A NEW ENERGY PARADIGM FOR OUR "COMMON FUTURE"
U.S./India Synergies in Renewable Electricity

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Although fossil fuels have been prominent in the electricity industry in the last century, their role is being increasingly questioned. Industrial countries question fossil fuel's effect on the environment and security of supply, while developing countries face the inefficiencies and high cost of a centralized fossil fuel based grid network. Despite liberal reforms, the electricity industry remains concentrated and is getting increasingly complex with sophisticated market designs meant to make it competitive. Consequently, customers are increasingly considering whether all domestic energy needs should come from such electricity, which requires a monopolistic grid and imperfect regulation.

At the same time, a more competitive electricity market is slowly but steadily growing in the renewable energy segment. Technological innovation, social awareness, and increasingly volatile electricity costs are creating a niche renewable market worldwide providing a potential threat to grid electricity. However, to establish themselves as a credible substitute, renewables have to conquer their twin weaknesses: high initial cost and poor reliability. We believe they certainly will, if the learning curves are to be believed. By combining the technological expertise of the U. S. with the millions of customers in India, economies of scope and scale can further deepen the learning curve effects. We present an introduction to our larger ongoing study (Kar and Dahl (2003)) that uses a dominant firm model to explore such international synergies in renewable electricity. We use our model results to argue that the resulting competitive market will increasingly make imperfect and costly grid base regulation obsolete and simplify complex electricity markets.

INTRODUCTION

A quarter of the world's population–400 million households–do not have access to electricity. Rather they use kerosene lamps for lights; wood and biomass for cooking and heating; and ancient hand tools for other household needs at an un-quantified cost in lost income opportunities, personal health and the global environment. The majority of those who have access to electricity are households with income of a few dollars a day consuming less than 100kWh per month. Still, they pay 6-8% of their income for this meager consumption at a high price. Some get free power either through explicit subsidy; the legally or economically debarred sometimes resort to power theft.

Instead of reducing prices from expansion of their natural monopolies, the electric companies regularly pass on their inefficiencies, business risks and power thefts through prices above the true marginal economic cost of service in a blatant abuse of market power. This increase in price leads to a vicious cycle of more payment default, more power theft and higher prices but with little increase in revenue collection. The cost goes up, but grid supply, quality and reliability is getting more and more miserable from the lack of investment. Electricity is not available when it is required the most and only meets the off peak demands on an availability basis. Faced with the double jeopardy of high cost and poor quality most homes in developing countries keep kerosene lamps for back up lights and biomass technologies for cooking and heating just as those who do not have electricity. Some rich consumers can afford battery and voltage stabilizers to protect them from damages to their costly appliances. Likely, this high cost and poorly functioning electricity grid has kept these countries poor by retarding the economic development and quality of life. Governments, developmental agencies, and high profile foreign investors thought profits could be made in this chaos. None of them anticipated that the poverty of the vast majority reduces their capacity to pay for commercial electricity. It is yet to be learnt that increasing price is not the solution; only lowering cost and increasing income can make the business viable. Can fossil based expensive electric grid solve these persistent problems of developing countries?

But before we attempt to answer this question, it will be instructive to see the grid success stories of developed countries. The developed nations have ensured universal electric service by subsidizing a few poor households. Electricity cost is relatively low compared to their income and abundantly available, which has contributed to their high standard of living. For example, we can see from Figure 1 that Indian per capita electricity consumption is below 400kWh while all four developed countries in the figure have consumption above 5000kWh. Although Indian prices are low by world standards, they are much higher in terms of purchasing power parity. In Figure 2 we also see income and electricity spending for 4 developed countries compared with India. The developed countries income is 50-80 times higher than India and they spend only 1-4% of their income on electricity giving a large surplus fund for reinvestment in electricity industry.

Figure 1 Tariff and Electricity Consumption

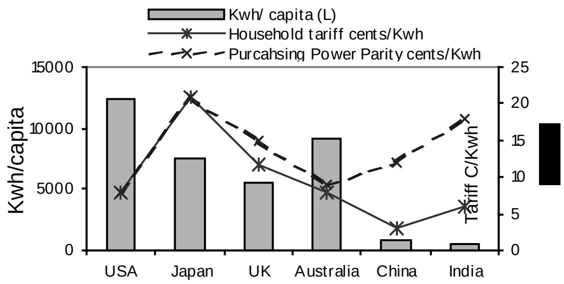
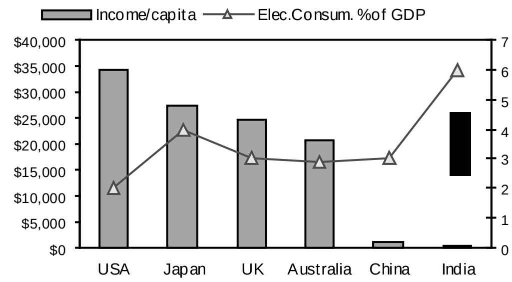


Figure 2 Income & Electricity Consumption % of GDP



Electricity revenue actually collected in India is as high as 4% of GDP requiring electricity subsidies to the tune of 2-3%. The costs thus claimed by the Indian utilities are about 6-7% of national income, which is even higher than in the high electricity cost countries like Japan, Denmark and U.K.. With low income and a high proportion of this income going to electricity consumption, it is doubtful if a sustainable Indian electric industry can grow any faster than the real income growth of consumers. Thus, a monopolistic fossil-grid based option may not be an optimal choice for India considering the renewable option with both income generation and energy conservation capabilities.

Initially electricity was considered a natural monopoly and countries, both more developed and less developed, either regulated private utilities or provided electricity through government monopolies. By the 1970s, the more developed countries became increasingly concerned with water heat and mercury pollution, sulfur dioxide, particulates and other utility based externalities. Although environmental laws were passed, exempt old plants could continue to polluter and more recent concerns about CO_2 and other contaminants had not been completely internalized in the market prices.

Also with changing technologies, it was thought that at least parts of the electricity system could be restructured to introduce more competition, reduce regulatory costs, and further reduce prices. As it turns out, this restructuring has been fraught with numerous difficulties. For example, the brown-outs, black-outs, price volatility, and bankruptcies in the California market were little anticipated. Nor is it clear that costs to customers are necessarily lower.

Thus, both regulation and restructuring have been problematic, complex, and costly in India and the U. S. After over a decade of restructuring, India still has high costs with low consumption, while the U. S. has costs that do not reflect all externalities with over consumption. Although the symptoms are different, we believe the root causes are repeated regulatory failures and elusive competition in the grid-only power market. Regulators in India and other developing countries have yet to realize that the electricity industry can only be commercially viable through lower cost and higher income growth. A regulatory price increase does not automatically create enough revenue for sustained investment. Rather in India, it created dysfunctional bad receivables, power theft and rent seeking.

It was thought that restructuring in the U. S. electricity grid could deal with market power and provide a competitive market model for fossil generation. Such a model could be exported to India and other developing countries with further regulation required to internalize externalities such as pollution costs. However, competitive markets even if attainable would not necessarily deal with unstable fossil fuel prices and security issues of a centralized grid. Nor does competition necessarily solve the "Not In My Backyard" (NIMBY) resistance to siting new large-scale fossil and grid facilities. Further, environmental regulation, for CO_2 in the U.S., has been successfully opposed politically.

Given these problems with the existing grid structure in the U. S. and India, it may be time to move on to a new paradigm which will be smaller scale and competitive; will potential increase consumer income and reduce its cost; will have positive rather than negative externalities; and will transition the existing grid to be more competitive. We argue that it is time to consider a renewable paradigm of sun, wind, biomass, and small-scale hydro. These sources are widely available and use the current sources of energy efficiently in an endless chain rather than burning the previously accumulated limited fossil fuel in an inefficient and non-sustainable way. However, studies have examined the competitiveness of these renewables from the U. S., Japan and EU perspectives and have shown difficulties in their penetration with robust grid systems except for small niche markets. However, very little research literature was found on the renewable penetration in the high cost and unreliable grid markets of the densely populated rural economies of India. Studies show the potentially large size of the markets in developing countries in general. None of these studies, however, has brought out the fallacies of the fossil plant based electric grid model in India that has persistently failed to remove economic deprivation.

India, like many developing countries, possesses a large renewable resource base and a large potential market for power. It also has an inexpensive but highly educated scientific and technical labor force. India, however, does not possess the technology and investment capital to move these renewable technologies forward. But, the U. S. with its huge existing grid and cheap fossil fuels does not have the necessary market to develop the economies of scope and scale to make renewable technologies competitive, while it has advanced technology and investment capital to solve the global energy problems.

Some European countries such as Germany, UK, and Denmark are already pursuing this route and we believe that the U. S. should explore these options as well. Thus, our contribution will be to consider the synergies between the U. S. and Indian renewable markets that solve the existing market inefficiencies in both the countries. We employ a dominant firm model in which the grid is the dominant firm and renewables are the competitive fringe. By estimating the true social costs of grid electricity, grid quality renewables and possible production cost decreases from increased production, we estimate a socially optimal renewable penetration when the U. S.-Indian synergies are exploited. Space constraints prevent us from presenting our complete study, references, and results to date, but we refer the interested reader to our longer paper Kar and Dahl (2003) which is available upon request. Here, we outline the arguments for the synergy focusing on the Indian side of the market and briefly present the dominant firm model as the framework for our study.

A DEVELOPING COUNTRY PERSPECTIVE— INDIAN ELECTRICITY INDUSTRY

Since Indian independence in 1947, there has been rapid expansion of the Indian Power sector from less than 1,500MW to more than 108,000MW capacity in 2002 with 63,801 MW from coal, 11,633 MW from gas, 1,173 MW from diesel, 2,720 MW from nuclear while wind accounts for the balance of 1,736 MW. The per capita consumption of electricity has increased impressively from a negligible 20kWh in 1950 to 355kWh in 2002 but is still much lower than the 12,000kWh in the U. S.

Although the Indian economy has grown at an average rate of 5-6%, more than 450 million rural people in India still live without electricity. Those who have managed to be hooked to the country's inefficient electricity networks have to be content with high prices and poor quality, which limits their consumption. Grid electric supply is also facing significant cost increases not covered by prices leading to a perpetuation of poor quality and insufficient investment.

In the next 10 years, another 110,000 MW of capacity has been planned by the Indian government for meeting moderate growth needs and the promise to make electricity available on demand to all villages. Can it be done? There is no cheap, clean and large-scale hydroelectric potential left to be exploited easily although government has recently announced a grand plan to build 50,000MW from large dams. The need for longer power transmission lines from distant coal and hydro plants and the high cost of capital have increased the marginal cost of electricity, the more so to distant rural areas. Prices set politically too low in 1980s at 1-3 cents/kWh are increasing now to 5-8 cents/ kWh but are still not high enough to provide investment capital. Most of the State Electricity Boards (SEBs) are bankrupt. T&D loss constitutes about 25-50% and accumulated commercial losses well exceed the gross assets. At the national level, electricity-generating companies, though technically efficient, are economically inefficient with huge revenue arrears of more than 6 billion U. S. from the SEBs. Further, since liberal foreign official investment funding has dried up, the government opened up to foreign private direct investment. As shown below, this experiment has had disastrous effects. Consequently, the government is largely returning to their previous model of investing in and producing coal and nuclear power.

In Table 1, we show the price and quantity faced by the Indian electricity consumers compared with U.S. averages which clearly shows Indian tariff is unsustainable compared to its income. We did not find a viable electric industry anywhere in the world that demand more than 4% of their GDP for electricity spending while for India it was above 6% of GDP in 2002. It is therefore not surprising the annual commercial losses of the distribution utilities are as high as 1.1% of its GDP, and annual subsidies claimed are 2% of GDP—just a reflection of administrative cost increase not reflecting consumers' income and their ability to pay.

Table 1 Contrasting Capacities To Pay: The U. S. and Indian Residential Electricity Consumers

(for a representative consumer in 2002)	Units	INDIA		U. S.
		Rural-Rich Class	Urban-Middle Class	Lower-Income
1. Annual Electricity Consumed	Kwh	1,200	2,400	4,000
2. Electricity Price Actually Paid	Cents/ Kwh	6	8	8.5
3.Typical Annual Family Income	$U. S.	1500	3000	30,000
4. Purchasing Power Parity Income	$U. S. (PPP)	7,500	12,000	30,000
5. Purchasing Power Parity Price	Cents/ Kwh	30	40	8.5
6.a) Spent For Food / Milk	%	90%	70%	10%
6.b) Spent For Electricity	%	4.80%	6.40%	1.13%

A series of regulatory commissions have been instituted recently and a new Electricity Act, 2003 has come into force this year to control acute power theft and provide a remunerative power tariff to make the power sector viable. To us, the power theft and un-remunerative tariffs are not the primary reasons of power sector woes. They are the symptoms of two fundamental regulatory diseases-- management inefficiencies and regulatory capture of the electric monopolies. Such regulatory failure has increased electricity prices to a level that consumer's income may never absorb. None of the proposed theft control measures are going to solve the basic economic problems. It may create political backlash along with other law and order problems unless the price is reduced or the quality of supply is improved significantly. Not only are consumers paying high relative prices that are increasing, they are also receiving a poor quality of service.

Table 2 Contrasting the Quality Of Electric Service: The U. S. and India (Rounded for 2002)

WILLINGNESS TO PAY **(Quality better if numbers are low)**	**Units**	**INDIA**	**U. S.**
1. Reliability in Loss Of Load Probabilities (LOLP) Self provide battery / inconvenience **(Black Out)**	(LOLP)	40%	0.028%
2.Voltage Variation -Appliances damage/ inconvenience **(Brown Out)**	+/-	40%	5%
3. Frequency Variation Appliance damage/ Safety / Noise/ Harmonics. **(Churn Out!)**	+/-Hz, % Nominal	>1, 2% 50Hz	<0. 3, 0.5% 60 Hz
4. Poor customer relations, billing inaccuracy, coercion for supply restoration, and electrical noises **(Drive Out!)**	No data	Not in utility strategy	Increasingly cared for
5. Estimated Power Theft as % of Generation		15-20%	1-2%
6. Un-collectible bills (Yearly increase)	% of Sales	5%	< 1%

Table 2 also shows the quality of service in India and the U.S. illustrating the magnitude of the quality problems in India. Some Indian states experience a loss of load probability of above 40% (3504 hours per year) and such power supply 'black out' occurs mostly in the highest value peak demand periods. Low voltage 'brown outs' during peak period, excessive frequency variations of above the technical safe limits, poor consumer services including defective and delayed billing, delayed power restoration, unsafe supply reduce the consumer satisfaction and their willingness to pay a high price, and ultimately 'drive out' of the honest paying consumers. Not surprisingly, brown outs, black outs, and other quality problems are viewed as routine in nature as a fact of life and tolerated without any severe criticism so far as there is no coercion to pay the bill. Still, quality conscious customers routinely invest in backup storage and inverters to provide themselves a more reliable service. Further, devices like voltage stabilizers are routinely purchased to protect appliances and equipment from damage to avoid cost, inconvenience and productivity loss. None of these costs, nor any un-quantifiable damages are included in the regulated price of electricity even if these are the real private costs incurred by the consumers. These quality deficiencies in India are contrasted with the superior qualities of the U. S. grid supply in Table 2.

Electricity is such a valuable commodity for the society that many countries have mandated universal service and have lifeline rates to provide some minimum quantity to the poorest segment of the society. Mostly this subsidy comes from the affluent section of the society and in developing countries mostly from business customers that might have jeopardized industrial competitiveness and business growth dwarfing economic growth and grid industry.

We first look at public sector performance problems followed by problems associated with opening up to the private sector that all contributed to poor quality of supply, high cost, and current and projected capacity shortfalls. Quality shortfalls are the result of less investment. Investment shortfalls are the result of revenues being less than costs. Revenue shortfalls result from the combined effect of inability of the poor to pay high prices, the political inability to charge high prices to the rich, and the diversion of payments to rent seeking employees and influential local politicians from industrial and commercial customers who must provide cross subsidies to the poor and agricultural sectors. High costs result from classical technical and managerial inefficiencies in state owned utilities. Technical inefficiencies include poor maintenance and large transmission and distribution (T&D) losses. The poor also increased the T&D losses by taking the law into their own hands and illegally hooking to the low voltage transmission system when they were disconnected for nonpayment or financially unable to get a legal grid connection.

Managerial inefficiencies include poor resource management, billing, metering, and collection problems. States traditionally have controversial tariffs that are politically set to satisfy both the consumers and suppliers and so do not reflect all the true economic cost of overstaffed, unscrupulous and inefficient electricity boards. It will be a difficult political process to convince a strong unionized workforce of these state utilities for grid reform like privatization or cost control. These inefficiencies further reduce revenues and increase costs and reduce state investment. State utilities then bought high priced wholesale power from the federal power companies who increased their production from negligible amount in 1980 to 32,000MW in 2002 through new investments and takeover of state plants against receivables. Although federal power companies are technically efficient, from 1992 they have been charging monopoly prices reducing welfare. In addition, all other federal resource suppliers to state utilities also increased their prices to increase their revenues by charging higher risk premium due to SEB's managerial weakness and poor credit quality.

These additionally administrative cost, risk premium, and own operating inefficiencies have further raised the cost to state utilities and the prices to their consumers choking off investment in an even more vicious cycle. Consequently, by 2002, more than 20 state utilities are incurring losses of 7 billion U. S. annually. They have not paid 6 billion U. S. of power purchase from federal suppliers while accumulating unpaid retail electric revenue of over 6 billion U. S. dollars as accounts receivables from their customers. With increase in this unpaid bill of 1 billion every year, annual losses of 7 billion and a government actual subsidy of 2 billion, the annual gap between the actual cash flow and the cost of supply is estimated at an astounding 10 billion dollars U. S. in 2002. This is 2.2% of the GDP gap in revenue collection uncollected because of consumers' incapacity or unwillingness to pay.

In order to alleviate some of these problems, the Indian government allowed private participation in electricity generation in 1992. Domestic and foreign investment mostly from the U. S. concentrated their investment proposals in generation capacity from coal, petroleum, and natural gas. However, these proposals did not materialize despite attractive long-term power purchase contracts with higher profits, accelerated tariff, tax depreciation and take-or-pay guarantees. These guarantees from state distribution utilities were not credible because of severe financial constraints. At the same time, the federal government offered large coal and LNG based projects for development under a controversial Mega-Power Policy to Independent Power Producers (IPPs). Since these projects were expected to derive economies of scale and private sector efficiencies, state guarantees and federal counter guarantees provided non-payment risk protection for a few large investors. While as many as 59 large projects with 27,800 MW capacities were awarded from 1992 only 36 smaller projects with 7, 000MW capacities have been completed.

These projects also failed to achieve the cost reduction from the technical economies of scale that was neutralized by the higher cost of financing and increased risk of large private investments in developing countries. The lower prices whenever offered by large investors were apparently driven by the liberal tax incentives rather than any real economies of scale. However, government tax revenue could not sustain guarantees for potential payment defaults by state utilities. Thus, governments refused to support guarantees after the tragic outcome of Enron's stranded Dabhol Power Project. Indian power policy has now reverted back to public sector mode as private investors are fully cognizant of the risks involved and have pulled out of the Indian market. Privatization experiment saw a backlash in last decade when regulatory system only tried to replace an inefficient public monopoly with a profit seeking private monopoly instead of a true competitive market place amenable to cost reduction. Ultimately both the systems have failed.

This meager energy supply at competitive price can be achieved many ways, but most of them point to effective and economic ways of meeting this need through renewables for the following reasons: First, the renewables increase jobs, income and hence the paying capacity of consumers while reducing the demand for costly electricity catalyzing a low electricity intensive economic growth by moderating the demand for costly grid electricity. Renewables like biogas and solar thermal can cheaply supply the domestic energy needs for cooking, heating and other non-electric energy. Renewables based income can create spending capacity for the high cost electricity needs of lighting and appliances that too can be met competitively by high cost solar photovoltaic (SPV). Second, premium renewables like SPV and wind generators show a strong learning curve effects for future cost reduction that will make it more affordable. Third the increased grid cost can no longer sustain the cross subsidy without creating dysfunctional tariff leakages or out of grid inefficient captive diesel generations. Rural renewable energy can result in a substantial reduction in total future grid-based cross subsidies even if initially it needs a higher subsidy, popularly known as learning investment. The increased grid cost, however, will always demand an increasing level of cross subsidy propagating negative externalities of tariff leakages or inefficient distributed diesel generations. The less pressure on cross subsidy from business consumers will increase usage efficiency, economic growth, income simultaneously reducing the leakage and rent-seeking attitude. Fourth, competition from renewables can ultimately make utilities more responsible further reducing the market price for long-term sustainability. Finally, renewables and energy conservation are complementary products providing electricity and improved quality of the life for the "teeming millions" of developing countries. Conservation of energy, which is now of paramount importance for developed countries, has been too difficult to achieve in a grid environment even if not impossible through proper but complex tariff and metering systems that only those high-income countries can achieve.

Whatever policy is proposed it must fit into the Indian economic system and correct the planning process that has been grid based and energy intensive. Eighty % of Indian population lives in rural areas making a grid-based solution quite expensive India has experienced uneasiness in large-scale urban migration. If rural migration to cities is unchecked, the quality of urban life will deteriorate even further. Further, grid expansion to rural areas is unsustainable because its large poor population does not support the investment needed. We also showed in the previous section that any supply side investment that does not create comparable demand side income growth is not self-sustainable in the market. Further, the entire supply chain starting from generation, transmission, distribution, through to retail supply has to be competitive. We will show in the next theory section that monopoly cannot be asked how to reduce price. They have to face a real credible threat of entry of a substitute to reduce the price. Such choice can come from renewable energy if its economic and commercial viability can be proved. The present rural population depends on low technology renewables by burning low cost wood and cow dung that is not good for improving income, health, or the environment. So, we will consider renewables for electricity and other rural energy, but new technology products like photovoltaic, micro-hydro, wind, or biogas whose costs can be expected to decrease with high production volume in the Indian renewable market place.

The Indian Ministry of Power estimates that there are about 80,000 villages in the country not yet electrified. So, there will be plenty of opportunities and challenges for private investment and international efforts to meet the total new demand. One or more of the renewables (solar, wind, hydro, and biomass) are always available near the rural habitations. In the eastern, southern and western coasts with high population density there is plenty of water, sun, wind and biogas resources. In the northwestern dessert, sun and winds are plentiful with few days of cloudy sky. In the central heartland, the dense forest and associated biomass along with wind and sun are plentiful. So the diffusion of advanced renewable technology in Indian economy is more a result of their low deployment rather than their scarcity. For a more complete discussion to renewable availability in India, see Kar and Dahl (2003). The Table 3 shows the market size, cost and prices of some predominant renewables in India.

Table 3 Market, Cost and Prices of Renewables as of 31.03.2001

Energy Source	Estimated Potential	Commutative Achievements	Capital Cost (MM Rupees /MW)	Price (Rupees/ kWh)	Price in Cents / kWh	Competitive to grid cost of 8 Cents/kWh
Solar PV	30,000 MW	42 MW	250 - 300	10-12	20-25	In remote hamlets
Solar Heater	Vast Area in Sq.m	480,000	--	--	--	--
Solar Cookers	>100 Million	481,112	< 1000	--	--	Yes
Wind Energy	20,000 MW	1,500	35 - 40	2.00 - 2.75	4-6	Yes
Small Hydro	10,000 MW	1,423	30 - 60	1.00 - 2.00	2-5	Yes
Biogas Plants	12 Million	2.95	30 - 40	1.75 - 2.00	4-5	Yes

We will look at the potential of these renewables for a comprehensive solution to Indian problems that is equally applicable to all third world countries rich in renewable resources. This search for an alternative energy paradigm raises an important question: Are renewables really credible substitutes that can solve the grid problems described above? The answer is less clear if we compare the present day costs and the reliability features of these products with those of the grid power in developed countries. But if we compare the cost and reliability of the poor grid with those of the renewables in India the answer is very clear. Rural energy needs and most of the residential needs in urban area can be met by the costliest renewable option—the SPV.

Forty % of the people with no access to electricity or a cleaner form of energy depend on nature for basic cooking, lighting and heating through crude ancient technology. It is possible to meet most of the energy for cooking through inexpensive solar stoves or biogas and for heating through solar collectors. We will show that all such rural based energy technologies are already competitive to grid power and so can be removed from the electricity demand of the rural consumers. The remaining premium energy needs for lighting, fans, electronic, and domestic appliances have to come from electricity. This can be from the costliest SPV or other cheaper hydro and wind resources if available in the particular location. Indian rural people at present do not consume a large amount of energy for home weatherization. The photovoltaic technology can provide coincident electricity to meet the large pent up cooling demand as an excellent match for the summer peak loads dramatically improving the rural productivity and quality of life. The cost of many of these SPVs is falling and reliability features improving with technological evolution, production volume, and hybrid-product packaging. For a rural home today, the SPV based cooling fan is adequate to achieve this objective. With increasing income and decreasing SPV costs, air conditioning will be more affordable in the future through SPVs than the grid alternative.

Renewables do not raise the debate of environment verses development. They actually meet non-ambitious consumption habits of rural India by simultaneously creating income and a better quality of life with reduced pollution. The green attributes of renewables are a strong driver of renewable penetration in the developed world. In the developing world, renewables can reduce the need for expansion of increasingly inefficient and costly grid. They do not raise electric metering, billing, power theft, safety and security issues. They can also bring consumer choice and competitive supply to the consumers' doorstep to encourage utilities to control price and avoid regulatory capture.

The reliability shortcomings of renewables are addressed through design of a hybrid model with suitable battery back up to provide a reasonable quality of power. In the Indian grid, the dominant competitor is also a supplier of intermittent electricity. The poor quality requires batteries and stabilizers to avoid inconvenience. So all the costs of owner-provided power-conditioning devices must be added to the grid cost for proper comparison with renewables. Initially, we simplify our economic analysis with a reasonable assumption that such power conditioning costs meant to rectify the same problem of intermittence are almost the same for both renewables and the grid and so may be removed for cost comparison.

However, even if we can show that renewables are a competitive substitute to the grid in both cost and reliability and are immediately necessary to bring discipline to the grid market, they are still a new concept. India lacks the latest technology and financial capital to provide renewable energy to its deprived millions and depends on foreign capital and technology. Some severe barriers for renewable penetration in India that need international efforts–can be grouped under technology, capital, and marketing resources adequacies as follows:

- Low R&D spending in industrial and technological development of renewables
- Renewables need higher up front investment due to their high capital cost and low variable cost. The Indian economy is not large enough to support such high fixed investment. The life time subsidy for renewables even if low compared to that required for fossil-grid will have a high up front subsidy. Such investment in subsidy otherwise known as learning investment has to be supported from external private and public funding.
- Lack of international aid and soft long-term loan to renewables in comparison to what was available for fossil fuel projects will be a major handicap.
- Lack of well trained personnel to construct, maintain and operate renewable projects
- Lack of environmental awareness
- Lack of marketing and regulatory support such as government mandated purchase or green pricing
- Poor paying capacity of consumers and lack of consumer credits to boost demand.
- The high risk of new renewables technologies with no assurance of after sales service, performance warranty and consumer education on use and maintenance.

Having seen the difficulties with grid-based electricity and some level of difficulties in renewables commercialization in spite of its suitability in India, now lets move to the U. S. We will examine if its relatively efficient electricity grid and emerging renewable energy technologies can create a long-term competitive model for the U. S. and Indian electricity market. This will also throw some light on the possible synergies in renewable cooperation between the two countries.

MARKETS FOR RENEWABLES IN THE U. S.

As a follow up to the global oil crisis, renewable energy got a push from lawmakers and has been actively supported by green enthusiasts. With the passage of PURPA in 1978, the utilities were asked to buy the green power at their avoided cost. While the renewable and cogeneration seeded the initial competition, the legal support alone was unable to create a sustainable renewable market. Additional market and financial support has been initiated. First under the System Benefit Charge, utilities recover a small increased electricity rate to buy the costlier renewable energy and pay for Demand Side Management (DSM) and conservation programs. Second, the Renewable Portfolio Standard (RPS) in most states mandates utilities to buy a small but increasing percentage of their total energy from renewable energy sources. Third under the net metering the retail consumers sell any surplus electricity they produce from their own renewable plants to the local utilities at their distribution rate. Finally, in a more market friendly environment utilities have also tried to get voluntary buyers for the renewable energy at a slightly higher price. The producers of the renewable energy and their equipment suppliers have benefited from these incentives and the industry has grown in the U. S. in last 10 years.

Market savvy green marketers have invented new instruments like green tags to sell separately the green attributes of renewable energy at a premium from 2-4 Cents/kWh. Table 4 shows the market, cost and the prices of some important renewables for the U. S. that could be linked to Indian renewable markets. The suggested introduction of Locational Marginal Pricing (LMP) in the wholesale market will bring opportunities and challenges to renewables. Renewables can add locational value due to scarcity of water, infrastructure, peaking capacity, or siting permits for fossil-grid expansion. Due to near zero variable cost, they can be always on the merit order dispatch. But renewables may face greater barrier if they have to face an intermittence penalty by the system operator and have to self provide the energy imbalance to keep up with the day-ahead or hour-ahead schedules. Renewables value can increase with additional investment in battery storage, pumped storage hydro or the upcoming hydrogen economy due to additional flexibility in dispatch. Fierce competition without marginal social cost pricing to include the environmental externalities discussed before may promote coal and diesel

Table 4 Market, Cost and Prices of Renewables as of 2002

Source	Estimated Potential In 2020	Cumm Achievemt 2001- 02	Cap..Cost U. S.$/ KW	Levelized Price in C/ kWh	Competitive to grid cost of 7-12 C/kWh
Solar PV	50-400 kWh/sqm/y	310 MW	8,000	30-42	In remote hamlets
Wind Energy	710,620 MW	4245 MW	1000	4-6	Yes
Small Hydro	12,500 – 40000 MW	--	4,000	7-8	Yes
Biogas digester	6000-12000 large farms	< 50 farms	4,000	3-5	Yes

plants instead of renewables. So it will be necessary to provide level playing fields to renewables either by taxing the fossil plants for environmental damage or subsidizing the renewables for their green attributes. Unless this is done the U. S. market will remain inefficient with externalities.

In the U. S., renewable energy faces a natural market barrier. The electricity market is fairly well developed. The entire country is connected by the power grid network and is basically assured of reliable and relatively inexpensive electricity from the conventional nuclear, fossil fuel and large hydroelectric power plants. There is no competitive substitute for this versatile electrical energy that can power the numerous domestic appliances and industrial and agricultural equipment at the flip of a switch. The U. S. electricity markets are saturated with few new customers. The existing suppliers do not want to try a new production technology to supply the same or an inferior product. New renewable suppliers would have to face a huge cost and monopoly structural barrier to provide renewable supply to the same customers. Renewables cannot fully meet the premium quality and reliability needs of the rich urban population and high tech service industries at a competitive price. Renewables basically compete at the wholesale level but are generated from highly diffuse low quantity sources that need to be gathered and transported back to urban areas where more than 90% of the energy consumed. This contrasts with the Indian situation where the renewables are closer to the rural consuming centers. Transportation in the U. S. increases renewable's cost to urban centers in the same way fossil electricity is transported through an expensive grid to rural consumers in India.

Even if the citizens are concerned about the environmental pollution and international security threats to their fuel and electric plants, the costs of the inclusion or exclusion of any defensive measures are not part of the electricity price. This hidden socialized cost appears in the health and defense sectors. The absence of explicit accounting of these costs in grid power is a major threat to renewables. Unless and until such costs are part of the private price paid in the market place, the existing regulated market needs an extra subsidy for solar PV, which is yet to be competitive. LMP based market reforms that do not include such external social costs are bound to lead socially inefficient market that needs government or regulatory correction through suitable pollution tax or emission trading. Besides in the regulated electricity market current price does not reflect the future uncertainties and costs related to any stranded assets, market power abuse, regulatory mistakes and market failures, fuel risks, and increased O&M costs due to NIMBY pressures. Recent market failure and the wide spread credit risks in the industry shows the fallacy of the grid market to reflect the true cost of electricity during actual consumption and so increases the price and volume risk to consumers after the contract commitments.

Subsidies have been proposed for renewables to promote its market share. The government-mandated tax credits for renewables are often squandered ineffectively. The incumbent utilities will show more reluctance to subsidize renewables through net metering and RPS when these are surely going to reduce their own market share in generation. Still, we have reasons why the policy should support such subsidies. The coal and other grid-based technologies have been long supported by governments, which does not appear in their market prices, even if they are not environment and market friendly. The subsidy on renewables is miniscule compared to these hidden subsidies that is most visible in the era of open market. However, there should be greater market friendly methods of using such subsidy and some long-term strategy to use those in the initial product life cycle of renewables.

Private companies can increase the market size for renewables through the marketing and cost reduction strategies. But we bring two important reasons-- technological and financial-- why the private attempt must have government support. Renewables like SPV are still on the steep portion of the learning curve. Benefits of this learning curve from high R&D and market investment by one firm have a tendency to spillover to other firms. A firm can use reverse engineering, rely on informal contacts with employees at rival firms, hire employees from a competitor, or pursue industrial espionage. So, firms will under-supply renewable technologies whose benefits cannot be fully secured for private profits. For a technology that exhibits strong learning effects and provides public benefits, the case for government sponsored R&D is usually common and once the technology reaches the commercial stage, demand-pull efforts is particularly strong for an infant industry with considerable positive social externalities.

Private cost of capital is high as they discount the future at much higher rate than the individual consumers, local communities, governments and multilateral aid agencies. So it is likely that the communities or governments will find the renewable projects more viable in long term. The longer life of the renewable projects beyond 25 years generate wealth for community and individual owners but not for a profit seeking investors as such assets are not liquid and saleable like the capital stocks in the organized stock exchanges.

These structural barriers need to be removed before private companies in an infant industry can participate in a concentrated monopoly markets with a level playing field. Some of these structural barriers like insufficient capital, technology, and the market for the renewables require a international partnership just like the U. S. partnered with other countries for fossil power plants to promote exports through export credit agencies and for R&D support through international programs. As the benefits in renewable cooperation are not only global but help each partner also to take advantages of others strengths to address in one's weakness, we will discuss some of these barriers in the U. S. that could be addressed through collaboration with India.

THEORETICAL UNDERPINNING

Theories of cost of service regulations are controversial due to lack of empirical evidence of their success even in many strong democratic countries. The U.S.'s long established cost based regulation has recently been exported to India starting with Orissa Electricity regulatory Commission in 1995 and Central Electricity Regulatory Commission in 1998. Subsequently, more than 15 states have introduced reforms by introducing similar regulatory commissions. No significant improvement is seen from the rate of return regulation in India as political systems are not yet well equipped for public scrutiny of regulatory agencies, and the institutional structure and public knowledge to support such a system is at infancy. We have also seen the influence of suppliers and the ignorance or hidden motives of the regulators that has always set a wrong price either too low during pre-1990s or too high as now. In spite of all care the regulators can never be truly independent of the monopolists and governments controlling both of them. Again the knowledge, information and resources available with the regulators to extract efficient result from regulated companies is too limited. So there is no justification in wasting considerable time and resource in first learning and then unlearning such imperfect systems. The solution lies with creating credible substitutes to grid electricity that will address most of its market failures.

We have a renewable solution now to market power, regulatory failures and the externalities. We will first study the learning curve theory of renewables to reduce costs that strongly favor a government-sponsored investment or marketing support. We will describe a market segmentation approach that fits into the U. S. and Indian renewable market. We will see the market friendly attributes of the renewables and incorporate them into a dominant market model to create a more competitive market model to solve U. S. and Indian energy and development related problems.

If all subsidies are removed and externality costs are accounted for, the cost of grid electricity in rural areas is truly expensive. The present tariff charged by many states in India is as high as 10 cents, which may even yet include some subsidy elements. Further, the present cost of the grid and fossil fuel is increasing sharply due to industry concentration, market power, regulatory capture and environmental awareness creating delays and other compliance costs. The electricity price in the U. S. is projected to increase from present 7-cents/ kWh average to more than 11 cents/ kWh in 2012. It is instructive to observe the reduction in the cost of renewables over the last 10 years as shown in Table 5. Do they signal that the grid may soon be loosing its market share?

Table 5 shows that all renewables when available at a particular site except photovoltaic are potentially cost competitive with grid power. Hydrogen, storage batteries, and power conditioning systems are now capable of storing intermittent renewable energy and making it available for consumption at any time. They increase the value of the renewable energy and solve many quality and reliability problems. Some renewable resources are currently being deployed in some areas in the U.S.—solar and wind in the west and south, wind and biomass in other places.

Table 5 Cost Reductions for Leading Renewables

Technology	Current cost of delivered energy (U. S .$/kWh) 2000	Decrease in capital cost over last 10 years (%)	Expected decrease in capital cost over next 10 years (%)	Avg. Energy Cost After 10 years	Competitiveness at 11 cents/kWh
Small-scale hydro	0.02-0.10	constant	slight increase	0.06	Yes
Biomass					
Wastes combustion	0.02-0.14	constant, rising	likely to rise	0.08	Yes
Anaerobic digestion	0.02-0.14	5-10	5-10	0.07	Yes
Landfill gas	0.04-0.06	10-15	slight increase	0.05	Yes
Energy forestry And crops	0.05-0.08(heat) 0.08-0.15 (elect)	5-10(heat) 10-15 (elect)	10-15(heat) 30-50 (elect)	0.06 0.08	Yes
Solar					
Active solar heating	0.03-0.20	30-60	30-50	0.08	Yes
Solar thermal power	0.10-0.25	50	25	0.12	Almost
Photovoltaic	0.50-1.50	40	40-50	0.20-50	remote appl
Land-based Wind	0.04-0.10	30-50	20-35	0.05	Yes

Renewables can strongly contribute to the political and economic objectives of higher employment and poverty eradication when the fossil world energy industry is either shedding labor force or saddled with an inefficient labor force. A Danish study establishes that the multiplier effect of renewable wood energy on income in rural areas is much higher than the multiplier affect of traditional energy on urban incomes. So by increasing the availability of energy to rural people, the economy will grow much more rapidly with a positive income distribution impact than is possible with grid development.

Grid suppliers are trying to incorporate conservation and adaptation habits in their consumers with mixed success as the design and administration of a suitable time-of-use rates and metering are complex and expensive. Due to direct knowledge of the scarcity of available radiation, households using new Solar Home Systems (SHS) quickly learn and adapt a conservation compatible lifestyle providing necessary Nega-watts otherwise difficult from traditional grid network. Similarly new developments in the energy efficient appliances have made SPV commercially feasible now.

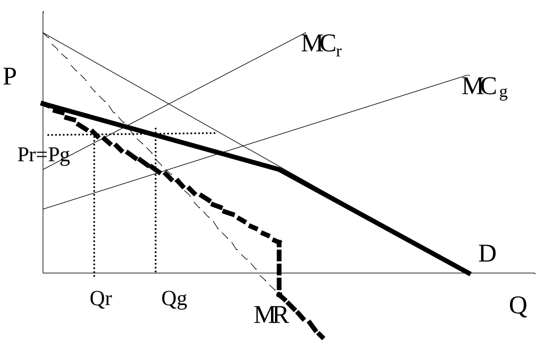
Renewables can use relatively smaller energy conversion processes compared to the huge grid based fossil plants. With no lumpy economies of scale, they should not get the status of natural monopoly. The attractive competitive feature of renewables are their near zero short run marginal cost of production, small economy of scale in generation and distribution, non intrusive and distributed nature of generation, and non polluting with no substantial threat to environment. There can be many suppliers and there is a range of technologies and products available to meet the diverse energy needs of customers in a competitive environment.

Another advantage of sun and biomass energy conversion is co-products and by products that may reduce their costs and enhance their overall value. Solar panels can be easily integrated with new buildings to provide roofing structure while hybrid solar photovoltaic and solar thermal can be integrated in new buildings to optimize the total building and energy costs. Similarly, biogas plants can produce heating and cooking gas along with useful bio-fertilizers for the rural agricultural needs. Biomass can be particularly popular in rural areas due to its abundance, low price and ease of use provided some critical mass in the technology penetration is achieved. Windmills can help water pumping for irrigation and drinking water in remote hamlets and may even add to the aesthetics of landscape in certain circumstance. Similarly, market innovators and early adopters are willing to pay a higher price for the better reliability, independence, snob appeal, aesthetics, or green qualities of the PV.

DOMINANT MARKET MODEL

To study the potential for renewables, we employ a dominant firm model as shown in Figure 4.3. For a more complete description of this model, see Dahl (2003). In this model, D, the straight line which is lighter on the top than on the bottom, is the total demand for electricity. MC_g is the private marginal cost of grid power. To make the model dynamic, the marginal cost is the levelized cost and so captures the cost over the life cycle of the grid facilities. A non-regulated monopoly firm would want to produce where marginal revenue (the lighter dotted line) equals marginal cost and charge a price higher than where MC_r crosses D. In a regulated world, the social optimum would be where MC_g crosses D at a lower price and higher quantity.

Figure 3 Dominant Market Model With Renewables



Now introduce renewables into the model with MC_r, the private marginal cost curve for a competitive renewable fringe. Since the renewable market is competitive, its marginal cost curve represents supply. Since the grid cannot control the competitive renewable producers at market price, the grid demand is equal to total demand minus grid production. Now grid power demand is the darkened kinked curve. When price is above MC_r, grid demand is less than the total, but when price is below MC_r, grid demand is the total market demand. Marginal revenue under the dominant firm model with a competitive renewable fringe is then the darkened dotted line. The grid will produce where its marginal revenue crosses its marginal costs. Its price will be higher than the competitive price but lower than the monopoly price. So even though renewables are more expensive, they may still have a moderating effect on grid monopoly power. Further, we argue that fringe costs (MC_r) will come down from learning curve effects if the U.S. and India jointly work to produce renewables. For a literature survey on and a model of learning curve effects, see Kar and Dahl (2003). MC_r will come down even more if the positive external effects of the renewable are deducted. Also MC_g will increase if negative externalities of the grid are included in MC_g. All these effects will serve to moderate the monopoly power of the grid and reduce grid shares. The results of quantifying the model and showing the learning curve effects are contained in Kar and Dahl (2003). Further, work will include extending this analysis to include biomass and other renewable sources, applying the results provide electrification to a village in India as well as measuring the benefits in the U.S. market from a U.S./Indian collaboration.

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