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The DG Revolution – A Second Indian Miracle

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Executive Summary: A distributed generation revolution has begun in India with 87 new local power projects producing 710 megawatts from sugar cane waste. These projects will save Indian society $135 million per year while reducing both conventional pollution and greenhouse gas emissions. When fully implemented, the DG revolution could save India $4.7 to $7.6 billion/year and slash CO_2 emissions by 250 to 400 million metric tons per year versus conventional central generation.

Background

In the 1960's, world population began to exceed food production, leading to widespread starvation in underdeveloped countries. Some scholars concluded that world agricultural systems could never support the growing population and went so far as to suggest the world practice "triage" on much of Asia, writing off India and China and concentrating efforts on feeding people in other countries. Before the ink on these Malthusian analyses dried, a miracle began to take shape – the green revolution.

Foundations, especially Rockefeller Brother's and Ford, refused to accept starvation as an outcome and funded, among other organizations, the International Maize and Wheat Improvement Center, home of 1970 Nobel Prize winner Norman Borlaug. These research efforts produced new strains of wheat and rice that responded to fertilizer and were resistant to disease. The green revolution enabled farmers to increase food production faster than population growth, and truly initiated a miracle for starving people in India and China.

Electric Power Starvation

Flash forward to the late 1990's. Roughly one-third of the world's six billion people, many in India, are without electric power, an absolute essential to modern life. Studies have shown that access to electric power increases standards of living, raises women's rights and reduces population growth rates. But the conventional approach of producing electricity in remote central plants that feed vast webs of copper wires is not delivering the goods to one out of three people on the planet. India's 80,000 megawatts of central electric generation capacity flows to users through overtaxed wires that leak power losing over 40% of generated power to technical losses and theft. The Indian economy has many elements in place for rapid economic growth - - a 600 million person common market, good levels of education, and solid basic industry - - but these losses and widespread electricity shortages block progress.

The Indian Distributed Generation Revolution

Here is breaking news. Once again foundations, notably Winrock and Rockefeller Brother's, have stepped up, refusing to accept electricity starvation as inevitable. Three other organizations, Cogeneration Association of India (Cogen India), US AID and the World Alliance for Decentralized Energy (WADE), agreed to help. These organizations have started another revolution – the Distributed Generation or **DG Revolution** by providing information, technical assistance and financial support. They have helped the Indian sugar industry recycle bagasse – the residue from pressing sugar cane to remove the juice – as electricity for a nation starved of power. They have persuaded India's state electricity boards to modernize electric regulatory rules, which were blocking more efficient and cleaner local power.

Resulting policy changes have already induced 710 megawatts of new local power generation projects that recycle bagasse. Some data will clarify the vision behind the India DG revolution.

- First fact: One third of the bagasse provides enough fuel for the steam and electricity needs of a sugar mill. The remaining two thirds could be burned to generate power for neighbors. But for years, State Electricity Boards, intent on protecting their electric generating monopoly, have either refused to purchase local power or have offered to pay only the cost of fuel to make a kilowatt-hour remotely, ignoring line losses and capital costs for wires. Facing laws against

selling power to neighbors and a hostile grid, the sugar mills had no reason to invest in added generation. They simply incinerated all bagasse not needed for on-site power, wasting the energy content.

- Second fact: Excess power generated locally, flows automatically to the nearest users – the local farmers who are starved for power. Local generation would greatly reduce transmission losses by reducing excess loads on the T&D wires.
- Third fact: Because of the leaky Indian T&D system, every kilowatt-hour generated locally will replace 1.5 to 1.8 kilowatt hours of generation at a remote central plant. Central plants need to burn nearly two units of coal with attendant pollution to deliver the power that is generated with one unit of bagasse. And since the bagasse would have been burned anyway, generating power with bagasse produces no net added pollution.
- Last fact: Many other Indian industries also have waste energy streams that could be recycled under more friendly regulatory rules.

The organizations proposing an Indian DG revolution realized these facts and saw local generation, especially with recycled energy, as a way to supply adequate power to the world's poor, at affordable prices and with minimal pollution. They believed that local power generation would reduce India's contribution to global warming while improving the standard of living.

In 1994, the Indian Ministry of Non Conventional Energy Sources began urging State Electricity Boards (SEB's) to overturn decades of hostility towards local generation and adopt a new model policy, offering to purchase local power at full avoided costs under 13 year contracts with built in inflation, and offering to pay half of the cost of grid interconnection. But many obsolete government policies stood in the way of efficient DG and conservative regulators resisted rule changes until shown proof that both the economy and the environment would benefit from local power generation. The foundations and US AID made grants to eight demonstration projects that provided proof of concept. Slowly, one SEB after another adopted policies along the lines of the model DG regulation. In 2001, Cogen India hosted WADE's international conference in New Delhi that brought Indian government regulators from central and state bodies together with WADE experts from around the world to share DG experiences and knowledge. The pace of regulatory change accelerated.

Last month, Sunil Natu, a key leader of Cogen India, released interim results that demonstrate the extent of the DG Revolution now underway in India.

DG Revolution Results to Date

Since the first Indian State Electricity Board changed its policy, 87 sugar mill projects with total generation capacity of 710 megawatts of new local power capacity have been built or are under contract. This adds almost 1% to total Indian generation, adds nearly 2%, as Table 1 shows, to delivered power, and it has all been built in the past five years. These new bagasse recycling plants are already changing the lives of hundreds of thousands of Indian rural families who now receive more reliable power. Millions will benefit as the sugar industry realizes its potential of 5,000 megawatts of new generation that recycles the energy stored in bagasse.

What about the costs to the Indian society? Table 1 and Table 2 compare costs of delivering power from central generation or with local power from recycled bagasse. Had the 710 megawatts of new sugar mill generation been supplied from central plants, India would have required 1,183 megawatts of new coal fired central generation and equivalent T&D, enough to cover the roughly 40% line losses of the current system. The capital cost of this new central generation and T&D would have exceeded $3 billion, and would have required 7.6¢ per delivered kWh for debt service. Purchasing coal to generate nearly two kWh for every kWh reaching users would have cost 2.6¢ per kWh, so the all in central costs would have been 10.2¢ per kWh delivered to users. By contrast, the sugar mills are selling power for 7¢ per kWh and making money, which improves their competitive position and enables larger payments to cane farmers. It would have cost roughly $431 million per year to supply the same power with conventional central generation that DG is supplying for only $296 million, a savings of $135 million per year or 31%.

The second columns of Table 1 and Table 2 extend the analysis to the full potential to recycle bagasse in India - - 5,000 megawatts. The savings per kWh remain the same – 3.2¢, but the potential savings to Indian society reaches $953 million per year.

Table 1
Bagasse Recycling in India

Item	Units	Contracted Bagasse Generation	Potential Bagasse Generation
Generating capacity	Megawatts	710	5,000
Full load equivalent operation	Percent of year	68%	68%
Delivered useful power / year	Gigawatt-hours	4,229	29,784
Equivalent Need for Central Generation, Transmission and Distribution			
Losses from central stations	Percent of generation	40%	40%
Avoided central capacity	Megawatts	1,183	8,333
Avoided central generation	Gigawatt-hours/year	7,048	49,640
Avoided generator cap.	$ per kW	$1,000	$1,000
Total avoided cent. Cap	$ millions	($1,183)	($8,333)
Avoided T&D cost	$ per kW	$1,250	$1,250
Avoided T&D with local generation	Percent T&D avoided	90%	90%
Total avoided T&D	$ millions	($1,331)	($9,375)
Total avoided capital	$ millions	($2,514)	($17,708)
Capital Amortization			
Allowed utility rate of return	Percent	12%	12%
Time to amortize investments	Years	25	25
Annual capital charge if central	$ millions	($321)	($2,258)
Avoided capital amortization	Cents per delivered kWh	7.6	7.6
Avoided Fuel			
Central generation fuel @ 33% eff.	MMBTU millions	72.9	513.2
Central fuel cost	$ per MMBTU	$1.50	$1.50
Total central fuel cost/year	$ millions	$109	$770
Central fuel/delivered kWh	Cents per delivered kWh	2.6	2.6
Total Purchase Cost			
Total cost of central power	Cents per delivered kWh	10.2	10.2

Table 2
Comparative Economics, Central vs Local Power

Total cost of Central Power	Cents per delivered kWh	10.2	10.2
Paid to Sugar factories	Cents per kWh	7.0	7.0
Societal savings per kWh	Cents per kWh	3.2	3.2
Cost per year for Central Power	$ millions	$431	$3,038
Payments/year to Sugar Factories	$ millions	$296	$2,085
Annual Savings to Indian Society	**$ millions**	**$135**	**$953**
Savings as % of Central Power	**Percent**	**31%**	**31%**

Sugar Cane DG also provides a strong and positive dynamic impact beyond the new value stream for Indian sugar producers and farmers. Transportation fuel may be impacted as well, as DG

revenues lower the net cost of producing ethanol from molasses and second pressing of the cane and may make it economic for some mills to make only ethanol and compete with OPEC for supply of motor fuel. The ethanol is then blended into gasoline to reduce oil imports.

Reduced Emissions

What about emissions? Table 3 analyzes emissions of DG versus central power. The emissions per megawatt-hour reflect equivalent coal units in the USA. SO_2 and NO_x emissions from burning bagasse are negligible. By contrast, coal fired central generation would have emitted significant NOx and SO_2. And the local generation slashes greenhouse gas emissions. All carbon in the bagasse will be converted to CO_2 regardless of disposal method. If bagasse is returned to fields to compost, micro organisms convert the carbon to CO_2 and methane, a greenhouse gas 27 times more potent than CO_2. Incinerating the bagasse converts the carbon to CO_2 without producing any useful energy. Thus, burning bagasse to produce power adds no net CO_2 emissions and reduces methane emissions. The bagasse recycling plants already built or under construction will reduce Indian CO_2 emissions by 7 million metric tons per year and by 49.6 million metric tons if the full bagasse potential is met

Table 3
Emission Savings From Recycling Bagasse

Avoided CO2 per MWh	Metric tones	1.0	1.0
Total avoided CO2	Million Metric Tonnes/Year	7.0	49.6
Avoided SO2 per MWh	Pounds per MWh	12.7	13.7
Total avoided SO2	Metric tonnes/year	40,688	309,122
Avoided NOx per MWh	Pounds per MWh	4.7	4.7
Total avoided NOx	Metric tonnes/year	15,058	106,049

Indian DG Beyond Sugar Cane Recycling

India's DG revolution is just beginning. Given time, these enlightened regulatory policies will call forth a great deal more than the 5,000 megawatts of local generation from sugar mills. Carbon black manufacturers in India (raw material for tires and inks) have similar recycling opportunities. They currently burn only one-third of the waste gas to produce heat and power, and then flare the

remaining two-thirds because of low power purchase prices for the plant offered by the grid, which ignore the locational value of the power. Under these new policies, flare gas from carbon black plants, chemical factories, refineries and steel mill's blast furnaces will be economically recycled into power with no incremental emissions. Other power will be produced from presently wasted streams of hot exhaust at coke plants, glass plants, primary metals and foundries. Over time, India could produce between 25,000 to 40,000 megawatts of recycled energy with local power that does not require new transmission wires. This could save the Indian economy $4.7 to $7.6 billion dollars per year and cut greenhouse gas emissions by 250 to 400 metric tons per year.

When history is written, it may well be that the DG Revolution will be accorded equal importance with the Green Revolution in improving the human condition. As with the Green Revolution, the DG Revolution will spread far beyond India, producing benefits for many of the world's citizens. At WADE, we tip our hats to the far sighted leaders in India who have bucked the 120 year old central generation paradigm to leapfrog the grid and encourage local power. We tip our hats to the vision and innovative funding of Winrock Foundation and US AID, producing not one, but two important revolutions. We encourage other countries, especially the developed nations, to learn from the Indian miracle and embrace DG for the benefit of their citizens and the health of the planet.