PN-ACX-632

RESEARCH REPORT

70

Energy-Irrigation Nexus in South Asia

Improving Groundwater Conservation and Power Sector Viability

Tushaar Shah, Christopher Scott, Avinash Kishore and Abhishek Sharma

FUTURE HARVEST

IWMI is a Future Harvest Center supported by the CGIAR

Research Reports

IWMI's mission is to improve water and land resources management for food, livelihoods and nature. In serving this mission, IWMI concentrates on the integration of policies, technologies and management systems to achieve workable solutions to real problems—practical, relevant results in the field of irrigation and water and land resources.

The publications in this series cover a wide range of subjects—from computer modeling to experience with water user associations—and vary in content from directly applicable research to more basic studies, on which applied work ultimately depends. Some research reports are narrowly focused, analytical and detailed empirical studies; others are wide-ranging and synthetic overviews of generic problems.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI's own staff and Fellows, and by external reviewers. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

Research Report 70

Energy-Irrigation Nexus in South Asia: Improving Groundwater Conservation and Power Sector Viability

Tushaar Shah, Christopher Scott, Avinash Kishore and Abhishek Sharma

International Water Management Institute
P O Box 2075, Colombo, Sri Lanka

C

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Ghana, Pakistan, South Africa, Sri Lanka, and Thailand.

The authors: Tushaar Shah is a Principal Researcher and Theme Leader, Sustainable Groundwater Management and Christopher Scott is a Principal Researcher and Regional Director, South Asia, respectively, at the International Water Management Institute's regional office in India. Avinash Kishore and Abhishek Sharma are Junior Consultants in IWMI-Tata Water Policy Research Program at the Anand, India office of the International Water Management Institute (IWMI).

The research was made possible through a generous support from Sir Ratan Tata Trust, Mumbai, India.

Shah, T.; Scott, C.; Kishore, A.; Sharma, A. 2003. *Energy-irrigation nexus in South Asia: Improving groundwater conservation and power sector viability.* Research Report 70. Colombo, Sri Lanka: International Water Management Institute.

/ water use efficiency / groundwater irrigation / tubewells / sustainability / irrigated farming / households / farmers / irrigation systems / energy consumption / pumps / food security / water demand / electricity supplies / India / Pakistan / Bangladesh / Iran / Mexico / China / South Africa /

ISBN: 92–9090–518-2

ISSN: 1026-0862

Copyright © 2003, by IWMI. All rights reserved.

Please send inquiries and comments to: *iwmi@cgiar.org*

Contents

Summary *v*

Introduction *1*

Energy-Irrigation Nexus *2*

Sectoral Policy Perspectives *6*

Making a Metered Tariff Regime Work *8*

From a "Degenerate" Flat Tariff to a "Rational" Flat Tariff Regime *13*

Conclusions *22*

Literature Cited *27*

Summary

In the populous South Asian region, pump irrigation, mostly from open wells and tubewells, has gained ascendance over gravity-flow irrigation in recent decades, and the success of groundwater and energy economies have become closely interrelated. New paradigms in water resource management, which advocate the pursuit of basin-level water productivity in favor of classical water use efficiency—tend to treat the energy costs of irrigation to be insignificant relative to the social cost of the use of water. But in South Asia, which uses energy worth US$5 to US$6 billion per year (Rs 250 billion) to pump approximately 210 km^3 of water, mostly for irrigation, classical efficiency would be difficult to dislodge because it advocates the optimal use of both water and energy contemporaneously, whereas the notion of basin level productivity advocates optimal water sector outcomes but only suboptimal energy sector outcomes. Little can be done in the groundwater economy that will not affect the energy economy, and the struggle to make the energy economy viable is frustrated by the often-violent opposition from the farming community against efforts to rationalize energy prices. As a result, the region's groundwater economy has boomed at the expense of the energy economy. This report suggests that this need not be so. The first step to initiate a sustainable and prosperous groundwater economy with a viable power sector is for the decision makers of the two sectors to talk to each other, and jointly explore better options for energy-groundwater co-management—which has not happened so far.

At the heart of the matter is the need to devise appropriate policies for the pricing and supply of power to pump irrigators. For three decades, both power industry managers as well as international players, especially the World Bank and the Asian Development Bank (ADB), have insisted that the flat tariffs charged to irrigators based on the capacity of the pump rather than the metered consumption of power, is the principal source of loss for the power industry, and have advocated a transition to metered power supply. We suggest that doing so may not be helpful unless the power industry addresses the formidable logistical problems of supplying power to almost 14 million scattered, small users, which forced them to abandon metering in favor of flat tariff during the 1970s. On the other hand, we suggest that what has been so far passed off as flat tariff is a "degenerate" pricing policy. Zero tariff, as found in the Indian Punjab and in Tamil Nadu, does not qualify as a flat tariff; moreover, flat tariffs make no sense without a proactive rationing of supply. Levied as a tax rather than as a price, a scientific flat tariff for the supply of power used for pump irrigation can be a logical and viable alternative when the transaction costs of metering and metered charge collection are exceedingly high, as Pakistan learned after it reverted to a metered power supply in 2000. We explore metered and flat tariff regimes not just as alternative pricing policies but as alternate "business philosophies:" in the first, the industry delights the customer by providing quality power on demand; in the second, flat tariffs accompanied by sophisticated high quality management and the careful rationing of power supply will maintain both the financial sustainability of energy use in agriculture and the environmental sustainability of groundwater irrigation in regions where depletion or deterioration of this resource can spell doom for farming and livelihoods.

The report suggests that the inability to manage groundwater and energy economies as a "nexus" is a great opportunity missed. In South Asia, there appears to be no practical means for the direct management of groundwater. Laws are unlikely to curtail the chaotic race to extract groundwater because of the logistical problems of regulating a large number of small, dispersed users. Water pricing and property right reforms also will not work for the same reasons. A rationed power supply and an acceptable tariff system, however, offer a powerful toolkit for the "indirect" management of both groundwater and energy use. In this report, we outline the simple logic of what might be a win-win strategy for an energy-irrigation nexus in South-Asia, at least in the short run. In particular, we conclude that:

(a) The metering of the power supply to 14 million electric tubewells—the solution most widely espoused—poses a formidable and logistical challenge and faces strident, mass farmer opposition, which would make it politically difficult to implement quickly;

(b) Even if it is accepted, the logistical problems and high transaction costs of metering and billing a large number of dispersed power supplies to farms—which compelled governments to shift from metered tariff to flat tariff during the 1970s in the first place—continue to remain on a far larger scale today;

(c) If metering is to be introduced, its chances of success depend critically on the privatization of metering and billing at the feeder level or at a lower level as has happened in China;

(d) In the short run, the best course is to transform the existing "degenerate" system of flat tariff into a "rational" flat tariff system;

(e) For this transformation to take place first; flat tariffs need to be raised moderately and regularly rather than in big jumps. Second, a proactive power supply policy for the farm sector needs to be implemented by capping the total hours of power supply over the entire year to a level both viable and relative to the level of flat tariffs, and with the goal of meeting the farmers' irrigation needs as best as possible. Pursuing this strategy of the proactive management of a rationed power supply can reduce power industry losses from its farm operations, reduce overall technical and commercial losses of power, curtail wasteful use of 12-20 km^3 of groundwater per year, and improve farmer satisfaction with the power industry.

Energy-Irrigation Nexus in South Asia: Improving Groundwater Conservation and Power Sector Viability

Tushaar Shah, Christopher Scott, Avinash Kishore and Abhishek Sharma

Introduction

In the highly populated South Asian region, power utilities have been at loggerheads with the region's groundwater economy for over 15 years. As groundwater irrigation has come to be the mainstay of irrigated agriculture in much of India, in Pakistan's Punjab and Sindh provinces, in Nepal terai and in Bangladesh, the energy sector's stakes in agriculture have risen sharply. Around 60 percent of current Water Extraction Mechanisms (WEMs) use electricity, which is provided by public sector power utilities, to pump water. Until the mid-1970s, electric WEMs were charged for the metered consumption of electricity at lower rates than those charged from industrial and commercial users. However, frustrated by the logistical difficulties and high transaction cost of metering a large and growing number of WEMs dispersed over a huge countryside, electricity boards in Indian states changed in quick succession to a system of charging for the consumption of electricity by WEMs on what has popularly come to be known as the "flat tariff," which is based on the horsepower rating of the motor rather than the metered power consumption.

In many states, this change was associated with increased subsidies for power in agriculture. Some states stopped charging WEM owners for power altogether; but most others found that the flat tariff, once fixed, tended to be inflexible and efforts to raise it to cover increased costs prompted massive opposition from the farming community. At the same time, as a "vote bank," farmers have been able to oblige political leaders to maintain a high supply of power to agriculture throughout the year. Over the years, this inability to increase flat tariffs and reduce the power supply to agriculture has led the electricity industry in India and Pakistan to the verge of bankruptcy. Electricity utilities, multi-lateral and bi-lateral donors and energy experts have found the system of "flat tariff" to be the key culprit and have advocated the return to charging WEM owners for their use of power on a metered consumption basis. However, much of the efforts by state chief ministers after 1995 failed, as swift and strident mass farmer opposition compelled them to continue the flat tariff system and undertake damage control.[1] This has discouraged many states from

[1]Pakistan, which changed from metered tariff to flat tariff during the later part of the 1980s, reintroduced meters in 1999, but its experience so far suggests that neither farmers nor the electricity industry are doing any better after the change, as we note later.

implementing extensive reforms to the power sector.

In this report, our objective is to reevaluate the entire debate on the system of charging WEMs for their electricity consumption, from the perspective of the energy-irrigation nexus. We begin with the premise that electricity pricing and supply policies for agriculture in South Asia are closely linked with the policy goals of managing groundwater irrigation in pursuit of efficiency, equity and sustainability. Analyzing the energy and groundwater economies as a nexus could help develop joint strategies that can help South Asia both conserve its groundwater and at the same time improve the viability of its power industry.

Energy-Irrigation Nexus

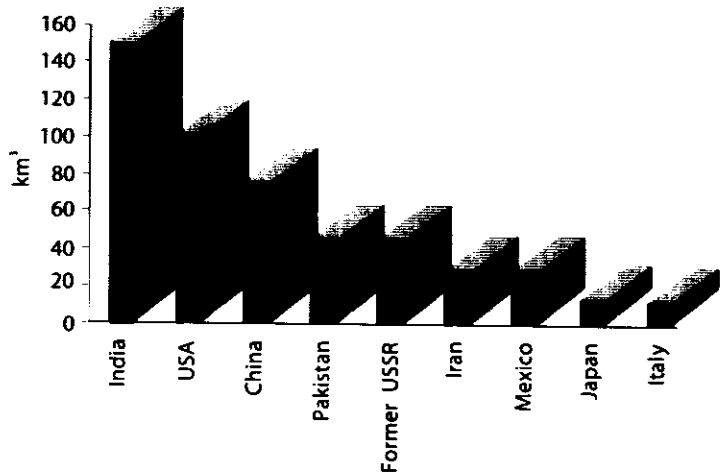
The energy-irrigation nexus focuses on a series of issues, which are unique to the South Asian region. Many countries, including the USA, China, Iran, and Mexico, make intensive use of groundwater in their agricultural sectors. Yet, in the course of interviews in Mexico and even in China, electricity industry officials drew a blank regarding the existence of an energy-irrigation nexus. A typical response was: "What nexus? Electricity is a separate industry and so is groundwater. The latter is but a customer of the former's outputs and is treated as such." In these countries, groundwater irrigation affects a small proportion of their people, energy use in agriculture is a small proportion of the total energy use, and the cost of energy use in farming is a small proportion of the total value-added in farming.

South Asia's groundwater economy differs in unique ways from those of other intensive groundwater using countries. India, Pakistan, Bangladesh and Nepal (but not Bhutan, Myanmar, Sri Lanka and the Maldives) constitute the biggest groundwater user countries in the world. Between them, they pump around 210 km^3 of groundwater every year (figure 1). In doing so, they use almost 20-21 million pump sets, of which approximately 13 million are electric and around 8 million are powered by diesel engines. If we assume that an average electric tubewell lifting water to an average head of 20 meters uses 0.5 kWh per m^3 of water lifted, the total electricity equivalent of energy used in these countries for lifting 210 km^3 of groundwater is around 100 billion kWh per year. Supplying such an output costs the region's energy industry approximately Rs 250 billion (US$5.2 billion) and the market value of the extent of irrigation is around US$12 billion (Shah et al. 2003). In these emerging low-income economies, pump irrigation has significant and wide impacts, both positive and negative, on the national economy.

Unlike in other groundwater using countries, the pump irrigation economy in South Asia also affects vast numbers of low-income households and large proportions of people. This growth in groundwater irrigation in the region is relatively recent (figure 2). In India, gravity systems dominated irrigated agriculture until the 1970s, but by the early 1990s, groundwater irrigation had surpassed the use of surface irrigation (Debroy and Shah 2003; Shah et al. 2003). Between 55 and 60 percent of India's irrigated lands is supplied water from groundwater.

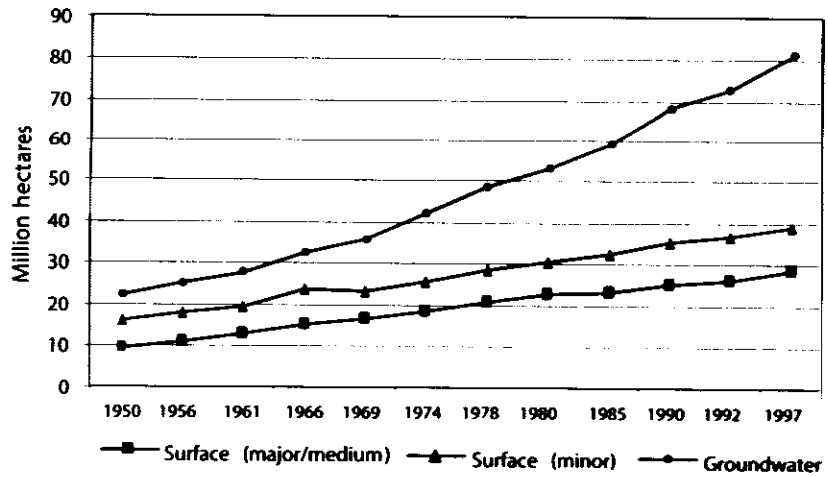
India's near 100 million farming families have over 19 million tubewells and pump sets among them. On average, every fourth farming family has a pump set and a well, and a large proportion of non-owners depend on pump-set

FIGURE 1.
Groundwater use in selected countries in the 1980s.



Source: Llamas et al. 1992.

FIGURE 2.
Irrigated area by source in India.



owners for supplying pump irrigation to the former through local, fragmented groundwater markets (Shah 1993). According to a World Bank estimate, groundwater irrigation contributes around 10 percent of India's GDP (World Bank and the Government of India 1998); but this is made possible because groundwater irrigation accounts for between a quarter and a one-third of the total national electricity consumption.

The use of a large number of small pumps is a peculiarly South Asian practice. The USA, Iran, Mexico and China, although major groundwater users, have a fewer number of individual groundwater irrigators. However, these irrigators produce 10–50 times more than the groundwater users in India, Bangladesh and Nepal. In the Guanajuato province, the heartland of Mexico's intensive groundwater irrigated agriculture, a typical tubewell is of 100–150 horsepower and operates for over 4,000 hours per year (Scott et al. 2002). In India, Bangladesh and Nepal, the modal pump size is 6.5 horsepower and the average hours of operation are around 40–500 per year (Shah 1993). In Iran, only 365,000 tubewells are pumped to produce 45 km^3 of groundwater (Hekmat 2002), while India uses 60 times more wells to extract three times as much groundwater.

From the viewpoint of managing groundwater as well as energy supply to irrigation, these differences prove crucial. In Iran, when groundwater overdraft in the hinterland threatened the water supply to cities in the plains, the Ministry of Power (which also manages water resources) was able to enforce a complete ban (provided under its Water Law) on new groundwater structures coming up in two-fifths of the area covered by the plains (Hekmat 2002). In Mexico, the Commission National de Aqua (CNA) has been able to establish and enforce a system of water rights in the form of concessions and have initiated a program to create groundwater user organizations, which will promote sustainable water resource management. While it is early to tell how effective these reforms will be, after 1948, Guanajuato, which is an intensive groundwater user, was prompted to impose bans on new tubewell construction in 13 different areas (Scott et al. 2002). While many factors may have worked in favor of such direct management, a very important factor, is that groundwater administrations in these countries have to regulate a relatively small number of fairly large pumps, unlike in the South Asian region.

An aspect related to such a system of administration is the relationship between groundwater irrigation, food security and the type of livelihood of the particular population. In countries with a shrinking agricultural sector, the proportion of people dependent on groundwater-irrigated agriculture tends to be small (last column in table 1). This, for example, is the case in the USA, Mexico and Iran. One would have normally thought that in such situations, it would be easier for governments to adopt a stringent system of regulation of irrigators, especially if serious environmental anomalies were involved. However, we find that this is not so. For example, Mexico was unable to divest substantial energy subsidies to agriculture (Scott et al. 2002), the USA could only restrict the rate of, but not halt, mining of the great Ogallala aquifer, and, Iran, even after imposing a ban, is still struggling to eliminate its 5 km^3 annual groundwater overdraft (Hekmat 2002). In South Asia, the dependence on groundwater is far greater and, therefore, restricting groundwater use to sustainable levels is more difficult. In India, for instance, pump irrigation accounts for 70–80 percent of the value of irrigated farm output. And rapid groundwater development is at the heart of the agrarian dynamism found in some areas in eastern India, which for a long period of time was stagnant (Sharma Kumar and Mehta 2002). The greatest social value of groundwater irrigation is that it has helped make famines a matter of history. This can be seen from the contrast between the droughts of 1963 and 1987. During 1963–1966 a

TABLE 1.
Extent of dependence of population on groundwater and average size of water extraction mechanisms in different countries.

Country	Annual groundwater use (km^3)	No. of groundwater structures (million)	Extraction per structure (m^3/year)	% of population dependent on groundwater
Pakistan	45	0.5	90,000	60-65
Punjab				
India	150	19	7,900	55-60
China	75	3.5	21,500	22-25
Iran	29	0.5	58,000	12-18
Mexico	29	0.07	414,285	5-6
USA	100	0.2	500,000	<1-2

Sources: Hekmat 2002 for Iran; Mukherji and Shah 2002 for India; Scott et al. 2002 for Mexico and Shah et al. 2003 for China and Pakistan

small deficit in rainfall left reservoirs empty and sent food production plummeting by 19 percent. However, during the 1987–1988 drought, when the rainfall deficit was 19 percent, food production fell by only 2 percent, owing to widespread groundwater irrigation (Sharma Kumar and Mehta 2002).

It is often argued that with 60 million tons of food stocks, India can now take a tough stand on groundwater abuse. However, this view misses the point of groundwater irrigation—the contribution of groundwater to farm incomes and rural livelihoods is far more crucial than its contribution to food security, especially outside canal commands.[2] It seems that other things being equal, poor countries, though not necessarily poor households, achieve food production levels necessary for ensuring household food security at far lower levels of per capita income than required to achieve livelihood security, by reducing the population pressure on agriculture. In South Asia, the proportion of the total population that is directly or indirectly dependent on groundwater irrigation, is many times larger than that of Iran and Mexico. Indeed, our surmise is that by the turn of the millennium, three-fourths of the rural population and over half of the total population of India, Pakistan, Bangladesh and Nepal would depend for their livelihoods directly or indirectly on groundwater irrigation. In this context it is not surprising that the energy-irrigation nexus has been at the centre of the vote-bank politics in the region.

[2]Dhawan (cited in Samra 2002), for instance, has asserted that in low rainfall regions of India, "a wholly (*groundwater*) irrigated acre of land becomes equivalent to 8 to 10 acres of dryland in production and income terms."

Sectoral Policy Perspectives

Groundwater policymakers face contrasting challenges in managing this chaotic section of the economy in different areas. Particularly after 1970, agrarian growth in the region has been sustained primarily by private investments in pump irrigation, the result of which, however, has been highly uneven. In the groundwater-abundant Ganga-Brahmaputra-Meghana basin—home to 400 million of the world's rural poor in Bangladesh, and in the Nepal terai and eastern India, groundwater development can produce significant livelihood and ecological benefits (Shah 2001), but is currently slow and halting. In contrast, Pakistan and Indian Punjab, Haryana and all of peninsular India are rapidly overdeveloping their groundwater to a stage where agriculture in those parts faces the serious threat of resource depletion and degradation. The priority in such areas is to find ways of restricting groundwater use. In stimulating or restricting groundwater use as appropriate, the tools available to resource managers are few and inadequate. Regulating groundwater draft and protecting resources is proving far more complex and difficult. The direct management of an economy with such a vast number of small players would be a Herculean task in most circumstances. In South Asia, it is even more impracticable because the groundwater bureaucracies are small, ill-equipped and outmoded. They were created during the 1950s for monitoring the resource. As a result, India's Central Groundwater Board (CGWB), for example, has no field force or operational experience or capability in managing groundwater. In 1992, ruling on a public-interest-suit, the Supreme Court of India ordered the Forest Department to stop the felling of trees in the reserved forests of the country, and the Forest Department was able to effectively carry out the court order within a week because it had an elaborate field force with both operational experience and management capability. In 1996, the same Supreme Court appointed the CGWB as the Central Groundwater Authority, conferred on it elaborate powers and designated it with the task of restricting further groundwater development in assigned areas. Today, 7 years later, the Authority has been unable to stop new tubewells being dug even in the Union Territory of Delhi, leave alone the rest of India (Down to Earth 2002a). The direct management of the groundwater economy is, therefore, an impractical idea in South Asia.

The failure of direct management makes "indirect" management relevant and appealing in South Asia. A controlled electricity supply and pricing policies offer a potent tool kit for indirect management, provided these are used as such. Regrettably, these have so far not been used efficiently. In the groundwater-abundant Ganga basin, a favorable level of power supply can accelerate groundwater development and stimulate opportunities of livelihood creation for the poor, but as described later in this report, this region has been very nearly de-electrified (Shah 2001). Elsewhere, where there is a dire need to restrict groundwater draft, an abundant power supply and perverse subsidies are accelerating the depletion of the resource. All in all, power supply and pricing policies in the region have so far been an outstanding case of perverse targeting.

A major reason for this is the lack of dialogue between the two sectors and their pursuit of sectoral optima rather than of managing the "nexus." To the power industry in the region, the groundwater economy is an anathema, since agriculture uses up to 27–35 percent of total power, and power pricing to agriculture is a hot political issue. In states like Punjab and Tamil Nadu, the power supply to farmers is free and in

all other states, the flat electricity tariff[3]—based on the horsepower rating of the pump rather than actual metered consumption—charged to farmers is heavily subsidized. Losses to electricity boards on account of power subsidies to agriculture are estimated at Rs 260 billion (US$5.4 billion) in India, and these losses are growing at a compound annual growth rate of 26 percent per year (Lim 2001; Gulati 2002). At this rate, it will not be long before the power industry finances are completely in the red. These estimates have been widely contested and State Electricity Boards (SEBs) have been showing their growing transmission and distribution (T&D) losses in domestic and industrial sectors as agricultural consumption, which in turn is unmetered and, therefore, unverifiable.[4] However, the fact remains that the agricultural power supply under the existing regime is the prime cause of the bankruptcy of SEBs in India.

As a result, there is a growing movement now to revert to a metered power supply. The power industry has been leading this movement from the front but international agencies—particularly, the World Bank, the USAID and the ADB have begun to insist on metered power supply to agriculture as the key condition for financing new power projects. The Central and State Electricity Regulatory Commissions have been setting deadlines for SEBs and governments to make a transition to metering. The government of India has resolved to: (a) provide power on demand by 2012; (b) meter all consumers in two phases, with phase I to cover metering of all 11 KVA (kilovolt-ampere) feeders and high tension consumers, and phase II to cover all consumers; and (c) to install regular energy audits to assess T&D losses and eliminate all power thefts within 2 years (Godbole 2002). This is an ambitious agenda, indeed. However, all moves towards metered power consumption have met with opposition from farmers on an unprecedented scale in Andhra Pradesh, Gujarat, Kerala and in other states of India. All new tubewell connections generally come with metered tariff, and most states have been offering major incentives to tubewell owners to opt for metered connections; Andhra Pradesh charges metered tubewells only Rs 0.20 per kWh, and Gujarat and several other states, up to only Rs 0.50–0.70 per kWh against the supply cost of

[3]Way back in the 1950s, when the rising rate of energy consumption was considered synonymous to economic progress, state owned power utilities aggressively persuaded unwilling farmers to install electric tubewells. In states like Punjab and Uttar Pradesh, Chief Ministers gave steep targets to district-level officials to sell electricity connections to farmers. All manner of loans and concessions were made available to popularize tubewell irrigation. During the 1960s and 1970s, the World Bank supported huge investments in rural electrification infrastructure to stimulate groundwater irrigation and agricultural growth. These policies were vindicated when the Green Revolution was found to follow the tubewell revolution with a lag of 3–5 years. By the 1970s, the energy-irrigation nexus had already become a prominent feature of the region's agrarian boom, and even in canal commands—such as Indian and Pakistan Punjab—groundwater irrigation had grown rapidly. However, the enthusiasm of State Electricity Boards (SEBs) towards its agricultural customers had gradually dampened. All of them were charging tubewell owners on a metered consumption basis. However as the number of tubewells increased, SEBs found it costly and difficult to manage metering and billing. The cost of meters and their maintenance was the least of their worries; but containing the tampering of meters, pilferage, under-billing, corruption at the level of meter readers, the cost of maintaining an army of meter readers and the other transaction costs were far bigger and difficult to regulate. A study by Rural Electrification Corporation showed that the metering cost alone was 15–20 percent of the cost of power supplied to agriculture in Maharashtra (cited in Shah 1993). Introduction of flat tariff in each state during the 1970s and 1980s was a response to this already high and still rising transaction cost of the metered power supply. Flat tariffs linked to the horsepower rating of the pump eliminated the hassle and cost of metering. It still afforded scope for illicit practices, such as under-reporting the horsepower rating, the controlling of which, however, was easier than controlling pilferage. Flat tariffs, however, became "sticky," as power supply to agriculture emerged as a major feature of the region's mass politics, and Chief Ministers found it a powerful weapon in "vote bank politics." Unable to raise flat tariffs for years on end and under pressure to supply abundant electricity to farms, power utilities began to find their balance sheets turning red, and the industry as well as its protagonists veered around to the view that reverting to metered tariff for the supply of power to farms is a precondition to restoring its viability.

[4]Shah (2001) has analyzed this aspect for the Uttar Pradesh State Electricity Board. Based on a World Bank study in Haryana, Kishore and Sharma (2002) report that the actual agricultural power consumption was 27 percent less than reported, and the overall T & D losses were 47 percent, while officials claimed it to be 36.8 percent, making the SEB more efficient than it really was. The power subsidy ostensibly meant for, agricultural sector but benefiting to other sectors, was estimated at Rs 5.5 billion (US$112.2 million) per year for Haryana alone.

Rs 2.50–3.80 per kWh. In a recent move, the Gujarat government has offered a drip irrigation system free to any farmer who opts for metering.

Yet, there still remain only a small number of farmers who opt for metered connections. The farmers' opposition to metered tariff has only partly to do with the subsidy contained in flat tariff. One of the major reasons for farmers opting for flat tariff is because of the transparency and simple comprehensibility of the system. It also spares them from the tyranny of corrupt meter readers. Finally, there are fears that once under metered tariff, SEBs will start enforcing an unending series of new charges under different names. Despite these fears, the power industry persists in its belief that its misfortunes will not change until agriculture is put back on a metered electricity tariff. Strong additional support to such a conversion is lent by those working in the groundwater sector, where it is widely held that zero and flat power tariffs produce strong perverse incentives for farmers to indulge in profligate and wasteful use of both water as well as of power because such tariffs reduce the marginal cost of water extraction to nearly zero. Professionals of the water and power sectors are aggressively campaigning to revert to the metered tariff regime, which is vehemently opposed by the farmers. This, in our view, sidelines the more significant issue of transforming a vicious energy-irrigation-nexus into a virtuous one in which a booming, and better managed, groundwater-based agrarian economy can coexist with a viable electricity industry in the region.

Making a Metered Tariff Regime Work

The arguments in favor of a metered tariff regime are manifold:

(a) It is considered essential for SEBs to manage their commercial losses; you cannot manage what you do not monitor, and you cannot monitor what you do not measure;

(b) Once power supply to farms is metered, SEBs cannot use agricultural consumption as a carpet under which they can sweep their T&D losses from other sectors;

(c) Metering would give farmers correct signals about the real cost of power and water, and force them to economize on the use of these resources;

(d) For reasons which are not entirely clear, it is often suggested that compared to the flat tariff regime, metered tariff would be less amenable to political manipulation and, therefore, would better accommodate the rising cost of supplying power;

(e) The flat tariff is inequitable towards small landowners and to irrigators in regions with a limited supply of groundwater.

The logic in support of metered tariff is obvious and unexceptionable. The problem is how to make metered tariff work in the manner envisaged. Two issues seem critical: first, how to deal with the relentless opposition from farmers to metering; second, how will SEBs now deal with the problems that forced them to switch to flat tariff during the 1970s.

The extent of farmer resistance to metering can be seen from the repeated failure of SEBs in various states to entice farmers to accept

metered power at subsidized rates, ranging from Rs 0.20-0.70 per kWh as against the actual cost of supply, which is in the range of Rs 2.00–3.80 per kWh. In late 2002, Batra and Singh (2003) interviewed 188 WEM owners in Punjab, Haryana and western Uttar Pradesh in order to understand their WEM pumping behavior. They noted that in Punjab and Haryana, an average electric WEM owner would spend Rs 2,529.65 and Rs 6,805.42 (US$51.6 and US$138.8) less on their total power bill if they accepted metering at the prevailing rates of Rs 0.50 per kWh and Rs 0.65 per kWh, respectively. However by choosing not to go for metered connection, in effect, this is the price they are willing to pay to avoid the hassle and costs of metering.[5]

Before 1975, no SEB charged for the supply of power to farms on a flat tariff basis, but rather used the metered basis. But the logistical difficulty and transaction costs of metering became so high that the flat tariff seemed the only way of containing such losses. A 1985 study by the Rural Electrification Corporation in Uttar Pradesh and Maharashtra estimated that the cost of metering the rural power supply absorbed 26 and 16 percent, respectively, of the total revenue of the SEB from the farm sector (Shah 1993). And this estimate included only the direct costs, such as the cost of installing a meter and maintaining it, cost of the power consumed by the meter, and cost of reading the meter, billing and collecting payments. These costs are not insignificant. A recent World Bank study for the small state of Haryana estimated that the cost of metering all the power supplies to farms in Haryana would amount to US$30 million in capital cost and US$2.2 million per year in operational costs (Kishore and Sharma 2002). The Maharashtra Electricity Tariff Commission estimated the capital cost of metering farm supplies to be at Rs 11.5 billion (US$239.2 million), (Godbole 2002). However, the main transaction costs of metering are the costs of containing pilferage and tampering with meters, and costs of under-reading and under-billing by meter readers with the connivance of farmers.

The power sector's aggressive advocacy of the metered tariff regime in agriculture is based, in our view, on an excessively low estimation of the transaction costs of metering, meter reading, billing and collecting payments for several hundred thousand tubewell power supply connections scattered over the vast area[6] that each SEB serves. Most SEBs find it difficult to manage the metered power supply even in industrial and domestic sectors where the transaction costs involved are bound to be lower than in the agricultural sector. Even where meters are installed, many SEBs are unable to collect payments based on metered consumption. In Uttar Pradesh, 40 percent of low tension power supplies are metered but only 11 percent are billed on the basis of metered use; the remaining were billed on a minimum charge or on a previous average (Kishore and Sharma 2002). In Orissa, under far reaching power sector reforms, private distribution companies have brought all users under the

[5]According to Batra and Singh (2003), farmers resist metering "because of the prevalence of irregularities in the State Electricity Boards. Complaints of frequent meter burning, which costs the farmer Rs 1,000 (US$20) per meter burn, false billing, uncertainty in the bill amount, etc., discourage farmers from accepting metering. The farmers also resist metering because of the two part tariff (energy charge and rental for the meter) system. They are reluctant to pay the minimum bill (rental charge), which they have to pay, even if they don't use the pump in that month."

[6]Rao and Govindarajan (2003) lay particular emphasis on the geographic dispersion and remoteness of farm consumers in raising the transaction costs of metering and billing: "To illustrate, a rural area of the size of Bhubaneshwar, 'the capital of Orissa state,' will have approximately 4,000 consumers. Bhubaneshwar has 96,000. The former will have a collection potential of Rs 0.7 million a month (US$14.28); for Bhubaneshwar, it is Rs 22 million a month (US448.98)."

metered tariff regime. However, 100 percent collection of amounts billed is possible only in industrial areas. In the domestic and farm sector—with a large number of scattered small users—collection as a percentage of billing declined from 90.5 percent in 1995/1996 to 74.6 percent in 1999/2000 (Panda 2002).

Under the Nawaz Sharif government, Pakistan changed from metered to a flat electricity tariff for the same reasons that the Indian states did during the 1970s and 1980s. The military government led by General Musharraf reverted to metered tariff in 2000 and all the problems of the metered tariff regime came to the fore. An IWMI note from Pakistan (Qureshi 2002) says, "Power theft and meter tampering is a pressing issue. The total power theft was estimated at seven billion units worth Pakistan Rs14 billion (US$243.04 million). Finally, the army was called in to look for illegal connections and rigged meters. By March 2001, after a single campaign, the army has lodged 5,687 complaints."

In order to make the metered tariff regime work reasonably well, three things seem essential: (a) the metering and collection agent must have the requisite authority to deal with the deviant behavior among users; (b) the discharge of his duties should be subject to a stringent control system so that he can neither behave arbitrarily with consumers[7] nor form an unholy collusion with them; and (c) he must have proper financial incentives to enforce the metered tariff regime. In agrarian conditions comparable to those in South Asia, a quick assessment by Shah (2003) suggests that the metered tariff regime works reasonably well in areas like north China.

The Chinese electricity supply industry operates on two principles (a) total cost-recovery in generation, transmission and distribution at each level with some minor cross-subsidization across user groups and areas; and (b) each user pays in proportion to his use. Unlike in much of India where farmers pay for power either nothing or much less than domestic and industrial consumers, agricultural electricity users in many parts of north China pay the highest charge per unit, followed by household and industrial users, respectively. The operation and maintenance of local power infrastructure is the responsibility of local units like the Village Committee at the village level, the Township Electricity Bureau at the township level, and the County Electricity Bureau at the county level. The responsibility of collecting electricity charges is also vested in local units in ways that ensure that the power used at each local level unit is paid for in full. At the village level, for example, the total power use recorded in the meters attached to all irrigation pumps has to tally with the power supply recorded at the transformer for any given period. At the township level, the unit or person appointed with the responsibility of fee collection has to ensure the payment of charges to the Township Electricity Bureau commensurate with the power use recorded at the transformer level. In many areas, however, where power supply infrastructure is old and worn out, line losses below the transformer level make this difficult. To accommodate for these losses in the normal course of collection of fees, a 10 percent leeway is given by the Township Electricity Bureau to the village unit. However, even with this allowance, it was difficult for the village unit to tally the recorded level of electricity consumption with the

[7]In states like Gujarat, which had metered tariff until 1987, an important cause of opposition to metering is the arbitrariness of meter readers and the power they had come to wield over electricity consumers. In many villages, farmers organized opposition for the sole purpose of resisting the tyranny of the meter reader. In some areas, this opposition became so serious that meter readers were declared *persona non grata*. Even today, electricity board field staff seldom goes to a village except in fairly large groups, and often with police escort.

amount consumed by users. As a result, an Electricity Network Reform Program (ENRP) was undertaken by the national government to modernize and rehabilitate rural power infrastructure. Where this was done, line losses fell sharply.[8] Among the nine villages that the lead author visited in early 2002 in three counties in the Hanan and Hebei provinces, none of the village electricians interviewed had a problem tallying power consumption recorded at the transformer level with the sum of the consumption recorded by individual users, especially with the line-loss allowance of 10 percent.

The village electrician, the ENRP, Township Electricity Bureau, the incentive payments, and a new service organization[9] are all elements of the Chinese strategy that have turned the energy-irrigation nexus into a beneficial one. Before the Network Reform Program, it was difficult to contain losses to a level below 10 percent, and as a result, electricians and Village Committees were unwilling to operate as "electricity retailers" for the Township Electricity Bureau but now, the situation has changed. By and large, distribution losses are restrained to much less than 10 percent in areas covered by the ENRP. Most of these losses are technical losses, and there are hardly any commercial losses. In areas not yet covered by the ENRP, the line losses remain high and the electrician often imposes a cess on the standard charge so as to cover the losses. By the same token, renewed efforts are also being made to improve the services provided to users.[10] An important reason for the success of this institutional arrangement is the strength of the local authority structures in Chinese villages. The electrician is feared because he is supported by the Village Committee and the powerful party leader at the village level, while the new service orientation is designed partly to project the electrician as the friend of the people. But the same Village Committee and Party Leader can also regulate flagrantly arbitrary behavior of the electrician towards the users. The hypothesis that with better quality of power supply and support service, farmers would be willing to pay a higher price for power is best exemplified in Hanan where at Yuan 0.7 per kWh (US c 8.5/ kWh, Rs 4.27/kWh) farmers pay a higher electricity rate than all other types of users in India and Pakistan, as also compared to the diesel price at Yuan 2.1(US$0.25) per liter.

In India, there has been some discussion about the extent of incentives needed to make the privatization of electricity retailing attractive at the village level. The village electrician in Hanan and Hebei works for a fairly modest reward

[8]The reward system granted to the village electrician encourages him to take measures like cutting line losses, to achieve greater efficiency. In Dong Wang Nu village in Ci county, the village committee's single large transformer, which served both domestic and agricultural connections, caused heavy line losses of 22–25 percent. Once the Network Reform Program began, the Village Committee was pressurized to sell the old transfromer to the Township Electricity Bureau and raise Yuan 10,000 (US$1,250): partly by collecting a levy of Yuan 25 per family (US$3) and partly by a contribution from the Village Development Fund to get two new transformers, one for domestic connections and the other for pumps. Since then, power losses have fallen to the permissible 12 percent level.

[9]In many areas covered by the Electricity Network Reform Program, a new organization for maintenance and service delivery has been created. In many townships in Hanan, all the villages are formed into four to six "electricity classes," each having 5–7 contiguous villages. In these areas, it is common for the Township Electricity Bureau to appoint and train a local farmer as the village electrician with the dual responsibility of maintaining the power supply infrastructure in the village as well as of collecting user charges based on metered individual consumption from all categories of users. The electricians in each class form into a group that is collectively responsible for service provision and individually responsible for collecting electricity charges and paying them to the Township Electricity Bureau. The group has a common office and a telephone number accessible to all the villages; and every electrician takes a 4-hour duty turn so that there is always an electrician available any time of the day. Any villager from the member villages can call an electrician for help in fixing electrical problems and, in Yanjin county, their goal is now to reach the customer within 5 minutes after a call for help is received. They levy a service charge for attending each request for help and this covers the cost of repair and transportation on motor cycle. The idea now is mooted to provide these electricians a transport subsidy from the Township Electricity Bureau.

[10]US$1 = Yuan 8 = IN Rs 49

of Yuan 200 per month (US$25), which is equivalent to half the value of wheat, produced on a *mu* (or one-thirtieth of the value of output on a hectare of land). For this rather modest wage, the village electrician undertakes to make good to the Township Electricity Bureau the full amount on line and commercial losses, which are in excess of the 10 percent allowance against the power consumption recorded on the transformers. If the village electrician can manage to curtail losses to less than 10 percent, he can keep 40 percent of the value of power saved.

All in all, the Chinese have all along had a working solution to a problem that has befuddled South Asia for nearly two decades. Following Deng Xiaoping who famously asserted that "it does not matter whether the cat is black or white, as long as it catches mice," the Chinese built an incentive-compatible system that delivered quick results rather than lingering on rural electricity cooperatives and Village *Vidyut Sanghas* (Electricity Associations), which are being tried in India and Bangladesh. In the way the Chinese collect metered electricity charges, it is well nigh impossible for the power industry to lose money in distribution since such losses are firmly passed on downstream from one level to another. For example, the malpractice common in South Asia of end-users tampering with meters or bribing the meter-reader to under-report actual consumption, would be less common in the Chinese system, since the village electrician is faced with serious personal loss if he fails to collect from the farmers their respective electricity charges for at least 90 percent of the power consumption reported at the transformer meter. And since malpractice by a farmer directly affects other farmers in the village, peer pressure from the community may develop an internal system of regulation. There are similar incentive-control mechanisms at the level of the Township Electricity Bureau as well, so that major malpractices at the transformer level can be detected and curbed quickly.

If South Asia is to revert to a metered tariff regime, the Chinese offer a good model to emulate, except for two problems. First, the agricultural productivity in China is much higher than that of most regions in South Asia, in that even with power charged at real cost, tubewell irrigation costs constitute a relatively small proportion of the gross value of output. In many parts of South Asia, irrigation costs of this order—that is Rs 2,100–Rs 8,600 per hectare (US$43 –US$175) would make groundwater irrigation unviable in all regions except parts of Punjab and Haryana, where farm productivity approaches those levels found in China.

The second problem is that while the South Asian power industry can mimic, or even outdo the Chinese incentive system, it cannot replicate the Chinese authority system at the village level. And the absence of an effective local authority that can protect the farmers from the possibility of arbitrary recording by the metering agent, or protect the latter from lack of cooperation from the users, may create unforeseen complications in adopting the Chinese model in South Asia. India has only recently begun experiments to find new metering solutions with NGOs like Indian Grameen Services experimenting in the Hoshangabad district of Madhya Pradesh. Though it is too early to learn lessons from these experiences, it is all too clear that the old system of metering and billing, in which SEBs employed an army of unionized meter readers, would just not work.[11] That model seems passé;

[11]A 1997 consumer survey of the power sector revealed that 53 percent of consumers had to pay bribes to electricity staff for services supposed to be provided for free; 68 percent said redress to a grievance was poor or worse than poor; 76 percent found staff attitudes poor or worse; 53 percent found repair fault services poor or worse; 42 percent said they had to make 6–12 calls just to register a complaint; 57 percent knew of power thefts in their neighborhoods; 35 percent complained of excess billing; 76 percent complained of inconvenience in paying their bills (Rao 2002).

in power as well as in surface water, volumetric pricing can work, where needed, only with the use of cleverly designed incentive contracts. Delhi's power utility (Delhi Vidyut Board) farmed out meter reading and billing to a private company, thus curtailing commercial losses significantly.[12] Orissa's private power distribution companies, which tried out Village level *Vidyut Sanghas* have now introduced private metering-cum-billing agents whose incentives are similar to those given to China's village electricians. These agents get a fixed commission of Rs 3.50 per customer for meter reading, billing and collection; but an incentive of 1 percent of total collection if it ranges from 35–49 percent of the energy supply measured at 11 kV feeder; and
2 percent of total collection if the "collection ratio" exceeds 50 percent (Rao and Govindarajan 2003). A high performing franchisee who achieves a "collection ratio" of over 49 percent is expected to earn a net income of Rs 8,000 per month (US$163). The results so far, of this limited but growing pilot project, are encouraging. However, extending these results to agricultural power supplies in other states is problematic, since less than 4 percent of the power supplied in rural Orissa goes to WEMs, as against 25–40 percent in many other states.

From a "Degenerate" Flat Tariff to a "Rational" Flat Tariff Regime

The implementation of a flat tariff for power supplied to farms is universally written off as inefficient, wasteful, irrational and distortionary, and also being inequitable, as seen in the South Asian experience. It was the change to flat tariff that encouraged political leaders to indulge in populist whims such as doing away with power tariffs to farms altogether (as Punjab and Tamil Nadu have) or to peg it at unviably low levels regardless of the true cost of the power supplied. Such propositions developed the general perception that the flat tariff regime has been responsible for ruining the electricity industry and for causing groundwater depletion in many parts of South Asia.

However, we would like to suggest that the flat tariff regime is wrongly blamed. In fact, the flat tariff that South Asia has used in its energy-irrigation nexus so far, is a completely "degenerate" version of what might otherwise be a highly rational, sophisticated and scientific pricing regime. Zero tariff, we submit, is certainly not a rational flat tariff, nor is a flat tariff without proactive rationing and supply management. To most people, the worst thing about flat tariff is that it violates the marginal cost principle that advocates parity between the price charged and the marginal cost of supply. Although businesses commonly price their products or services in ways that violate the marginal cost principle, such a system of pricing makes overall business sense. For example, airlines and railway companies world over offer unlimited travel within a specified period at a flat rate because it

[12]Another technological device being tried in many countries is the prepaid card, which is similar to a phone card. South African power utility, Eskom, which faces a similar challenge of supplying power to a large number of small users scattered over a large area, has experimented with prepaid cards with some success. However, the prepaid card technology is expensive for low volumes and is not entirely tamper-proof (Tewari and Shah 2001). Prepaid electricity cards have been tried on a pilot basis by West Bengal Renewable Energy Agency for supplying power to 1,000 households from locally managed 25 kw and 100 kw solar power plants (Down to Earth 2002b).

helps improve facility utilization during lean periods. Restaurants commonly offer a complete, unlimited buffet meal at a lower price, instead of à la carte menus because their business strategy is to maximize volume rather than margins.

In general, the flat tariff regime is used to achieve the important business objective of reducing transaction costs. Organizations, for example, hire employees on a piece rate when the assigned work is easy to measure by marginal unit output. Flat rate compensation, however, is popular worldwide because it is not easy to measure the marginal product value of an employee on a daily basis. Similarly, Indian telephone departments charge a flat minimum rate against 250 free local calls, and charges pro rata for calls that exceed the minimum. This makes great business sense because a sizeable proportion of their low-income customers manage with what they consider are "free calls;" the logic clearly being to greatly reduce their metering and billing costs. Also, urban public transport systems offer passes to commuters at attractive flat rates, in part because commuters offer a stable clientele, but equally because it reduces queues at ticket windows and reduces the cost of ticketing and collecting fares daily. Cable operators in India still charge a flat tariff for a group of television channels rather than charge for each channel separately, because the latter system would substantially increase their transaction costs. In addition, the Indian Income Tax Department, a few years ago, offered all businesses in the informal sector a flat income tax of Rs1,400 per year (US$28.50) instead of launching a nationwide campaign to bring these millions of small businesses within its tax net, because the cost of the latter would have been far greater than the revenue realized. A major reason municipal taxes are levied on a flat rate is the high transaction cost of charging citizens according to the marginal value they place on municipal services.

Are all these businesses that charge for their products and services on a flat rate destined to make losses? No: often they make money because they charge a flat rate. Many private goods providers, like the providers of public goods, charge flat rates for services, owing to the high transaction costs of charging a different price to different customers based on their use of the product and the value they place on it. Canal irrigation is a classic example of this. For ages we have been hearing about the exhortations to charge irrigators on a volumetric basis, however, nowhere in South Asia can we find volumetric water pricing practiced in canal irrigation. In our view, the transaction costs of collecting the volumetric charges for canal irrigation become prohibitively high because:

(a) in a typical South Asian system, the number of customers involved per 1,000 ha command is quite large; and the cost of monitoring and measuring water use by each user would be high;

(b) once a gravity flow system is commissioned, it becomes extremely difficult in practice for the system managers to exclude defaulting customers from the command area from availing of irrigation when others are;

(c) the customer propensity to frustrate the seller's effort to collect a charge based on use would depend in some ways on the proportion the charge constitutes of the overall scale of the customer's income.

On all these counts, one can surmise that the volumetric pricing of canal irrigation would be far easier in, for example, South African irrigation systems serving white commercial farmers. In such systems a branch canal serving 5,000 ha might have 10–50 customers, the charging of whom according to actual use would be easier

than the Indian system in which the same command area would contain 6–8 thousand customers. The only way of making canal irrigation systems viable in the Indian situation is to raise the flat rate per hectare to a level that ensures overall viability.

Supply restriction is inherent to flat rate pricing and by the same token, flat rate pricing and on-demand services are incompatible. In that sense, consumption linked pricing and flat rate pricing represent two different business philosophies: in the first, the supplier will strive to "delight the customer" as it were, by providing an on-demand service without quantity or quality restrictions of any kind, while in the latter the customer has to adapt to the supplier's constraints in terms of the overall quantum available and the manner in which it is supplied. In the case of buffet meals, for example, restaurants give customers a good deal but save on waiting costs, which are a substantial element in the economics of a restaurant. In the Gujarati *thali* system, where one gets a buffet meal served on one's table, the downside is one cannot have a leisurely meal since the restaurant aims to maximize the number of customers served during a fixed working period and in a limited space. Thus, there is always a price for the products and services offered to customers on flat tariff, but that does not mean the seller or the buyer is worse off because of flat rate pricing.

The reason why flat tariff for power supplied to WEMs, a pricing policy currently practiced in South Asia, is degenerate and the power industry is in the red, is because the power utilities are compelled to offer farmers on-demand power without the requisite quantity or quality restrictions. Raising the flat tariff to a level that covers the cost of present levels of supply would make the tariff so high that it will send state governments tumbling in the face of farmer wrath.[13] However, we believe it is possible for the SEBs to satisfy farmer needs while reducing total power supply to farmers during a year, by fine-tuning the scheduling of power supplied to meet the irrigation needs of farmers. Ideally, the business objective of a power utility charging a flat tariff should be to supply the best quality service it can offer to its customers, in line with the flat tariff pegged at a given level. The big opportunity for "value improvement" in the energy-irrigation nexus and by "value improvement," we mean "the ability to meet or exceed customer expectations while removing unnecessary cost" (Berk and Berk 1995:11), arises from the fact that the pattern of power demand in the farming sector differs in significant ways from the demand pattern of domestic and industrial customers. The domestic consumer's idea of good quality service is having power of uniform voltage and frequency supplied 24 hours per day, 365 days of the year, while the irrigators' idea of good quality service from power utilities is having power of uniform voltage and frequency supplied when their crops face critical moisture stress. With the intelligent management of power supply, we argue it is possible to satisfy irrigation power demand by ensuring 18–20 hours a day for 40–50 key moisture-stress days in the kharif (crop sown in early summer for harvesting in the autumn) and rabi (crop sown in Oct-Nov and harvested in Mar-Apr) seasons of the year, with some power (1-2 hours) available on rest of the days. Against this, Tamil Nadu supplies power to farmers 14 hours per day for 365 days of the year! Such an

[13]In Madhya Pradesh, the latest state to announce power-pricing reforms, the Chief Minister announced a sixfold hike in flat tariff. No sooner was the announcement made, there was a realignment of forces within the ruling party and senior most cabinet ministers began clamoring for leadership change. Subhash Yadav, the Deputy Chief Minister, said in an interview with India Today: " A farmer who produces 100 tons of wheat earns Rs 60,000 (US$1,224) and he is expected to pay Rs 55,000 (US$1,122) to the electricity board. What will he feed his children with and why should he vote for the Congress?" (India Today 2002.32).

output resembles a command area of an irrigation system with all branches of the distribution network operating at Full Supply Level every day of the year.

Groundwater irrigators are always envious of farmers in command areas of canal irrigation projects. But in some of the best irrigation projects in South Asia, a typical canal irrigator gets surface water for no more than 10–15 times in a year. In most irrigation systems, in fact, a canal irrigator would be happy if he gets water six times in a year. In the new Narmada project in Gujarat, the policy is to provide farmers with a total of 53 cm depth of water in five–six installments during a full year. For a WEM with a modest output of 25 m^3 per hour, this would require the ability to pump for 212 hours per ha. In terms of water availability, a WEM owner with 3 ha of irrigable land would be on par with a farmer with 3 ha in the Narmada command if he gets 636 hours of power in a year. He would be better off if the 636 hours of power are supplied when he needs the water most, which Narmada project will certainly not provide. When the Gujarat government commits to supply 8 hours per day of power to the farmer year-round, it in effect offers WEM owners water entitlements 14 times larger than the water entitlements that the Narmada project offers to farmers in its command.[14] Under metered tariff, this may not matter all that much since WEM owners would use power and groundwater only when their value exceeds the marginal cost of pumping, but under flat tariff, they would have a strong incentive to use some of these "excess water entitlements" just because the marginal cost of pumping groundwater is zero. This is why the present flat tariff in South Asia is "degenerate."

Rational flat tariff, if well managed, can confer two larger benefits. First, it would curtail wasteful use of groundwater. If the supply of power to farms outside the main irrigation seasons is restricted to 1–2 hours per day, it will encourage farmers to build small on-farm storage tanks for meeting multiple uses of water. Using progressive flat tariff—by charging higher rates per connected horsepower as the pump size increases—will produce additional incentive for farmers to purchase and use smaller capacity pumps to irrigate small areas and thereby, reduce overdraft in regions where groundwater depletion is rampant. Above all, a restricted but predictable power supply will encourage water saving irrigation methods more effectively than raising the marginal cost of irrigation. Second, given the quality of power transmission and the distribution infrastructure in rural India, restricting the period of time when the power system to farms is "on" may by itself result in a significant reduction in technical and commercial losses of power. The parallel with water supply systems is clear here. In a 1999 paper, for example, Briscoe (1999) wrote that throughout the Indian subcontinent, the proportion of unaccounted water in the total supply of water is so high "that losses are 'controlled' by supplying water in the distribution system only for a couple of hours a day, and by keeping pressures very low. In Madras, for example, it is estimated that if supply was to increase from current levels (of about 2 hours supply a day at 2 meters of pressure head) to a reasonable level (say 12 hours a day at 10 meters of pressure head) leaks would account for about 900 million liters per day (MLD), which is about three times the current supply in the city!" Much of the same logic works in the supply of power to the farms, with the additional caveat that the T&D system for farm connections is far more widespread than in the urban water supply system.

We believe that transforming the present "degenerate" flat power tariff into a rational tariff

[14]At a rate of 25 m^3 per hour, a tubewell can pump 73,000 m^3 of water if it is operated whenever power supply is on. At the water entitlement of 5,300 m^3 per ha prescribed in the Narmada project, this amount of water can irrigate 13.77 ha of land.

regime will be easier, and more feasible and beneficial in the short run in many parts of South Asia than trying to overcome farmer resistance to metered tariff. A rational tariff regime can also significantly cut the losses of power utilities from their agricultural operation. Four things seem important and feasible:

(a) *Gradual and regular increase in flat power tariffs:* Flat tariffs have tended to remain "sticky" in most states, they have not been changed for over 10–15 years while the cost of generating and distributing power has soared. We surmise that such an increase is too drastic and that farmers would be able to cope with a regular 10–15 percent annual increase in flat tariffs far more easily than a 350 percent increase at one go from Rs 500 to Rs 1,750 per horsepower per year (US$10–US$36) as has been proposed by the Electricity Regulatory Commission in Gujarat.

(b) *Explicit Subsidy:* If we are to judge the value of a subsidy to a large mass of people by the scale of popular opposition to its curtailment, there is little doubt that, among the plethora of subsidies that governments in India provide, the power subsidy is one of the most valued. Indeed, a decision to curtail power subsidies is the biggest weapon that opposition parties use to bring down a government, and it is therefore, unlikely that political leaders will want to do away with power subsidies completely, no matter what the power industry would like. However, the problem with the power subsidy in the current degenerate flat tariff is that it is indeterminant. Chief Ministers keep issuing decrees to the power utility about the number of hours of power per day to be supplied to farmers. Instead, the governments should tell the power utility the amount of power subsidy it can make available at the start of each year, and the power utility should then decide the amount of power it could supply the farmers using the flat tariff and the government subsidy.

(c) *Use of off-peak power:* In estimating losses from power supply to the farms, protagonists of power sector reform, including international agencies, systematically over-estimate the real opportunity cost of power supplied to the farmers. For instance, the cost of supplying power to the domestic sector—including generation, transmission and distribution—is often taken as the opportunity cost of power to agriculture, which is clearly wrong since a large part of the high transaction costs of distributing power to the domestic sector, is reduced by the power supply to agriculture under flat tariff. Moreover, a large part of the power supplied to the farm sector is off-peak load power; indeed, but for the agriculture sector, power utilities would be hard-pressed to dispose of this power. Over half of the power supply to the farm sector is in the night, and this proportion can increase further. But in computing the amount of power that the prevailing flat tariff and prespecified subsidy can buy, the power utilities must use the lower opportunity cost of the off-peak supply.

(d) *Intelligent Supply Management:* There is tremendous scope for cutting costs and improving service here. The existing rostering policy, in many states, of maintaining power supply to the farm sector at a constant rate during prespecified hours, is in some ways mindless and is the prime reason for the wasteful use of power and

water.[15] Ideally, power supply to the farm sector should be scheduled to reflect the pumping behavior of a modal group of farmers in a given region when they would be subject to metered power tariff at full cost. However, it is difficult to simulate this behavior because farmers everywhere are subject to flat tariff under which they would have a propensity to use power whenever it is available, regardless of its marginal product. In many states, there is a small number of new tubewells whose owners pay for the supply of power on a metered basis. However, they are charged a rate almost as low as that levied on flat tariff paying farmers. Another method is to compare electricity use before and after flat tariff to gauge the extent of over-utilization of power and water attributable to flat tariff.[16]

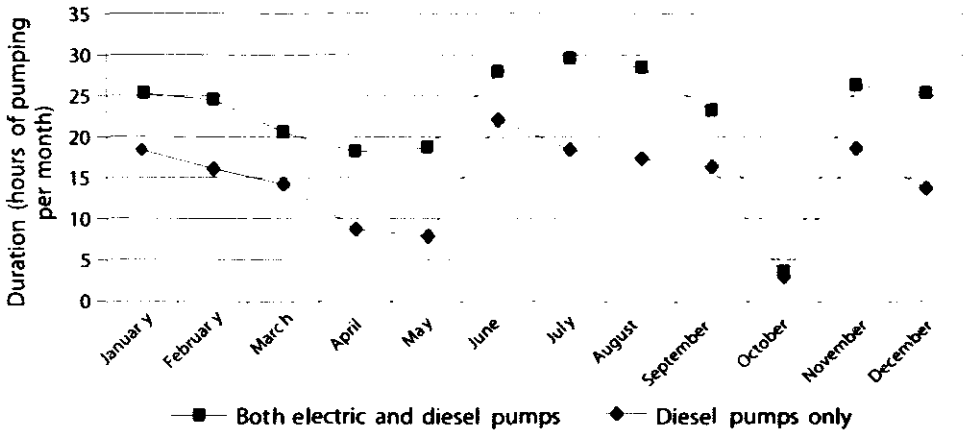
However, our surmise is that the pumping behavior of diesel pump owners, who are subject to full marginal energy cost comparable to the amount paid by electric tubewell owners under an unsubsidized metered tariff regime, would provide a good indicator of the temporal pattern of power use by electric tubewells under metered tariff. Several studies have shown that the annual pumping of diesel tubewells is often half or less than the amount of pumping of flat tariff paying electric tubewells (Mukherji and Shah 2002). Batra and Singh (2003) interviewed around 180 farmers in Punjab, Haryana and central Uttar Pradesh (UP) to ascertain if the pumping behavior of diesel and electric WEM owners differed significantly. They did not find significant differences in Punjab and Haryana but their results for central UP, shown in figure 3, suggest that diesel WEMs are pumped when irrigation is needed and electric WEMs are operated whenever electricity is available. Very likely, a good deal of the excess water pumped by farmers owning electric and diesel pumps is wasted, in that its marginal product value falls short of the scarcity value of water and power together.

Figure 4 presents the central premise of our case: a large part of the excess of pumping by electric tubewells over diesel tubewells is indicative of the wastage of water and power prompted by the zero marginal cost of pumping under the flat tariff regime. Figure 5 presents results of a survey of 2,234 tubewell irrigators across India and Bangladesh in late 2002, which shows that electric tubewell owners subject to flat tariff, invariably operate their pumps for much longer hours compared to diesel pump owners who face a steep marginal energy cost of pumping (Mukherji and Shah 2002). The survey showed the difference in annual pumping to be in the order of 40–250 percent; some of this excess pumping no doubt results in additional output, however, a good deal of it very likely does not, and is a social waste that needs to be eliminated.

[15]In Tamil Nadu where power supply to the farm is free, for instance, 14 hours of three-phase power—6 hours during day and 8 hours during night—is supplied throughout the year. In Andhra Pradesh, 9 hours of three-phase power supply is guaranteed, 6 hours during the day and 3 hours during the night (Palanisami and Suresh Kumar 2002). This implies that in theory, a tubewell in Tamil Nadu can run for over 5,000 hours in a year; and in Andhra Pradesh, it can run for 3,200 hours. If the real cost of power is taken to be Rs 2 per kWh (US$0.04 per kWh), depending upon how conscientious he is, a Tamil Nadu farmer operating a 10 hp tubewell can avail himself of a power subsidy ranging from Rs 0-Rs 75,000 per year (US$1,531); and an Andhra farmer, from Rs 0-Rs 48,000 (US$980). And the stories one hears of farmers installing automatic switches that turn on the tubewells whenever the power supply starts, suggests that a large proportion of farmers are choosing to go overboard in using power and water. Palanisami and Suresh Kumar (2002) mention that many borewell owning farmers lift water during the night to fill an open well using an automatic switch, and then lift water during the day from the open well to irrigate their fields! True, they would not indulge in such waste if they had to pay a metered rate at Rs 2 per kWh (US$0.04 per kWh); but they would also not do this if they got only 3–4 hours of good quality power at earthly hours on a preannounced schedule.

[16]An extreme case is Tamil Nadu, where electricity consumption per tubewell shot up from 2,583 kWh per year under metered tariff in the early 1980s to 4,546 kWh in 1997-1998. However, this jump would represent three components: (a) increased consumption due to degenerate flat tariff; (b) increased consumption because of the increased average lift caused by resource depletion; and (c) T&D losses in other segments that are wrongly assigned to agriculture. Palanisami (2001) estimated that 32 percent of the increased power use was explained by additional pumping and 68 percent by increased lift. However, he made no effort to estimate the (c), which we suspect is quite large.

FIGURE 3.
Duration of water extraction by the sample of farmers from central Uttar Pradesh owning only diesel pumps.or both electric and diesel pumps.



Source: Batra amd Singh 2003.

FIGURE 4.
Duration of power supplied and average daily operational duration of electric tubewells and diesel pumpsets.

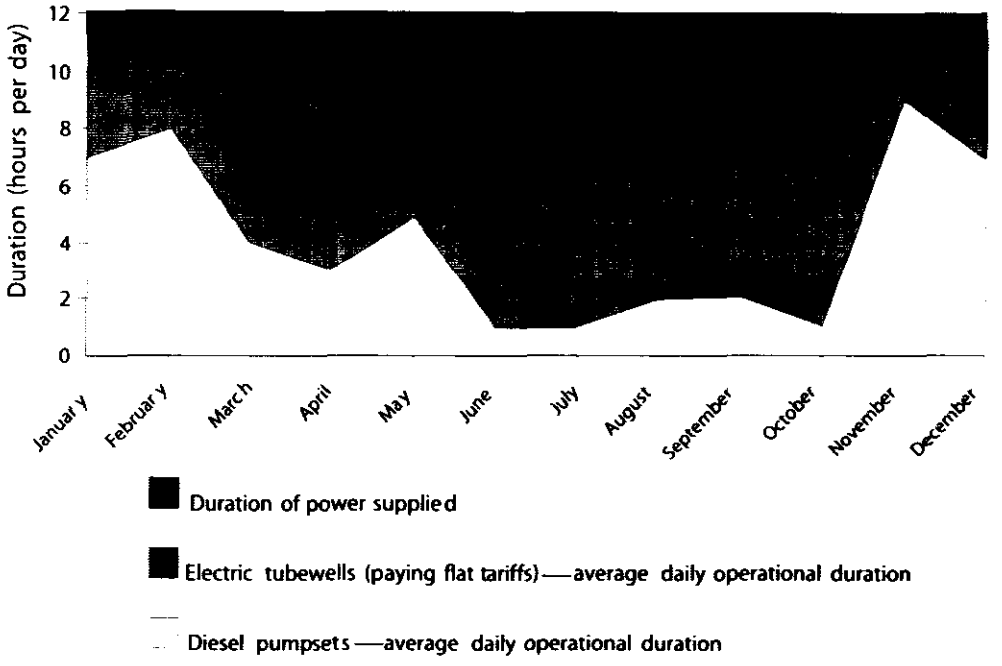
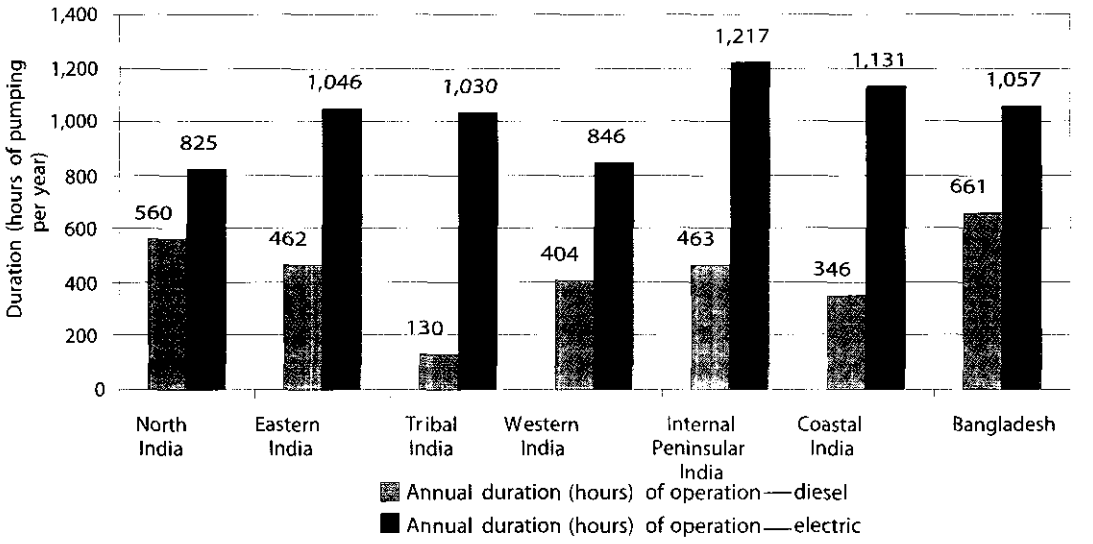


FIGURE 5.
Duration of pump operation by owners of electric (flat tariff) and diesel pumpsets.



Source: Primary survey of 2,234 tubewell irrigators in the year 2002.

If power utilities undertake a refined analysis of the level and pattern of pumping by diesel pump owners in a region and shave off the potential excess pumping from flat tariff paying electric tubewells by fine-tuning power supply policies around the year, flat tariffs will not only become viable but also socially optimal in eliminating the "waste." The average number of hours for which diesel pumps operate is around 500–600 per year. At 600 hours of annual operation, an electric tubewell would use 450 kWh of power per hp; if all the power used is off-peak load and is commanding, for example, 25 percent discount on a generation cost of Rs 2 per kWh (US$0.04), then power supply to the farms by the power utility would break even at a flat tariff at Rs 825 per horsepower per year (US$17.18/hp/year) as against Rs 500 per horsepower per year (US$10.41/hp/year), which has been the case in Gujarat since 1989. The Government of Gujarat is committed to raise the flat tariff eventually to around Rs 2,100 per horsepower per year (US$43) at the instance of the Gujarat Electricity Regulatory Commission. However, chances are that if it does so, farmers will unseat the government. A more viable and practical course would be to raise flat tariff to Rs 900 (US$18) first and then to Rs 1,200 (US$24.50), and restrict the annual supply of power to the farms to around 1,000–1,200 hours, as against the existing regime of supplying power to the farms for 3,500-5,000 hours per year. A 5-hp pump lifting 25 m^3 of water per hour over a head of 15 meters can produce 30,000 m^3 of water per year in 1,200 hours of tubewell operation, which is sufficient to meet the needs of most small farmers in the region.

Farmers will no doubt resist such rationing of power supply, however, their resistance can be reduced through proactive and intelligent supply management, by:

i. Enhancing the "predictability" and "certainty" of power supplied: More than the total

quantum of power delivered, in our assessment, the power supplier can help the farmers by announcing an annual schedule of power supply that is finely tuned to match the demand pattern of farmers. Once announced, the utility should stick to the schedule, which will make the farmers certain about power availability;

ii Improving the "quality" of power supplied: Whenever power is supplied, it should be at full voltage and frequency minimizing both damage to motors and the downtime of transformers;

iii. Improved supply at peak periods of moisture stress: Most canal irrigators in South Asia manage with only three to four canal water releases in a season; there are probably 2 weeks during kharif in a normal year and 5 weeks during rabi when the average South Asian farmer experiences great nervousness about moisture stress to his crops. If the power utility accommodates these periods, 80–90 percent of farmers' power and water needs would be met. This will, however, not help sugarcane growers of Maharashtra, Gujarat and Tamil Nadu, even though such farmers are a major part of many of the problems plaguing the power utility;

iv. Better upkeep of the power supply infrastructure to the farms: Intelligent power supply management to agriculture is a tricky business. If rationing of power supply is done by arbitrary reduction in power cuts and at the neglect of rural power infrastructure, it can result in disastrous consequences. Eastern India is a classic example. After the eastern Indian states switched to flat power tariff, they found it difficult to maintain the viability of power utilities in the face of organized opposition to raising flat tariff, from militant farmer leaders. As a result, the power utilities began to neglect the maintenance and repair of power infrastructure and the rural power supply was reduced to a trickle. Unable to irrigate their crops, farmers began en masse to replace their electric pumps with diesel pumps. Over a decade, the groundwater economy got more or less completely "dieselized" in large regions, including Bihar, eastern Uttar Pradesh, and north Bengal. Figure 6 shows the electrical and diesel halves of India; in the western parts, electric pumps dominate groundwater irrigation, but as we move east, diesel pumps become more preponderant. The saving grace was that in these groundwater abundant regions, small diesel pumps, though dirtier and costlier to operate than electric pumps, kept the economy going. But in regions like north Gujarat, where groundwater is lifted from 200–300 meters, such de-electrification can completely destroy the agricultural economy.

Against this danger, the major advantage that the rational flat tariff regime offers is reducing the rate of groundwater depletion in western and peninsular India. Growing evidence suggests that water demand in agriculture is inelastic to pumping costs. While a system of metered charge without subsidy can make power utilities viable, it may not help reduce water use or encourage water saving agricultural practices. If anything, a growing body of evidence suggests that the adoption of water and power saving methods is more responsive to the scarcity of these resources than their price. Pockets of India where drip irrigation is spreading rapidly—such as Aurangabad region in Maharashtra, Maikaal region in Madhya Pradesh, Kolar in Karnataka, Coimbatore in Tamil Nadu—are regions where water or power is becoming scarce rather than costly. The rational flat tariff with intelligent power

supply rationing to the farm sector holds out the promise of minimizing the wasteful use of both resources and of encouraging a technical change towards water and power saving. Our surmise is that such a strategy can reduce annual groundwater extraction in western and peninsular India by 12–18 km^3 per year and reduce power use in groundwater extraction by around 2–3 billion kWh of power, valued at Rs 40 billion–Rs 60 billion (US$813.3 million–US$1.22 billion) per year.

FIGURE 6.
Percentage of electricity operated goundwater structures to total mechanized goundwater structures, 1993-94.*

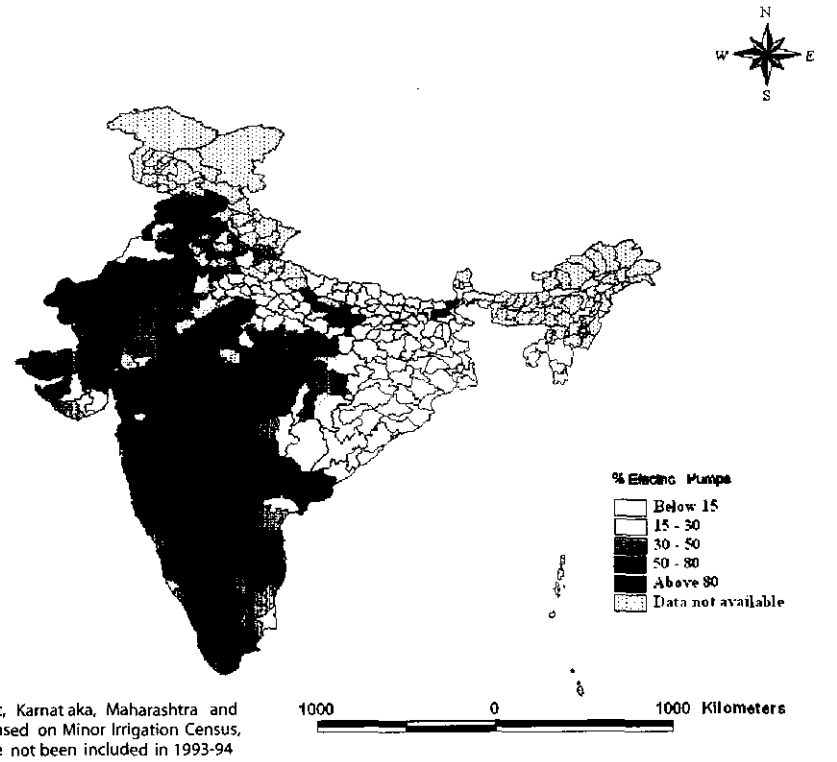


*Figure for Gujarat, Karnataka, Maharashtra and Tamil Nadu are based on Minor Irrigation Census, 1986 as they have not been included in 1993-94 MI Census. For the other states, data relates to 1993-94 based on MI Census, 1993-94.

Conclusions

Fifty years ago, when South Asian governments and international agencies thought that the increasing rate of energy consumption is equivalent to fostering economic progress, they used incentives in the form of subsidies, and pressure in the form of targets given to government officials to prompt farmers to take electricity connections and dig tubewells. Farmers were for long kept from coming face to face with the real resource cost of their power supply, and a huge farming economy and livelihood system evolved by feeding on cheap power; and they are now being asked to divest this important prop.

Today, the power industry looks at the farming sector as the Frankenstein that may gobble up the former, (see, for instance, Rao 2002). The energy-irrigation nexus in South Asia has to contend with the results of this "coaxed

demand creation." The most burning issue during the past 15 years, has been that of electricity pricing and supply to agriculture. In the heated discussion on the best remedial action, there is almost complete unanimity among practitioners and researchers within power and water sectors that the flat tariff for the power supplied to farms is the root of all evil, and reverting to the metered tariff is the only remedy. The problem is mass-based resistance to metered tariff from farming communities around the region. Under relentless pressure from international donors, some state governments in India even tried to "bite the bullet." However, spontaneous mass protests from farmers have been so swift and strident that shaken Chief Ministers have abruptly retracted from their moves; where they have not, as in Punjab recently, opposition parties will for sure make big capital out of the move in subsequent political campaigns. Frustrated by farmer resistance to metered tariff, many SEBs—such as in Gujarat—are threatening four to fivefold increases in the prevailing flat tariff to cover the average cost of supplying power for the number of hours promised by political leaders to farmer demands. But it is unlikely that farmers will accept such steep increases in flat tariffs.

The issue generates intense conflict and tension because it affects the livelihoods of 13 million electric tubewell owners who want to maintain the status quo that confers on them a subsidy on power, which they want more than most other subsidies. One reason is that the power subsidy reaches them far better than most other subsidies, the bulk of which gets gobbled up by rent-seeking intermediaries. Also, power subsidies reach medium and large farmers more efficiently than the landless and marginal farmers who have a smaller share of electric WEMs, and the former are far more vocal and strident in espousing their cause than the latter (Howes and Murgai 2003). Most importantly, power subsidies help farmers run a viable and productive agriculture.

We have argued in this report that either a switch to a metered tariff regime at this juncture or raising the flat tariff fourfold *a la* Gujarat in most Indian states, will very likely backfire. Metered tariff is highly unlikely to improve the fortunes of the power utilities, which have found no other way of dealing with the exceedingly high transaction costs of metered power supply to the farms, besides adopting the flat tariff regime as in 1970s. However, agriculturally dynamic states like Punjab and Haryana would be well-advised to create micro-entrepreneurs to retail power to meter individual power consumption and collect revenue, rather than experiment with wooly ideas of electricity cooperatives. In these states non-farm uses of three-phase power supply are extensive and growing in the village areas, and productive farmers are able to absorb the high cost of better quality power supply and want to experiment with metered power supply. Also, despite 50 years of continued effort, along with donor support, electricity cooperatives have not succeeded in India.[17] The 50-year old Pravara electricity cooperative in Maharashtra survives by owing the State Electricity Board several billion rupees in past dues (Godbole 2002). One more consideration that metering enthusiasts might keep in mind is the transaction costs of metering, which is by far the largest and the most difficult to manage, given user efforts to frustrate metered tariff regime by pilfering power, illegal connections, tampering with meters and so on. These costs soar in a "soft state" in which an

[17]Thus, Madhav Godbole notes, "But if cooperatives are to be a *serious and viable option (for power distribution)*, our present thinking on the subject will have to be seriously reassessed. As compared to the success stories of electricity cooperatives (in USA, Thailand and Bangladesh), ours have been dismal failures." (Godbole 2002:2197).

average user expects to get away easily even if caught indulging in such malpractices.[18] One reason why metering works reasonably well in China is because it is a "hard state"— an average user fears the village electrician whose informal power and authority is almost absolute in his domain.[19] The ongoing experiments on the privatization of electricity retailing in Orissa will soon produce useful lessons on whether metering-cum-billing agents can drastically and sustainably reduce the cost of a metered power supply in a situation where WEM owners account for a significant proportion of electricity consumption.

However, with tight and intelligent supply management, in the particular context of South Asia, rational flat tariffs can achieve all that metered tariff regimes can, and more. Flat tariffs will have to be raised, but the schema we have set out can cut power utility losses in the supply of power to farms substantially. The total hours of power supplied to farmers during a year will have to be reduced, but farmers would get good quality power aplenty at times of moisture stress, which is when they need irrigation most. The power supply to agriculture should only be metered at the feeder level so that power supplies to the farms could be monitored in order to manage them well, and also save on the huge transaction costs of metered charge collection. If power utilities shed their disdain for farm customers, the adversarial relationship between them could be turned into a benign one. While the metered tariff regime will turn groundwater markets into seller's markets, thus affecting the resource-poor water buyers, the rational flat tariff would help keep water markets as buyers' markets, albeit far less than would be the case under the present degenerate flat tariffs (for the detailed argument, see Shah 1993). Rational flat tariffs—under which power rationing is far more defensible than under the metered tariff regime—will make it possible to initiate an effective check on the total use of power and water and make their use more sustainable than under the present regime or under metered tariff. Moreover, restricting the total hours of operation of farm supply would help greatly curtail technical and commercial losses experienced by SEBs. Above all, rational flat tariffs can significantly curtail groundwater depletion by minimizing the wasteful use of this resource. Based on an IWMI survey of 2,234 owners of diesel and electric tubewells in India, Pakistan, Nepal terai and Bangladesh, it was concluded that electric tubewell owners, who were subject to the flat tariff on an unrestricted basis but received poor-quality power supply, pumped 40–200 percent more groundwater compared to diesel tubewell owners who have greater control over their irrigation schedules. Flat rate with restricted power supply can, however, easily curtail groundwater draft from 14 million electric tubewells by at least 15–20 percent, which is, around 12–20 km^3 every year, assuming electric WEMs pump a total of around 80–100 km^3 of groundwater every year.

Contrary to popular understanding, the rational flat tariff is an elegant and sophisticated regime, the managing of which requires a complex set of skills and a thorough understanding of agriculture and irrigation in different regions. Power utilities in

[18]Transaction costs of charge collection will be high even under a flat tariff regime if farmers think they can avoid payment. Throughout India and Pakistan, replacing name plates of electric motors on tubewells has emerged as a growth industry under flat tariff. In Haryana, a World Bank study had recently estimated that the actual connected agricultural load was 74 percent higher than that found in the official utility records (Kishore and Sharma 2002).

[19]Private electricity companies that supply power in cities like Ahmedabad and Surat instill fear of God in their users by regularly meting out exemplary penalties often in an arbitrary manner. The Ahmedabad Electricity Company's inspection squads, for example, have steep targets for penalty collection for pilferage. To meet these targets, they have to catch real or imagined power-thieves; their victims cough up the fine because in going to courts it would take years to redress their grievances while they stay without power. Although these horror stories paint a sordid picture, the Company would find it difficult to keep its commercial losses to acceptable levels, unless its customers were repeatedly reminded about their obligation to pay for the power they use.

South Asia have never had these skills or understanding, which is a major reason for the constant hiatus between them and the agriculture sector. One reason is that SEBs employ only engineers (Rao 2002). In the power sector reforms that are under way in many Indian states, this important aspect has been overlooked in the institutional architecture of unbundling. The distribution of power to agriculture is a different ball game in this region from selling it to urban users and industry.

Private distribution companies will, for sure, exclude the agricultural market segment in a hurry as being "too difficult and costly to serve," as Orissa's experience is already showing.[20] Perhaps, the most appropriate course of action would be to promote a separate distribution company for serving the agriculture sector with specialized competence and skill. Predetermined government subsidies to the farming sector should be directed to these agricultural distribution companies.[21]

[20] The Orissa Electricity Regulatory Commission has already opened the gate for the power utility to ask agriculture to fend for itself, when it decided that "any expansion of the grid, which is not commercially viable, would not be taken into account in calculating the capital base of the company. In future, unless the government gives grants for rural electrification, the projects will not be taken up through tariff route." (Panda 2002).

[21] T. L. Sankar, for instance, has already argued for the need to set up separate supply companies for farmers and rural poor that will provide cheap power from hydro-electric and depreciated thermal plants, and be subsidized as necessary, directly by governments (Rao 2002: 3435).

Literature Cited

Batra, S.; and Singh, A. 2003. "Evolving Proactive Power Supply Regime for Agricultrual Power Supply". Anand. India: IWMI-Tata Water Policy Program (Internal report available on request).

Briscoe, J. 1999. "The Financing of Hydropower, Irrigation and Water Supply Infrastructure in Developing Countries". *Water Resources Development*, vol. 15 (4): 459–491.

Berk, J.; and Berk, S. 1995. *Total Quality Management*, New Delhi; Excel Books.

Debroy, A.; and Shah, T. 2003. "Socio-ecology of Groundwater Irrigation in India," in *Groundwater Intensive Use: Challenges and Opportunities*, eds. Llamas, R & E. Custodio. The Netherlands: Swets and Zetlinger Publishing Co.

Down to Earth. 2002a. Ground reality. vol. 11, no. 1, May 31. p.38.

Down to Earth. 2002b. "Bengal got the power card," vol. 11, no. 7. August 31, p.16.

Godbole, M. 2002. "Electricity regulatory commissions: The jury is still out," *Economic and Political Weekly*. XXXVII (23) 2195–2201.

GOI (Government of India) Ministry of Water Resources. 1999. *Integrated water resources development: A plan for action*. Report of the National Commission for Integrated Water Resources Development Plan. vol. I. New Delhi: Ministry of Water Resources.

Gulati, A. S. 2002. (Unpublished) "Energy implications of groundwater irrigation in Punjab."Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center. New Delhi during September 2–6, 2002.

Hekmat, A. 2002. (Unpublished) "Overexploitation of groundwater in Iran: Need for an integrated water policy." Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center. New Delhi during September 2–6, 2002.

Howes, S.; and Murgai, R. 2003. "Karnataka: Incidence of agricultural power subsidies: An estimate," *Economic and Political Weekly*, XXXVIII (16) April 19.

India Today. 2002. "Running for cover: Demand for a tribal chief minister and a proposed hike in power tariffs pose a serious challenge to Digvijay Singh's leadership." *India Today*, XXVII (47). 32, November 19 – 25, 2002.

Kishore, A.; and Sharma, A. (Unpublished) 2002. "Use of electricity in agriculture: An overview." Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center. New Delhi, September 2–6, 2002.

Lim, E.R. 2001, presentation made at "Conference on Power Distribution Reforms." October 12–13. New Delhi.

Llamas, R.; Back, W.; and Margat, J. 1992. Groundwater Use: Equilibrium between Social benefits and Potential Environment Costs, Applied Hydrology, Vol. 1, February.

Mukherji, A.; and Shah.T. 2002. Groundwater socio-ecology of South Asia: An overview of issues and evidence." Paper presented at the Conference on "*Intensive Use of Groundwater: Opportunities and Implications.*" Valencia. Spain. November 25–28.

PREVIOUS PAGE BLANK

Palanisami, K. 2001. "Techno-economic feasibility of groundwater exploitation in Tamil Nadu." Paper presented at the ICAR-IWMI Policy Dialogue on Groundwater Management, November 6–7, 2001 at CSSRI, Karnal.

Palanisami, K.; and Suresh Kumar, D. 2002. (Unpublished) "Power pricing, groundwater extraction, use and management: Comparison of Andhra Pradesh and Tamil Nadu states." Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center, New Delhi, September 2–6, 2002.

Panda, H. 2002. (Unpublished) Power sector reform in Orissa and its impact on lift irrigation: An assessment and lessons. Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center, New Delhi, September 2–6, 2002.

Qureshi, A. 2002. *Energy-irrigation nexus in Pakistan: A brief note.* Lahore, Pakistan; International Water Management Institute (IWMI).

Rao, D. N; and Govindarajan, S. 2003. "Community intervention in rural power distribution." Water Policy Highlight no. 14. Anand, India: IWMI-Tata Water Policy Program.

Rao, S. L. 2002. The political economy of power, *Economic and Political Weekly* XXXVII (17). 3433–3445, August 17.

Samra, J. S. 2002. (Unpublished) "Impact of groundwater management and energy policies on food security of India." Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center, New Delhi, September 2–6, 2002.

Scott, C.; Shah, T.; and Buechler, S. 2002. (Unpublished) "Energy pricing and supply for groundwater demand management: Lessons from Mexico." Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center, New Delhi, September 2–6, 2002.

Shah, T. 1993. *Groundwater markets and irrigation development. Political economy and practical policy.* New Delhi, India: Oxford University Press.

Shah, T. 2001. *Wells and welfare in the Ganga basin: Public policy and private initiative in Eastern Uttar Pradesh, India.* Research Report 54. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Shah, T. 2003. Governing the groundwater economy: Comparative analysis of national institutions and policies in South Asia, China and Mexico. Water Perspectives. *International Journal on Water Policy and Practice.* Issue 1: 2-27.

Shah, T.; Deb Roy, A.; Qureshi, A. S.; and Wang, J. 2003. " Sustaining Asia's groundwater boom: An overview of issues and evidence". *Natural Resources Forum,* 27(2003) 130–141.

Sharma Kumar, S.; and Mehta, M. 2002. (Unpublished) Groundwater development scenario: Management issues and options in India. Paper presented at the IWMI-ICAR-Colombo Plan sponsored Policy Dialogue on "Forward-Thinking Policies for Groundwater Management: Energy, Water Resources, and Economic Approaches" held at the India International Center, New Delhi, September 2–6, 2002..

Tewari, D. D.; and Shah, T. 2001. *Can prepaid cards help management of farm power supply? Lessons for India from a South African experiment.* IWMI-Tata Water Policy Program working paper. Anand, India: IWMI.

World Bank and Government of India. 1998. *India- water resources management sector review: Groundwater regulation and management report.* Washington D.C.: World Bank, New Delhi: Government of India.

57. *Small Irrigation Tanks as a Source of Malaria Mosquito Vectors: A Study in North-Central Sri Lanka.* Felix P. Amerasinghe, Flemming Konradsen, Wim van der Hoek, Priyanie H. Amerasinghe, J. P. W. Gunawardena, K. T. Fonseka and G. Jayasinghe. 2001.

58. *Fundamentals of Smallholder Irrigation: The Structured System Concept.* B. Albinson and C. J. Perry. 2001.

59. *A Gender Performance Indicator for Irrigation: Concepts, Tools and Applications.* B. van Koppen. 2001.

60. *Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer.* Tushaar Shah, Barbara van Koppen, Douglas Merrey, Marna de Lange and Madar Samad. 2002.

61. *Poverty Dimensions of Irrigation Management Transfer in Large-Scale Canal Irrigation in Andra Pradesh and Gujarat, India.* Barbara van Koppen, R. Parthasarathy and Constantina Safiliou. 2002.

62. *Irrigation Sector in Sri Lanka: Recent Investment Trends and the Development Path Ahead.* M. Kikuchi, R. Barker, P. Weligamage and M. Samad. 2002

63. *Urban Wastewater: A Valuable Resource for Agriculture.* Wim van der Hoek, Mehmood Ul Hassan, Jeroen H. J. Ensink, Sabiena Feenstra, Liqa Raschid-Sally, Sarfraz Munir, Rizwan Aslam, Nazim Ali, Raheela Hussain and Yutaka Matsuno. 2002.

64. *Use of Untreated Wastewater in Peri-Urban Agriculture in Pakistan: Risks and Opportunities.* Jeroen H. J. Ensink, Wim van der Hoek, Yutaka Matsuno, Safraz Munir and M. Rizwan Aslam. 2002.

65. *Land and Water Productivity of Wheat in the Western Indo-Gangetic Plains of India and Pakistan A Comparative Analysis.* Intizar Hussain,R.Sakthivadivel, Upali Amarasinghe, Muhammad Mudasser and David Molden. 2003.

66. *Agro-Well and Pump Diffusion in the Dry Zone of Sri Lanka: Past Trends, Present Status and Future Prospects.* M. Kikuchi, P. Weligamage, R. Barker, M. Samad, H. Kono and H.M. Somaratne. 2003.

67. *Water Productivity in the Syr-Darya River Basin.* Hammond Murray-Rust , Iskandar Abdullaev, Mehmood ul Hassan, and Vilma Horinkova. 2003.

68. *Malaria and Land Use: A Spatial and Temporal Risk Analysis in Southern Sri Lanka.* Eveline Klinkenberg, Wim van der Hoek, Felix P. Amerasinghe, Gayathri Jayasinghe, Lal Mutuwatte and Dissanayake M. Gunawardena. 2003.

69. *Tubewell Transfer in Gujarat: A Study of the GWRDC Approach.* Aditi Mukherji and Avinash Kishore. 2003.

70. *Energy-Irrigation Nexus in South Asia: Improving Groundwater Conservation and Power Sector Viability.* Tushaar Shah, Christopher Scott, Avinash Kishore and Abhishek Sharma. 2003.