From Bellavista To India: Extrapolating By Three Orders of Magnitude

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Introduction

It is imperative to satisfy the energy demand of developing countries, but the means by which that demand is met may have extraordinary consequences for the global environment. This study will focus on India, the world's second most populous country: whatever solution India adopts will affect every human being on earth.

Although India is a great industrial power in terms of its potential resources, it is still in the early stages of development in relation to the sub-continent. The energy requirements to maintain development in India is huge and is heavily dependent on a continuos supply of electricity[1]. But the supply of energy to sustain industrial growth will be a problem, since the country depends mostly on imported oil stocks to draw on power generation, not to mention the dwindling hydropower resources. Several analyses from policy makers, sociologists, and economists, have considered different possibilities on classical grounds, and they seem to have concluded that burning coal is the only solution which is economically attractive[2]. This seems logical, because coal is cheap and abundant in India.

There is a major problem with this solution, however. If future development is based on coal power, extrapolating to a future economy where a billion people have standards of living to which they legitimately aspire leads to a qualitatively different world environment. As environmentalists and other concerned groups have repeatedly pointed out, burning of coal represents a grand scale version of the " Tragedy of the Commons " - and a billion " shepherds " have a lot of sheep. Coal burning is a major contributor to the buildup of carbon dioxide (CO_2) levels in the atmosphere, whether a coal process is classified as ' lean burning ' or not. Other obnoxious gases and solid emissions will all result from a coal-based economy. The long term disadvantages of a development model emphasizing the mining and burning of coal will easily offset economic and any other desired benefits of any short term program, making coal in-fact unacceptable.

Although the immediate environmental consequences are extremely grave, they are only the beginning of a far reaching problem: coal-powered stations imply a classical economic development model which hides huge " external " social and health costs which may not be " affordable " at all. India is seeking to develop rapidly, building more and more industries - and those industries tend to be built around the cities. Electricity " for industrialization " often merits subsidies of some sort: funds are thus transferred to the cities from elsewhere. Mass urbanization occurs at an accelerated rate: millions are uprooted to face uncertain futures as the poor underclass in crowded megalopolises. In an alien environment, they try to survive, fearful, alienated, and often desperate. There is no reason why people should be forced to leave their land and their communities to exist, but electricity subsidies are one of the mechanisms by which

mass migration is encouraged. Token efforts at rural development, although important from a political perspective, are not enough to compensate for this transfer.
In any case, the urgency of the challenges facing authorities and developers makes it difficult to concentrate on long-range consequences. The lack of power resources has forced the government to build as many coal powered generation stations as possible - and the government expects to continue doing so in the years to come. If present demand trends persists, coal consumption in India will double in the next seven years[1].

Environmental problems:

Doubling the use of coal by the year 2000 will result in a huge increase in the generation of carbon-dioxide, and will contribute heavily towards global pollution. CO_2 buildup in the atmosphere is already an international concern. India already contributes about 4% of the total world emissions of CO_2; even at this " low rate ", there are objections to the fact that India burns coal in its " unwashed " state. CO_2 emission is only part of the problem, however; burning coal also releases huge amounts of ash into the atmosphere.

The air in major Indian cities such as Calcutta and New Delhi is already more polluted than in cities of western industrialized countries. According to the World Health Organization guidelines, the concentration of suspended particulate matter in air should not exceed 230 micrograms per cubic meter more than seven days in a year: in the above referred Indian cities, those levels are exceeded more than 200 days a year[10].

Electricity Consumption:

Although per capita energy consumption in India is still 1/40 of that in the U.S., there has been a large increase in recent years, resulting in part from the rise in the average incomes and in part from the increase in the average number of persons holding jobs or otherwise earning money in each family. Both these factors increase per capita consumption levels of energy. Furthermore, the largest increase in the energy demand has been in the household sector: in the year 1970, on the average, households consumed 8% of all the electrical energy generated in the country; and in the early 1990's, they consumed approximately 30%[1]. Another factor affecting the increase has been internal migration - city dwellers are more ready to adopt westernized standards, which demand more electricity. They also have access to electricity which is effectively subsidized, and therefore they use more of it.

Rural Electrification:

Successive governments have launched electrification programs for rural areas, but there is never enough money for extending the grid: when funding is provided for a five year plan, for example, a typical program does not generate sufficient revenue for further expansion at the end of the plan. Also even if the grid is extended, there is simply not enough installed generating capacity.

Power to remote areas has traditionally been subsidized: this is true of either kerosene or electricity. Villagers often pay for kerosene less than city dwellers - and they pay less for electricity, when electricity is available. The primary consumers of power are in the city, however, and rural subsidies obscure the fact that direct and indirect government power subsidies necessarily favor the urban areas.

The funds for the subsidies have to come from somewhere. If there is 40% subsidy for kerosene, for example, petrol prices must go up. A system of cross subsidies has developed, which tries to control or mitigate market forces, with the best of intentions but with results which are not always benign. For example, the funds from subsidies may be raised through higher tariffs on the export-oriented industry - which is thus made less competitive internationally. To compensate for this, the government offers some tax relief to the industry in the form of " export-oriented incentives ", for example. With all these maneuvers, the government loses revenue which it desperately needs. Because resources are finite, the system can only tolerate a moderate amount of subsidy - and it can afford only a modest electrification effort in rural areas.

In any case, most rural households even in the so-called " electrified " rural areas remain "unhooked " to the grid. It has been estimated that only about 15% of the households in a rural area secure an electrical connection to the grid in the first five areas of implementation of an electrification program in that area. The financial burden of obtaining a connection falls on the poor farmer. When one considers that the total cost of drawing a low tension power line through an additional km of rural country has been estimated to be nearly US$10,000[3], it is clear that remote installations will never generate sufficient revenue to fund continued expansion at the present low rural tariff levels. Therefore, much of the installed capacity remains unutilized in the rural country. The load factor, which is defined as the fraction of utilized load to the installed load, is very low in many remote locations in India: it varies from a low of 0.06 in Karnataka to 0.016 in Haryana. the implication of a low load factor is that the return-on-investment of many electrical installations does not justify the investment. The cost of electrifying remote regions is huge: in some cases, it has been estimated that the total cost of providing electricity in rural area is as high as Rs 32 /kWh[4], compared to the cost of Rs 1/KwH, which is taken as the standard for urban.

Transmission losses are also high for rural areas. In the last two decades, transmission and distribution (T& D) losses in India have soared from 13% to 22% of the total generated power. In hilly states of Manipur and Tripura, these losses have been as high as 45%. In the state of Karnataka, in areas of low population density, the total T&D losses are double those of nearby cities. It has been calculated that, to provide 1kWH of electricity to a village home in Karnataka, the nearby power plants have to generate 1.67 kWh.

Thus rural electrification through a national power grid involving conventional economic procedures is clearly expensive and most of the high cost of initial investments invariably befall on the shoulders of the poor rural dweller and the industry. Government subsidies in the meantime bleed resources needed for meeting more urgent social needs.

It is sobering to consider what would happen if, in spite of all financial and social obstacles, the resources and the commitment are somehow marshaled to push forth a model for industrial growth and continued electrification based mostly on burning of coal. The effect would no doubt be disastrous and there are already examples elsewhere of relatively industrialized countries, where the economic future has been made much bleaker by the reality of an environment damaged beyond the possibility of economic remediation. It may be much more expensive to clean up a mess than to acting upon so that a mess will not result in the first place. If present coal plans are pushed forthwith, the future generations of India - and much of the third world - may be so improvised by efforts to clean up the environment and to heal the wounds that they may never be able to reap economic and life-enhancing benefits of current industrialization efforts.

Photovoltaic Advantages

In many rural areas of the world, solar PV electrification has already established itself as a viable, cost effective option in comparison with centralized grids. For communities off the grid network, and for customers whose electrical demands are limited (for example, less than 5 kWh per month), the grid is not a viable option. The most important arguments in favor of solar electricity include the following:

- PV Technology and electric generation is cost-competitive with rural grid extension. Despite initial costs, requiring the purchase of more than two decades of electricity at one time, solar electricity remains a least-cost alternative when amortized over the effective life time.
- PV systems provide global, regional, and local air quality advantages and can generate electricity without emitting greenhouse gases. In a typical rural house application, PV systems typically replace kerosene lamps with electric lights, directly avoiding the release of an estimated 5.1 to 6.2 tonnes of CO_2 per system during an effective system life time of two decades[5].
- Solar electricity will, in the long term, help developing countries such as India to reduce its debt problems. Importing mid-east fuel for generators and kerosene lamps adds to the foreign debt burden - and to the uncertainties in the future related to that burden. Given a large internal market, solar systems can be manufactured in India itself on a very large scale. Even if, during the early stages of market penetration, funds must be spent in the importation of solar modules, those funds do not commit the country to further expenses. Because the cost of the systems and running costs are well known, there is no penalty associated with the financial risks of future supplies since the only fuel needed, sunshine, is free.
- Solar PV electrification creates jobs and industries in the rural country thus alleviating unemployment and related problems. With one single week of training, a local worker can be taught to expertly install a PV system, and assemble and/or manufacture most parts of the system in the village itself. This gives rise to self-employment opportunities. Further, the availability of electricity raises productivity (a seamstress may be able to work longer hours, and a school-going child may be able to study in the evening, for example). The

availability of electricity can also stimulate new small enterprises - a new artisan, a new factory, a new service business. As the economies develop and the communities thrive, the private sector may take a leading and productive role in a vast self-sustaining model, offering the potential to lower capital costs of the whole enterprise and thus giving rise to wider employment opportunities.

Enersol's Puerto Plata PV project:

In the mid 1980's, a US-based nonprofit organization, Enersol Associates, launched a remarkable project in the Dominican Republic, a country with the social and economic scenarios characteristic of any developing country. The goal of the project was to supply solar electricity to a region around the village of Bellavista, in the northern part of the Republic. From a very humble beginning in the mid 1980's, the project, through a combination of local involvement and openness to external technology, and support, has brought electricity, and a better way of life, to many rural families. The program is simple, and involves a ' seed ' fund on which a revolving credit facility is developed. Families pay an up-front deposit and purchase a solar electric system, and pay off the balance of the cost of the system in a predetermined time. The returns from systems accrue on a 'village fund', and go to develop additional solar installations on families on the 'waiting list'. This is the so-called Sobasec model.

Typically, a rural house is provided with a system consisting of a 48 Watt(peak) solar panel and a battery: the system provides enough power to light a 25 watt incandescent lamp or small tv and two 8 watt fluorescent lamps. At present exchange rates, this system costs $500.00 (without the tv set). Enersol installs and finances the system at market discount rates[6].

The progress achieved by the project is remarkable: over the last four years, more than 1200 systems have been installed. In addition to bringing a better of quality of life to many rural dwellers, the project has also provided very practical information as to what can be expected in similar projects.

For example, we all know that electricity is deemed to be desirable resource by most people, but it is hard to make a quantitative estimate of how much is it really worth. The reasons for this uncertainty are obvious. Electricity, in both developing and developed countries, is as pointed earlier, frequently subsidized. The government may directly fund the installation of generation capacity, or allow favorable exchange rates for the importation of equipment or fuel, for example. Invariably, there is also subsidy in the form of a benign neglect of external costs. As a result, electricity is always relatively cheap, and therefore it is "a good deal", even when alternatives are available.

The Sobasec model eliminates some of these uncertainties, because there is no government subsidy involved, and no "special exchange rate for hard currency", together with the elimination of a few, obvious external costs. In the Enersol example, people "buy" the financed system, at its real cost. The project has demonstrated the true meaning of the word,

"affordable": a family will purchase a solar system which provides them with a few lights and power for a small tv set if they can buy that system: all for 15% or less of their monthly income.

Thanks to Enersol, solar rural electrification in the Dominican Republic has "taken off": it is self supporting, and the market has just begun to be tapped. So far however, only about 5% of total rural families who "can afford" the system have been able to buy it, not the least because of lack of their interest, but because the 'marketing' of the effort to reach other regions of the rural population has been done without any major government intervention and support and purely based on Enersol's promotional strengths.

Applicability of the Enersol Project to an Indian Scenario:

In Karnataka, 60% of the rural households depend on kerosene as the prime source of energy. At least half of these households have incomes equivalent to those families who bought PV systems in the Dominican Republic: unless life styles and associated values are significantely different between rural populations of the Dominican Republic and India, and they are not, it is not far-fetched to assume that they would be willing to buy "Enersol" type of solar power systems costing between US$275 and $500, if the means were available to finance those systems, over 8 years, at a "real" interest rate of 10%.

At a level of market penetration similar to the level achieved in the DR five years after the start of the project, 5% of the rural Karnataka population presently not served by the electric grid would have access to modest PV installations in their homes. This represents 140,000 households. At the present level, these 140,000 families burn kerosene: If some form of electricity without the obnoxious effects of CO_2 does not reach these families, in a period of 20 years they would be releasing 0.7 million tonnes of CO_2 to the atmosphere. On the other hand, if these houses were all provided with 50 watt panels, they would use the equivalent of 7MW of electricity, additively. It can be computed that if the same quantum of power was generated in a coal-fired plant, this would result in the emission of 28 million tonnes of CO_2 in 20 years.(Appendix 1)

A proposal to electrify therefore, at least as a model, to initially electrify at least 5% of the Karnataka rural families should be supported. From established experience, it can be proclaimed that the model will be self-sustaining. Even if one assumes that the market is "constant", that is, the level of economic activity and the average income does not approve as the system "takes off", the demand escalation and scaling up rapidly lowers costs as the technology penetrates the market. If all 5% of the Karnataka families who can now afford the system were to buy it, so as to have a TV and better lights to replace their existing kerosene lamps, the model would avoid the release of 28 million tonnes of CO_2 in 20 years.

Once the model is planted, it will be a straightforward matter to extend the model to other parts of India. Affordability is a relative term, of course. If national or regional level financing could be made to finance installations to amortize the systems over longer time periods, at fixed interest rates, more and more families can afford to purchase them. Based on the rule of thumb hat a family will be willing to buy a system if they can do so by spending less than 15% of their

income, it is possible to estimate the percentage of families in a given region who constitute the market.

Assuming a fixed "real" interest rate of 10%, the fraction of the rural population who constitutes the market for a $500 solar system has been calculated for both the Dominican Republic and Karnataka. This is shown in Figure 1. Note that if financing is available for 10 years, 38% of the rural population will be able to pay for its own system.

The figure assumes no subsidies. The government of India subsidizes kerosene by 40%. If the same subsidies were given to PV systems instead of kerosene, the systems become surprisingly affordable. The environmental benefits can easily be calculated.

One can only speculate on other benefits also; it will benefit the environment tremendously. Not only will it stop the use of kerosene and its harmful effects on rural health, it will also promote the use of all environmentally benign and economical rural energy alternatives for rural electrification.

Conclusion:

It has been argued that limiting CO_2 emissions in developing countries inflicts too heavy a penalty on the future living standards of the rural populations. As a corollary, authorities may decide on supporting (i.e., subsidizing) wasteful centralized models for power generation in coal-fired power plants with long transmission lines. Those models, by subsidizing energy use and *de facto* ignoring "external" costs, promote wasteful uses of energy, resources, and the environment, and impoverish the countryside, and also encourages the destruction of the environment. They also promote mass migration, impose the need for government intervention, and encourage industrialized levels of living, too costly from an energy standpoint. The models are not likely to work in the long range: even if they did, the environment and social consequences of "successes" would be devastating.

A completely different approach, based on the Sobasec model, provides an attractive alternative. Decentralized power generation, financed through a model such as the one used by Enersol, actually empowers the users, removes the incentive to waste, encourages the creation of skilled and semiskilled jobs, encourages the emergence of private enterprises, and allow people in rural areas to survive without forcing them to migrate to crowded cities.

There are also practical considerations which make the model attractive. External capital may hasten the rate at which the legitimate expectations of the Indian population are met. Foreign funds may be more readily available for electrification when those who can provide the funding do not have to worry about what that funding will ultimately do to the environment we all share.

The model has the potential for generating an enormous market which can support a strong industrial sector and can help make India more independent of external fuel supplies. It also makes it possible to leave to future generations a world where the earth is not poisoned and the

air is breathable. If a family can afford a chakra[1], the family can make its own "rui". If a family can afford a pv system, it does not need a coal plant to provide it with electricity.

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