Reading

Bhalla, A. S. And A. K. N. Reddy (eds.). 1994. *The Technological Transformation of Rural India*. London: Intermediate Technology Publications.

Ramani, K. V., A. K. N. Reddy, and M. Nurul Islam (eds.). 1995. *Rural Energy Planning: A Government Enabled Market-Based Approach*. Kuala Lumpur: APDC and GTZ.

Reddy, A. K. N. (ed.). 1980. *Rural Technology*. Bangalore: Indian Academy of Sciences.

Reddy, A. K. N. 1995. 'The Blessings of the Commons or How Pura Village Dealt with the Tragedy of the Commons.' *Energy for Sustainable Development* 2, no.1: 48–50.

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1 Reddy, A. K. N., 'Blessing of the Commons', *Energy for Sustainable Development* 2, no. 1 (1995), pp. 48–50.

2 Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams, 'Basic Needs and Much More with 1 kW Per Capita', *Ambio* 14, no. 4–5 (1985), pp. 190–200.

3 Larson, E.D. 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, August 29 – September 2, 1999.

4 Reddy, A.K.N., *Technology, Development and the Environment: A Reappraisal* (Nairobi: United Nations Environment Programme, 1979).

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