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# ETHICAL PRIORITIES IN ENVIRONMENTALLY SUSTAINABLE ENERGY SYSTEMS: THE CASE OF TROPICAL HYDROPOWER

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# ABSTRACT

Today's polarization of society "for" and "against" big hydroprojects relates to environmental costs, particularly borne by vulnerable ethnic minorities and the poor; such costs include societal deracination, species extinctions and loss of habitat. Affected people are aggrieved if the least damaging solution to nationally agreed on power needs is not selected. This counter-productive polarization can be reconciled by transparency of planning, pluralism involving the societies, and especially all affected people, and by engendering national consensus or agreement on the least bad project. Selection of any but the least damaging project is unethical.

General criteria for consensus are discussed, such as promotion of energy efficiency and conservation, unconventional power projects, population stability, and ranking of alternatives to the next hydro project. In principle, it is unethical to select projects imposing greater than necessary environmental impacts. Specific criteria also are proposed for ethical-environmental ranking of potential hydro sites. First, environmental impact is roughly proportional to area inundated. Therefore, the proposed dam must have the highest feasible ratio of power production per area inundated. Second, there should be no vulnerable ethnic minorities living in or using the general area of the proposed site. And there should be no other human settlements to be affected, unless oustees livelihood after resettlement is guaranteed to improve promptly. Eventual regaining of before-move livelihood standards means that oustees were penalized.

This pre-supposes that thorough environmental assessments have been carried out for all alternative projects beforehand, and are used in the selection process to narrow down the choices to one. To be ethical, the project with the least environmental impacts should be selected. Societal agreement is needed on which choice has the least impacts. Environmentally well designed hydro can be preferable to alternatives, such as coal and nuclear, and most environmental costs can, in principle, be prevented. To the extent environmental damage is prevented, fully mitigated, or well compensated, hydro becomes renewable, sustainable, and ethical.

## ETHICAL PRIORITIES IN ENVIRONMENTALLY SUSTAINABLE ENERGY SYSTEMS: THE CASE OF TROPICAL HYDROPOWER

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### Abbreviations and Acronyms

| | |
|---|---|
| Gwh | Gigawatt hour |
| ha | Hectare |
| Kwh | Kilowatt hour |
| kw | Kilowatt |
| MW | Megawatt |
| NGO | Non-Governmental Organization |
| UNEP | United Nations Environment Program |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| vp | Various pagination |

**ETHICAL PRIORITIES IN ENVIRONMENTALLY SUSTAINABLE ENERGY SYSTEMS: THE CASE OF TROPICAL HYDROPOWER**

## 1. INTRODUCTION

Society in an increasing number of tropical forest-owning countries has become polarized into two extremes: "for" and "against" big hydroprojects.[1] The media informs us about opponents brandishing machetes at confrontations with power engineers in the Amazon, thousands of demonstrators opposing dams in several countries, hundreds of thousands of signatures on petitions to the United Nations received by the Secretary-General, and even an international celebrity, Baba Amte, starving himself to death on the banks of the Narmada river in India. One government is alleged to have fallen partly because of a hydroproject proposed for a valuable southern rainforest, and several projects slated for tropical forest areas have been canceled or indefinitely postponed partly or entirely on environmental grounds.[2]

This polarization stems partly because the affected people suspect that the least damaging power solution has not been selected. Affected people feel it discriminatory and unethical to select any but the least damaging solution. The tropical forest dam controversy transcends helping power utilities win consensus and defuse polarization. The aim is to approach environmentally sustainable energy systems.[3] One of the most effective ways to achieve sustainability is to accelerate the transition to renewable energy. Hydroprojects proving that they have lower impacts and higher benefits than alternatives may be a substantial part of this transition. The world cannot afford business as usual. This is doubly true for big dams: there is not enough capital available at affordable cost to meet projected demand for power (Imran & Barnes 1990, Moore & Smith 1990, World Bank 1989).

The polarization for and against hydropower seems most extreme in countries with tropical forests. Tropical forests, the world's richest source of biodiversity, are often associated with major unharnessed rivers "flowing wasted to the ocean" as a power engineer may perceive it. Such countries exist in Latin America, Africa, and Asia. But recent disputes on the Danube and at James Bay show that similar polarization is worldwide. So this is very much a global debate, and is not restricted to one or two countries. People at both poles often adopt extreme positions and are unwilling to explore any middle ground. The most promising approach to possible reconciliation is to build on the progress in hydroprojects by broadening the design constituency (*Table 1*). The aim is to promote a national debate to ascertain if there are criteria under which some reservoirs could be developed in tropical forest regions that might be acceptable and sustainable. The question then becomes, which stakeholders have what proportion of the final decision-making power?

Transparency and pluralism in decision-making are necessary for success in such a debate and will themselves significantly contribute to consensus-building. The whole environmental assessment

Table 1

*BROADENING THE DESIGN CONSTITUENCY OF HYDROPROJECTS*

| Design Team | Approximate Era |
|---|---|
| 1. **Engineers** | Pre-WWII Dams |
| 2. Engineers + **Economists** | Post-WWII Dams |
| 3. Engineers + Economists + **then add EIS on to end of completed design** | Late 1970s |
| 4. Engineers + Economists + **Environmentalists** | Late 1980s |
| 5. Engineers + Economists + Environmentalists + **Affected People** | Early 1990s |
| 6. Engineers + Economists + Environmentalists + Affected People + **NGOs** | Mid 1990s ? |
| 7. Engineers + Economists + Environmentalists + Affected People + NGOs + **National "Acceptance"** | Early 2000s ? |

Note: These dates hold more for industrial nations than for developing ones, although meaningful consultations with affected people or their advocates and local NGOs, and the involvement of environmentalists in project design are now mandatory for all World Bank-assisted projects. "EIS" means "environmental impact statements" which were added onto the ends of previously designed projects, a certain recipe for confrontation and waste. The World Bank's mandatory environmental assessment procedures are outlined in the three-volume "Environmental Assessment Sourcebook" (World Bank, 1991).

process must be transparent, including access to consolidated budgets so that who gets which subsidies will be known to all. For multi-stakeholder pluralism, academia, NGOs, the private sector -- as well as the government -- all must be included. This implies a certain amount of decentralization, especially of mitigatory measures. Full participation, especially of all affected people and their advocates, also is essential. This brings responsibility: all groups must be held accountable for objective performance standards. In addition, environmental standards for development projects are improving. Therefore, because a reservoir may take twenty years from investigation to completion, today's best practice is the absolutely minimal acceptable standard. Any project grudgingly or only barely meeting today's environmental precautions probably will be unacceptable under the more stringent standards expected when the project is completed a decade or so later.

## 2. ENVIRONMENTAL AND ETHICAL CRITERIA

Assuming national criteria can be agreed upon, and assuming they can be substantially met, are there conditions under which such a reservoir could be justified on ethical and environmental grounds? My personal opinion is a guarded yes: most hydroprojects are fraught with major environmental problems, but in the case of others, such problems can be soluble -- although with far more effort than is accorded today. Under certain conditions, recreation, tourism, irrigation, recession agriculture, fish production, flood control, and navigation can be made compatible with hydropower. Even without the added benefits of hydropower, the environmental problems of coal (eg; carbon dioxide / greenhouse effect) and of nuclear power are much less soluble (*Table 2*). Now that economic development is being decoupled from energy consumption, damping of electricity demand need not constrain economic development for many developing countries. On the contrary, the less investment needed in energy, the more becomes available for job creation and poverty alleviation elsewhere.

What might such national ethical-environmental criteria be? Producers, consumers and the national society should compile their own lists and their own ideas on the criteria they judge necessary. This list is suggestive only. The criteria-setting process must be widely transparent in order to engender national consensus. **The purpose of this paper is to outline some of the ethical dilemmas in approaching environmental sustainability of tropical forest reservoirs.** Essential but in no way less important -- just less environmental and ethical -- assumptions and pre-requisites of this discussion form *Annex 1*. In particular, much environmental damage can be avoided by wringing most of the efficiency and conservation potential out of the system before considering any new generation capacity. It is economically and environmentally imprudent to do less.

Assuming all the general power sector criteria outlined in *Annex 1* are fulfilled beforehand, the dozen or so main impacts of hydroprojects (*Annex 2*) should be addressed. These are boiled down to the following six ethical-environmental criteria.

> **First, environmental impact is roughly proportional to area inundated (*Table 3*). Therefore, the proposed dam must have the highest feasible ratio of power production per area inundated. If not, then the project has a higher than necessary environmental impact, which could be unethical.**

Some hydroprojects have no reservoirs. On a ratio of kilowatts per hectare[4], the reservoirs with the highest ratios, in the many hundreds, include Pehuenche, Guavio and Paulo Afonso: all exceed 100.[5] The lowest ratio reservoirs, less than 10, include Balbina, Sobradinho, Samuel, Babaquara, and Curua-Una, all are under 5. Babaquara's low ratio contributed to its cancellation. Few are less than 1, such as Suriname's Brokopondo and Burkina Faso's Kompienga.

Could one admittedly arbitrary criterion or cutoff point be 30, as in Tucurui? (*Table 3*). Clearly this depends on an expanded cost-benefit analysis in each case. If the ecosystem to be flooded is intact primary tropical forest, the ratio should be set much higher (say 100); if the ecosystem is agricultural or degraded land, then the ratio should be set lower. Economists are struggling to assign prices to intangibles, irreversibles, non-linearity, and intergenerational equity, such as are involved in extinction of species.

**Second, there are no vulnerable ethnic minorities living in or using the general area of the proposed site, and there are no other human settlements to be affected. Unless oustees livelihood after resettlement is guaranteed, or at least realistically likely, to be promptly better than before any moves, as measured by systematic socio-economic surveys, especially of relevant previous projects. Unless involuntary resettlement success can be guaranteed, which is unlikely with vulnerable ethnic minorities and rare with other people, the project cannot be construed as ethical.**

Higher "firmGwh/family-displaced ratio" projects take have preference. But more significant is the subsequent improvement in livelihood. This means the proposed site has been thoroughly assessed by sociological and anthropological professionals, well before any decisions can be made. Involuntary resettlement is arguably the most serious issue of hydroprojects nowadays; it may not be improving, and is numerically vast (*Table 4*). Direct internalization of costs needed for adequate resettlement is essential for normal oustees. But for vulnerable ethnic minorities, experience shows that it has rarely, if ever, been possible to achieve adequate resettlement yet. I question the "no-omelette-without-breaking-eggs" argument here. It is still unethical to harm numerically small groups (eg: ethnic minorities) for the sake of dominant groups (eg: city dwellers, or heavy industry). City dwellers are less vulnerable than ethnic minorities.

Sometimes it is not obvious who the beneficiaries are. For example, in tropical forest reservoirs used for export aluminum smelting, the beneficiaries are the industrial countries aluminum consumers. The question then arises, for whom are the tropical hydroproject-owning decision-makers deciding? Dual or multiple claims to the same land are not infrequent. These questions highlight the need to address explicitly the tradeoff between the beneficiaries (eg: city dwellers) and the people bearing the costs (eg: vulnerable ethnic minorities, peasants).

**Third, there are no water-related diseases, such as malaria, Japanese 'B' encephalitis, and schistosomiasis anywhere in the general region. Nor are they likely to arrive. It is unethical to promote disease.**

The risk of disease arrival is reduced by destruction of the nearest foci. If water-related diseases or toxins such as soluble mercury (EPRI, 1991), are present, they are preferably prevented before the impoundment creates more disease-vector habitat, or more toxins. If this is impossible, the diseases should be at least controlled and a public health component integrated into project design. A judgement is needed as to whether adequate control measures are likely to be sustained throughout the life of the project, including decommissioning and rehabilitation. Malaria alone kills more than a million people a year (some say 4 million); its preventability makes that unethical. Poverty, the reason for most malaria deaths, also is preventable and unethical. Global society lacks the political will to solve either. In addition, poverty alleviation is essential for environmental sustainability (Goodland and Daly, 1993), but is outside the scope of this paper's hydropower theme.

## Table 2

### *ENVIRONMENTAL RANKING OF NEW ENERGY SOURCES*

**THE BEST**

| | |
|---|---|
| 1. EFFICIENCY & CONSERVATION<br>2. SOLAR & HYDROGEN<br>3. PHOTOVOLTAICS<br>4. WIND<br>5. TIDAL & WAVES<br>6. BIOMASS (+ alcohol) | RENEWABLE & SUSTAINABLE |
| 7. HYDRO | POTENTIALLY SUSTAINABLE |
| 8. GEOTHERMAL<br>9. GAS<br>10. OIL<br>11. COAL<br>12. NUCLEAR | NON-RENEWABLE & UNSUSTAINABLE |

**THE WORST**

Note: As energy efficiency and energy conservation are becoming recognized as supply options in tropical nations, they top this ranking. The nuclear industry has spent about 75% of total R & D budgets over the last four decades, but even now only generates 3% of global commercial energy. Rather than earning a profit after all these subsidies, abandonment of nuclear plants in the US alone caused $10 billion losses for shareholders. As 10,000 to 20,000 new nuclear plants would be needed over the next 40 years to replace coal (i.e., opening a new plant every 3 or 4 days for decades), this is highly inadvisable. Should the victims of the 1986 Chernobyl accident exceed 4 million, as seems likely, this will postpone any recrudescence of nuclear projects. If even the skilled and disciplined Japanese can be crippled by the "very serious" 9 February 1991 accident in Mihama, the possibilities in 10,000-20,000 new nuclear plants are not reassuring. If radioactive waste storage is solved, and, in addition, if "inherently" safe designs are achieved, then prospects would improve.

**<u>Fourth</u>, the proposed site and surroundings have no centers of species endemism, rich biodiversity or other special features. If not, the ethics of extinction of species have been disregarded.**

The ecosystem of the proposed site should be well conserved in perpetuity nearby, as a compensatory area ecologically equivalent to or better than the flooded area. The biotic salvage should be effective. [6]

**<u>Fifth</u>, the reservoir water retention time is brief; days or weeks, rather than many months. If not, then the project may have an unethically great environmental impact.**

Rapid circulation rate decreases environmental impact. The shorter the water retention time, the less time for anaerobic conditions to be created, and the better will be the water quality both in the impounded area, as well as downstream for all uses.[7] The nearer to "run-of-river" the project is, the fewer will be the environmental problems. Two types of sites are especially valuable. First, canyons in which the reservoir does not rise above the lip; these do not need large flows. Harnessing waterfalls that fish never ascend, prevents migratory fish problems. Second, no-head in-stream axial turbines which do not flood any forest.

The best sites have such low volumes of biomass that its decay will not contribute significantly to greenhouse gases, nor impair fish and water quality, nor will valuable biomass be wasted, nor clog turbine intakes. Removal of economically extractable biomass decreases greenhouse gas production and water quality risks. Brief retention time has to be balanced with storage needed for irrigation and navigation.

**<u>Sixth</u>, the proposed dam is sited above undammed tributaries, to help minimize changes in flood regime (on which wetlands depend) and to provide alternative upriver sites for migratory fish. It is unethical here, as elsewhere, to select higher than necessary environmental impacts.**

There is much uncertainty even in the relatively very simple, depauperate northern fish biological systems, and their behavior related to impoundments. Certainly much more effort than has been given up till now is needed to increase the benefits and opportunities from fisheries. From the environmental point of view, dams should be concentrated on already dammed rivers, rather than siting one or a few dams on a larger number of rivers. Thus, a representative sample of the nation's rivers would remain in their natural, free-flowing state. This tradeoff with the risk of low flows curtailing power output should not be common to the extent tropical wet forested catchments are not usually seasonal. In multi-purpose dams, the enormous value of the annual flood restoring productivity downstream should be factored in.

It is relatively easy to include bottom sluices at the design stage for such releases. Dams should be avoided that would cause species extinctions (including those of migratory fish that would be denied access to breeding or feeding sites). This means the damming of the last few free-flowing rivers in a region will be even more difficult to justify. In tropical forest areas, roads built to facilitate hydroproject construction or operation can "open up" significant areas to colonization and deforestation. Therefore, care must be taken during road and other project related features to reduce this effect. Roads, transmission corridors, resettlement sites, construction camps, line-cutting, quarries, borrow and fill-disposal sites etc. should routinely be included in the environmental costing, and not separated out so as to reduce their connection to the whole project.

## Table 3: Rank of Hydropower Generated per Hectare Inundated

| Project (Country) | Final Rated Capacity (MW) | Normal Area of of reservoir (ha) | Kilowatts per hectare |
|---|---|---|---|
| Owen Falls (Uganda) | 150 | 1 | 150,000 |
| Arun (Nepal) | 401 | 43 | 9,325 |
| Kihansi (Tanzania) | 153 | 30 | 5,100 |
| Paulo Afonso I-IV (Brazil) | 3,984 | 1,600 | 2,490 |
| Pehuenche (Chile) | 500 | 400 | 1,250 |
| Guavio (Colombia) | 1,600 | 1,500 | 1,067 |
| Kapachira (Malawi) | 125 | 200 | 625 |
| Ertan (PRC) | 3300 | 10,100 | 326 |
| Rio Grande II (Colombia) | 324 | 1,100 | 295 |
| Longtan (PRC) | 5,800 | 37,000 | 148 |
| Itaipu (Brazil/Paraguay) | 12,600 | 135,000 | 93 |
| Aguamilpa (Mexico) | 960 | 12,000 | 80 |
| Sayanskaya (USSR) | 6,400 | 80,000 | 80 |
| Xiaolangdi (PRC) | 1,800 | 27,200 | 66 |
| Grand Coulee (USA) | 2,025 | 32,400 | 63 |
| Urra I (Colombia) | 340 | 6,200 | 55 |
| Jupia (Brazil) | 1,400 | 33,300 | 42 |
| Sao Simao (Brazil) | 2,680 | 66,000 | 41 |
| Tucurui (Brazil) | 7,600 | 243,000 | 31 |
| Ilha Solteira (Brazil) | 3,200 | 120,000 | 27 |
| Guri (Venezuela) | 6,000 | 328,000 | 18 |
| Paredao (Brazil) | 40 | 2,300 | 17 |
| Urra II (Colombia) | 860 | 54,000 | 16 |
| Cabora Bassa (Mozambique) | 4,000 | 380,000 | 14 |
| Three Gorges (PRC) | 13,000 | 110,000 | 12 |
| Churchill Falls (Canada) | 5,225 | 665,000 | 8 |
| Furnas (Brazil) | 1,216 | 144,000 | 8 |
| Aswan High Dam (Egypt) | 2,100 | 400,000 | 5 |
| Curua-Una (Brazil) | 40 | 8,600 | 5 |
| Samuel (Brazil) | 217 | 57,900 | 4 |
| Tres Marias (Brazil) | 400 | 105,200 | 4 |
| Kariba (Zimbabwe/Zambia) | 1,500 | 510,000 | 3 |
| Petit-Saut (French Guiana) | 87 | 31,000 | 2.8 |
| Sobradinho (Brazil) | 1,050 | 421,400 | 2 |
| Balbina (Brazil) | 250 | 236,000 | 1 |
| Babaquara (Brazil) | 6,600 | 600,000 | 1 |
| Akosombo (Ghana) | 833 | 848,200 | 0.9 |
| Kompienga (Burkina Faso) | 14 | 20,000 | 0.7 |
| Brokopondo (Suriname) | 30 | 150,000 | 0.2 |
| Garafiri (Guinea) | 75 | 8,800 | 0.12 |

**Note:** This table is indicative only, since it does not reflect the value of the land inundated, which differs greatly in value. Some of the "land inundated" is river bed. The more reliable ratio derived from "kwh/ha" varies from year to year. The ranking would be improved, but little altered, if river bed or normal annual flood areas were subtracted. Islands in the reservoir also could be subtracted in certain cases. Some of these figures are for non-forest reservoirs and most are hydropower, rather than irrigation reservoirs. Area inundated is the key issue. Less seasonal tropical wet forest reservoirs do not need to be large. Optimizing the tradeoffs at the margin of reservoir capacity, is more influential than between having or not having a reservoir. An example of project selection to reduce oustees is PRC's Xiluodo near Leibo in Sichuan in the Jinsha river canyon, before it becomes called the Yangtze downstream of Yibin. This 12,000 MW project would be almost as powerful as the 13,000 MW Three Gorges, but with 20,000 oustees instead of over one million!

## Table 4: People Displaced by Reservoirs

| Reservoir/Project | Type | Country | People Displaced | Year Completed (est.) |
|---|---|---|---|---|
| Three Gorges | M | China | 1,100,000 | 2015 |
| Danjiangkou | M | China | 383,000 | 1974 |
| Sanmenxia | M | China | 319,000 | 1960 |
| Xinjiang | M | China | 306,000 | 1961 |
| Dongpinghu | M | India | 278,000 | 1958 |
| Upper Krishna II | M | India | 160,000 | late 90s? |
| Xiaolangdi Multipurpose | M | China | 171, 000 | 2001 |
| Gujarat Medium Irrigation II | M | India | 100,000 | mid 90s? |
| Andhra Pradesh Irrigation II | M | India | 150,000 | end 90s? |
| Sardar Sarovar | M | India | 127,000 | 1994? |
| Aswan High | P/M | Egypt | 120,000 | 1970 |
| Tehri | P | India | 105,000 | 1997? |
| Subernarekha Group | P | India | 100,000 | late 90s |
| Kossou | P | Cote d'Ivoire | 85,000 | 1972 |
| Akosombo/Volta | P | Ghana | 84,000 | 1965 |
| Long'tan | P | China | 73,000 | end 90s? |
| Shuikou I & II | P | China | 67,000 | 1993 |
| Saguling | P | Indon. | 60,000 | 1984 |
| Kariba | P | Zambia Zim. | 57,000 | 1959 |
| Sobradinho | P | Brazil | 55,000 | 1978 |
| Kainji | P | Nigeria | 50,000 | 1968 |
| Yacyreta | P | Paraguay/Arg | 50,000 | 1997 |
| Cirata | P | Indon. | 56,000 | 1987 |
| Paulo Af. IV | P | Brazil | 52,000 | 1979 |
| Itaparica | P | Brazil | 40,000 | 1986 |
| Yantan | P | China | 40,000 | 1993 |
| Ertan | P | China | 30,000 | 1998 |
| Tucurui | P | Brazil | 15,000 | 1983 |

**P= Mainly power; M= mainly multipurpose, irrigation, or flood control. These projects are not all associated with the World Bank Group.**

## 3. CRITERIA FOR SMALL-SCALE AND UNCONVENTIONAL POWER SOURCES

Small-scale and unconventional power sources should be compared with the alternative. Privately owned renewable energy generators can sell surplus to utilities.

**a) No-dam (or very low head) axial tube turbines within river.[8]**
**b) Small generating systems (including water wheels).**
**c) Solar elsewhere in the country (includes photovoltaics, tidal, wind and hydrogen from splitting water molecules).[9]**
**d) Biomass energy production (biomass plantations, alcohols, garbage and sewage).**

Many tropical forest countries contain dry sunny or even desert regions where solar powered electric plants can be sited. They occupy 1/10th to 1/20th the land of even the "best" (eg: high head / low area) hydroschemes, and often can put otherwise unproductive land to sustainable use. Similarly, Sahel and other plains and steppe often have steady year-round winds. Such systems are already economic in comparisons with hydro when the value of inundated forest or other land is internalized, even imperfectly. Therefore, small-scale and unconventional power sources should be among the alternatives subjected to environmental assessment.

## 4. POPULATION STABILITY CRITERIA

The world has changed from the long-vanished and idyllic era of a world largely empty of people, to one full or overfull of people. The nearly 100 million people added to the world every year will need some energy; much less than the 7.5 kw used by one average rich person, but certainly more than the 1 kw used by one poor person. In today's overfull world, the best (empty of people) hydrosites have already been used. This means involuntary resettlement is -- regrettably -- becoming increasingly unavoidable, unless the poor are consigned to a brutish life of backbreaking toil and high birth rates. Thus it is essential that oustees' livelihood must promptly be improved, and be seen to be improved. If prompt improvement is unlikely, social strife and resistance to involuntary resettlement must be expected to intensify. Ethical and environmental precautions are highly cost-effective. If their absence or inadequacy leads to delays or violence, they become even more economic.

Human population stability is an essential precondition for all sustainable use of renewable resources, including use both of hydropower and of tropical forests. Human populations of tropical moist forest-owning countries annually increase by more than 2.4%, which means a doubling in 25 years. Sustainability criteria will be difficult enough to fulfill without having to double the electricity supply every 25 years. The situation is more severe in those countries in which the per capita electricity use also is rising. Average planned power demand growth is about 7% in developing countries -- a doubling every ten years. In Brazil, per capita use is projected to rise 55% by the year 2000.

It is sensible to permit electricity companies to profit from their customers' investments in conservation. Utilities should not be penalized for investments in conservation. An increasing number of Northern utilities now find it more economic to provide free fluorescent light fixtures and to promote or even to subsidize insulation and more efficient appliances for consumers, rather than generating more electricity. This suggests the pricing policy is wrong in these cases, as noted above. Although this requires sensible action on pricing in the power market which scarcely exists yet in most developing countries, the preference is clear. Utilities now conduct free energy audits for consumers, showing where energy can be conserved cheapest.

To the extent this holds for population, Power Corporations' support of governmental family planning goals will reduce national controversies and project delays commonly experienced. Power Corporations already help to the extent light bulbs and televisions are mildly contraceptive. Although the power sector should not be expected to right all societal ills, population stability is so important for Power Corporations and for environmental sustainability, as well as for all social values, that family planning or similar activities should be components of all relevant projects, including those in the power sector. The power utilities would gain vastly therefrom.

## 5. CONCLUSION

Resolution of the polarized debate (*Table 5*) devolves on the likelihood of a country fulfilling most of the above criteria. These criteria are stringent even for industrial countries. To what extent will such criteria be fulfilled? Skeptics rightly claim not all these criteria will be fully met. But the process of agreeing and approaching the criteria will be salutary. Do sites fulfilling most criteria exist? The least bad site certainly exists. The answers will be difficult in some cases, but possible in others. Although difficult, this course is better than the alternatives, better than business-as-usual, and much easier than damping demand until "solar/hydrogen" energy becomes feasible in the next decades. Mandatory rationing and other service interruptions are likely to be exceedingly painful to consumers and to the development of the country. The damping pain should be discussed with all interested parties, as part of the criteria-setting and consensus-building exercise. Proper pricing makes the choices more obvious. In sum, we need to compare environmental costs and benefits much more rigorously and comprehensively than has been the case so far.

In our imperfect world, the reality is that not all these criteria will ever be totally met. Therefore, national consensus or some widely shared agreement is needed to decide if conservation, efficiency, environmental precautions and other alternatives are being pursued adequately or not. National agreement or "consensus" is essential in order to agree on the threshold at which the second best -- or least bad -- site should be developed.[10] National agreement on criteria will reveal where the thresholds lie. As soon as the various environmental impacts can be valued, the polarization of society will be defused. The need is to make uncertainty transparent and positive, rather than covert and manipulative.

As hydropower is exceptionally capital intensive and capital availability is a major constraint in nearly all nations, tropically forested or not, it is imperative to follow the least cost (as defined above to include all social and environmental costs) sequence of development. Least cost specifically includes saving kilowatt-hours, not just generating them, based on consumer choice when facing appropriate prices. Proper opportunity cost of capital must be used. Arguments for simultaneous development of higher cost alternatives should be rigorously resisted. Power corporations are commendably making the transition away from sole focus on new capacity, and towards conservation and efficiency. This is difficult for them because new capacity is under their almost total control, whereas conservation means they have to persuade other sectors outside their control. Power corporations wanting to promote sustainability, and to reduce national controversies and delays would follow a vigorous and transparent action program with serial steps along the following lines (Goodland 1988; 1990 a,b,c; Goodland et al. 1992).

1. **Promote fulfillment of nationally agreed-on criteria.**
2. **Manage demand to the fullest extent justifiable.**
3. **Promote agreed-on valuation of impacts.**
4. **Seek sites fulfilling nationally agreed upon criteria.**

**5. Sequence all sites in a national least-cost power program, under credible scenarios.**
**6. Rank all potential sites on the basis of these criteria.**

**And only then:**

**7. Develop the least bad new site fulfilling such criteria.**

## Table 5: Contrasting Views on Hydroprojects

| PROPONENTS | OPPONENTS |
|---|---|
| It is possible to mitigate hydro's impacts, given political will | Historically, hydro's impacts have scarcely ever been mitigated in practice |
| Developing countries need large power projects; many small power projects (deforestation, old diesels, can be environmentally and economically worse than the best hydro | Developing countries are better served by less lumpy power investments than big hydro |
| The impacts of hydro's alternatives (coal, nuclear) cannot be mitigated | Lumpy power projects demote DSM, so small coal and gas turbines make DSM more likely |
| Hydro generates much less GHG compared with coal alternatives | GHG reduction by hydro is unlikely to be the least cost; (improve transport) |
| Gas is best reserved for transport fuels or for chemical feedstock; inappropriate for base load | Use natural gas for the next decade or so at which time solar will be competitive |
| Many countries still have good hydro sites left; the best hydro sites should be developed to export electricity to neighbors, to postpone coal or nuclear alternatives, to benefit the country by attracting energy intensive industries, and to produce hydrogen to sell to OECD. | Practically all good hydro sites have already been developed |
| The worst hydro sites should not be built: tropical, many oustees & species, large reservoir areas, shallow, etc. | The only good hydro sites are non-tropical (that is, mountainous), no biomass or resettlement, no fish or a few endemics, high head, deep reservoirs |
| Government regulation is needed | Government regulation unlikely and weakening |
| Privatization needs government regulation | Private sector less regulable by government |
| Public and private power projects should follow least cost | Private sector less likely to follow least cost; prefers to externalize all it can |
| Electricity sales help the country irrespective of the use to which the power is put, such as exports or for the already electrified elites. | More electricity for the elite is not needed. Electricity for basic needs, health, education and for the poor is not best met from big hydro feeding the national grid. |
| Enforcement possible | Enforcement historically lax at best |
| Must not let water "waste to sea" unharnessed. | Water to sea not wasted, but used by ecosystems. |
| Need large scale for urban, industries and surpluses | Poor & rural benefit less, if at all, from large scale, priorities should be poor before industries |
| Subsidies to rich can be cut; pricing can help poor. | Subsidizes the rich; decreases equity. |
| Foreign contractors create jobs too | Too dependent on foreign exchange and contractors |
| LDCs lack capacity to build large. | Indigenous approaches better, cheaper |
| Big/small not substitutable | Small substitutes for big with more equitable goals |

## ENDNOTES

1. The most comprehensive documentation of this polarization is Goldsmith and Hildyard's (1985-1992) magisterial three volume opus; also see Williams (1991).

2. Recent costly dam fights, mainly over environmental issues, include: India's 240 MW Silent Valley hydroproject in Kerala's remnant rain forest was canceled in 1980; Thailand's 1986 Nam Choan: 2000 MW were lost after feasibility stage; Thailand's 1991 Pak Mun: dam was relocated and the dam height was lowered, delayed but now proceeding with violence and occasional bloodshed; Brazil's 1988 Babaquara: 6000 MW were lost, due in part to a collaborative campaign between the affected and vulnerable ethnic minorities (Amerindians) and the rock singer "Sting"; India's Narmada: five year delay after feasibility, 1991-1992 Independent Commission (Bradford Morse, Thomas Berger), World Bank loan canceled by Government in April 1993; Australia's 180 MW Franklin River in Tasmania's World Heritage Rain Forest was shelved in 1983.

3. Sustainability as a concept has been formally endorsed as an official priority of the United Nations system, and by the World Bank, although it is difficult to operationalize the concept in all sectors immediately. As they depend on the hydrological cycle, hydroprojects are theoretically renewable indefinitely. Sustainability here refers to two levels. First, environmental and social costs -- often not fully internalized -- must be valued and clearly outweighed by the benefits. Second, the life of the project must not be curtailed by environmental abuse, such as rapid sedimentation due to lack of watershed management upstream. Daly and Cobb (1989) have thought through the concept of sustainability the furthest, as have Adams (1990), Goodland, Daly and El Serafy (1992), and Goodland & Daly (1991, 1992). For recent notes on sustainable energy in sustainable economic development see Collette (1992) and Abdalla (1992).

4. This is a serviceable but arbitrary ratio. Both GWh and Kwh/ha would be better indicators.

5. This paper focuses on hydro-reservoirs which are increasingly common in tropical moist forest, rather than on irrigation reservoirs which do not occur in tropical moist forest; some multipurpose reservoirs and those in tropical dry forest remnants (eg: India's Narmada) are mentioned. Irrigation reservoirs may be slated for the tropical dry forest remnants and these would be even more problematic than those in tropical wet forest.

6. Live rescue for release into biotically impoverished habitat or into zoos and arboreta has rarely been effective historically, although captive breeding and reintroduction merits invigoration. More cataloguing and preservation of seeds and dead specimens also is urgently needed.

7. Tropical forest decays while inundated thus generating massive volumes of greenhouse gases, especially methane, which is 32 times more damaging than carbon dioxide. Large, shallow reservoirs from which forest is not removed before flooding may generate vastly more greenhouse gas than a coal-fired thermal equivalent (cf: Gupta & Pachauri 1990).

8. In view of the environmental advantages of small hydro (SHP, 1993), the balance between big and small hydro merits more analysis. Several smaller hydros may damage the environment and society more than one large project, especially where human population density decreases away from the river.

9. A few hundred sq. kms. of solar power systems in the Sahara desert could supply most of Europe's current electricity needs (cite). Hydrogen from splitting water molecules is likely to become economic and technically feasible very soon (Ogden & Williams 1989; Ogden & Nitsch 1993), and can be transported relatively easily. While it is difficult to generate 500 MW from garbage and sewage today, a large number of smaller such plants reduce the need for large projects.

10. Consensus strictly implies that each stakeholder could block decisions. Practice is improving in this regard, although not fast enough. Only a few decades ago, involuntary resettlement would be lucky if the Army's loudspeaker truck warned a village that it had a month to save itself. Bloodshed was not unknown. Later the Government may have contributed some poles and thatch for the new dwellings. And later may have even lent a truck to move the villagers and chattels to the new site. Not much more than one decade ago the costs of resettlement started to become integral to the project. A few years ago development officials left resettlement up to the government; contact with NGOs was prohibited or strongly discouraged. Now, at least in the World Bank, NGOs and oustee's advocates must be consulted well in advance. Their views must be meaningfully sought, although they do not have veto power. The ethical questions much in need of airing and resolution are: to what extent should a sub-dominant minority be able to block or influence benefits for a dominant majority? To what extent should a dominant majority be able to penalize a subdominant minority? Does the government fairly balance the costs and benefits between such minorities and majorities? What degree of evidence or track record should be demanded that the oustees will indeed promptly be better off after the possible relocation? Can "no worse off" be construed as development, especially if there are reasons to suspect pre-move levels of livelihood may not be regained for some years or more after involuntary resettlement?

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## ANNEX 1: PRE-CONDITIONS TO BE MET BEFORE DECIDING ON NEW GENERATION CAPACITY

Assume that a hypothetical nation, some of which is tropical forest, has reached national consensus that more energy is needed; and agreed on criteria on "need" have been met. Efficiency and conservation have been substantially achieved. Brownouts, load shedding and rationing already are predicted to be unavoidable shortly. For the purposes of this discussion, assume that the following conditions prevail before the decision is taken to expand new power generation: The price of electricity must substantially have already reached long run marginal cost. Practically all consumers are metered; meters are substantially precise; and major arrears cause prompt cessation of service. The financial stability of the power utility has to be ensured.

The choice is between coal, nuclear and hydro. All gas and oil has been exploited, or is not economic. The scope for interconnections with neighboring countries has been exploited, or is not feasible. This is important because interconnections enable a more acceptable site in a neighboring country to be taken up before a worse site in the country in question. Cooperation between Uganda and Kenya is a case in point.

Trade-offs are being faced in many countries, such as between massive increases in coal burning on the one hand, and the world's biggest dam, Three Gorges on China's Yangtze river, and the Narmada river dams in India, on the other. Global common property issues such as carbon dioxide accumulation and biodiversity conservation, should not be compromised by country-specific criteria.

Most energy conservation and efficiency measures must substantially be in place, both in generation and transmission, as well as inside homes and factories (Shepard, 1991). "Substantially in place" can be determined when the marginal economic cost (including environmental externalities) of saving an additional kilowatt-hour through conservation becomes as high as the marginal cost of a new kilowatt-hour produced and delivered to the consumer. This follows from the assumption above. As conservation measures are always advancing, implementation will always lag behind savings potential. The goal is to minimize this lag. Also, conservation cannot reap results overnight because of restraints on the pace of replacing capital stock, and other factors. A long-term, least-cost energy services perspective is needed. And "least" cost here must fully include environmental and social costs borne in the future (inter-generational costs). Decoupling of profits from sales is in the utilities interest, so that they can make money on margin and not on volume (as markets are not perfectly efficient). Progressive utilities have started selling conservation to consumers. Utilities should be rewarded for efficiency.

Further assume that discounts encouraging overconsumption by large consumers already have been repealed, but not so penalized that they start to generate their own power with possibly worse impacts. Large consumers have shifted to less electricity-intensive methods, where economically feasible. (Aluminum smelting will always be energy intensive.) National energy efficiency equipment standards are in place. Cogeneration potential has been rationally exploited.

All economically perverse subsidies and other incentives are assumed to have been rescinded. For example, some electricity and fuel pricing policies mandate that electricity and gasoline/diesel prices be the same at the powerplant, refinery, port, or capital city as they are at the furthest frontier outpost. Such policies promote excessive consumption of fuel, distort industrial, population, and agricultural-siting policies, raise prices in the main load centers, and discourage efficient energy production in remote areas.

All rehabilitation and expansion of existing sites already has been accomplished. This is almost always achieved at much less environmental and economic cost than construction of new sites. The large number of hydroprojects completed in the 1950s and 1960s can be modernized to postpone the need for new projects. Owen's Falls, for example, only turbines 50% of the available water. Assume also that all reservoir sites outside tropical forests already have been developed, or are not socially, environmentally or economically acceptable. The above pre-conditions are generic rather than specific to any particular country. They shall all be substantially met before deciding to go for new generating capacity. It is economically and environmentally imprudent to do less.

## ANNEX 2: THE MAIN ENVIRONMENTAL IMPACTS OF HYDROPROJECTS

1. **INVOLUNTARY RESETTLEMENT** of humans is difficult at best and of vulnerable ethnic minorities even more so. Restoration of pre-move levels of livelihood is delayed by the social trauma of deracination (Goodland 1982). Some agencies may not even agree that the minimal aim should be the prompt restoration of pre-move standards.

2. **LAND LOSSES**: Large tracts of agricultural lands, forests or other wildlands may be inundated. Careful siting can minimize such losses (e.g., by selecting reservoirs with high Kwh-generated/ha land area inundated: see Table III). The value of lost timber and other resources, and foregone use of inundated land should be estimated in the economic analysis.

3. **HEALTH**: Some water-related diseases (e.g., schistosomiasis, malaria, onchocerciasis and Japanese B encephalitis) may increase unless precautions or mitigatory me ·:es are implemented. Vector control, environmental modifications, and education of residents may need to be incorporated in.o the project.

4. **PLANT AND ANIMAL LIFE**: Biotic surveys normally are essential; plant and animal extinction can be prevented or minimized by careful project siting. Loss of wildlife may be mitigated by including elsewhere in the country a wildlands management area equivalent to the inundated tract (Ledec & Goodland, 1990). Animal rescue, replenishment, and relocation can be useful. Canal and other crossing facilities are often essential.

5. **WATER WEEDS**: Proliferation of floating weeds (e.g., water hyacinth [*Eichhornia*] and water lettuce [*Pistia*]) can impair water quality and increase disease vectors and water loss (through evapo-transpiration). Clogging impairs navigation, recreation, fisheries and irrigation. The potential to use weeds for compost, biogas or fodder should be investigated.

6. **WATER QUALITY**: Suitability of water quality for drinking, irrigation, fisheries or other uses, both within reservoirs and downstream, should be addressed. Issues include saline intrusions, water retention time (i.e., flow/volume), loss of flushing, increased nutrients in reservoir, pollution (e.g., agricultural leachates, pathogens, industrial effluents, mercury released from the soil), raising or contamination of water table, and salinization.

8. **ANAEROBIC DECOMPOSITION**: Inundated vegetation on the bottom of reservoirs decomposes, consuming much oxygen. If thermal stratification occurs, mixing of surface and bottom water is impeded, and the bottom water may become anaerobic. Anaerobic decomposition of organic material produces noxious gases toxic to aquatic life and harmful to machinery. If discharged by the dam, downstream fish could be killed. Multiple-level outlets in the dam can avoid the discharge of anaerobic water. Inexpensive models are available to predict thermal stratification. Conversion of forest to timber before reservoir filling reduces project contribution to greenhouse gases.

9. **EROSION**: Erosion upstream in the catchment area leads to sedimentation or land slips which can impair storage; catchment area management should be encouraged where appropriate. Increased erosivity of the water (the so-called "hungry waters" effect), on the riverbed and structures below the dam -- including deltaic and coastal changes -- should be considered during preparation. Trap efficiency, the capacity of the reservoir to store sediments, can be estimated, because many dams have low trap efficiency, do not store much sediment, hence do not increase erosivity downstream.

10. **DOWNSTREAM HYDROLOGY**: Changes in downstream hydrology can impair ecosystems dependent on seasonal flooding, including areas that may be important for fisheries (e.g., floodplains, lagoons, marshes, mangroves) or for traditional flood-recession agriculture. Sometimes management of downstream water releases can minimize such damage by partially replicating natural flooding regimes.

11. **INTACT RIVERS**: Hydroelectric and other developments should preferably be concentrated on the same rivers if hydrological risks and other circumstances permit, in order to preserve elsewhere a representative sample of rivers in the natural state. This should be considered part of the trade-offs.

12. **MULTIPLE USE**: Multiple use should by addressed through tourism, irrigation, fisheries, bird and other biotic sanctuaries, and recreation. Water flow regulation can convert seasonal rivers into perennial waterways, reduce flooding and improve drinking and irrigation. Communal access should be perpetuated.

13. **CULTURAL PROPERTY**: Archaeological or historic patrimony should be sought, avoided, conserved or relocated (Goodland & Webb 1987).

## ANNEX 3. THE EXAMPLE OF BRAZIL

Brazil in general and Eletrobras (Brazil's federal power agency) and Eletronorte in particular are deeply concerned with both energy conservation and environmental impacts. As indeed is the citizenry -- if not more so (Eletrobras 1986, 1987, 1990; Goldemburg 1987, Juras 1990, 1991; Serra 1992). Brazil has probably saved more than US$1 billion in new generation capacity avoided, because of recent major improvements in the electricity tariff structure, which led to more conservation and efficiency (Geller 1986, 1988, 1990). The World Bank has commended Brazil for moving towards a more appropriate tariff structure, and in the direction of the difficult goal of raising the price of electricity towards the long run marginal cost of production. The World Bank values the partnership with Eletrobras, and has assisted in financing the federal electricity conservation program, under the direction of Science and Technology Secretariat. The World Bank also is glad to be partners with National Environmental Secretariat in the first and biggest loan solely for national environmental priorities and institutional strengthening (US$117 million in February 1990).

The government, Eletrobras, Eletronorte, and environmentalists are now adopting a new position concerning new Amazonian hydroprojects, resulting from evolution of environmental awareness, specific legislation and experience with Amazonian issues (Adam 1988, Eletrobras 1986, 1987, 1989, 1990, Goldemberg & Barbosa 1989). Current construction rankings suggest that environmental criteria are most effective when applied proactively. This emphasis on environment, conservation and efficiency is exceptionally well placed. The recent hiring of substantial numbers of environmental professional staff by all Eletrobras' concessionaries is encouraging. For example, Eletronorte's environmental staff rose from less than one at the time Tucurui was designed in the late 1970's, to over 100 today (Goodland 1978, 1990, 1991). Environmental training throughout the entire power sector has increased dramatically.

Capital availability is a major constraint on the power sector, which has been responsible for as much as 25% (US$30 billion, 1973-83; now about 19%) of Brazil's foreign debt. Eletrobras may require of the order of US$75 billion to meet its 1991-2000 demand projections. In today's era of severely limited capital, such huge public investments in any sector such as power supply could imply reducing investments in other sectors, especially environment and the social sectors: education, nutrition, and health, as well as in poverty alleviation. Thus electricity, formerly a driving force behind social and economic development, could instead hinder vital welfare gains, if improved pricing, conservation and environmental precautions are not achieved. Could we be entering an era in which power investments reduce investments in other sectors whose growth was the driving force underlying electricity demand projections? Electricity rationing started during the Northeast 1985-86 drought, and is projected to increase in the mid-1990's. Eletrobras projects electricity demand will double between 1988 and 2000. This means 37,000 MW need to be installed by 2000. How best to install the equivalent of three new Itaipus -- the world's largest hydroproject -- in this decade? How to avoid repeating delays, confrontations and wastage?

Reports are guardedly encouraging. One of the next Amazonian dams may be the 1328 MW Serra Quebrada project just upstream from Tucurui. This meets many of the criteria listed above, and contrasts starkly with the Balbina / Babaquara-type (Cummings 1991, Dwyer 1990, Fearnside 1989, 1990 a,b, Gribel 1990, Moreira 1987, Sao Paulo Energia 1988, Visao 1985). According to Eletronorte, there are no Amerindian settlements, and little involuntary resettlement. The reservoir is small and practically run-of-river, and has a high ratio (31.5) of KW/ha. of land flooded, which is slightly better than Brazil's biggest hydroproject, Tucurui. In addition, it is on the already dammed Tocantins river, rather than being the first on a hitherto undammed Amazonian river.

This presages well for the ranking of the next Amazonian dams potentially identified by Eletrobras' "Plano 2010" for the next twenty years. The range between the "best" and "worst" hydro sites is so wide that the least cost (after conservation) power investment program will include a full array of sources, such as gas, and imported power. Coal and possibly at some time in the future even nuclear (with best technology), may be found by Brazil to be better than the "worst" hydro on future ranking on national criteria. A mixed hydro-thermal system implies fewer reservoirs.

Eletronorte has a massive challenge. Recent developments (eg: PROCEL, cancellation of Babaquara, criteria of Serra Quebrada) suggest promising improvements. National consensus on the kind of criteria suggested above will ensure that the trend is strongly positive.

## ANNEX 4: THE EXAMPLE OF INDIA

Kindly supplied by Dr. Rajendra Pachauri,
Director of the Tata Energy Research Institute, New Delhi

The case of India differs substantially from that of Brazil in the sense that India has not invested a substantial share of its power sector resources in hydroelectric plants. The main reasons for this are first that India has 148.6 billion tons of non-coking coal, and second that development strategies have relied only to a very small extent on foreign borrowings. Even though the Indian economy has generally recorded a savings rate of over 20%, resource mobilization in the power sector remains severely constrained.

This has happened for three main reasons. First, power sector demand growth in recent years has been rather high (9-10% p.a.), with a growing peak demand relative to base load demand. Second, the electric utility industry has accumulated heavy losses on account of suppressed tariffs and operational inefficiencies. Third, high human population growth (1.8 % pa) continues to impose onerous demands on investments in education, health care, welfare schemes and infrastructure, thereby relegating the power sector to one of many sectors competing for limited resources.

These factors have resulted in a preference for relatively short gestation thermal power plants, as opposed to hydroelectric capacity. While hydro and thermal had almost the same share of power generation (45% vs 55%) in 1965-66, this is now 30% hydro vs 70% thermal. Fortunately, Indian coal is low in sulfur, even though its ash content exceeds 40% in some power stations. As a result, the main environmental problems of thermal power stations are particulate emissions and ash disposal. Except in regions like the Rihand reservoir -- now well known for the Singrauli thermal power plants -- acid rain is not now, nor is it likely to become much of a problem in the future.

India's main hydrosites are in the Himalayas, with a large share concentrated in the North-East. Unlike Brazil, India has a land to population ratio of 0.004 sq km per capita, as compared with Brazil's 0.07 sq km per capita. High population densities, land scarcity, particularly agricultural, and disappearing forests are three crucial factors in Indian hydro planning. For example, the major issue in the 1200 MW (US$1.13 billion) Sardar Sarovar hydro and irrigation project on the Narmada river is the involuntary resettlement of people. These 90,000 oustees are not well equipped to adapt to new habitats, having historically a long inter-generational dependence on the land and its specific biota. In addition, the track record of Indian involuntary resettlement is poor, so that hydroprojects are likely to run into heavy public resistance (Goodland 1985, 1989, Pachauri 1990 a,b,c).

Capital constraints in the Indian economy are intensifying, therefore the impact on the power sector is likely to become more serious in coming years. Typically, the power sector has accounted for less than 20% of planned public sector investments, but the targets for the current (eighth) five-year plan demand a higher share. Therefore, energy efficiency improvements become more urgent. Conservation is important here not only at the end-use level, but also in the energy supply industry itself. For instance, official transmission and distribution losses have risen to 22%, and to as high as 40% in some states. Similarly, coal thermal efficiencies are well below state-of-the-art levels, with some plants attaining only 20%. There are, therefore, tremendous opportunities for efficiency improvements in the power industry which would moderate new capacity growth, without sacrificing electricity supply.

Irrationally low energy tariffs, far below long-run marginal costs, is the main reason for lack of energy conservation. This is particularly true in the power sector wherein some end-user subsidies are extremely high. Efficiency improvements must begin with adjustment of energy tariffs, in order to provide the consumer with appropriate signals. Improved efficiency may not significantly reduce aggregate demand for power to the extent that overall quantity of available power also constrains. Investments in physical capital have to be matched with investments in human capital, especially in power sector planning and environmental assessment. Such human capital investments would have larger returns than almost any other form of investment in the power sector.