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The Water-Energy Nexus in India: Approaches to Agrarian Prosperity with a Viable Power Industry

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The Water-Energy Nexus in India: Approaches to Agrarian Prosperity with a Viable Power Industry

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Pump irrigation in India, which is mostly from open wells and tubewells, has gained ascendance over gravity-flow irrigation, thus tying the fortunes of the groundwater and energy economies. India uses US $4-5 billion/year (In Rs 20000 crores) of energy each year to pump some 150 km^3 of water, mostly for irrigation. 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 farming communities' often violent opposition to efforts to rationalize energy prices. As a result, the country's groundwater economy has boomed by bleeding the energy economy. This paper suggests that this does not have to be so: the first step to sustaining a prosperous groundwater economy while making the power sector viable is for decision makers in the two sectors to jointly explore options for energy-groundwater co-management that have thus far been overlooked.

At the heart of the matter is designing appropriate pricing policies for supplying power to pump irrigators. Power industry managers as well as international players (especially the World Bank and Asian Development Bank) insist that the flat tariff charged to irrigators based on the capacity of the pump (as distinct from metered supply based on actual energy consumed) is the key reason for the current poor financial health of the power industry as well as negative developments in groundwater resources, and have advocated the transition to a metered power supply.

We suggest that, although metering may appear to be the cure for most of the ailments afflicting both energy and groundwater resources, there are several formidable logistical problems associated with metering some 14 million scattered small users. Incidentally, the earlier metered supply was converted to a flat rate-based supply during the late 1970s, because the cost of metering (installing meters, reading them, billing and collecting) was higher than the revenues being generated. The number of pumps has more than quadrupled since this shift occurred, and in many states per-pump electricity consumption has declined due to power rationing and falling groundwater levels, which means that the costs of metering would turn out to be even more prohibitive. Further, what has been passed off to date, as a flat tariff is a *degenerate* pricing policy. A flat tariff makes no sense without a proactive rationing of supply. Levied as a tax rather than as a price, a scientific flat tariff for power supply to pump irrigation can be a logical and viable alternative in a situation where the transaction costs of metering and metered charge collection can be exceedingly high, as Pakistan has been discovering after it reverted to metering two years ago.

Metered and flat tariff regimes are explored here, not as mutually exclusive pricing policies, but as alternate *business philosophies,* each with its own logic and timeframe for implementation in the prevailing Indian context. On the one hand, industry could satisfy customers by providing quality power on demand. But this would increase pressures on

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already stressed groundwater resources and in all likelihood, would spell disaster for the livelihoods of the several million Indian farmers who are increasingly relying on groundwater for irrigation. On the other hand, a flat tariff accompanied by sophisticated management of a high-quality but carefully rationed power supply could achieve both the financial sustainability of energy use in agriculture and the environmental sustainability of groundwater irrigation. However, inadequate managerial capabilities at the utilities and political interferences for quick gain have rendered this otherwise best solution void, thus making the present tariff structure a “degenerate flat tariff.”

An evolutionary approach to pricing policy may ultimately be the most feasible: converting the degenerate tariff into a progressive flat rate tariff (a per horsepower tariff that increases with increasing motor capacity) initially, followed by intermediate scale-metering at the sub-station, electrical feeder, or transformer level to obviate the need for end-use metering of 14 million (and growing) small-volume consumers.

The move toward metering is gaining momentum. The recently passed Electricity Bill, 2003 makes it mandatory for all electricity consumers to be provided with metered supply. National and state governments are committed to meter all their consumers in the near future and to meter all feeders and transformers in the immediate future; many states have commenced activities in this regard. However, metering agricultural consumers needs to be carefully designed and implemented in light of past experiences and costs. Most states insist on metering new connections, while some states like the Punjab would be metering pump sets, even if the flat rate option were adopted by the consumer to enable the performance of proper energy audits.

This paper suggests that the simultaneous management of the groundwater and energy economies, as a *nexus,* is a great opportunity and can be achieved. Since, in the Indian context, there seems to be no practical way to directly manage groundwater, laws are unlikely to check the chaotic race to extract it, water pricing and/or property rights reforms, too, do not promise much hope in bringing about the desired change. Power supply and pricing policy offer a useful means to initiate *indirect* management of both groundwater and energy use. But perfecting and using this policy effectively requires a fusion of energy and water perspectives, which fortunately is emerging as the new paradigm in power supply to agriculture in India.

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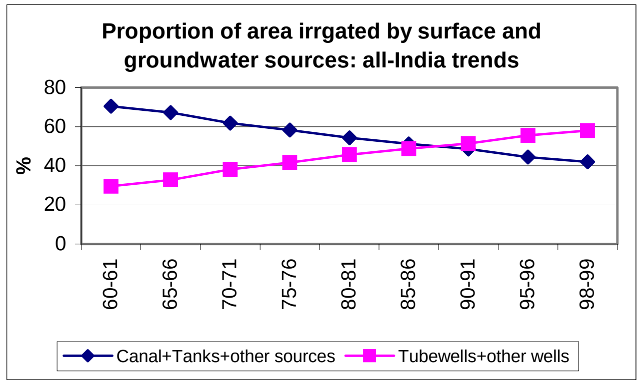
1. THE USE OF GROUNDWATER IN INDIA

In India, gravity systems dominated irrigated agriculture until the 1970s; but by the early 1990s, groundwater irrigation had surpassed surface irrigation (Debroy and Shah 2001; Shah, Debroy, Qureshi and Wang 2002). Between 55 and 60% of India's irrigated lands are served by groundwater wells. According to a World Bank estimate, groundwater irrigation contributes to about 10% of India's GDP; but this is made possible by using between one-fourth and one-third of the economy's energy. India's 100 million farming families have over 19 million tubewells and pump sets among them, averaging out to one pump set for every four farming families. In addition, a large proportion of non-owners depend on pump set owners to supply them with pump irrigation through local, fragmented groundwater markets (Shah 1993). Thus, a vast majority of India's population (55-60%) is directly influenced by groundwater.



Source: Centre for Monitoring Indian Economy (CMIE), Agriculture, 2002.

The US, Iran, Mexico and China are other major groundwater users. However, here the groundwater irrigation affects only a small proportion of their population. In terms of the capacity of the pumps used to lift groundwater, there are striking differences. While most of South Asia uses pumps of very small capacities, in the other countries, the pumps are typically 10-50 times larger and are highly energy efficient. In Mexico's Guanahuato province (the heartland of the country's intensive groundwater irrigated agriculture), a typical tubewell is of 100-150 horsepower and operates for over 4000 hours/year (Scott, Shah and Buechler 2002). In India, Bangladesh and Nepal, the modal pump size is 6.5 hp and average hours of operation are around 400-500/year (Shah 1993).

Country	Annual groundwater use (km3)	No of groundwater structures (million)	Extraction/ structure (m3/year)	% of population dependent on groundwater
India	150	19	7900	55-60
Pakistan-Punjab	45	0.5	90000	60-65
China	75	3.5	21500	22-25
Iran	45	0.37	123000	12-18
Mexico	29	0.07	414285	5-6
USA	100	0.2	500,000	<1-2

In Iran, only 365,000 tubewells are pumped to produce 45 km^3 of groundwater (Hekmat 2002). India uses 60 times more wells than Iran to extract only three times more groundwater. A large number of small pumps is a peculiarly South Asian aspect, more so in the Indian context.

From the perspectives of energy economies and groundwater economies, 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 150 km^3 of groundwater is around 75 billion kWh/year. Supplying this costs the region's energy industry some US $5.2 billion (In Rs 25000 crore); and the market value of the irrigation produced is around US $13 billion. In these emerging low-income economies, pump irrigation is serious business with economy-wide impacts, both positive and negative.

2. THE USE OF POWER IN AGRICULTURE

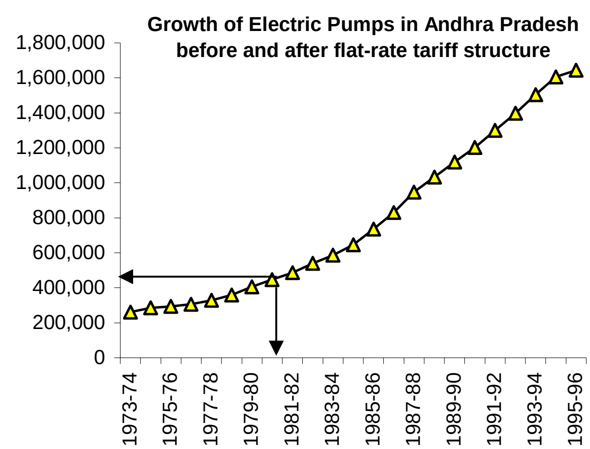
The Green Revolution in India ushered in a drastic change in the status of agriculture. Supported by extension services for using appropriate chemical inputs, high yielding varieties, etc., the country slowly moved from being a net importer of food grains to a surplus producer. While this has indeed heralded a positive change in Indian agriculture, there is another, not so positive development, viz., the use of power and groundwater in agriculture. In the past, irrigated agriculture largely depended on surface water and groundwater contributed to a relatively smaller proportion of the total area irrigated. Since the groundwater levels were relatively shallow, farmers were able to access this water through shallow tubewells using diesel-powered pumps. As the number of diesel pumps increased, the burden on the national foreign exchange started increasing. In order to reduce this dependence on diesel for lifting groundwater, the Government of India initiated a massive program for agricultural pump set energization through rural electrification programs in the mid-1970s. This was followed by a change from a metered supply to a flat rate-based supply. By the early 1980s, most of India's states had effected this change. As a result, the extent of power use in agriculture started peaking.

Period	Compounded Annual Growth Rate (CAGR)			
	Domestic	Commercial	HT/LT	Agriculture
70-75	8.4	6.4	6.0	14.3
75-80	9.7	5.9	7.2	10.7
80-85	13.3	9.3	11.0	10.1
85-90	13.1	8.9	6.9	16.5
90-95	10.1	8.7	4.3	11.2

Source: CMIE, Energy, 2000

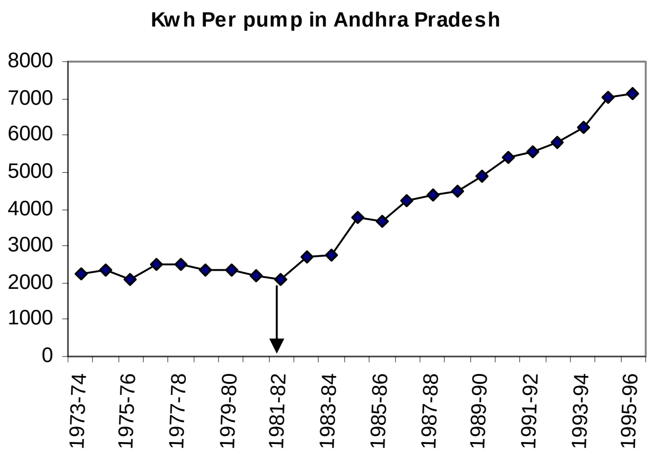
The growth of agricultural power consumption was highest immediately following the switch from metered supply to flat rates (see table). The need for moving from metered supply was a result of the increasing number of agricultural consumers, which added significantly to overheads (for installing meters, reading meters, billing and collection), and farmers were largely getting subsidized power. To reduce these avoidable administrative costs, the state electricity boards decided to switch from metered supply to flat tariffs.

The switch from metered supply to flat rates, together with the intensification of pump set energization, led to a sharp rise in the number of bore wells. For example, the pumps in Andhra Pradesh increased from about 262 thousand to about 1.8 million by 1997. We note that the growth in the number of pumps took a quantum jump after 1982, when power supply to agriculture was shifted to a flat-rate based supply. Currently, there are about 2.1 million pumps in Andhra Pradesh alone. In contrast to the past, then the majority of pump owners were large landholders, presently; this has shifted in favor of small and marginal holdings.

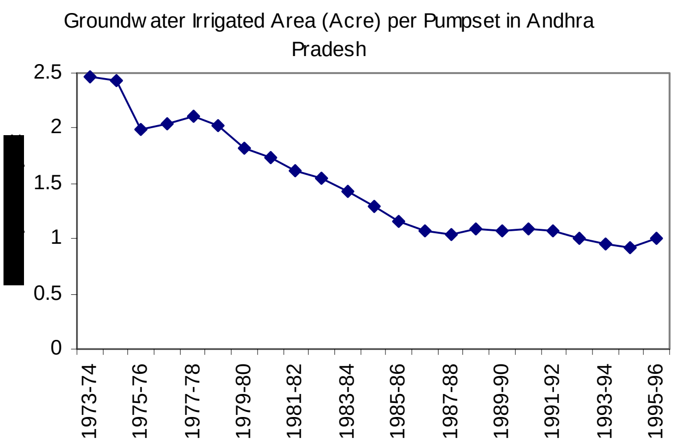


Source: CMIE, Energy, 2000

The figures below show the energy-water nexus. As the number of pumps has been growing in Andhra Pradesh, the competition for groundwater has been increasing. This has resulted in a steady fall in discharge and consequently, the extent of area irrigated per pump has been declining. The sinking groundwater table has also necessitated increases in pump capacities, with a consequent increased energy draw per pump. This is accentuated further by the intensification of groundwater-irrigated agriculture. As assured access to irrigation water is achieved, farmers have intensified their cropping, planting more than one crop in a year.



Source: CMIE, Energy Report, 2000



Source: CMIE, Energy Report, 2000

4. SECTORAL POLICY PERSPECTIVES

Groundwater policy makers face contrasting challenges in managing South Asia's chaotic energy/groundwater economy. Particularly after 1970, agrarian growth in the region has been sustained primarily by private investments in pump irrigation. However, the development of the groundwater resource has been highly uneven. In the groundwater-abundant Ganga-Brahmaputra-Meghana basin – home to 400 million of the world's rural poor in Bangladesh, Nepal *terai* and Eastern India – groundwater development can produce stupendous livelihood and ecological benefits (Shah 2001). Yet, it is precisely here that it is slow and halting. In contrast, Pakistan and Indian Punjab, Haryana and all of peninsular India are rapidly over-developing their groundwater to a stage where agriculture in these parts faces serious threats from resource depletion and degradation. Regulating groundwater draft and protecting the resource are proving to be complex and difficult. Direct management of an economy with such a vast number of small players through regulating groundwater use would be a Herculean task that could be achieved only with the intensive restructuring of groundwater bureaucracies.

The other option would be to explore *indirect* management opportunities. In this regard, electricity supply and pricing policies offer a potent tool kit, provided these are used as such. Regrettably, these have so far not been used with imagination and thoughtfulness. In the groundwater-abundant Ganga basin, a favorable power supply environment can stimulate livelihood creation for the poor through accelerated groundwater development, but this region has been very nearly de-electrified (Shah 2001). In other parts of the country where there is a dire need to restrict groundwater draft, abundant power supply and perverse subsidies are making it possible for farmers to deplete the resource with abandon. 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 managing the *nexus.* To the region's power industry, the groundwater economy is an anathema. Agriculture uses up 27-35% of total power; and power pricing to agriculture is a hot political issue. In states like Punjab and Tamilnadu, power supply to farmers was free; and in all other states, the flat electricity tariff (based on the horsepower rating of the pump) charged to farmers contained heavy subsidies. This form of charging also gives incentives to the farmers to under-report their pump capacities (see text box). Losses to electricity boards on account of power subsidies to agriculture are estimated at In Rs 26,000 crores in India, and these are growing at a stupendous 26%/year CAGR (Lim 2001; Gulati 2002). These estimates have been widely contested, and SEBs have been showing their growing T&D losses in the domestic

> In the Chittoor district of Andhra Pradesh, when field data were collected on 85 randomly selected pump sets on a single feeder in the later half of 2002, it was seen that 45% of the pump sets are of a higher horsepower than the contracted load. These readings were taken for the AIJ-World Bank study.
>
> Likewise, when readings on 523 pump sets belonging to 6 feeders were taken in Tamil Nadu, it was seen that the horsepower of the pump sets were more than the contracted loads in 55% of the cases. These studies were part of a pump set efficiency study funded by the World Bank for TNEB and WRO of Tamil Nadu.

and industrial sectors as agricultural consumption, which is unmetered and so unverifiable.[2] Even so, the fact remains that agricultural power supply under the existing regime is the primary cause for State Electricity Boards (SEBs) in India being bankrupt.

As a result, there is a growing movement to revert to metered power supply. 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:

- Provide power on demand by 2012
- Meter all consumers in two phases, with phase I to cover metering of all 11 kV feeders and high-tension (HT) consumers, and phase II to cover all consumers
- Conduct regular energy audits to assess T&D losses and eliminate all power thefts within two years.

This is an ambitious agenda indeed. However, all moves towards metered power consumption have met with farmer opposition on an unprecedented scale in Andhra Pradesh, Gujarat, Kerala and in other states of India.[3] All new tubewell connections generally come with a metered tariff; but most states have been offering major inducements to tubewell owners to opt for metered connections; Andhra Pradesh charges metered tubewells at only Rs 0.20/kWh, and Gujarat and several other states at about Rs 0.50/kWh against the supply cost of Rs 2.50-3.50/kWh. Yet, there are few takers for metered connections.

Farmers' opposition to metered tariffs has only partly to do with the subsidy contained in the flat tariff; they find flat tariffs more transparent and simple to understand. It also spares them the tyranny of the meter readers. Finally, there are fears that once under metered tariffs, SEBs will start loading all manner of new charges under different names.

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[2] Shah (2001) has analyzed this aspect for Uttar Pradesh State Electricity Board. Based on a World Bank study in Haryana, Kishore and Sharma (2002) report that actual agricultural power consumption was 27% less than reported, and the overall T&D losses were 47%, while official claims made it 36.8%, showing the SEB to be more efficient than it actually was. Power subsidies ostensibly meant for the agricultural sector, but actually accruing to other sectors, were estimated at Rs 550 crore/year for Haryana alone.

[3] In Andhra Pradesh, the Chief Minister had to retract a public announcement of the government's decision to revert to metering within a week after he made it, and it could not help his party from being completely routed in the Panchayat elections that followed. In Haryana, farmers in several villages held a district magistrate hostage for several days to protest possible power tariff reforms. In Kerala, the Chief Minister had to totally give in and withdraw all his proposals for tariff reforms. In Gujarat, the Electricity Tariff Regulatory Commission had mandated the state government to introduce metering as required by the Asian Development Bank to release a US $350 million loan; however, as soon as Narendra Modi was elected to lead the BJP government, he made it clear he had no intention of metering agricultural pumpsets.

5. *MAKING THE METERED TARIFF REGIME WORK*

There are several arguments in favor of metered tariff regimes. For one, 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. Second, once farm power is metered, SEBs cannot use agricultural consumption as a carpet under which they can sweep their T&D losses in other segments. Third, metering would give farmers correct signals about the real cost of power and water, and thus become an incentive to economize on their use. Fourth, for reasons that are not entirely clear, it is often suggested that compared to flat tariff regimes, metered tariffs would be less amenable to political manipulation and easier to raise as the cost of supplying power rises.

The logic in support of metered tariffs is obvious. The problem is how to make them work as envisaged: how will SEBs deal with the problems that forced them to switch to flat tariffs during the 1970s? Before 1975, no SEB charged farm power on a flat tariff basis; all of them were charging on a metered basis. But the logistical difficulties and transaction costs of metering had become so high that flat tariffs seemed the only way of dealing with the problem. A 1975-76 study by the Rural Electrification Corporations in Uttar Pradesh and Maharashtra estimated that the cost of metering rural power supply was 26 and 16%, respectively, of the total revenue of the SEB from the farm sector (Shah 1993). And this estimate included only the direct costs, such the cost of the meter and its maintenance, the power consumed by the meter, reading the meter, and billing and collections. And these are not insignificant; a recent World Bank study for Haryana estimated that metering all farm power connections in this small state would imply US $30 million in capital cost and $2.2 m/year in operating costs (Kishore and Sharma 2002). The Maharashtra Electricity Tariff Commission estimated the capital cost of metering farm connections at Rs 1150 crores (US $240 million) (Godbole 2002). However, the far larger part of the transaction cost of metering is the cost of pilferage, of tampering with meters, and of under-reading and under-billing by meter readers in collusion with farmers.

There are technological solutions to mitigate the excessively high transaction costs of reverting to metered tariff regimes. Andhra Pradesh has shown that with political will and appropriate use of information technology, this could be possible (Muralidharan, 2003). High-accuracy electronic meters with time-of-day (ToD), tamper-proof, and remote reading facilities have been fixed by Andhra Pradesh power companies at all HT services. All 11 kV feeders also are provided with high-accuracy data loggers with storage for the past 35 days of readings. These are connected to the network and are being remotely monitored to check pilferages and supply schedules. The present technological backup seems promising and has provided ample examples for other states to adopt similar supply systems.

In order to make metered tariff regimes work reasonably well, three things seem essential:

- The metering and collection agent must have the requisite authority to deal with deviant behavior amongst users
- He should be subject to a tight control system so that he can neither behave arbitrarily with consumers[4] nor form an unholy collusion with them

[4] In states like Gujarat, which had metered tariffs until 1987, an important source of opposition to metering is the arbitrariness of meter readers and the power they had come to wield. In many villages, farmers had organized themselves into groups for the sole purpose of resisting the tyranny of the meter reader. In some areas, this became so serious that meter readers were declared

- He must have proper incentives to enforce metered tariff regimes.

The Xavier Institute of Management, Bhubaneshwar has been engaged in organizing Village Vidyut Sanghas (Village Electricity Associations) that are to collect metered charges from members in exchange for promises of better service. But it will be some time before we know how well these are working.

Under the Nawaz Sharif government, Pakistan changed from metered to flat electricity tariffs pretty much for the same reasons as Indian states did during the 1970s and 1980s. The military government led by General Musharraf reverted to a metered tariff in 2000; and all the problems of metered tariff regimes have come to the fore. An IWMI note from Pakistan (Qureshi 2002) laments, "Power theft and meter tampering is a pressing issue. The total power theft [was estimated at] seven billion units worth Pak Rs 14 billion. Finally, the army was called in to look for illegal connections and rigged meters. By March 2001, the army has lodged 5687 complaints."

We saw a metered tariff regime that works reasonably well in North China, which has many conditions similar to those in South Asia (Shah, Qureshi and Wang 2002), with the sole but important difference being the administration mechanism. The Chinese electricity supply industry operates on two principles:

- Total cost-recovery in generation, transmission and distribution at each level with some minor cross-subsidization across user groups and areas
- Each user pays in proportion to his use.

Interestingly, agricultural electricity use in many parts of North China attracts the highest charge per unit, followed by household users and then industries. Operation and maintenance of local power infrastructure is the responsibility of local units, the Village Committee at the village level, the Township Electricity Bureau at the township level, and the County Electricity Bureau at the county level. Equally, the responsibility of collecting electricity charges too is vested in local units in ways that ensure that the power used at each level is paid for in full. At the village level, this implies that the sum of 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. The unit or person charged with fee collection has to pay the Township Electricity Bureau for power use recorded at the transformer level. In many areas, where power supply infrastructure was old and worn out, line losses below the transformer made this difficult.

To allow for normal line losses, a 10% allowance is given by the Township Electricity Bureau to the village unit. However, even this must have made it difficult for the latter to tally the two; as a result, an Electricity Network Reform program was undertaken by the national government to modernize and rehabilitate rural power infrastructure.[5] Where this

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persona non grata. Even today, electricity board field staff seldom go to villages except in fairly large groups, and often with police escorts.

[5] Although the Network Reform program is a national government program, the government contributes only a part of the resources, the balance being contributed by the Village Committee. Just to give an example, Guantun village in Yanjin county of Hanan got a grant of Y 60,000 under this project for infrastructure rehabilitation. To match this, the village contributed Y 60000 too; of this, 60% came from the funds of the village collective; the remaining 40% was raised as farmer contributions by charging Y 80/person. All the power lines and other infrastructure were rehabilitated in recent years under this national program. New meters were purchased by the township in bulk and installed in users' homes on a cost recovery basis. A system of monitoring meters was installed too.

was done, line losses fell sharply,[6] and among the nine villages we visited in three counties of Hanan and Hebei provinces in early 2002, none of the village electricians we met 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%.

The village electrician, Network Reform Program, Township Electricity Bureau, the incentive payments and new service organization[7] are elements of the Chinese strategy to turn the energy-water nexus into a positive phenomenon. Before the Network Reform Program, losses were difficult to contain below 10%; as a result, electricians and Village Committees were unwilling to operate as the "electricity retailer" for the Township Electricity Bureau; but now, the situation has changed. By and large, distribution losses are kept to much less than 10% in areas covered by the Network Reform Program: most losses are technical losses, and there are hardly any commercial losses. In areas yet not covered by the Network Reform Program, where line losses are high, the electrician often imposes a cess on the standard charge to cover the losses.

In Zhao Zhuang village of Ci county, for instance, many tubewells were far from the transformer, resulting in high line losses. The village electrician levied a "power loss fee" of Yuan 0.05/ kWh to cover these losses.[8] An important reason why this institutional arrangement works is because of the strong local authority structures in Chinese villages: the electrician is feared because he is backed by the Village Committee and the powerful party leader at the village level, and the new service orientation is designed partly to project the electrician as a friend of the people. But the same Village Committee and party leader can also keep in check any flagrantly arbitrary behavior by the electrician towards users. The hypothesis – that with better-quality power and support service, farmers would be willing to pay a higher price for power – is best exemplified in Hanan, where at Yuan 0.7/kWh (US c 8.5/ kWh, In Rs 4.27/kWh), farmers pay a higher electricity rate than any

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[6] The village electrician's reward system encourages him to exert pressures to achieve greater efficiency by cutting line losses. 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 at 22-25%. Once the Network Reform Program began, the Village Committee sold the old transformer to the Township Electricity Bureau and raised Y 10,000 (partly by collecting a levy of Y 25/family 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% range.

[7] In many areas covered by the 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 collecting user charges based on metered individual consumption from all categories of users. The electricians in each class are formed into a group which is collectively responsible for service provision and individually responsible for collecting electricity charges and reimbursing them to the Township Electricity Bureau. The group has a common office and a telephone accessible to all the villages; and every electrician takes a 4-hour duty turn so that one of them is available 24 hours a day. Any villager from the member villages can call them 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 their cost of transport on motorcycle. It has now been proposed that electricians be given a transport subsidy from the Township Electricity Bureau.

[8] 1 US $ = 8 Yuan = In Rs 49.

category of user in India or Pakistan pays, and also at a price higher than that of diesel (Y 2.1/liter).

In India, there has been some discussion about the level of incentive needed to make the privatization of electricity retailing attractive at the village level. The village electricians in Hanan and Hebei are able to deliver on a fairly modest reward of Yuan 200/month, which is equivalent to half the value of wheat produced on a *mu* (or 1/30th of the value of output on a hectare of land). For this rather modest wage, the village electrician undertakes to make good the full amount of the Township Electricity Bureau's line and commercial losses in excess of 10% of the power consumption recorded on the transformers. If he can manage to keep losses to less than 10%, he can keep 40% of the value of the power saved.

All in all, the Chinese have found a working solution to a problem that includes a built-in incentive-compatible system that delivers quickly.

The way the Chinese collect metered electricity charges makes it nearly impossible for the power industry to lose money in distribution losses since these costs are passed downstream from one level to the level below it. There is little scope for malpractices to occur on a large scale because the village electrician would be faced with serious personal losses if he failed to collect electricity charges for at least 90% of the power consumed as reported at the transformer meter. Since malpractice by a farmer directly hits other farmers in the village, there likely exists strong peer control over such practices. There are similar incentive-control mechanisms at the Township Electricity Bureau level as well, so that major malpractices at the transformer level would likely be detected and curbed early.

If South Asia is to revert to a metered tariff regime, the Chinese offer a good model. The only problem is that while South Asia's 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 dissuade farmers from the arbitrary behavior of the metering agent or protect the latter from user non-compliance may create unforeseen complications in adapting the Chinese model to South Asia.

Given the unique Indian conditions, an intermediate solution (between flat and metered tariffs) is to introduce transformer-wise tariffs as follows:

a) The pump sets are not metered. Only the flat rate operates.

b) The transformer is metered in pursuance of the GoI's decision.

c) For each of the networks under the transformer, certain norms are agreed to for each low-tension (LT) feeder[9] for the line losses based on km-kVa.

> India has begun experiments to find new metering solutions only recently; Delhi's power utility (Delhi Vidyut Board) farmed out meter reading and billing to a private company that was able to cut commercial losses significantly. Though it is still early, it is all too clear that metering and billing costs will tend to be high if these tasks are managed by a power utility bureaucracy whose track record of service and professionalism has been abysmal. That model seems passé. In power as well as surface water, volumetric pricing can work, where needed, only by smartly designed incentive contracts.

[9] A strong relationship was established between the peak power loss on the LT feeders and the km-kVa and the tail-end voltage with respect to LT feeders for which load flow studies were carried out on city distribution in Hyderabad. When similar exercises were carried out for some of the LT

d) After subtracting these technical losses from the units sent out from the transformer, the balance units are valued at the agricultural tariff rates on a metered basis.

e) This is the amount receivable from the sale of power to the consumers under the transformer. From this amount, the amount realized through the flat rate sales is subtracted.

f) The difference, if positive, is imputed as due to commercial losses. These losses are distributed proportionately to each consumer based on their contracted load.

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feeders in rural areas also, similar results were noted. One can carry out load flow studies on typically loaded LT feeders and establish a relationship between the kW loss and the kVa-km and tail-end voltage so that suitable norms can be established for the technical losses in LT distribution for various districts/regions.

6. *FROM A DEGENERATE FLAT TARIFF TO A RATIONAL FLAT TARIFF REGIME*

Flat tariffs are almost universally written off as inefficient, wasteful, irrational and distortionary, besides being inequitable.[10] And in the South Asian experience, it has indeed proved to be so. It was the change to flat tariffs that encouraged political leaders to indulge in populist whims such as doing away with farm power tariffs altogether (as Punjab and Tamilnadu have) or to peg it at levels low enough to be unviable, regardless of the true cost of power supply. This has resulted in 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 has been unjustly blamed; in fact, the flat tariff that South Asia has used in its energy-water nexus so far is a completely *degenerate* version of what might otherwise be a highly rational, sophisticated and scientific pricing regime. Flat tariffs without proactive rationing and supply management are bound to be ineffective. To most people, the worst thing about flat tariffs is that they imply a zero marginal cost of power; however, businesses often price their products or services in ways that violate the marginal cost principle, but make overall business sense. Airlines and railway companies the world over offer unlimited travel within a specified period at a flat rate because it helps them improve facility utilization during lean periods.

However, due to bureaucratic inaptitude, we have seen that the prevailing flat rate regime has given utilities the latitude to hide their own inefficiencies and T&D losses. Farmers, too, do not have enough incentives to use power and groundwater rationally because this tariff structure offers zero marginal cost. Thus, there is some merit in the prevailing anxiety of the power industry as well as the international funding agencies to revert to metering. However, the prohibitive transaction costs still remain an anathema to this process.

It could be worthwhile to examine the concept of “micro-enterprise” as an option. A manager (preferably a farmer from the same village) who is influential and powerful is given a transformer to be managed as a commercial enterprise, with all necessary incentives to ensure billing and collections. In situations where such an individual is not available, a group of farmers (along the lines of farmers’ clubs) could be given this responsibility. All connections to the transformer are his customers and he is responsible for acting as the liaison between the power distribution company and the customer, and undertakes management of the lines and fault repairs with technical support from the power distribution company. He gets a percentage of the total collection, provided he manages to collect the charges from customers up to a given level. The state subsidizes the line losses up to the transformer and the farmers would be paying for the losses in the distribution system. The transformers would be metered and converted from the large 100 or 60 kVa to smaller capacities under an HVDS system. This would ensure there would be no pilferages and all farmers would have to pay for the power they are drawing.

We believe that transforming the present *degenerate* flat power tariff into a rational tariff regime will be easier, and more feasible and beneficial in the short run in many parts of

[10] The Andra Pradesh Electricity Regulatory Commission (APERC 2002) expressed this general understanding when it wrote: “Under flat rates, in the absence of the incentive to limit consumption, the tendency to waste is more and also where the usage is limited, the farmer pays for units not consumed. Slab rates are an inefficient method of levying usage charges. The Commission therefore directs that the metering of all consumers under this category shall be completed by 21.3.2003 positively” (cited in Panda 2002).

South Asia than trying to overcome farmer resistance to metering. We also believe that doing so can significantly cut power utilities' losses from their agricultural operations. Four things seem important and feasible:

- *A gradual and regular increase in the flat power tariff*: Flat tariffs have tended to remain "sticky"; in most states, they have not been changed for quite a few years, while the cost of generating and distributing power has soared. We surmise that farmers would be able to cope with a regular 10-15% annual increase in a flat tariff far more easily than a five-fold increase at one go, as has been proposed by the Electricity Regulatory Commission in Gujarat.

- *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 curtailing it, there is little doubt that, amongst the plethora of subsidies that governments in India provide, the power subsidy is one of the most valued. Indeed, a decision to curtail a power subsidy is the biggest weapon that opposition parties use to bring down a government. So it is 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 its indeterminacy. Chief Ministers keep issuing *diktats* to the power utility about the number of hours of power per day to be supplied to farmers; that done, the actual subsidy availed by the farmers is, in effect, left to them. 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 farm power the flat tariff and the government subsidy can buy.

- *Use of off-peak power:* In estimating losses from farm power supply, 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 saved in power supply to agriculture under flat tariffs. 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 occurs during the night, and this proportion can increase further. But in computing the amount of power the prevailing flat tariff and pre-specified subsidy can buy, the power utilities must use the lower opportunity cost of the off-peak supply.

- *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 pre-specified hours is in some ways mindless and the prime reason for the wasteful use of power and water.[11]

[11] In Tamilnadu where farm power supply is free, for instance, 14 hours of three-phase power – 6 hours during the day and 8 hours during the 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 Tamilnadu can run for over 5000 hours in a year; and in Andhra Pradesh, it can run for 3200 hours. If the real cost of power is taken to be Rs 2/kWh, depending upon how conscientious he is, a Tamilnadu farmer operating a 10 hp tubewell can avail himself of a power subsidy ranging from Rs 0-75000/year; and an Andhra Pradesh farmer, Rs 0-48000. And the stories one hears of farmers

> 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 tariffs at full cost. However, it is difficult to simulate this behavior because farmers everywhere are subject to the flat tariff under which they would have a propensity to use power whenever it is available, regardless of its marginal value.
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> In many states, there is a small number of new tubewells whose owners pay for power on a metered basis; however, they are charged such a low a rate that they operate pretty much like flat-tariff paying farmers. Another method is to compare electricity use before and after a flat tariff to gauge the extent of over-utilization of power and water attributable to the flat tariff.[12] However, we surmise that the pumping behavior of diesel pump owners, who are subject to full marginal energy cost comparable to what electric tubewell owners would pay under an unsubsidized metered tariff regime, would provide a good indicator of the temporal pattern of power use by electric tubewells under a metered tariff.
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> Several studies have shown that annual pumpage of diesel tubewells is often half or less than for flat tariff paying electric tubewells. The temporal pattern of pumping by diesel tubewells too is different. The excess of pumping by electric tubewells over diesel tubewells is indicative of the waste of water and power that is encouraged by the zero marginal cost of pumping under a flat tariff regime. A survey of 2234 tubewell irrigators across India and Bangladesh in late 2002 showed that electric tubewell owners subject to a flat tariff invariably operate their pumps for much longer hours than diesel pump owners who face a steep marginal energy cost of pumping. The survey showed the difference in annual pumpage to be on the order of 40-250%; 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.

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 by flat-tariff paying electric tubewells by fine-tuning power supply policies, the flat tariff can not only become viable but also socially optimal by eliminating waste. The average number of hours for which diesel pumps operate is around 500-600/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 – commanding, say, a 25% discount on a generation cost of In Rs 2/ kWh – then farm power supply by the power utility would break even at a flat tariff of In Rs 825 /hp/year as

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installing automatic switches that turn on the tubewells whenever 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/kWh; but they would also not do this if they got only 3-4 hours of good quality power on a pre-announced schedule.

[12] An extreme case is Tamilnadu where electricity consumption per tubewell shot up from 2583 kWh/year under metered tariffs in the early 1980s to 4546 kWh in 1997-98. However, this jump would represent 3 components: [1] increased consumption due to the degenerate flat tariff; [2] increased consumption because of the increased average lift caused by resource depletion; and [3] T&D losses in other segments that are wrongly assigned to agriculture. Palanisami (2001) estimated that 32% of the increased power use was explained by additional pumping and 68% by increased lift. However, he made no effort to estimate the T&D losses, which we suspect are quite large.

against Rs 500/hp/year in force in Gujarat since 1989. The Government of Gujarat is committed to raise the flat tariff eventually to Rs 2400/hp/year at the insistence 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 the flat tariff to Rs 900 first and then to Rs 1200, and restrict the annual supply of farm power to around 1000-1200 hours versus the existing regime of supplying farm power for 3500-5000 hours/year. A 5 hp pump lifting 25 m^3 of water/hour over a head of 15 meters can produce 30000 m^3 of water/year in 1200 hours of tubewell operation, 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:

- Enhancing *predictability* and *certainty.* Power supplier can help farmers by announcing an annual schedule of power supply finely tuned to match the demand pattern of farmers. Once announced, the utility should then stick to the schedule so that farmers can be certain about power availability.

- Improving *quality.* Whenever power is supplied, it should be at full voltage and frequency, minimizing damage to motors and transformer downtime.

- Better *matching* of supply with peak periods of moisture stress. Most canal irrigators in South Asia manage with only 3-4 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 can take care of these periods, 80-90% of farmers' power and water needs would be met. This will not, however, help sugarcane growers in Maharashtra, Gujarat and Tamilnadu; but then, they are the largest part of the power utility's problems.

- Better *upkeep* of farm power supply infrastructure. Intelligent power supply management to agriculture is a tricky business. If rationing of power supply is done by arbitrary reductions in power and the neglect of rural power infrastructure, it can have disastrous consequences. Eastern India is a classic example. After the eastern Indian states switched to a flat power tariff, they found it difficult to maintain the viability of power utilities in the face of organized opposition to raising the flat tariff from militant farm leaders like Mahendra Singh Tikait. As a result, the power utilities began to neglect the maintenance and repair of power infrastructure; and 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 became more or less completely dieselized in large regions, including North Bihar, Eastern Uttar Pradesh, and North Bengal. In the western parts of India, groundwater irrigation is dominated by electric pumps; 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, 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 the rational flat tariff regime offers is in putting a brake on groundwater depletion in western and peninsular India. Growing evidence suggests that water demand in agriculture is inelastic to pumping costs. While a metered charge without a subsidy can make power utilities viable, it may not help much to cut water use and encourage water-saving agriculture. If anything, a growing body of evidence suggests that the adoption of water and power saving methods respond more strongly to the scarcity of these resources than their price. Pockets of India where drip irrigation is spreading rapidly – such as the Aurangabad region in Maharashtra, Maikaal region in Madhya Pradesh, Kolar in Karnataka, and Coimbatore in Tamilnadu – are all regions where water and/or power is scarce rather than costly. A rational flat tariff with intelligent power supply rationing to the farm sector holds out the promise of minimizing the wasteful use of both the resources and of encouraging technical change towards water and power saving. Such a strategy can reduce annual groundwater extraction in western and peninsular India by 12-18 km^3/year and reduce power use in groundwater extraction by 2-3 billion kWh of power, valued at In Rs 4000-6000 crores/year.

7. CONCLUSIONS

There is a natural process of demand creation for a productive input such as energy, in which suppliers spotting an economic opportunity develop a new industry and business practices best suited to serving the new demand in a viable fashion. In many parts of India, where electricity supply is still unavailable, local entrepreneurs have devised ingenious locality-specific ways of serving the emerging power demand. Kishore (2002) studied the rise and growing sophistication of private power markets in small urban centers of North Bihar. Such demand-led development of power supply, however, is rare in the South Asian region.

Fifty years ago, when governments and international agencies thought that increasing energy consumption was equivalent to fostering economic progress, they used incentives in the form of subsidies and pressure in the form of targets for government officials to get farmers to take electricity connections and make tubewells. Consumers were long sheltered from facing the real resource cost of power supply; and a huge farming economy and livelihood system evolved, feeding on cheap power. Now, they are being asked to forsake this important prop.

In the heated and growing discussion in the region on the best way out of this mess, there is almost complete unanimity amongst practitioners and researchers within the power and water sectors on the criticality of reverting to the metered tariff regime. International donors have been putting relentless pressure on governments and SEBs in this regard. Some state governments even tried to bite the bullet; however, spontaneous mass protests from farmers have been so strident that shaken Chief Ministers have abruptly retracted from their moves. Where they have not, as in Punjab recently, opposition parties will certainly capitalize on such actions.

We have argued in this paper that the entire discourse on the virtues of metering and the perils of flat tariff regimes are based on an inadequate and incorrect understanding of the issues involved. We have argued that a switch to metered tariff regimes at this juncture in most Indian states will very likely backfire. It is highly unlikely to improve the fortunes of the power utilities, which have found no smarter ways – than in the 1970s – of dealing with the exceedingly high transaction costs of metered farm power supply, which led them to flat tariff regimes in the first place.

However, if agriculturally dynamic states like Punjab and Haryana – where non-farm uses of 3-phase power supply are extensive and growing in the villages – want to experiment with metered power supply, they would be well-advised to create micro-entrepreneurs to retail power, meter individual power consumption, and collect revenue rather than experiment with electricity co-operatives as Orissa did. Despite 50 years of effort to make these work, including with donor support, co-operatives have not succeeded in India.[13] The 50 year old Pravara electricity co-operative in Maharashtra survives by owing the State Electricity Board several hundred crores in past dues (Godbole 2002). One more piece of advice metering enthusiasts might keep in mind: the component of the transaction costs of metering, which is by far the largest and most difficult to manage, arises from containing user efforts to frustrate metered tariff regimes, by pilfering power,

[13] Thus, Madhav Godbole notes, "But if co-operatives 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 co-operatives [in the USA, Thailand and Bangladesh], ours have been dismal failures." (Godbole 2002).

illegal connections, tampering with meters and so on. These costs soar in a "soft state" in which an average user expects to get away easily, even if he or she is caught.[14] One reason why metering works reasonably well in China is the "hard state": an average user fears the village electrician, whose informal power and authority border on the absolute in his domain.[15]

With tight and intelligent supply management, in the particular context of India, rational flat tariffs can achieve all metered tariff regimes can, and more. Flat tariffs will have to be raised, but the schema we have set out can substantially cut power utility losses from farm power supply. The total hours of power supplied to farmers during a year will have to be reduced, but farmers would get plenty of good-quality power at times of moisture stress when they need irrigation most. Power supply to agriculture should still be metered at the feeder level so as to be able to measure and monitor farm power in order to manage it well. However, the huge transaction costs of metered charge collection would be saved; and if power utilities were to shed their disdain for farm customers, the adversarial relationship between them could even be turned into a benign one.

While metered tariff regimes will turn groundwater markets into sellers' markets, hitting the resource-poor water buyers, rational flat tariffs would help keep water markets buyers' markets, albeit far less so than would be the case under the present degenerate flat tariffs (for a detailed argument, see Shah 1993). Above all, rational flat tariffs – under which power rationing is far more defensible than under metered tariff regimes – will make it possible to put effective checks on the total use of power and water; it will also create powerful incentives to improve the classical efficiency of water use and the effective efficiency of power use in pump irrigation, thereby making the use of both these precious resources more sustainable than under the present regime or under metered tariffs.

Progressive flat tariffs should be viewed as a sophisticated regime that requires a complex set of skills and deep understanding of agriculture and irrigation in different regions. Power utilities in South Asia lack these skills and 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 underway in many Indian states, this important aspect has been overlooked in the institutional architecture of unbundling. Distributing power to agriculture is a different ball game in this region from selling it to townspeople and industry; and private distribution companies will surely quickly cut the agricultural market segment as being too difficult and costly to serve, as Orissa's experience is already showing.[16] Perhaps the most appropriate course would be

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[14] The transaction costs of charge collection will be high, even under a flat tariff regime, if farmers think they can avoid it. Throughout India and Pakistan, replacing the nameplates on tubewell electric motors has emerged as a growth industry under flat tariffs. In Haryana, a World Bank study recently estimated that the actual connected agricultural load was 74% higher than the official utility records showed (Kishore and Sharma 2002).

[15] Private electricity companies that supply power in cities like Ahmedabad and Surat instill the 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, are given 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 going to court 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.

[16] 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

to promote a separate distribution company for serving the agriculture sector. This would require a specialized competence and skills base, and pre-determined government subsidies to the farming sector should be directed to the agricultural distribution companies.[17]

In the final analysis, a phased approach will be required to get the groundwater and energy economies out of their current morass. Converting to a progressive flat rate tariff regime will allow utilities to recoup much of their lost revenue while at the same time avoiding the difficult process of universal metering of 14 million small, dispersed users. At the same time, utilities must be in a position to meter at different levels in the supply system (sub-station, feeder, and transformer) in order to monitor and ultimately regulate power supply to agriculture. The need for intermediate-level institutional arrangements of who will meter and collect from a large number of users (e.g., if transformer supply is metered but users are billed on a flat rate basis) has yet to be addressed in India. The working model in China appears to be based more on an enforceable rural power authority system than on "getting the price right." In India, new arrangements such as micro-enterprises to retail power at the transformer and feeder levels will have to be devised.

Policy makers must be attuned to the fact that such institutional arrangements will require legal and regulatory backing if they are to function effectively.

commercially viable, would not be taken into account in calculating the capital base of the company. In future unless government gives grants for rural electrification, the projects will not be taken up through tariff route." (Panda 2002).

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

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