Improving Efficiency in Electricity Distribution

A Holistic Approach

Global Energy Efficiency Workshop
Washington, DC
March 9, 2010
Why are efficient electric distribution networks important?
Because electricity is the preferred form of end-use energy

• Electricity is the fastest growing form of end-use energy
  - Non-OECD countries will account for 58% of world energy use by 2030
  - In the USA – a mature economy – power generation will increase by 77% between 2006 and 2030, i.e. from 18.0 to 31.8 trillion kilowatt hours
  - The fraction of US energy needs met by electricity increased from 20% in 1960 to 40% in 2000

• The power sector is also one of the largest sources of carbon emissions
  - In India, the 100 GW of thermal power generation capacity accounts for 60% of net power generation capacity and 57% of total greenhouse gas emissions
  - Based on current plans, this scenario is expected to persist until 2020
Although much energy value is lost before it is used

- Average energy lost in converting fuel to electricity is about 30-35%
  - For each 100 units of energy in coal, 30-35 units are lost at the power plant
  - Internal consumption can add another 5-10%
  - Of the 60 units that enter the T&D grid, technical losses range from 7% to 25%
  - Adding commercial losses can increase combined losses to 50% or more


- Experience shows that technical and commercial losses can be managed. Experience also shows that the approach taken can have a huge impact on results achieved.

- The principle of “control the controllables” suggests that increasing distribution efficiency should be a top priority for management
An historic convergence is reshaping the electric business

• Unrelenting increases in demand for electricity
  - Population growth
  - Increasing affluence creates higher demand for more reliable power
  - Electricity is the premium source of energy
  - An increasingly digital world requires it

• Technological advances
  - Information and communications technology (ICT)
  - Metering
  - Generation

• The need to reduce carbon emissions
  - A growing consensus about climate change
  - Electricity production is one of the largest sources
These forces are changing the industry’s business model

Cost Curves for Optimal Plant Size per MW

Thermal Plants

Source: Sally Hunt and Graham Shuttleworth - Competition and Choice in Electricity
John Wiley & Sons, Chichester, 1996
Meanwhile, the customer value exchange is deteriorating

- Unit costs have turned up
- And service quality measures are declining
  - In the USA, SAIDI increased (worsened) by 21% from 2000 to 2005
  - SAIFI increased 13%
  - CAIFI increased 8%

Sources:
PA experience
Developing economies have added challenges

- Supply shortfalls
- Peak load management issues
- Higher technical and commercial losses
- Increasing global competition for resources

An infrastructure spending boom will trigger global competition for resources

Between 2005 and the end of 2010, China will have spent $494 billion on infrastructure. India estimates $250 billion in spending for the power sector alone over the next eight years and total spending on infrastructure of $447 billion for 2006 through 2012.

One US company, Southern California Edison, recently launched a $30 billion, ten-year construction program to replace almost half its transmission and distribution assets.

In *Perfect Power*, co-authored by the retired CEOs of Motorola and the Electric Power Research Institute, the International Energy Agency’s *World Energy Outlook* estimated that over the next 25 years, China’s power sector will need $3 trillion in investment, India’s will need $1 trillion, Latin America’s $750 billion and Africa’s about $500 billion.
Is there a ‘best practice’ way to improve electric distribution efficiency in a developing economy?
Yes, but first some results

• Four discoms used this methodology on a pilot basis
  - Two urban divisions
  - Two rural sub-divisions
• The companies included three state-owned discoms and one private
• Total no. customers in the pilot areas was 214,000 ranging from 24,000 to 74,000
• More than 100 projects were proposed with capital investment of $60 M
• Most of the capital requirement was obtained from banks on commercial terms
• The initiatives have been underway for over five years
• Savings of $70 million per year were identified
• Actual savings achieved to-date were $17 million p.a. as of mid-2009
• One company reduced its total technical and commercial losses from 53% to 23% of total electricity input to the distribution network
• Another developed an agricultural demand side management (Ag DSM) program to cut in half the 30% of electricity provided “free” to farmers
One discom cut its AT&C losses by more than 50%
It also slashed its distribution transformer failure rate
The Success Formula
Begin at the end

ARC + GCR = Customer Satisfaction

Σ (Availability + Reliability + Cost) + Good Customer Relations = Customer Satisfaction
The methodology is straight-forward, but not simple

- Define key results *from the customer’s perspective (see prior slide)*
- Identify the major business processes that drive results
- Define a model according to People, Process, Technology
- Identify best practices
- Specify key performance indicators (KPIs) to measure results
- Conduct an “As Is” assessment to enable gap analysis
- Develop candidate projects to create a center of excellence
- Implement and measure results
The Model Discom & Best Practices
The Model Discom: The Analytic Framework

<table>
<thead>
<tr>
<th>People</th>
<th>Process</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization Structure</td>
<td><strong>Asset Management</strong> – Planning and managing the</td>
<td>Distribution Network</td>
</tr>
<tr>
<td>Work Management</td>
<td>company’s investment in the physical assets used</td>
<td>- Wires</td>
</tr>
<tr>
<td>- Work Analysis &amp; Staffing</td>
<td>to provide high quality electric service to</td>
<td>- Transformers</td>
</tr>
<tr>
<td>- Work Management Systems</td>
<td>customers.</td>
<td>- Capacitors</td>
</tr>
<tr>
<td>Compensation and Benefits</td>
<td><strong>System Operation &amp; Dispatch</strong> – The activities</td>
<td>- Substations</td>
</tr>
<tr>
<td>Training</td>
<td>involved in optimising the flow of electricity,</td>
<td>- Poles</td>
</tr>
<tr>
<td></td>
<td>incl. purchasing &amp; trading plus economic dispatch,</td>
<td>- Etc.</td>
</tr>
<tr>
<td></td>
<td>etc.</td>
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<tr>
<td></td>
<td><strong>Field Operations</strong> – Includes the classic</td>
<td>Metering Equipment</td>
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<tr>
<td></td>
<td>operations and maintenance activities, including</td>
<td></td>
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<tr>
<td></td>
<td>new hook ups, trouble calls and turn offs as</td>
<td>O&amp;M Equipment (trucks, tools, etc.)</td>
</tr>
<tr>
<td></td>
<td>well as meter testing and repair and other</td>
<td>Computing and Telecommunications</td>
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<tr>
<td></td>
<td>activities involved in the day-to-day operation</td>
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<tr>
<td></td>
<td>of the business.</td>
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<tr>
<td></td>
<td><strong>Customer Processes</strong> – Includes the meter-billing-</td>
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<tr>
<td></td>
<td>collection (MBC) process plus all customer</td>
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<tr>
<td></td>
<td>interfaces, incl. customer relations and</td>
<td></td>
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<tr>
<td></td>
<td>marketing as well as consumer education and</td>
<td></td>
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<tr>
<td></td>
<td>outreach.</td>
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<tr>
<td></td>
<td><strong>Corporate Processes</strong> – This includes activities</td>
<td></td>
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<tr>
<td></td>
<td>that enable the management of the primary</td>
<td></td>
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<tr>
<td></td>
<td>business processes (above) or that are executive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>functions.</td>
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</tbody>
</table>
## Business Process: Asset Management

*Asset Management* activities related to the planning and management of physical assets employed to provide high quality service to customers. This is a corporate-level business process.

<table>
<thead>
<tr>
<th>Process Component</th>
<th>Best Practice</th>
<th>Technology</th>
<th>People</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Planning</strong></td>
<td>• Proven load forecasting methodology</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td></td>
<td>• Empirical inputs, e.g. load flow studies</td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
<tr>
<td><strong>Capital Expenditure Analysis</strong></td>
<td>• Use of sound engineering-economic principles</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td><strong>Long-term Investment Plan</strong></td>
<td>• Rigorous challenge &amp; review process</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td>(15 year horizon)</td>
<td>• Use of ROA / SVA principles</td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
<tr>
<td></td>
<td>• Link to capital structure management</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Post-completion evaluations done</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Short-term Capital Budget (3 yrs)</strong></td>
<td>• Bottom-up link to operating budget</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td></td>
<td>• Pre-launch authorization required</td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
<tr>
<td><strong>Major Project Management</strong></td>
<td>• Specialized project management group</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
<tr>
<td><strong>System Mapping</strong></td>
<td>• Global mapping system</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td></td>
<td>• Comprehensive data base</td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
<tr>
<td><strong>Maintenance, Analysis &amp; Planning</strong></td>
<td>• Reliability-based maintenance plans</td>
<td>• Modern IT systems</td>
<td>• Adequate staff no. &amp; mix</td>
</tr>
<tr>
<td></td>
<td>• Comprehensive data base</td>
<td>• Advanced software</td>
<td>• Continuous training</td>
</tr>
</tbody>
</table>
### Business Process: System Operations & Dispatch

**System Operations**: optimising electricity flows plus purchasing, trading & economic dispatch

<table>
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<tr>
<th>Process Component</th>
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<th>Technology</th>
<th>People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real time power supply monitoring and control incl. load dispatch center</td>
<td>• State estimator to estimate load flow on hourly, weekly, mo. basis to ensure 24 hour stable parallel operation with neighbouring grids</td>
<td>• Modern IT systems&lt;br&gt;• SCADA to optimise dispatch of electricity&lt;br&gt;• Remote grid stations</td>
<td>• Adequate staff no. &amp; mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Energy Audit and Accounting</td>
<td>• Energy audit &amp; accounting of network, feeder-wise and dist’n transformer-wise monthly.&lt;br&gt;• 100% reads of boundary meters&lt;br&gt;• Load parameters.</td>
<td>• Modern IT &amp; s/w systems&lt;br&gt;• High Voltage Distribution System&lt;br&gt;• Continuous update of GIS maps&lt;br&gt;• Feeder wise, distribution transformer wise energy balance</td>
<td>• Adequate staff no. &amp; mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Operational load forecasting.</td>
<td>• Load forecasting (Short term)&lt;br&gt;• Load flow / monitoring studies&lt;br&gt;• Contingency / security analysis.&lt;br&gt;• Effective outage management</td>
<td>• Advanced computer systems&lt;br&gt;• State-of-the-art software for automated dispatch management&lt;br&gt;• SCADA system</td>
<td>• Adequate staff no. &amp; mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Power procurement from market</td>
<td>• Evaluate power production &amp; cost + cost of available power&lt;br&gt;• Measurement of purchasing &amp; trading of economical power</td>
<td>• Advanced computer systems&lt;br&gt;• State-of-the-art software</td>
<td>• Adequate staff no. &amp; mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Load Management</td>
<td>• GIS/GPS digital mapping&lt;br&gt;• Load mgmt by feeder control, DTC control, customer load control, capacitor introduction</td>
<td>• State-of-the-art SCADA System&lt;br&gt;• Distribution automation.&lt;br&gt;• GIS/GPS mapping system</td>
<td>• Adequate staff no. &amp; mix&lt;br&gt;• Continuous training</td>
</tr>
</tbody>
</table>
## Business Process: Field Operations

*Field Operations* includes those activities related to the classic operations and maintenance (O&M) activities of the distribution business including construction, new hook ups, repair and other activities involved in the day-to-day operations of the business.

<table>
<thead>
<tr>
<th>Process Component</th>
<th>Best Practice</th>
<th>Technology</th>
<th>People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Maintenance Management</td>
<td>• Maintenance manuals&lt;br&gt;• Prioritize sked for life cycle maint&lt;br&gt;• Reliability based maintenance plan&lt;br&gt;• Veg. mgmt, periodic overhauls</td>
<td>• Modern IT systems&lt;br&gt;• Advanced software&lt;br&gt;• GIS/GPS utility map&lt;br&gt;• Feedback from outage mgmt</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Revenue Expenditure Analysis</td>
<td>• Use engineering-economic principles</td>
<td>• Modern IT systems&lt;br&gt;• State-of-the-art software</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Asset Outage Management and Disaster Management</td>
<td>• Fault detection system for 11KV feeders&lt;br&gt;• Emergency load shedding schedule&lt;br&gt;• Utility map integrated with SCADA</td>
<td>• Modern IT systems &amp; s/w&lt;br&gt;• GIS/GPS Maps&lt;br&gt;• Mobile maintenance crews&lt;br&gt;• Mobile transformers</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Building Vendor analysis</td>
<td>• Analyze equipment failures</td>
<td>• Modern IT systems&lt;br&gt;• State-of-the-art software</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Releasing service connection</td>
<td>• Specialized commercial group w KPIs for time period to release a particular category of service</td>
<td>• Modern IT systems&lt;br&gt;• State-of-the-art software&lt;br&gt;• GIS/GPS maps integrated w asset &amp; customer D/Bs</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
<tr>
<td>Trouble Call Management</td>
<td>• Specialised ops group w link to assets, billing data base, complaint center and maintenance crews</td>
<td>• Mobile phones to field staff&lt;br&gt;• Toll free no. for customers&lt;br&gt;• Call processing &amp; analysis&lt;br&gt;• Mobile maintenance crews</td>
<td>• Adequate staff no. and mix&lt;br&gt;• Continuous training</td>
</tr>
</tbody>
</table>
## Business Process: Customer Processes

*Customer Processes* includes the meter-billing collection (MBC) process plus all the customer interfaces, including customer relations and marketing (including advertising as well as customer education).

<table>
<thead>
<tr>
<th>Business Process Component</th>
<th>Best Practice</th>
<th>Technology</th>
<th>People</th>
</tr>
</thead>
</table>
| Metering, Billing and Collection (MBC)      | • Installation of Electronic meters with appropriate networking interface.  
• Central billing & administration unit  
• Advanced techniques e.g. automatic / remote meter reading, spot reading & billing, online bill payment / query  
• Meter testing, meter inspection and replacement order for faulty, slow and fast meters. | • Advanced computer systems  
• State-of-the-art software  
• RS 232,485 / radio telephone modems, data collection devices e.g. hand held MRIs, data concentration devices  
• Spot / pre-paid billing  
• Online bill payment system  
• Billing system integrated with trouble call system, | • Adequate staff no. & mix  
• Continuous training |
| Customer Relationship Management (CRM)      | • Trouble call management  
• Metering and billing management  
• On-line billing and collection  
• New Customer management  
• Customer communication / updates on power status / planned outages  
• Customer awareness re energy efficiency & DSM | • Modern IT systems  
• State-of-the-art software  
• Integrated trouble call center w asset database, customer database with customer indexing; MBC center, inventory and stores wing, public relations wing, etc | • Adequate staff no. & mix  
• Continuous training |
# Business Process: Corporate Processes

Corporates Processes include purely executive-level functions, or that support the management of primary (“line”) business processes. These include: organization structure, policy setting, planning and control, performance measurement, treasury and cash management, finance and accounting human resources in formation management, procurement and inventory management.

<table>
<thead>
<tr>
<th>Process Component</th>
<th>Best Practice</th>
<th>Technology</th>
<th>People</th>
</tr>
</thead>
</table>
| Executive management | • GTG (Good to Great) principles  
• Effective mgmt selection, devel’t & training  
• Emphasize quantification and measurement | • Modern IT systems  
• Advanced software | • Adequate no. & mix of specialized staff  
• Continuous training |
| Planning and Control, including Performance Measurement and KPIs | • Use of global performance standards  
• Extensive use of quantification  
• Extensive benchmarking  
• Balanced scorecard & KPIs | • Modern IT systems  
• Advanced software | • Adequate no. & mix of specialized staff  
• Continuous training |
| Marketing and Sales | • Marketing analysis & consumer analysis  
• Empirical measurement of service quality  
• Consumer satisfaction surveys  
• Stratification of markets  
• Key account personnel | • Modern IT systems  
• Statistical analysis tools  
• Customer Relationship Management s/w | • Adequate no. & mix of specialized staff  
• Continuous training |
| Treasury and Cash Management | • Prepayments, where feasible  
• Automatic deduct for commercial accounts  
• Cash management system  
• Automated cash collection centers  
• Lock box system | • Modern IT systems  
• Advanced software | • Adequate no. & mix of specialized staff  
• Continuous training |
The Analytic Ingredients

KPIs and KKPIs

Gap Analysis

Best Practices

Gap Analysis

“As Is” Assessment

Projects

DPR

Legend

Process

Lists

Document
High impact detailed project report (DPR) projects

• Distribution transformer replacement
  - Plus DTR management system
• Substation upgrades, replacements and new additions
  - In conjunction with line reconfiguration
• 11kv line & LT line refurbishment
• Meter replacements
• Remote monitoring of SAIDI, SAIFI and voltage levels
Key Performance Indicators
Key Key Performance Indicators (KKPI)

1. Transformer Failure Rate
2. Cable/Overhead Line Failure Rate (11 kV)
3. SAIDI – System Average Interruption Duration Index
4. SAIFI – System Average Interruption Frequency Index
5. CAIDI – Customer Average Interruption Duration Index.
6. Response time to voltage complaints.
7. End-to-end money-flow efficiency: Ratio of bank deposits to energy received (monetized) from Transco
8. Customer Satisfaction Index
9. AT& C Losses - Aggregate Technical and Commercial Losses
10. ROCE - Return on Capital Employed
11. O&M (Revenue Expenses) per unit energy input.
12. Training Statistics
## KKPI Algorithms

<table>
<thead>
<tr>
<th>Perspective</th>
<th>UOM</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAIDI – System Average Interruption Duration Index</td>
<td>Hours</td>
<td>( \sum ) (Duration of outage) ( \times ) (No. Customers affected) (Total No. of Customers)</td>
</tr>
<tr>
<td>Distribution Transformer Failures</td>
<td>%</td>
<td>(No of DTR failure during a year) Average No of DTRs during the year</td>
</tr>
<tr>
<td>CAIDI – Customer Average Interruption Duration Index</td>
<td>Minutes per occasion</td>
<td>( \sum ) (Customer Interruption Durations) (Total No. of Customer Interruptions) = SAIDI/SAIFI</td>
</tr>
<tr>
<td>OH/Cable Failure Rate</td>
<td>Faults per 100 ckt-km of 11 kV line</td>
<td>No of Faults during a year ( \times ) 100 (Total 11 kV circuit kilometer)</td>
</tr>
</tbody>
</table>
## KKPI Algorithms (cont.)

<table>
<thead>
<tr>
<th>Perspective</th>
<th>UOM</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAIFI – System Average Interruption Frequency Index</td>
<td>Instances</td>
<td>$\sum (\text{No of interruptions}) \times (\text{No Customers affected})$&lt;br&gt; (Total No. of Customers)</td>
</tr>
<tr>
<td>Customer Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer satisfaction index</td>
<td>% customers, somewhat or very satisfied</td>
<td>No of customers expressed satisfaction&lt;br&gt;Sample size of customers interviewed</td>
</tr>
<tr>
<td>Response Index to voltage complaint</td>
<td>% complaints resolved in time</td>
<td>No of complaints resolved within time-limits&lt;br&gt;(Total No of complaints)</td>
</tr>
</tbody>
</table>
### KKPI Algorithms (cont.)

<table>
<thead>
<tr>
<th>Perspective</th>
<th>UOM</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Technical &amp; Commercial Losses</td>
<td>%</td>
<td>Energy Realized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy Import</td>
</tr>
<tr>
<td>End-to-end Money Flow Efficiency</td>
<td>%</td>
<td>Collection Deposited In Bank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy Delivered to the Division (Monetised)</td>
</tr>
<tr>
<td>ROCE – Return on capital employed</td>
<td>%</td>
<td>(Profit before Interest &amp; Tax)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Long term loan + Equity)</td>
</tr>
<tr>
<td>O&amp;M expenses per unit of energy input</td>
<td>Paise</td>
<td>Total O &amp; M expenses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total energy imported</td>
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</tbody>
</table>
### KKPI Algorithms (cont.)

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td></td>
</tr>
<tr>
<td>% of People having undergone training</td>
<td>Actual Versus Training</td>
</tr>
</tbody>
</table>
There are some important lessons learned

• The ‘how’ of the process (not just the ‘what’) makes a big difference
• Begin with a definition of desired – and measurable – results
• An integrated and holistic approach get the best results
• Start in a small area, then set up “shadow” units to promulgate results
• Rigorous planning and analysis pays off
• Dedication of an experience team with the right skills mix a must
• Senior executive support is essential
• Collaboration is the most critical ingredient
Who are these discoms?
The Companies

• North Delhi Power, Ltd.
• Bangalore Electricity Supply Company
• Maharashtra State Electricity Distribution Company, Ltd.
• Madhya Gujarat Vij Company, Ltd.
Post Script
Inefficient irrigation pumps waste electricity ... and water

• Water is an increasingly scarce resource
• Many countries are pursuing increased agricultural production
• Pumping irrigation water from underground aquifers has increased
• Some countries have granted preferential tariffs to farmers
• This can lead to wasteful consumption of both electricity and water
• If efficient tariffs aren’t politically viable, an Ag DSM methodology is an option
• The approach is complex and has notable risks
• An article explaining a concept that is currently in a pilot process is available for those interested
Thank you

Additional information on these projects can be found at:
www.drumindia.com
www.waterenergynexus.com

If you send me a question by email, I will do my best to respond quickly:

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