THE ELECTRICAL PART OF THE SARDAR SAROVAR PROJECT

PART I: INTRODUCTION AND MAIN CONCLUSIONS [1]

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1. The Sardar Sarovar Project (SSP) has both an irrigation and electrical part, but this presentation will restrict itself to the electrical part.

2. My request is that your review of the electrical part of the SSP project must take note of the fact that the approach to energy in general, and electricity in particular, is undergoing a basic change. The old paradigm is breaking down and a new paradigm is emerging.

3. The old paradigm consisted of the following perspective:

   Development = Economic Growth = Energy Consumption =
   Demand projection = Supply Increase = Centralized Mix +
   Grid Transmission and Distribution

   This perspective ignored energy conservation based on end-use efficiency improvements and energy carrier substitutions, environmental impacts and decentralized renewable sources as part of the energy planning exercise, though they may come in as after-thoughts, add-ons and retro-fits.

4. This conventional paradigm has resulted in two main consequences.

   - The Environmental-Development Trap: The so-called <u>developers</u> pursue economic growth, to achieve which they insist there must be increases of energy consumption. When, however, this energy is produced, there are a number of side effects, particularly environmental degradation. Seeing the environment degrading, or expecting it to degrade, the <u>environmentalists</u> oppose the energy projects. Thus, a conflict grows in intensity - the developers say that the environmentalists are preventing development and progress, and the environmentalists say that the developers and planners are destroying the environment making further development impossible and the development process unsustainable. The two sides are locked in battle. This conflict cannot, I submit, be resolved within the framework of the conventional paradigm based on the assumption of an energy-GDP correlation.

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[1] Presentation to the Sardar Sarovar Project Review Committee at Yojana Bhavan, Delhi, on October 11, 1993.

- The Capital Crisis: The financial requirements of the electricity system are several times more than what can be provided by the suppliers of capital. The "unbridgeable gap" between capital demand and supply was first highlighted[1] at the level of the whole developing world by the World Bank in 1989. Since then, this capital crisis has been experienced at the level of the central government and at the level of the states. Thus, there is an enormous mis-match between what the electricity sector would like and what can be allocated by the planners. No wonder that the electricity sector has been compared to Bakasura, the demon of Indian mythology, who had an insatiable appetite and however much he was fed, wanted more.

5. The root cause of the environment-development trap and the capital crisis threatening the electricity system is the conventional energy paradigm or mind-set dominating the thinking of virtually all energy decision-makers and planners not only in India but in most other developing countries.

6. This mind-set is based on the *so-called energy-GDP correlation* which may be described thus. Every economy consists of a number of energy-utilizing activities each of which involves an *energy intensity*, I_j, and a fraction or contribution, $C_j = f_j$ (GDP), to the GDP. Hence, the energy demand E is the sum of the energy demands, $E_j = C_j \times I_j$, of the various activities:

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\begin{aligned}
E = \text{SUM } E_j &= \text{SUM } [C_j \times I_j] \\
&= \text{SUM } [f_j \text{ (GDP)} \times I_j] \\
&= [\text{SUM } f_j \times I_j] \times \text{GDP}
\end{aligned}
$$

from which we see that the Energy Demand is proportional to GDP if and only if the term [SUM $f_j \times I_j$] is a constant. Thus, the *so-called energy-GDP correlation* according to which a country's energy consumption is proportional to its gross domestic product, is valid only during periods when there is no change in the economy's (1) energy efficiency and (2) structure.

If, however, there are changes in energy intensity due to efficiency improvements, process changes or product changes and/or there are changes of the contributions of different activities to the GDP (e.g., the share of basic materials manufacturing goes down and the share of less-energy intensive activities increases), the proportionality breaks down. A decrease of [SUM $f_j \times I_j$] can offset an increase in GDP so that the coupling between GDP and energy is reduced. There can even be a decoupling so that there is a decrease in the energy consumption associated with an increase in GDP -- as was observed in the 1980s in Japan and the OECD countries.

7. In this conventional paradigm, *the magnitude of energy consumption is deemed to be the indicator of development*. And once projections are made of energy requirements in the future, the attention shifts to increasing supplies to meet these estimated energy requirements. If one supply option (for example, hydroelectricity) fails, the focus is moved to another supply option (for example, nuclear power). Thus, the conventional approach is based on a Growth-oriented Supply-Sided

CONsumption-biased (GROSSCON) paradigm for energy.

8. The way out of the crisis is through a new paradigm for energy in which it is recognized that what human beings and their individual and collective activities require is not energy ***per se*** but the work that energy performs and the services that energy provides: illumination, warmth, "coolth" (to coin a word), mobility, etc. In this approach, it is the level of energy services -- and not the magnitude of energy consumption -- that must be taken as the indicator of development. Thus, development requires a substantial increase of energy services (particularly for the poor). But, such increases can be achieved not only by increasing the supply of energy to the devices (lamps, heaters, air conditioners, vehicles, appliances, etc) but also by increasing the efficiency with which these devices provide energy services and/or shifting to more efficient energy carriers.

   [Incidentally, it was such increases of services through efficiency improvements and carrier substitutions that were responsible for roughly half the decoupling of GDP from energy consumption that characterized the economies of many industrialized countries particularly Japan during the 1980s. In these countries, growth of GDP was achieved in the 1980s with even a *fall* in energy consumption.]

9. It is also crucial to emphasize energy services for the poor. Electricity, therefore, must acquire a human face and become an instrument of development. Electricity planning must acquire a development focus and an end-use orientation directed towards energy services. Electricity for whom? electricity for what? electricity how (efficiently)? become central questions. What is required, therefore, is a new paradigm for energy -- a *development-focused end-use-oriented service-directed* or DEFENDUS paradigm to defend us against the crises.

10. The energy characteristics of an economy can described by its *energy intensity* which is the energy consumption required to increase its GDP by an unit amount. The energy intensities of economies show an interesting pattern -- they first rise, reach a maximum and then fall (Figure 1). However, the maxima (of energy intensities) reached by countries have progressively decreased over time, i.e., the later the country industrialized, the lower its maximum. This very interesting phenomenon is due to the fact that the energy required to produce a unit quantity of materials such as steel, cement, etc. and the quantity of materials such as steel, cement, etc. required to perform a particular function, say hold up a building, have both *decreased* with progress in materials science and technology.

    Hence, developing countries must not "copy the worst", i.e., the early industrializers which show the highest maxima; they need not even "copy the best", i.e., the latest industrializers (e.g., Japan) which show the lowest maxima; they can even "beat the best" through technological leap-frogging.

    Thus, reduced coupling between GDP growth and energy consumption through efficiency improvements and carrier substitutions is not a "luxury" that can be enjoyed only by the industrialized countries -- as is commonly believed.

Underlying this mistaken belief is the assumption that energy conservation means decreases in the levels of energy services brought about by decreases in energy consumption levels which are much lower in developing countries. If, however, efficiency improvements (leading to decreases in energy consumption) are implemented to achieve increases in the energy services, then it is obvious that energy conservation does not necessarily mean decreases in the level of energy services.

11. Even at India's present stage of development, efficiency improvements are possible in all sectors and with all end-uses of energy. Whether it is motor drive systems, lighting, cooling, heating, etc., there is always a *menu of technological options* for each of these tasks. Further, the different options are associated with different costs and energy efficiencies, and quite often, the higher efficiency option has a higher initial cost even though the so-called *life-cycle cost*, i.e., the cost over the entire life of the device, is lower.

12. When energy is used efficiently, the expansion of energy supplies to increase the level of energy services can be partly, if not completely, avoided. Hence, the adage: *a kilowatt hour saved is a kilowatt hour generated*, which is not strictly accurate because the energy saved is at the *consumption* end of the transmission-distribution system whereas the energy generated is at the *generation* end, and in between are all the T & D losses. In fact, therefore, a kilowatt hour saved is equivalent to more than one 1.29 kilowatt hour generated at 22.5% T & D losses.

13. Very often the life-cycle costs of saving energy are only one-third to one-half the costs of generation. Nevertheless, the costs of saving energy must be carefully compared with the costs of producing energy. Also, the magnitude of energy that can be saved must be taken into account. All this means that it is necessary to pursue integrated electricity planning and identify a *least-cost mix* of saving and generation options for energy.

14. Thus, the new challenge to electricity systems in India is *to reduce the coupling between GDP growth and energy consumption* by identifying and implementing a *least-cost mix of generation and saving* options for increasing energy services. Apart from including saving options in this integrated electricity planning, it is essential that the generation options are not restricted to centralized options on the one hand and fossil-fuel/non-renewable options on the other hand. Decentralized options must be included for consideration as well as renewables particularly because the costs of electricity from sources such as biomass, wind, photovoltaic, etc., are falling rapidly[2].

15. Least-cost planning involves four important steps:

- construction of frozen efficiency scenarios to estimate the requirements of energy in some future horizon year which do not assume efficiency improvements and energy carrier substitution
- listing of options (for meeting energy requirements) ensuring that the list includes options for saving energy as well as options for energy generation with both centralized and decentralized systems
- ranking of options in the order of increasing unit cost (Rs/kWh) taking into account the environmental costs, i.e., internalizing the externalities,
- defining the "supply"[2] mix by taking the cheapest technology and making it the first element of the mix, and when its potential is exhausted, going to the next cheapest technology, and so on, climbing this cost-supply staircase till the energy requirement is met. All the technologies lying on the cost-supply staircase up to the energy requirement are the components of the supply mix that has to be used to meet the demand requirements. In this process, there must be no favourites at all. If, for instance, a conservation measure comes into the mix, it is accepted; if it is too expensive, it rules itself out.

16. Least-cost planning is becoming increasingly standard in the industrialized countries. In many states of the USA, it is even becoming mandatory. In India, a least-cost electricity plan has been made for Karnataka and Maharashtra. Soon, Kerala and West Bengal are likely to have least-cost plans. All the least-cost planning exercises show that the least-cost supply mix consists of three components: (1) clean(er) centralized sources, (2) decentralized sources and (3) efficiency improvements and carrier substitutions. Even the 2030 scenario of the Pacific Gas and Electric -- one of the largest utilities of the USA -- has proposed a "supply" mix with the three components.

17. Further, two important lessons are emerging:

- neither efficiency improvements nor decentralized sources, either singly or together, can meet the whole requirement, but

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[2] Saving options must be included as "supply" options because they avoid supply options and therefore fulfil the same role in the system as conventional supply.

- when both efficiency improvements nor decentralized sources are included in the supply mix, the demand for centralized sources is drastically reduced.

18. By and large, in the past, the energy establishment and the energy planners in India have been unaware of least-cost planning. But, now that the capital crisis is acute, there is a favourable environment for searching for least-cost solutions. My International Energy Initiative has held two workshops on Integrated Electricity Planning for the Chairmen of Electricity Boards in Bangalore and for electricity decision-makers in West Bengal in Calcutta, and both these workshops evoked an enthusiastic response from the participants.

19. This is the background against which I must ask this review committee:

    - is your focus on energy services, rather than on energy consumption?
    - is your focus on electricity for whom?
    - is your focus on electricity for what?
    - is your focus on electricity with what efficiency?
    - have you looked at efficiency improvements and carrier substitutions as ways of demand-side management?
    - have you looked at both demand-side management and supply-side management?
    - have you considered all (or at least, the important) saving and generation options?
    - have you attempted to arrive at a leat-cost "supply" mix?

    If your answer to all these questions is "No!", then I am sorry to say that you are still trapped in the old obsolete paradigm for energy planning. If I were to be less charitable and more professorial, I would say; "You have not done your homework!"

20. Let me turn now to the electrical part of the Sardar Sarovar Project (SSP) which, I understand, accounts for 56.1% of the costs and involves a 455 ft embankment that would create a reservoir that would lead to the submergence of 240 villages, 40,000 families, 39,000 hectares (of which 13,744 hectares is prime forests).

21. This electrical part of the SSP may be considered to consist of three components:

    - <u>conventional generation</u> from a 436 ft embankment reservoir
    - <u>pumped storage generation</u> from the same 436 ft reservoir
    - <u>generation from an 19 ft increment in height to the 436 ft</u>

22. <u>Conventional Generation</u>: If one thinks of a hydroelectric project as being based on a waterfall with a high head, then it is important to note that the SSP is not such a project -- it is, in fact, a mega-tank where the head is created by the wall or embankment of the tank.

Further, if the downstream canal system is built and in place when the dam is built, then the water can be evacuated from the reservoir as and when required for irrigation and other end-uses of water -- and there would be little water available for electricity generation. However, it is envisaged that the canal system cannot be completed before 15 years before which the water cannot be evacuated for irrigation.[3]

This mis-match between the gestation periods of the dam and the canal system has led to the idea of generating electricity from the un-evacuated water. An electrical capacity of 1,450 MW has been installed for this purpose in the Canal Height Power House (CHPH) and the River Bed Power House (RBPH). Unfortunately, to the seasonality of the water flow into the reservoir, the available capacity is much less -- 439 MW with 415 MW from the RBPH and 24 MW from the CHPH.

As the canal system is built up and is able to withdraw the water, the capacity for conventional generation goes down -- and after 15 years, it will go down to 0 MW in the RBPH and 50 MW in the CHPH making a total of 50 MW. Thus, conventional generation will decline from a firm initial 439 MW to 50 MW after 15 years. So, in costing the conventional generation component of SSP, it has to be treated as a hydroelectric project with a lifetime of 15 years and a declining capacity during that lifetime.

The situation may actually be worse because the estimate of the electricity generation assumes large releases from the upstream Narmada Sagar Project the delay of which will decrease the conventional generation by about 25%. Further, it appears that the water flow of the river is actually 17% less than assumed -- this will decrease the available capacity.

23. Pumped Storage (PSTOR) Generation: To compensate for the shortcomings of the conventional generation, to utilize the reservoir storage capacity, and to generate power during the periods of peak demand when it is badly needed, the SSP has a scheme for pumped storage (PSTOR) -- pumping the water into the reservoir when there is surplus power in the grid, and running it down into the turbines and generating power during the hours of peak demand.

Unfortunately, the SSP PSTOR scheme has not been compared with other PSTOR possibilities In the Western India region. If such a comparison were made, the SSP PSTOR scheme is bound to fare badly because of the low head available in SSP compared to the high heads possible in other projects (for instance, the Pimpalgaon Joge PSTOR Scheme which costs about 25% less than the SSP). The high heads of other schemes also mean less water needs to pumped and stored, and therefore less submergence -- the 1,450 MW Pimpalgaon Joge PSTOR Scheme requires less than 0.5% of the submergence of the SSP.

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3 The situation is quite analogous to many electrical projects where the transmission an distribution lines are not erected in time to evacuate the electricity that is generated.

The SSP PSTOR scheme has also not been compared with a number of other conventional supply schemes such as gas turbines and cogeneration of surplus electricity for instance in sugar factories[4]

Finally, the SSP PSTOR scheme has not been compared with Demand-Side Management (DSM) alternatives. This omission is particularly serious because it is well-known that the evening peak in Indian electricity systems is largely due to lighting, and drastic reductions in peak demand can be achieved by adopting efficient lighting devices.

24. Generation from the 19 ft Increment in Dam Height: Though the suggestion of this 19 ft increment came from a water tribunal award, the extra energy it will yield (230-350 million units) is less than 10% of the total energy. For this is trivial benefit, a tremendous price has to be paid -- 5 villages and an additional 9,500 ha will be submerged, mostly in Maharashtra. So, there is a trivial amount of energy produced at enormous human, social and environmental cost -- all because there are as yet no vested interests, or governments are too lazy, to twist in efficient lamps, improve irrigation pumpsets and implement cogeneration in sugar factories.

25. To summarize my assessment of the three component of the electrical part of the SSP:

- there seems no justification whatsoever for the negligible generation from the 19 ft increment in the dam height
- the conventional generation declines rapidly to a trivial capacity that is hardly worth it
- the SSP PSTOR scheme -- to compensate for the weaknesses of the conventional generation -- is so intrinsically inappropriate and expensive compared to other supply-side and DSM schemes that it is like "throwing good money after bad".

26. This assessment is based on quantitative analysis which will be presented in Part II of this submission by colleague Mr. Girish Sant. In his presentation in which a least-cost "supply" curve is presented for the SSP and the alternative options with which it should be compared, you will see that there are many low-cost power options that are far more economical than the electrical part of SSP.

27. Let me now conclude my part of the presentation. Since decision-making involves the identification of options/alternatives and the choice of the best option/ alternative, your committee must review the options that were considered -- and those that were ignored either deliberately or innocently -- by the formulators of the SSP. It must then review the choice that was made -- and that should now be made in the light of the new options that have been presented.

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[4] Over double the capacity of SSP is available from cogeneration in Gujarat and Maharashtra.

28. I put it to you that it is human to make mistakes in decision-making and in reviews of decisions -- my plea to you is to let these mistakes be small and reversible, not gigantic and irreversible.

29. I have just come from Calcutta where I learnt that the 60 ft height of the new Howrah Bridge was fixed on the assumption that ocean-going ships would pass under it. Before the bridge was built, it became clear that that would not happen because (1) the Hooghly port would decline and (2) the importance of Haldia port would increase. But, the decision-makers, reviewers of decisions and implementors stuck to their erroneous assumption -- today, no ocean-going ships are passing under the bridge! The result was an tremendous infructuous expenditure of which the only beneficiaries were the steel/cable/structurals manufacturers, the erection contractors, etc. Fortunately, there was little human and environmental damage.

30. I hope your committee will not end up like those involved in the Howrah decision. In your case, apart from wasted financial resources, there are catastrophic impacts as far as human lives, social cultures and ecological inheritances are concerned. I wish you the best of luck in your un-enviable decision.

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1...A.A. Churchill, and R.J. Saunders, *Financing of the Energy Sector in Developing Countries*, 14th Congress of the World Energy Conference, Montreal, 14-22 September, 1989.

2...T.B. Johansson, H. Kelly, A.K.N. Reddy and R.H. Williams, Editors, *Renewable Energy: Sources for Fuels and Electricity*, Island Press, Washington, D.C, 1993.