THE INDIAN PERSPECTIVE: APPROPRIATE ENERGY TECHNOLOGIES*

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I. Introduction

A. The search for appropriateness has perforce to begin against the background of the conventional paradigm for energy planning. According to this paradigm, development is equated with economic growth which, in turn, is assumed to depend upon the magnitude of energy consumption to increase which there has to be an ever-increasing supply of energy. So, it is a growth-oriented supply-sided consumption-directed paradigm for which a possible acronym is GROSSCON even though, according to the Little Oxford Dictionary, "gross" means "flagrant" and "con" means "confidence trick".

B. This conventional paradigm for energy planning has resulted in

- the economic problem of mounting costs
- the environmental problem of impacts on the local and global environment
- the social problem of people located at the energy generation sites being subjected to displacement, pollution, hazards, etc.

Due to these problems, the conventional paradigm is in serious trouble and it has become clear even to conservative planners that alternatives approaches are essential.

II. A DEFENDUS Perspective for the Indian Energy System

A. The search for appropriate energy technologies must turn therefore to a new paradigm shaped by the goal of the Indian energy system.

B. The goal of the Indian energy system may be taken to be sustainable development. Accordingly, the energy system must become an instrument for sustainable development. The perspective here is that, though economic growth is a necessary condition for sustainable development, it is not a sufficient condition. In addition, the process of growth must be directed towards

- the satisfaction of basic needs, starting from the needs of the neediest
- the strengthening of self-reliance
- environmental soundness.

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C. The focus on development necessarily means an emphasis on providing the energy services required for the satisfaction of basic needs. The true indicator of development is therefore the level of energy services enjoyed by the population, particularly by its poorest sections. This standpoint generates the challenge of making the poorest sections the main beneficiaries of the energy system.

D. The stress on energy services -- rather than energy consumption per se -- means that there must be an emphasis on the end-uses of energy and therefore on the end-use devices that convert the final energy delivered to consumers into the required energy services. The level of energy services is determined by the magnitude of "useful" energy, i.e., how much of the input energy is converted by the end-use device into energy that is actually used for the task. Thus, the useful energy depends upon two factors -- the input energy and the efficiency of the end-use device. Hence, there must be an end-use orientation to energy planning.

E. What is required therefore is a development-focussed end-use-oriented service-directed paradigm that we shall refer to by the acronym DEFENDUS.

F. There are three well-known options for increasing energy services. The first one is based on the conventional GROSSCON paradigm of maintaining current efficiencies and ensuring that the supply and input of energy are increased. This is a supply-biased approach. The second option also stresses an increase of energy, but there is an insistence that the supply should come from so-called "clean" sources, i.e., renewable and environmentally benign sources of energy, and not from the conventional centralized and environmentally malign sources. Then, there are the conservation purists who argue that all that is required is an increase of efficiency.

G. According to the DEFENDUS paradigm, all these are extreme positions that must be rejected. What is required is a holistic integration of the three options, i.e., the increase of energy services that is the essential basis of development must be achieved through a mix of efficiency improvements, decentralized renewable sources and centralized sources. It is this mix that defines the set of appropriate technologies.

H. The basic approach to the identification of the elements of the mix is the technique of "least cost planning" that is being increasingly adopted by the electricity utilities in the United States. The technique involves the construction of least-cost curves in which the Y axis is the unit cost of the energy technology (irrespective of whether it is a source of generation or a conservation measure) and the X-axis is the magnitude of energy that is saved/generated by that technology. Before such a curve can be constructed, it is necessary to make a comparison of the costs of different ways of saving and generating energy electricity and to rank them according to increasing cost. The procedure in least-cost planning is to take the cheapest technology and make it the first element of the mix. This technology enables a partial advance from the present energy demand to the energy goal. When its potential is exhausted, the procedure is repeated with the next technology, and so the cost-supply staircase is climbed till the energy goal is reached.

I. All the technologies lying on the cost-supply staircase up to the energy goal are the components of the supply mix that has to be used to meet the demand requirements. Indeed, they define the set of appropriate energy technologies. In this process, there must not be any favoured technologies. If, for instance, a conversation measure comes into the mix, it is accepted. If it is too expensive, it rules itself out.

J. An important precaution has to be observed in setting up the energy goal at which the cost-supply staircase ends. Efficiency improvement and energy saving are like a cheque that can be cashed only once. The cheque can either be cashed on the demand side or on the supply side. It cannot be cashed both on the supply and demand sides. If the energy goal has already taken into account energy conservation measures, then the inclusion of these measures in the construction of the cost-supply curve involves "double-counting". This problem does not arise in the case of the frozen-efficiency goal where it is assumed that energy efficiencies are frozen at current levels. The preferable energy goal is the frozen efficiency energy goal which does not assume efficiency improvements so that even conversation measures become ordinary candidates for a place on the cost supply-staircase.

K. Costs, however, cannot be the only criterion for deciding the appropriateness of tecnologies. Other criteria must be taken into account. For instance, environmental impacts must also be considered. Where such impacts can be quantified, it is possible to pursue least-impact planning by constructing impact-supply curves similar to cost-supply curves.

L. Attention will now be turned to the electricity and oil sectors in India where attempts at pursuing a DEFENDUS approach have identified sets of appropriate energy technologies.

III. A DEFENDUS Electricity Scenario for Karnataka State in India

A. The recent efforts at electricity planning in Karnataka State, South India, in particular the May 1987 report of the Committee for preparing a "Long Range Plan for Power Projects in Karnataka 1987-2000 AD" (LRPPP), are clear-cut examples of the failure of the conventional GROSSCON approach to energy planning. The LRPPP plan demanded that, in order to meet its energy requirement of 47.520 TWh and 9.397 GW in 2000 AD, the state should spend an astronomical sum of about $17.438 billion, develop a great deal of infrastructure (better transmission lines, coal transportation linkages, railway facilities, etc.), construct massive centralized power generation facilities (including a 1 GW super-thermal coal-based power station and about 2 GW of nuclear power), raise funds from the World Bank and the Central Government, divert at least 25% of Karnataka State's Plan for power and appeal to private industry to set up generation facilities. In return, the LRPPP plan promised that energy shortages will continue up to, and into, the next century. In other words, conventional plans are no longer solutions; they are exercises in profligacy.

B. An alternative scenario for the electricity sector of Karnataka has, therefore, been developed on the basis of the DEFENDUS paradigm. This DEFENDUS scenario for energy demand and supply focusses on people-based development through the promotion of energy services, identifying technological opportunities for better utilization of energy through a scrutiny of the end-uses of energy, and adhering to a least-cost approach to the mix of energy supplies. The DEFENDUS scenario turns out to be as promising as the LRPPP and other conventional plans are gloomy. In particular, even though the DEFENDUS scenario involves the illumination of <u>all</u> homes in Karnataka, an emphasis on employment-generating industry, the energization of irrigation pumpsets up to a limit imposed by the groundwater potential, and the establishment of decentralized rural energy centres in villages, it comes out with energy and power requirements in the year 2000 AD which are only about 38% and 42% respectively of the LRPPP demand.

C. This reduction in requirement is partly (59 %) due to a development focus and partly (41 %) due to simple efficiency improvement and carrier substitution measures. These measures consist of the replacement of inefficient motors and incandescent bulbs with efficient motors and compact fluorescent lamps respectively, the substitution of solar water-heaters and LPG stoves for electric water heaters and electric stoves, and the retro-fitting of irrigation pumpsets with frictionless foot-valves and HDPE piping.

D. To meet its demand, the DEFENDUS least-cost supply scenario involves a <u>mix</u> of efficiency improvements and electricity substitution, decentralized generation technologies and conventional centralized generation technologies in an approximately 40:40:20 ratio. The replacement of inefficient with efficient motors is the cheapest technology, and therefore, it comes out as the first element of the mix, then improvement of irrigation pumpsets, followed by small hydel, compact fluorescent lamps, cogeneration from bagasse fuel in sugar factories, biogas, producer gas and then natural gas.

E. As the energy requirement increases, i.e. as the demand increases, the more inescapable do the environmentally malign and harsh technologies become. As the demand goes down, it becomes possible to avoid some of these harsh technologies. So, the technologies that must be invoked are very much dependent upon the magnitude of the demand target. In other words, the appropriateness of technologies is also a function of the magnitude of the energy goal. This is the reason why the demand targets are often pushed to high values, so that they justify some of the harsh technologies that would not come in for lower demand targets. In the specific context of Karnataka, the reduced demand for centralized generation technologies means that the technologies that have become environmentally controversial in the state -- nuclear power plants, coal-based thermal power plants and hydroelectricity -- can be largely avoided.

F. Instead of the least-cost mix, the conventional LRPPP plan starts with nuclear, coal and hydel and leads to what we may call "maximum-cost planning". Since the area under a cost-supply curve [($/kWh)*(kWh/year)] yields the annual cost ($/year) for the mix of technologies defined by the curve, we can compare the cost of the DEFENDUS least-cost mix with the cost of the official maximum-cost plan. It turns out that the DEFENDUS supply scheme is only about one-third of the cost of the centralized supply scheme. At one third the cost, the energy goal can be met whilst providing more services to the people. Thus, the area between the maximum-cost and least-cost curve represents the squandering of public funds that results from adopting, not the least-cost mix of appropriate energy technologies, but an arbitrary mix of inappropriate energy technologies that has obviously been arrived at by considerations other than cost. After all, there are many vested interests that derive advantages from maximum-cost planning and large projects.

G. Even allowing for a five-year preparation period before efficiency improvements and electricity distribution measures are introduced, the DEFENDUS scenario involves a shorter gestation time. This is because it depends largely on efficiency improvements and electricity substitution and on decentralized technologies that can deliver energy and power almost immediately.

H. And finally, the DEFENDUS scenario is about 200 times far more environmentally benign in terms of millions of tonnes of CO_2 pumped into the atmosphere every year.

I. The cheaper, quicker, more environmentally sound and more equitable DEFENDUS electricity scenario is so obviously superior that it (or some variant of it) should be chosen without hesitation if rationality prevailed. Energy decision-making, however, is not done on the basis of rationality alone; there are powerful vested interests that have grown along with the conventional electrical supply industry. But, it appears that the supply lobby can no longer procure the capital to carry through its exorbitantly expensive schemes as easily as before. This is because the bankability of these schemes is being eroded by rising costs and environmental safeguards. Further, the funders are being confronted with alternative scenarios presented in increasingly quantitative detail. Whether these funding institutions will be able to resist these more cost-effective and environmentally sound alternatives may well depend upon the fact that development-focussed end-use-oriented scenarios may be difficult to implement, but the conventional plans are impossible to sustain.

IV. Appropriate Technologies to reduce India's Oil Dependence

A. Even before quantitative least-cost planning can be carried out, it is necessary to list the technologies that have to be considered in the least-cost mix. In contrast to the conventional supply technologies, the decentralized supply technologies that provide the same energy services as the conventional ones are not so obvious. The identification of technologies that conserve energy -- and therefore result in effects that are equivalent to energy generation -- can only emerge from a careful end-use analysis. In other words, the listing of technologies for a least-cost planning exercise is a complex issue in which a heuristic approach (that reduces the complexity of the search for solutions) is an extremely valuable precursor. An example of such heuristic approach to the identification of technologies for reducing India's oil dependence will now be presented.

B. India is currently facing a serious oil crisis. Further, it is not likely that India's current oil crisis will go away like the previous crisis of the 1970s. India is in a much graver situation today than ten years ago. The fundamental cause of the current oil crisis is not the invasion of Kuwait; it is the country's unchecked appetite for diesel, kerosene and gasoline due to railway freight being de-emphasized, homes not being electrified and personal transportation being preferred.

C. India's transport sector is a major oil consumer, but, quite unlike the industrialized countries, the country's transport runs mainly on diesel which accounts for 70% of the oil used in the transport sector. Diesel consumption is mostly due to trucks which are far less energy efficient than railways in hauling high-bulk-density goods. Despite this, the share of total freight transported by trucks has increased enormously because of the low price of diesel which has been subsidized and pegged at a price slightly above that of kerosene. Diesel prices cannot be increased without roughly equal increases in kerosene prices because, if the price of kerosene is very much lower than that of diesel, trucks adulterate their diesel fuel with kerosene and immediately create a kerosene shortage. This shortage causes great hardship to the poor because kerosene is used almost wholly in the household sector for lighting and cooking. And, for the same reason, kerosene prices cannot be increased under present conditions.

D. Though electrical illumination is far more energy-efficient than kerosene lamps, the number of un-electrified homes in the country is increasing at the rate of about a million households per year. Under these conditions, the country has been forced to increase kerosene consumption at the rate of 7.8% per year.

E. India's oil problem, therefore, is primarily a problem of the two middle distillates, diesel and kerosene, in that order. Together, they account for as much as about half of India's oil consumption, and incidentally account for the bulk of the country's imports of petroleum products.

F. In contrast, gasoline is currently a small problem because it represents less than one-tenth of the oil consumption. But, it is a rapidly growing problem in India because the decision-makers have, not only failed to provide the funds necessary for public transportation, but also encouraged the proliferation of mopeds, scooters, motorbikes, cars, and three-wheeler autorickshaws. De facto, the planners and government have "chosen" personal and hired vehicles as the preferred mode of intra-city passenger movement.

G. On the basis of this analysis, a four-pronged strategy for resolving India's oil crisis is suggested. It is based primarily on reducing the demand for diesel, kerosene and gasoline. The strategy consists of

(1) implementing efficiency improvements in the use of petroleum products,
(2) shifting passenger traffic from personal vehicles to public transportation,
(3) shifting freight traffic from road to rail, and
(4) replacing oil with alternative non-oil fuels, particularly biomass-derived fuels.

H. Efficiency improvements in the transport sector can be achieved straightaway by better house-keeping and by long-term measures such as improvement in the fuel efficiency of the vehicle fleet. In addition, there are several long-term measures that can play a major role.

I. In the case of diesel, for instance, the long-term measures would involve

- improvement in the fuel efficiency of the truck fleet through better engines (e.g., direct-injection stratified-charge or DISC diesel engines), transmissions and drives,
- reduction in chassis weight
- better streamlining
- greater payload capability by using multi-axle vehicles that consume one-third less fuel than the conventional Indian two-axle 10-tonne payload

trucks,

- better traffic flow on existing roads and better roads, etc.

In addition, the fuel efficiency of diesel buses can be improved by having special lower-power (90 BHP) bus engines to carry the smaller payloads (3-4 tonnes) of passenger buses compared to freight trucks which use 110 BHP engines to haul 10 tonne payloads.

Immediately, however, 10-15% reduction in diesel consumption can be achieved through training truck and bus drivers with regard to fuel-conserving driving habits. And of course, proper and timely maintenance yields significant fuel savings.

Substantial diesel conservation can also be achieved in diesel pumpsets where as much as 30% savings are possible with improved foot-valves and plastic piping.

Kerosene savings in cooking are possible through more fuel-efficient stoves, better cooking practices and the use of pressure cookers. These measures are also useful in reducing LPG consumption.

J. In the case of gasoline, the reduction of gasoline consumption also requires a change in the modal mix for passenger traffic away from personal vehicles to public transportation through overall measures that include steps such as massive investments on the infrastructure for public transportation. But, for <u>intra-city</u> passenger movement, special supplementary measures such as major increases in the number of buses, and where possible, suburban trains, are also necessary.

K. The crux of the third prong of the proposed strategy is a massive programme of <u>home</u> electrification. When <u>all</u> homes are electrified, kerosene becomes unnecessary as an illuminant. To make kerosene completely redundant, additional measures are required for replacing kerosene as a cooking fuel in cities. Once this is done, the subsidy on diesel can be removed and its price can be brought on par with that of gasoline.

L. The increase of diesel prices is a necessary, not sufficient, for decreasing truck freight; it would, however, create a favourable environment in which supporting policy measures can be adopted. For the railways to exploit the situation and increase their freight haulage, there must be substantial investments on the improvement of the railways' freight operations. These funds can come from the diversion of the implicit subsidies on kerosene and diesel.

M. The combination of this strategy of shifting freight from trucks to rail along with a strategy of shifting short-distance inter-city passenger traffic from diesel locomotives to buses can reduce the diesel demand in the transport sector from about 36 million tonnes in the year 2000 just projected by the Planning Commission of the Government of India to about 21 million tonnes which is only about 10% above the present consumption.

N. Even with this combination of strategies, the oil problem would not be eliminated. Intra-regional or short-haul traffic would still require road transport, and therefore, a considerable amount of oil. So, in order to advance the objective of sustainable development, the possibility must be explored of the dependence of road transport on non-renewable oil resources being eliminated completely. In other words, a comprehensive oil-reduction strategy requires, over the longer term, the much more radical solution of shifting to alternative fuels for road transportation.

O. Producer gas and biogas have limited scope for use in road transport. Since natural gas is more abundant than oil, much cheaper, far less polluting and as easily distributed, the compressed natural gas (CNG) option is an attractive alternative for urban fleets of vehicles -- buses, taxis, city delivery vehicles. Though, hydrogen produced by solar photovoltaics may well turn out to be the transport fuel of the future, it is only the liquid fuels -- ethanol and methanol -- that are widely applicable alternative fuels in road transport. They can be distributed through the nation-wide network already established for gasoline and diesel. Mixtures of ethanol and gasoline -- so-called "gasohol" -- can be used widely as gasoline extenders. And pure methanol, although never used extensively, is, like pure ethanol, an excellent fuel for internal combustion engines.

P. Producer gas, biogas, ethanol and methanol can all be obtained from biomass sources. A synergistic coupling between the transport sector and the agricultural sector is therefore possible whereby "fuel farms" can be established to supply fuels for transportation in the same way that rural farms produce food for urban demands.

Q. The fuel-food conflict can be avoided by turning to non-agricultural land for cellulosic resources, particularly fuelwood, to produce methanol and/or ethanol. But, the alcohol-from-fuelwood solution to the oil crisis can aggravate the domestic fuelwood problem particularly for the poor. Cooking fuel for homes, however, is one of the basic energy needs, and the satisfaction of this need has to be an essential feature of an overall development-oriented energy strategy. Hence, the solution to the oil crisis must be compatible with the solution to the fuelwood problem.

R. One way of achieving such a compatible solution is to extend in two steps the synergism between the agriculture and transport sectors to include the domestic sector also.

S. The first step is based on the fact that, if alternative high-efficiency fuels are provided for cooking, or the efficiencies of fuelwood stoves are radically improved, then the resulting drastic reductions in fuelwood consumption can free a vast fuelwood resource base for the production of liquid fuels for the transport sector. Either the biogas or high-efficiency fuelwood-stove options or a mix of them can be introduced in villages. In cities and towns, the LPG option can be adopted since there is considerable scope for the expansion of LPG supplies. And, once the pressure on forests as a source of cooking fuel decreases, conditions become established for managing the growth of forests, and dramatically improving their fuelwood yields. In other words, silvicultural practices -- agriculture in the general sense -- can be implemented to increase fuelwood availability. This is the second step in the extension of the synergism; it consists of including agriculture in the domestic-transport synergism.

T. In all, therefore, the provision of high-efficiency cooking fuels and/or devices in rural and urban areas would make available large amounts of wood provided that all the firewood being used today for cooking can still be collected. This saved fuelwood can be converted into methanol. If diesel fuel in truck and buses is replaced with methanol, then the only small diesel demand from the transport sector will come from the railways.

U. As in the case of economic growth, energy planning is meaningless unless one asks: "energy for whom?" and "energy for what?". In the case of India, it appears that the country has been engulfed by a grave oil crisis because it has ignored two crucial basic needs of poor households: efficient energy sources for lighting and for cooking. The DEFENDUS oil strategy proposed here shows that by the provision of electric lighting and efficient cooking fuels/devices to all homes, India can move towards a virtually oil-free road transport system and reduce drastically its dependence on oil. The lesson is simple: "Look after the people, and energy will look after itself!" This translates to mean that the appropriateness of energy technologies must be derived from a development-focussed end-use-oriented service-directed perspective, i.e., a DEFENDUS perspective.

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