RMA/IND-EMCAT-TR-22

Energy Management Consultation and Training Project (EMCAT): DSM Component and Project Management

Trip Report
INDIA

September 9 - October 1, 1996

Prepared by: Charles Fafard, Niels Wolter, and Dr. Hameed Nezhad
Resource Management Associates of Madison, Inc.

Prepared for: United States Agency for International Development (USAID)
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Preface

This report covers the trips made between September 9 and October 1, 1996, by Charles Fafard, Dr. Hameed Nezhad, and Mr. Niels Wolter under the Demand-Side Management (DSM) component of the Energy Management and Consultation and Training (EMCAT) Project for India. In addition, Mr. Fafard performed project management-related tasks. EMCAT is funded by the U.S. Agency for International Development (USAID) for which Resource Management Associates (RMA) serves as the prime contractor in implementing the project.

This is a working document published informally by RMA in a working document format to present the activities of the trip in a timely manner. It has thus received only light review.

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1. INTRODUCTION

During this period, the demand component of the EMCAT program has focused on disseminating information on the work developed over the past two years. Three RMA staff members (Charlie Fafard, program manager; Dr. Hameed Nezhad; and Niels Wolter) traveled to India in September to participate in several seminars and conferences. RMA staff participated as speakers and exhibitors in four separate programs during a three-week period.

In addition to disseminating information on project accomplishments, RMA staff also met with several other people to plan or coordinate future activities. RMA staff worked with a representative from the Electric Power Research Institute (EPRI) in identifying possible assistance to Ahmedabad Electric Company and other Indian Electric utilities in promoting energy efficiency programs. RMA staff also worked with a consultant for the International Institute for Energy Conservation (IIEC) in designing a revolving loan fund for AEC to finance their DSM programs. Other meetings had been planned with representatives of the World Bank and the Alliance to Save Energy, but these meetings did not take place because of scheduling difficulties.

During this trip, the fifteenth meeting of the Project Review Committee (PRC) was held. Charlie Fafard, Niels Wolter, and S. Easwaran attended the meeting on behalf of RMA. One of the major activities discussed was the energy efficiency conference being planned by RMA for January 1997. RMA will be looking to the PRC members to participate in the conference as well as to help in promoting the program. RMA is working with ASSOCHAM in Delhi in planning this conference.

2. TERI TRAINING PROGRAM

A training program on "Energy and Development" for Indian Administrative Service (IAS) officers was organized by Tata Energy Research Institute (TERI) and presented in Delhi. Dr. Hameed Nezhad (RMA) and Ms. Kavita Sinha (USAID) gave a joint presentation on "Policy Implications of AEC's DSM Pilot Project."

There were about thirty participants at this seminar. Ms. Sinha explained the objectives of USAID's EMCAT program. Her presentation was followed by Dr. Nezhad's presentation of AEC's DSM program design, implementation, and policy implications of these programs. Also discussed were barriers to expanded DSM activities in India. Many participants expressed interest in exploring DSM opportunities in their region. *Appendix 1* includes a letter from TERI indicating participants' positive feedback regarding the seminar and contains a copy of the program agenda. *Appendix 2* contains Dr. Nezhad's presentation to this conference.

3. CII CONFERENCE AND EXHIBIT

The Confederation of Indian Industry held its second Energy Summit meeting in Madras in September 1996. The first Energy Summit, held in 1994, was very successful, and this event was designed to build on that experience. CII's Southern Region office sponsored the event, which included many international as well as national speakers. The program was divided into several categories, including energy efficiency, renewable energy, and clean coal technologies. In addition, a product exhibition was included to enable sponsors and participants a chance to meet and to examine products. Many speakers emphasized the need for additional power capacity of 8,000-12,000 MW per year for the next two decades. They also stressed the need for expanded DSM programs in India.

Dr. Hameed Nezhad and Charlie Fafard both made presentations at the energy efficiency component of the conference. Mr. Fafard's presentation was on Energy Controls and Instrumentation, while Hameed Nezhad's presentation was on the DSM programs developed at Ahmedabad Electric Company. In addition, RMA purchased exhibition booth space, and distributed handouts, newsletters and reports from the EMCAT program. A large number of individuals stopped at the booth to learn more about the EMCAT program. *Appendix 2* contains Dr. Nezhad's presentation and Charlie Fafard's presentation is provided in *Appendix 3*. *Appendix 4* presents contact information collected at this event.

The general feeling was that the conference was very successful, and that many people were interested in the work being done by USAID in developing and furthering energy efficiency.

4. DA/DSM CONFERENCE

Dr. Hameed Nezhad and Mr. Niels Wolter attended the DA/DSM (distribution automation/demand side management) Asia sessions at the Power-Gen '96 conference and exhibition held in Delhi. The Power-Gen conference was very well attended, as there is great interest in the Indian private power development activities. There were about 15,000 attendees, 1,000 delegates, and 120 speakers at the conference. Unfortunately, the interest in the DSM session was very low as this aspect of the conference was overshadowed by the power generation topics. Very few Indians, other than those that presented papers, attended the session. The majority of the audience were either consulting firms, firms providing direct load control technologies (Scientific Atlanta, Siemens, Schlumberger, etc.), or Asian utilities (including Korea, and Taiwan).

A paper co-authored by Dr. Nezhad, Mrs. P.H. Patel (AEC), and Mr. S.B. Jani (AEC) was presented at the DA/DSM conference. The title of their paper was "Demand-Side Management: Evaluation of Options." Mr. Jani introduced AEC and its DSM objectives. Then, Dr. Nezhad discussed evaluation methodology and justification for selection of different DSM programs at AEC. *Appendix 5* contains the paper from Dr. Nezhad's presentation.

Mr. Wolter presented a paper entitled "Multi-story Building Water Pumping Efficiency Improvements: Recent Field Experiences with Ahmedabad Electricity Company, Ahmedabad India." The paper was coauthored by Mr. J. V. Mehta and Mr. S.B. Shah of AEC. Mr. Wolter presented the core of the paper; then, Mr. Mehta presented some of the technical and economic details of the paper. Several individuals from consulting firms and Asian Electric Utilities contacted Mr. Wolter and asked for copies of his paper, as it was not included in the conference proceedings. *Appendix 5* also includes the paper from Mr. Wolter's presentation.

5. PRC MEETING

Charlie Fafard presented an update on the status of RMA's EMCAT activities over the past quarter (see *Appendix 6* for PRC handout material). The major effort over the past quarter was focused on DSM activities with Ahmedabad Electric Company (AEC). RMA assisted AEC in coordinating an energy-efficient motors seminar, which was presented September 27-28, 1996. In addition to assisting in the seminar coordination, RMA staff prepared material for the exhibition and made presentations at the seminar.

During the past quarter, an LPD survey was conducted by US and Indian consultants in the textile industry. The survey was conducted at four Indian facilities in August, and the report will be drafted by the US consultant and forwarded to the Indian consultant for review. Plans were also being made for the next survey in the combined mini-steel/rolling steel mills. A US consultant was selected (the Indian consultant had been previously selected by IDBI, and preliminary energy data received by RMA in late August). The survey schedule was being finalized, when the US consultant changed his mind, and withdrew from the project. RMA staff was informed of this two days before the PRC meeting, and in turn relayed this information to the members of the PRC. RMA will proceed to identify other candidates for this activity.

RMA staff also emphasized the upcoming (January 1997) energy efficiency conference which will be held in Delhi. RMA will be looking to various members of the PRC to participate in the conference, which will focus on efforts undertaken by USAID on demand efficiency improvements. RMA will be working with ASSOCHAM to coordinate this conference.

6. ICLEI INTERACTIONS

September 23-26
Mr. Dan J. Goldberger, Director of Green Buildings, International Council for Local Environmental Initiatives (ICLEI), visited AEC as a consultant to the International Institute for Energy Conservation (IIEC) . Mr. Goldberger's task was to design a financial mechanism for the implementation of AEC's DSM programs. Dr. Nezhad accompanied Mr. Goldberger to meet the following AEC managers and senior officers of several local financial institutions:

- Mr. V.M. Thakor, AEC General Manager-Commercial, and Mr. J.V. Mehta, AEC's DSM Cell Advisor.
- Mr. Dharmesh S. Desai, Company Secretary at AEC.
- Mr. Ifran Koreishi, Area Manager of Housing Development Finance Corporation Limited
- Mr. Vasant Shah, Managing Director, Gujarat Lease Financing Limited
- Mr. Ravindra Biswas, Executive Vice President, Anagram Finance Limited

Mr. Goldberger also met with individuals at other financial institutions based in Mumbai. RMA staff did not accompany him to these meetings.

Mr. Goldberger had prepared a list of questions and three preliminary models which he presented to the people visited. *Appendix 7* includes the questions and the preliminary models. The conclusion drawn was that for the implementation of high-rise building water pump program, AEC must assume direct responsibility and perhaps create the revolving load fund internally. We are anticipating the draft report from Mr. Goldberger in the middle of October. His report will be forwarded to AEC and USAID upon completion.

Meeting Notes:

Meeting #1 Mr. V.M. Thakor, AEC General Manager-Commercial, and Mr. J.V. Mehta, AEC's DSM Cell Advisor

Initially, AEC is willing to play a central role in implementing the multi-story building water pump program, including convincing the customer to participate, providing savings guarantees, selecting contractors, overseeing contractors, providing quality control, borrowing the money in the name of the building committees, and managing the loan fund. AEC does not expect to make a profit by implementing the program.

AEC is willing to lead and oversee implementation of the water pump improvements; but gradually an outside agency needs to be trained as the implementing agency. It is Mr. Thakor's opinion that only small companies will be interested in the work, as it will come in a piecemeal manner. Note that AEC is showing some interest in forming an ESCO.

Several models for the relationships among the customer, AEC, the financial institution, and implementing agencies were considered. The lead alternative has the implementing agency in the center. The implementing agency is selected and overseen by AEC. AEC may provide the guarantees to the customer that the installation will be satisfactory. The implementing agency may hire other firms as subcontractors to implement portions of the work. AEC would get the financing, provide guarantees to the financial agency(ies) and distribute the funds to the building owners. AEC will head the marketing of the program, at least initially. Billing collection would be done by AEC through their utility bills.

To promote the program, AEC or a donor could buy down the interest rates for the loan.

The water pump efficiency improvements need to be promoted in new buildings as well as in existing buildings. This could be done by incorporating pumping system parameters in the city's building code.

Meeting #2 Irfan Koreishi of the Housing Development Finance Corporation (HDFC)

HDFC is in the private sector. They provide loans to the housing sector only. Their 28 branches across India provide financing for new construction and loans for repairs. Their recovery rate on loans is over 99%. Sixty percent of their loans go directly to individuals. They have several projects with the World Bank, International Finance Corporation, and General Electric Consumer Financing.

The water pumping improvements would best fit under the home improvement loan category. The term for these loans is typically one to two years. The current interest rate is about 18%. HDFC would prefer loaning the money to AEC who would then distribute it to their customers. If AEC borrows the money, they would provide it at a lower interest rate (but then AEC would carry more of the administrative costs). AEC could get an interest rate two points less than if the loans were distributed to individual building associations.

It needs to be determined if there is someway to bring down the interest rate. For some energy efficient technologies, customers can depreciate the full cost of an energy-efficient technology during its first year of operation. This would reduce interest rates, significantly.

Meeting # 3 Ravindra Biswas, Anagram Finance Limited

Anagram Finance's strategy is retail focused with 65 branches in 750 locations throughout India. They do small ticket financing to spread the risk; their car financing is number one in India. They have joint ventures with Australia and are discussing joint venture opportunities with GM. They have also financed solar water heaters and renewable-energy equipment. This equipment is 100% depreciable the first year of investment. Anagram will be interested in the water pump project if AEC is the borrower. Their interest rate at the time of interview was about 22%, and it could go down to 11% if the equipment is 100% depreciable.

Meeting # 4 Mr. Vasant Shah, Managing Director, Gujarat Lease Financing Limited

Gujarat Lease Financing is one of the largest (top 5) financing firms in India with 22 branches throughout India, and they are planning to open another 20 branches. They finance cars, trucks, computer equipment, fax machines, and appliances. Mr. Shah indicated that “people resist new technologies, and they look for problems to discredit the new technology.” For this reason, he suggested that there must be performance guarantees for the water pump project. Another suggestion was that AEC should propose 100% tax depreciation for the water pumping system. The organization to contact is Central Board of Direct Taxes (CBDT). Mr. Shah indicated that AEC has been their corporate customer and they are willing to provide loans to AEC for the water pump project.

7. AEC MOTOR SEMINAR

Electric motor-driven systems account for about 70% of India's energy usage and demand. There are more than 200,000 motors of all sizes in Ahmedabad, alone, creating a total load of about 675 MW. Realizing the importance of motors, particularly in industrial operations, AEC organized a motors seminar, with RMA's assistance, which was held in Ahmedabad on September 27 and 28.

RMA staff participated in several roles in the Energy-Efficient Motors Seminar. Charlie Fafard made a presentation in the opening session on the importance of DSM to electric utilities, Hameed Nezhad made a presentation on the multi-story water pump program, Niels Wolter demonstrated motor economic software, and Charlie Fafard chaired the closing session for the conference.

While in Ahmedabad, RMA staff visited several of the high-rise apartment buildings where the water pumping systems were modified as part of AEC's DSM program. USAID staff also visited these sites in preparation for a tour by an assistant USAID administrator, Ms. Margaret Carpenter. RMA staff reviewed the installation with AEC and their consultant (Professor Vyas) and made some minor suggestions for improving the piping installation.

On the second day of the motor seminar, the format switched from presentations in a great hall to small group demonstrations. In order to make the demonstrations effective, participants were segregated into ten groups and given half an hour at each of ten demonstration sites. Typically the demonstrations were very hands-on and allowed many opportunities for questions. Most demonstrations were given by local firms. Both the participants and the demonstrators found the demonstrations most useful. The participants were able to gain practical experiences, which is missed in seminars, and the demonstrators were given an opportunity to market their expertise and technologies.

The demonstrations covered the following areas:

Pumping systems audit
Flat belts
Motor systems auditing
Proper application of capacitors with
Harmonic filters
Best applications for adjustable-speed drives
Best applications for soft starters
Best practice for motor rewinding
Delta-to-star conversion of underloaded motors

Motor economics software demonstration
Motor efficiency software demonstration
Presentation of an integrated energy management system
Room air conditioner efficiency investigations
Energy-efficient motors: comparison to standard efficiency motor

The motor economics software was presented by RMA staff member, Mr. Niels Wolter. About 15 copies of the software were distributed to interested individuals. A “worksheet” version of the software was completed for individual without access to computers having spreadsheet applications. The motor economics forms are included as *Appendix 8*.

The Motor Seminar was a big success for AEC and RMA. There were about 200 enthusiastic participants at the seminar. The feedback received from the participants at the closing session clearly demonstrated the usefulness of the seminar, particularly the program which should be considered for any future technical seminar targeting utility customers.

8. EPRI VISIT TO AEC

Dr. Nezhad accompanied Mr. Tushar Prabhu, General Manager, International Operations, Customer Systems Group of EPRI, to Ahmedabad Textile Industry's Research Association (ATIRA) and AEC. The purpose of Mr. Prabhu's visit was to introduce EPRI services to ATIRA and AEC and to explore possible areas of assistance to AEC's DSM activities. A meeting was held with AEC management and the officers of AEC's Training Center. Mr. Prabhu suggested submission of a proposal by AEC for the establishment of a DSM training center at AEC. Dr. Nezhad assisted AEC in the preparation of this proposal. *Appendix 9* is a copy of this proposal.

9. MOTOR ALLY SESSION

Motor system efficiency improvements are easy to identify, but difficult to implement and often not cost-effective in India. Barriers for implementation of energy efficiency measures include lack of equipment availability, high costs, lack of appropriate standards, poor power quality, etc. Motor efficiency improvements can range from 1% to 7% depending on motor size, while motor system efficiency improvements can commonly exceed 50%. To complement AEC's Motor Seminar and to find solutions to some of the barriers to motor system efficiency improvements, RMA organized a "Motor Ally Session" from 7:30 to 9:30 p.m. on September 27. The were three major objectives of this session:

1. To identify specific barriers to motor system efficiency improvements in Gujarat.

2. To provide recommendations for motor system efficiency improvements.

3. To develop strategies to promote these improvements.

Based on the comments and the conclusions drawn by the ally group, RMA will prepare a paper reviewing the energy efficiency potential existing in motor systems and develop a detailed action plan to optimize motor system efficiency. This report will be distributed widely to Indian policy makers, utility managers, government officials, equipment manufacturers, energy institutes, aid agencies, industrial trade organizations, and other interested parties. A version of the report will also be submitted for publication in appropriate publications. The findings will also be discussed at the January seminar in Delhi.

RMA will actively encourage the motor ally session participants to meet on a quarterly basis to further promote the use of energy-efficient motor systems across the state of Gujarat and all of India.

Brainstorming Session

After each participant was introduced, a brainstorming session was held on each of the three areas listed above. The group then identified which of the identified barriers or strategies could be affected or promoted by the motor ally group. The barriers and strategies and their amenability to change or practicality is summarized below. A copy of the full questionnaire and a list of those attending this session are provided in *Appendix 10.*

QUESTION #1 What are the specific barriers to motor system efficiency improvements?

Amenable to Being Changed	Barrier
Yes	1. Awareness (of customers, engineering consultants, original equipment manufacturers, dealers and manufacturers) is needed
Yes	2. Availability (EEMs require a very long delivery period)
Yes	3. Cost (high)
Yes	4. Accuracy motor specifications (can not be trusted)
Yes	5. Need to demonstrable benefits and reliability of EEMs
Yes	6. Government policy (the following are needed: tariff reform, accelerated depreciation of EEMs, motor standards, etc.)
Yes	7. Code of practice for onsite motor efficiency testing in needed
Yes	8. Poor and lack of trust in rewinding practices (need to maintain efficiency level of EEMs)
No	9. Poor power quality
No	10. Energy cost is a small component of total costs

QUESTION #2 How specifically can motor system efficiency by improved?

Amenable to Being Promoted	Strategy
Yes	1. Energy audits
Yes	2. Technical support for motor manufacturers
Yes	3. Training for rewinders
No	4. Monetary incentives for energy efficient motors
Yes	5. Establish motor testing facilities

QUESTION #3 What are the best methods to promote these improvements?

Practicality	Strategy
Yes	1. Utility/Manufacturer partnership
No	2. Financial incentives
Yes	3. Awareness (general public and energy professionals)
No	4. Labeling and standards

Each of these areas will be more fully developed in the upcoming Motor Ally Session Strategy Report. RMA will forward a questionnaire to each of the participants soliciting further comments and opinions. These comments will be part of the position paper to be developed by RMA.

Appendix 1 - Letter from TERI & Program Agenda

No Electronic Version

APPENDIX 2 - DR. NEZHAD'S PRESENTATION TO TERI TRAINING PROGRAM AND THE CII CONFERENCE

Partial

DEMAND-SIDE MANAGEMENT AT AHMEDABAD ELECTRICITY COMPANY

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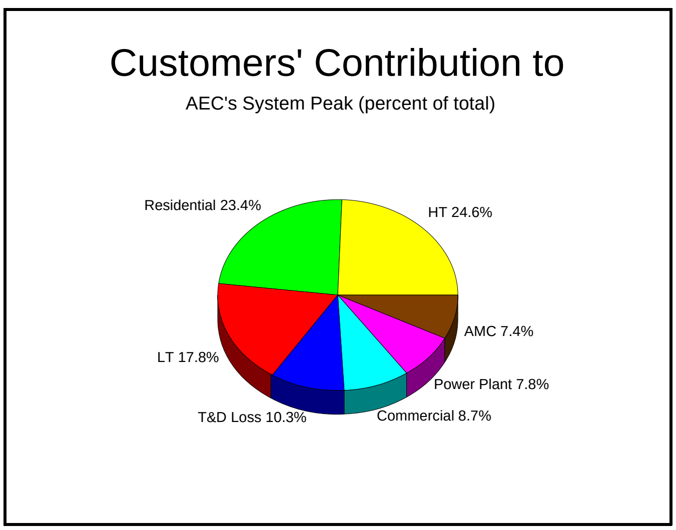
INTRODUCTION

Ahmedabad Electricity Company Ltd. (AEC) is a privately owned electric utility. AEC's 820,000 customers include industrial, commercial, residential, and a small number of agricultural users. AEC's demand ranges from 300 MW during off peak to 575 MW during peak periods. Peak demand normally occurs between 2 and 4 p.m. in summer and between 5 and 7 p.m. in winter. Total consumption in 1995 was around 2.4 billion kWh. Figure 1 shows customers' contribution to AEC's system peak.

AEC operates with a load factor of about 70%, which is much higher than the national average. However, AEC purchases about 10% of its power requirement from the Gujarat State Electricity Board (GEB) at a cost of about 50% higher than its marginal cost. Power purchases are most commonly made between the hours of 7 a.m. to 12 p.m. and 4 p.m. to 11 p.m. Even with power purchases, it is fairly common that peak demand cannot be met. In these cases, electricity supply to High-Tension (HT) customers, who pay the highest power tariff and account for a significant share of AEC's profits, are curtailed. The high costs of purchased power and new generation, as well as common power outages, underlie AEC's interest in promoting Demand-Side Management (DSM).

Realizing the significant potential for improving energy efficiency, particularly in electricity utilization, the United States Agency for International Development (USAID) and the Industrial Development Bank of India (IDBI) initiated a pilot project on Demand-Side Management at AEC. Resource Management Associates of Madison (RMA) was selected as the prime contractor in implementing this project.

Figure 1



THE PILOT PROJECT AT AHMEDABAD ELECTRICITY COMPANY

The following criteria were used to select pilot programs at AEC:

- Impacts on system peak
- Avoided cost to the utility
- Program visibility to consumers
- Ease of implementation
- Implementation lead time
- Availability of equipment
- Availability of data
- Replicability
- Market acceptability

Considering the above criteria and using a multi-attribute decision analysis tool the following programs were selected.

1. High-Rise Buildings Water Pump Program

In Ahmedabad municipal water is supplied to residents only a few hours a day, which happens to coincide partially with the utility's system peak. There are two water tanks in each building. The lower tank receives water from the city, when available. The upper tank, which is built on the top of the building, provides a continuous supply of water to residents. Water is pumped from the lower tank to the upper tank. There are about 4,000 such buildings in Ahmedabad using 4 million kWh of electricity and drawing about 20 MW.

The results of tests conducted at four sites showed energy savings ranging from 22% to 65% and demand savings ranging from 5% to 48% (see Table 1). Our analysis indicates that at least 25% savings in energy and 10% savings in demand could be achieved when this program is fully implements. Based on these assumptions, energy savings of about one million kWh and demand savings of about 2 MW could be achieved.

Table 1
Impacts of pumping system improvements at three sites in Ahmedabad

Site	System Efficiency After Improvements	kWh Savings	kW Savings	Payback Period
Site #1 Eshita Apartment Complex: C Block delivery and suction pipe, pumpset and foot valve replacement	33%	65%	43%	7 months
Site #2 Kothawala Apartment Complex pumpset and foot valve replacement	29%	20%	63%	9 months
Site #3 Kirtisagar Apartment Complex delivery and suction pipe, pumpset and foot valve replacement	30%	38%	46%	11 months
Site #4 Neeldeep Apartment Complex Delivery and suction pipe, pumpset, and foot valve replacement	45%	38%	35%	12 months

2. Flour Mill Program

It is customary in India to have wheat ground daily, weekly, or biweekly. Residents take their wheat to the neighborhood flour mills to be processed. There are about 3,000 such small flour mills in Ahmedabad. Four flour mills were tested by the end of March 1996. A summary of results are as follows:

<u>Motor and mill maintenance</u>
Savings of 2%-5%

<u>Capacitor installation</u>
Power factor improvement from 0.75 to 0.92

<u>Drive belt maintenance and conversion from V-belt to flat belt</u>
Savings from 1% to 12%

<u>Increasing mill speed</u>
Savings to a break even point, after which efficiency declines. As grinding speed is increased, the flour may be scorched.

<u>Installation of energy efficient motor</u>
Power consumption was reduced from 5.9 to 5.3 kW.
Energy consumption was reduced from 2.75 to 2.3 kWh per 50 kg of wheat.
Time to grind 50 kg of wheat was reduced from 28 to 26 minutes.

By improving the power factor, the reactive power demand could be reduced by about 1,000 kVA. Power factor improvements will not only reduce reactive power demand, but also reduce distribution losses in low voltage distribution system which is of great concern to the utility. This condition of low power factor is common among most industrial and commercial customers.

3. Time-of-Use Meters Program

Seventy-two TOU meters, purchased with USAID funds, were installed for AEC's high-tension (HT) customers. These meters measure kW, kVA, kWh, kVAR, and Power Factor (PF). AEC has installed 115 additional meters and is planning to install TOU meters for all of its 350 HT industrial customers as well as Low-Tension Maximum Demand (LTMD) customers; this category includes smaller industries and large commercial buildings. Data collected by these meters have been compiled since July 1995. Computer software is being developed to analyze data collected from these meters for load management and tariff restructuring purposes as outlined below:

- Tariff design
- Customers' demand coincident with system peak
- Customers' peak demand
- Customer contribution to Transmission & Distribution (T&D) losses
- Customer load profile

- Reactive power usage and improvement
- Power cut monitoring
- Customer classification and pattern
- Distribution system planning
- Load forecasting

4. Motor Program

The purpose of this program is to support penetration of energy-efficient motors and effective motor specification and maintenance practices in Ahmedabad. There are more than 2,000 motors of all sizes and functions in Ahmedabad. Even if 5% of these motors were replaced by energy-efficient ones, 800,000 kWh of energy will be saved annually, and demand will be reduced by 2 MW; this demand is mostly peak coincident. The following are some of the tests conducted so far. It should be mentioned that motor tests are also being conducted in other programs such as the flour mill, the HT energy audit, and at Ahmedabad Municipal Corporation's (AMC) water supply system.

- Testing of 5-HP and 7.5-HP rewound motors were conducted in the testing lab. Efficiencies were about 5 to 7% lower than the original manufacturers' suggested efficiencies.
- A local manufacturer improved the efficiency of a 7.5-HP motor from 85% to 87%. This improvement was the result of mechanical overhauling of this motor;
- To improve the energy efficiency of the motor after rewinding, the mechanical components of a 7.5-HP motor was overhauled. The energy efficiency improved from 81% to 85%. A study of the efficiency improvements resulting from efficient rewinding is underway.

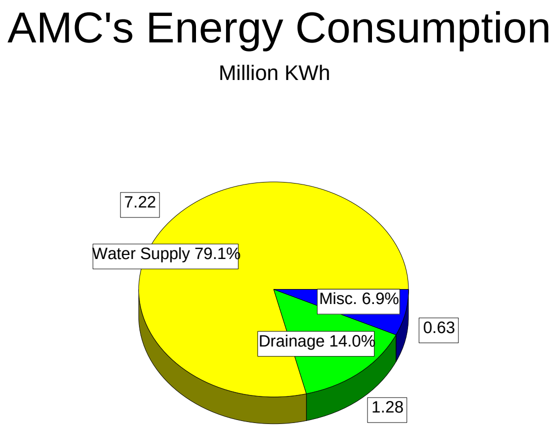
5. High-Tension Industrial Energy Audits

The High-Tension (HT) industrial group accounts for 25% of AEC's total system peak demand. The purpose of the Energy Audit Program is to improve the energy efficiency and reduce demand. Based on twenty-two preliminary audits and five detailed audits, it is estimated that with appropriate energy-efficiency measures, 2.4 million kWh can be saved monthly and customer demand can be reduced by about 8 MW. All HT industrial load is coincident with AEC's system peak demand.

6. Energy Conservation Program at Ahmedabad Municipal Corporation (AMC)

AMC is AEC's largest customer. As Figure 2 shows, the water supply system consumes 79% of total energy used by AMC followed by the drainage system (14%), and other uses (only 6.9%), which include street lighting, office and school buildings, and hospitals. Total demand varies between 15 MW and 30 MW over a 24-hour period. The maximum peak demand is used for only three hours per day. This pattern of energy use is not only costly to AMC; it is also very costly to AEC. Because the water supply system accounts for most of the power consumption and demand, the DSM effort initially focuses on this area.

Figure 2



Based on the recommendations from a preliminary energy audit the following tests were conducted:

< An existing 85-HP bore well pump had an efficiency of 46%. After renovating its pump bowl assembly, the pump efficiency increased to 54%. With installation of a new motor pumpset, the efficiency improved further to 60%

< An existing French well pump had an efficiency of 45% (compared to the manufacturer's rated efficiency of 65%). With replacement of the 8-inch delivery pipe by a 10-inch pipe, efficiency improved to 54%.

< Power factor was measured before and after the installation of capacitors at one 85-HP submersible bore well pump. (There are 200 such pumps in operation in the water intake system). The results were as follows:
  Power factor improved from 0.779 to 0.951;
  Power loss in distribution cable reduced from 6 kW to 4 kW;
  Estimated annual savings per pump is Rs 25,620;
  Estimated payback period is 4 months.

< Installation of a 25 kVAR capacitor at a 85-HP French well pump improved power factor from 0.82 to 0.93.

7. Training Programs

Several AEC senior managers and engineers have been trained in the United States on a variety of topics related to demand side management ranging from energy auditing and accounting to tariff restructuring. RMA also conducted training sessions at AEC during each visit.

8. Information Dissemination

Several seminar/workshops have been offered, and more are planned, covering all the above programs. Also, many articles, written in both English and Gujarati, were published in local and regional newspapers.

DSM IMPLEMENTATION AT AEC

The most important factor used by AEC to select a DSM Program for implementation is the financial impact on the utility. There are a large number of variables affecting a DSM program's financial feasibility, for example, future tariffs, choice of a new power plant, future capacity costs, and fuel costs. Because there are great uncertainties regarding the impacts of the above factors on the utility, our analyses are based on the following assumptions:

1. No change in existing tariffs
2. No change in import tariffs
3. New plant is coal-based
4. Plant life is 25 years
5. Annual interest rate of 20%
6. T & D losses of 5% for HT sector and 15% for LT sector
7. Prompt payment discounts of 3% for residential customers and 2% for all others

Two alternative scenarios are considered for AEC to meet its power shortfalls in the future. The first scenario would be the continuation of the current status — importing power from the State Electricity Board. The second scenario considers construction of a new coal-based plant. Figures 3 and 4 summarize the results of our analysis.

Based on these figures, AEC's main objective should be demand reduction in all sectors. Currently AEC benefits by selling imported power to HT, LTMD, LTMD-WP, and AMC-HT customers. However, imported power charges from GEB were established on May 21, 1993, and have not changed since that date. Because of the increasing gap between power demand and supply in Gujarat, it is very likely that costs of imports will increase substantially in the near future, making demand reduction profitable in all sectors.

Figure 3

Financial Impacts of AEC's Potential DSM Programs

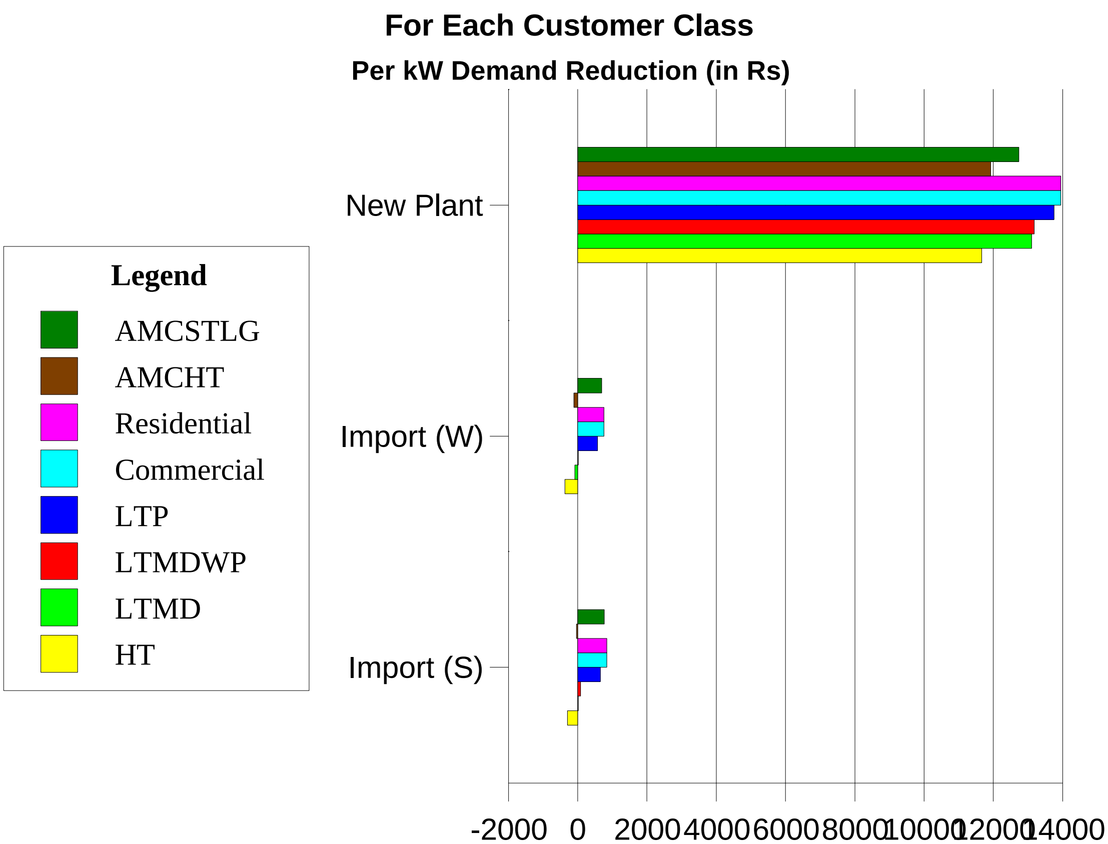
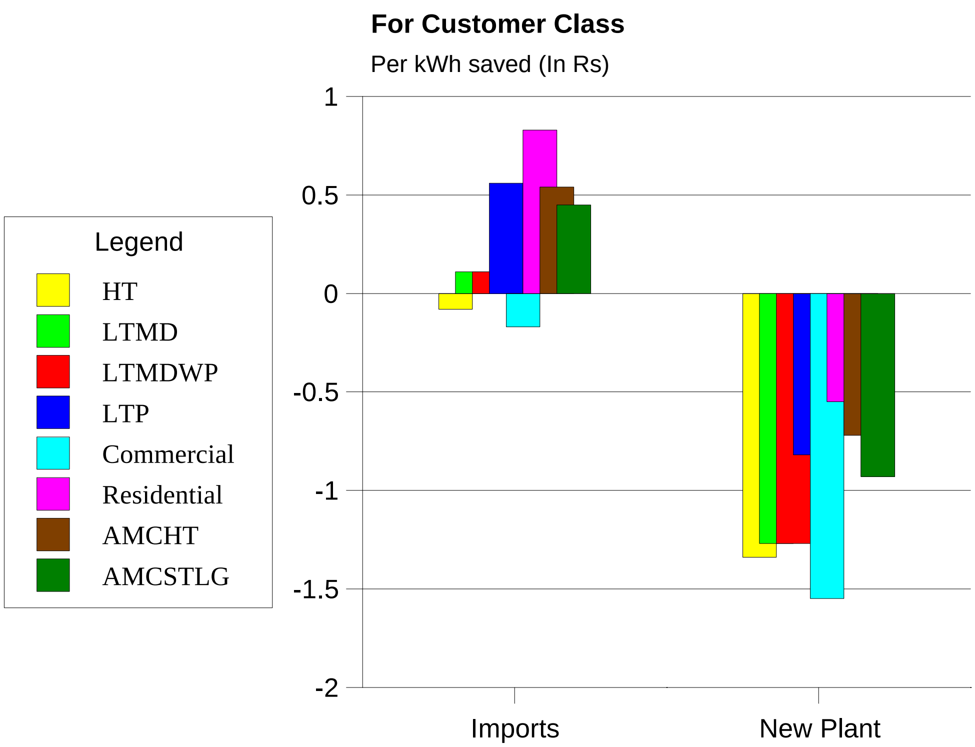


Figure 4

Financial Impacts of AEC's Potential DSM Programs



CONCLUDING REMARKS

- Customer acceptance is the first requirement of successful DSM program implementation. In less than one year, AEC's customer attitude toward DSM has changed from being highly suspicious to being very excited. At a presentation to a group of utility managers from Gujarat Electricity Board (GEB) and Surat Electricity Company (SEC), Mrs. Patel, Manager of DSM Cell at AEC stated:

  > "When we sent load research questionnaires to our customers last year, they did not complete them. They thought we were from the vigilance department. They were not sharing any of their load details with us. Through the DSM pilot projects, we visited a large number of our customers, we listened to them, and we realized their needs and concerns. Now, most of our customers think of DSM as a social responsibility. We have built up our customers' confidence."

- AEC's top-level management is now convinced that DSM is a good option for the company. As a result, their commitment to DSM has continued to grow. This is reflected in the DSM cell’s growing staff and budget.

- AEC's DSM activities have already improved the image of the utility among its customers. This was reflected in the participants' positive comments at several seminars and workshops sponsored by AEC, and their interest in hosting demonstrations of DSM technologies.

- Two years ago DSM was a new concept for AEC. Now, through DSM training and design and the development and implementation of several DSM programs, AEC personnel have been provided the theoretical and practical experiences needed to sustain and expand AEC’s DSM activities. The “bottom-up” approach taken by the project team allowed AEC management and staff to develop a hands-on understanding of DSM to support their theoretical understanding. Both theoretical and practical types knowledge are required to build a sustainable DSM movement in India.

- A major barrier experienced by AEC in the full-scale implementation of DSM strategies include lack of sufficient funding for implementation. To overcome such barrier, AEC has applied for several grants and loans from IDBI and international agencies.

- Residential and commercial sectors are the most profitable sectors to AEC as far as DSM is concerned. AEC has already begun conducting audits of these types of buildings, particularly for lighting and air-conditioning, which are major contributors to AEC's peak load.

- AEC’s DSM experience can easily be replicated at other utilities throughout India. This “technology transfer” process has already begun. Representatives from RMA, the Institute of International Education (IIE), and Hagler Bailly Consulting group conducted a needs assessment study of Gujarat Electricity Board (GEB) and Surat Electricity Company (SEC). The lessons learned and progress made with AEC will be used to accelerate the implementation of DSM programs at GEB and SEC. Over the next year, presentations on

AEC's DSM experience will be given at the DA/DSM conference in New Delhi, the CII conference in Madras, the ACEE conference in Atlanta, the EMCAT project conference in Delhi, and the IAEE conference in Delhi.

< DSM implementation, particularly in India, is a slow process and requires joint efforts by the utilities, consumers, government, and manufacturers, as well as financial institutions. Each of these groups must be educated and convinced of DSM’s benefits. Indian business people often require demonstrations of each and every aspect of a new idea or technology before they can be convinced of its value. This need for a hands-on understanding of new concepts and technologies by all parties is reducing the rate of DSM’s acceptance and program implementation. Demonstrations, seminars, workshops and one-on-one interaction with customers and counterparts have been used at AEC to overcome this barrier.

Secondly, the Indian business and social climate is very different from that of the countries where DSM was developed and where it has been most widely implemented. Thus, DSM program concepts, program details, and DSM technologies developed in the West often need to be modified for India.

< A major barrier experienced by AEC in the full-scale implementation of DSM programs is the lack of sufficient funding. Unlike the US where regulatory commissions allowed or even required utilities to develop programs and finance them from their rate base, no such funding is currently available or possible in India. Rather DSM programs have to be funded by general operating funds. Thus, funds are limited because the programs initially eat into profits. To overcome this barrier in the near term, AEC has applied for several grants and loans from IDBI and other international agencies. In the longer term, regulatory changes are needed at the Federal and State levels.

< DSM programs in the residential and commercial sectors offer the largest rewards to AEC. This is due to low electricity rates and the pattern of energy consumption by these groups. AEC has already begun conducting audits of commercial and residential buildings, particularly for lighting, air-conditioning, and water pumping, which are major contributors to AEC's peak load.

< To accelerate implementation of DSM programs, AEC should encourage creation of ESCOs in Ahmedabad, one of which could be a subsidiary of AEC. Currently, there are no full-service ESCOs operating in Ahmedabad. Leasing agents in Ahmedabad have already expressed an interest in financing energy-efficient equipment. Their interest is partly because 100% of energy-efficient equipment costs can be depreciated over the first year of operation.

< Given the Indian social and business climate standard customer or dealer rebate programs are unlikely to be successful. Yet there are opportunities to develop innovative customer rebate programs. For example, to ensure prompt implementation of DSM measures, the rebates should be given through customers' utility bills over a long period of time. Or a “star program" could be created, where each measure is rated based on the benefits to the customer

and AEC. The rating would be expressed in the number of stars the technology is given. The rebates would be based on the cumulative number of stars earned by the customer.

ACKNOWLEDGMENTS

The author would like to acknowledge the AEC's DSM Cell team whose members played key role in the design, development, and implementation of DSM programs. The DSM Cell team are: Mr. V.M. Thakor, Mr. S.B. Jani, Mrs. P.H. Patel, Mr. J.V. Mehta, Mr. H. N. Mehta, Mr. P.A. Purohit, Mr. D.R. Parmar, Mr. B. R. Shah and Mr. K. J. Shah. The author would also like to thank Mr. N. Wolter and Ms. L. Schmidt of RMA for their support in completing this document.

APPENDIX 3 - MR. FAFARD'S PRESENTATION TO THE CII CONFERENCE

No Electronic Version Attached

APPENDIX 4 - BUSINESS CARDS FROM CII CONFERENCE

No Electronic Version

APPENDIX 5 - DR. NEZHAD'S AND MR. WOLTER'S PRESENTATIONS TO THE DA/DSM CONFERENCE

PARTIAL

DEMAND SIDE MANAGEMENT

EVALUATION OF OPTIONS

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DEMAND SIDE MANAGEMENT
Evaluation of Options

Introduction

In developing countries the information needed to design DSM programs is commonly unavailable, inadequate or unreliable. Yet, utility managers are faced with developing successful DSM strategies which are profitable to the utility and acceptable to their customers as well as policy makers. A systematic methodology is needed which allows managers to view the big picture and consider all the critical factors of the decision problem. A new decision making tool (the "DECIDE" software), which incorporates the judgements of managers and outside experts to make decisions, has been developed. DECIDE is being used to evaluate DSM options at Ahmedabad Electric Company Ltd. (AEC). AEC is the first Indian utility to develop a comprehensive DSM program.

DECIDE is a powerful tool for structuring and solving complex decision problems and is particularly effective when dealing with qualitative problems or when there are no valid quantitative data available. By encouraging people to work together in solving a particular problem, DECIDE improves communications among the parties involved. Also, by documenting the judgmental process, DECIDE helps utility managers defend their plans logically when facing the public or regulatory agencies.

DECIDE has been used to solve variety of problems in planning, prediction, resource allocation, decision making, and conflict resolution. This hierarchical method is explained in the following sections.

The Methodology

Step 1: Constructing the Hierarchy

Structuring the hierarchy is truly an art. It involves the following steps:

1. We begin with a basic idea or object and break it down into its major parts. These parts are then broken into smaller parts and so on. This decomposition and organization of the problem creates a hierarchy.

2. Using fact, experience, insight and intuition, we determine interrelationships and inter-dependence of these parts with each other and look at the "big picture. " This process requires creativity, experience, and systematic thinking.

In Herbert Simon's words:
"In the application of the architecture of complex systems hierarchy simply means a set of Chinese boxes of a particular kind. A set of Chinese boxes usually consist of a box enclosing a second box, which, in turn, encloses a third-the recursion continuing as long as the patience of the craftsman holds out......It is commonplace observation that nature loves hierarchies. For

example, complex biological organisms are made up of subsystems-digestive, circulatory, and son on. These subsystems are composed of organs, organs of tissues, tissues of cells. The cell is, in turn, a hierarchically organized unit, with nucleus, cell wall, cytoplasm, and other subparts". The term "hierarchy" in Simon's view refers to "all complex systems analyzable into successive sets of subsystems" (Simon 1960).

Step 2: Pairwise Comparisons

Using fact and personal judgment we determine the degree of importance of the elements at a particular level with respect to those in the immediate upper level by a procedure of pairwise comparisons.

In comparing two elements, we find that one of them is either equally as important or more important than the other. If there are no numeric values for these two elements, we must use a scale to express our feelings numerically. In this method a relative scale from one to one hundred is used.

Step 3: Computing Relative weights of the Elements

Using normalized geometric means of the judgment values, priorities of the elements in a matrix are computed.

Step 4: Computing Composite Weights of the Elements at the Lowest Level of the Hierarchy

Composite weights are now determined for the elements in each level, beginning with level 3. For example, the weights obtained for an element in level 3 for each criterion in level 2, is multiplied by the weight of that criterion and the products summed for all criteria. This procedure is repeated for the elements in the lower levels of the hierarchy.

The judgment consistencies are determined by comparing the ratios of judgment values for each pair of elements. For example, the consistency index of the $_{ij}$th entry of the matrix would be:

EC = $a_{1j}/a_{1i} : a_{ij}$, where EC is the Element Consistency, a_{1j}, a_{1i}, are the relative weights of the $_j$th and $_i$th elements with the first element, and a_{ij} is their relative weights with each other. For perfect consistency EC must be one.

The consistency of the matrix is simply the average of the element consistencies. The consistency of our judgments depends on (1) the homogeneity of the elements in a group, i.e. not comparing a grain of sand with a mountain according to their sizes or onions with apples according to their tastes; (2) the number of elements in the group -- psychological experiments show that an individual cannot simultaneously compare more than seven objects (plus or minus two) without being confused (Miller 1956); and (3) the knowledge of the analyst about the problem under study.

Application of DECIDE to DSM Evaluation

1. The Pilot Project at Ahmedabad Electricity Company

Realizing the significant potential for improving energy efficiency, particularly in electricity utilization, United States Agency for International Development (USAID) and the Industrial Development Bank of India (IDBI) initiated a pilot project on Demand-Side Management in one of Indian utilities. Ahmedabad Electricity Company (AEC) which is one of few private sector utilities in India was selected for this project. Resource Management Associates of Madison (RMA) was selected as the prime contractor in implementing this project.

AEC is the sole supplier of electricity to Ahmedabad, a city of about 4 million people. Ahmedabad is the second most wealthy city in western India after Bombay. AEC's 820,000 customers include industrial, commercial, residential, and agricultural users. It's maximum demand is about 560 MW of which 90% is generated by the company and the rest is being imported from a neighboring government-run utility during peak periods at relatively high cost . AEC's demand ranges from 300 MW during off peak to 560 MW during peak periods. Peak demand normally occurs around 2-4 PM in summer and between 5-7 PM in winter season. Total consumption in 1995 was around 2.4 billion Kwh.

The Pilot Programs

The following pilot programs are considered for this analysis.

1. High Rise Buildings Water Pump Program
In Ahmedabad and most of India municipal water is supplied to residents only a few hours a day which happens to coincide partially with the utility's system peak. There are two water tanks in each building. The lower tank receives water from the city when available. The upper tank which is built on the top of the building provides continuous supply of water to residents. Water is pumped from the lower tank to the upper tank. There are about 4000 such buildings in Ahmedabad using 4 million Kwh of electricity and drawing about 20 MW.

The results of tests conducted at five sites showed energy savings ranging from 22% to 65% and demand savings ranging from 5% to 48%. Our analysis indicate that at least 25% savings in energy and 10% savings in demand could be achieved when this program is fully implements. Based on these assumptions, energy savings of about one million Kwh and demand savings of about 2 MW could be achieved.

2. Flour Mill Program
It is customary in India to have wheat ground daily, weekly or biweekly. Residents take their wheat to the neighborhood flour mills to be processed. There are about 3000 such small flour mills in Ahmedabad.

Several flour mills were tested and results indicate that by installation of energy efficient motors and improving the drive system, about 3-5% energy could be saved. Also, by improving the power factor, the reactive power demand could be reduced by about 1000 KVA. Power factor improvements will not only reduce reactive power demand, but also reduce distribution losses in low voltage distribution system which is of great concern to the utility. This condition of low power factor is common among most industrial and commercial customers.

3. Motor Program
The purpose of this program is to support penetration of energy-efficient motors and effective motor specification and maintenance practices in Ahmedabad. There are more than 2000 motors of all sizes and functions in Ahmedabad. Even if 5% of these motors were replaced by energy-efficient ones, 800,000 Kwh of energy will be saved annually, and demand will be reduced by 2 MW; this demand is mostly peak coincident.

4. High-Tension Industrial Energy Audits
The High Tension (HT) industrial group accounts for 36% of AEC's total system peak demand. The purpose of the Energy Audit Program is to improve the energy efficiency and reduce demand. Based on 22 preliminary audits and five detailed audits, it is estimated that with appropriate energy-efficiency measures, 2.4 million Kwh can be saved monthly, and customer demand can be reduced by about 8 MW. All HT industrial load is coincident with AEC's system peak demand.

Evaluation Criteria

The following criteria were used to evaluate DSM programs:

1. Avoided cost to AEC considering two scenarios, imported power and new generation scenarios.

2. Payback period to customers which includes initial cost, energy savings, and demand savings

3. Ease of implementation which includes reachability, technological factors, and human resource requirements

4. Implementation cost to AEC which includes educational and promotional activities, direct incentives, tariff incentives, and direct assistance costs

5. Lead time for implementation

Figure 1 shows the decision model.

Figure 1: DECIDE Model for DSM Evaluation

DSM Evaluation Model

Criteria:	Avoided	Payback	Cost	Lead	Ease

Subcriteria: Reach Tech. Human

DSM Options: Water Pump Flour Mill HT Audit Motor

Priority Weights

Using DECIDE, the following priorities were assigned to the above criteria and DSM options.

<u>Priorities of Criteria:</u>

Avoided cost to AEC:	30%
Payback period to customers:	24%
Ease of implementation:	20%
Implementation cost:	16%
Implementation lead time:	10%

<u>Priorities of DSM Options:</u>

Water Pump Program:	37%
Flour Mill:	21%
HT Audit:	23%
Motor Program:	19%

Sensitivity Analysis

One can change the priorities of the elements at one level of the hierarchy and analyze their impacts on other levels without going through the detailed pairwise comparisons. For example, if the weights of the criteria are changed to represent higher priority for implementation cost, as shown below, one can see the changes in the priorities of the programs.

Priority Weights

	Before	After
<u>Priorities of Criteria:</u>		
Avoided cost to AEC:	30%	25%
Payback period to customers:	24%	20%
Ease of implementation:	20%	13%
Implementation cost:	16%	35%
Implementation lead time:	10%	7%
<u>Priorities of DSM Options:</u>		
Water Pump Program:	37%	33%
Flour Mill:	21%	23%
HT Audit:	23%	24%
Motor Program:	19%	19%

Based on these priorities, the multi story water pump program has become AEC's top priority program for full-scale implementation .

Conclusions

Today, most managers, particularly those with the electric utility companies, face complex decision situations which involves numerous factors some of which are qualitative and others, though quantitative, no reliable data is available. When faced with such a complex problem , a manager cannot rely on his intuition alone. There must be a way to break down such complex problem into its component parts more systematically and analyze each part individually. Then, one can utilize the power of today's computers to synthesize these parts back together again and look at the big picture. DECIDE is such a tool.

In this paper, DECIDE has been used to solve the complex DSM evaluation problem for Ahmedabad Electricity Company. The advantages of this process:

(*a*) It provides a framework for breaking down such a large and complex decision problem into smaller and more manageable decisions.

(*b*) It leaves a permanent record of all the criteria, alternatives and their assigned priorities.

(*c*) It enhances our understanding of the problem by going through it step by step.

(*d*) It considers interactions and interdependence among all factors influencing our decisions.

(*e*) It incorporates data and judgments of experts into the model in a logical way.

(*f*) It is an excellent tool for resolving conflict among actors with different objectives and/or priorities.

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MULTI-STORY BUILDING WATER PUMPING EFFICIENCY IMPROVEMENTS:

RECENT FIELD EXPERIENCES WITH AHMEDABAD ELECTRICITY COMPANY, AHMEDABAD, INDIA

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Abstract

Ahmedabad Electricity Company Ltd. (AEC) is the first Indian utility to initiate a comprehensive, Demand-Side Management (DSM) program. The high cost of purchasing power, expensive supply options, and common power outages underlie AEC's interest in promoting DSM. Under a U.S. Agency for International Development (USAID) contract, Resource Management Associates (RMA) is providing technical assistance to AEC. Five pilot DSM programs have been developed thus far. The most successful is the multistory building water pumping program (WPP). Water pumps are used at about 4,000 multi-story buildings in Ahmedabad, and have a total demand of 20 MW and 4 million kWh/month. The WPP relies on energy efficiency measures such as properly sized, high-efficiency pumps and plumbing improvements, which optimize system performance. Three field tests have energy savings of 20% to 65%, demand savings from 40% to 50%, and payback periods of less than two years. An estimated 20% energy savings and 40% demand savings are achievable at the typical residential or commercial multistory building. The WPP has the potential to save 5 million kWh/year and 4 MW of (peak coincident) demand. AEC has developed a screening tool to rapidly identify WPP candidates. The WPP employs domestically available technologies and skills and can be easily replicated across India and other developing countries.

Introduction

AEC is a 550-MW, privately owned electric utility, providing power to the cities of Ahmedabad and Gandhinagar in the state of Gujarat in India. AEC serves 850,000 customers, 450 of them high- tension (HT) whose demands are greater than 100 kW. AEC is one of three privately-owned electric utilities in India. AEC's annual peak demand is 575 MW, which is about 100 MW higher than its derated supply capacity of 475 MW. The utility operates with a load factor of about 70%, which is much higher than the national average.

AEC is unable to meet peak demand and must purchase power from the Gujarat State Electricity Board (GEB) at a cost about 50% higher than its marginal cost. Power purchases are most commonly made between the hours of 7 a.m. to 12 p.m. and 4 p.m. to 11 p.m. Even with power purchases, it is fairly common that peak demand cannot be met. In these cases, electricity supply to HT customers, who pay the highest power tariff and account for a significant share of AEC's profits, are curtailed. In other words, every peak kWh saved through end-use efficiency improvements at AEC's non-HT customers, could be sold to HT customers where the profit margin is larger.

Peak demand shortfalls are only anticipated to increase, as demand has been increasing at a rate of over 5% annually while generation capacity expansion has lagged. Given the high cost of power purchases, revenue losses from AEC's most profitable customer sector, and the looming electric power crisis, AEC management is highly motivated to reduce peak demand by pursuing DSM.

In March 1994, AEC was identified as the demonstration site for a DSM Technical Assistance effort under the demand-side component of USAID's three-year Energy Management Consultation and Training (EMCAT) Project. RMA is the technical assistance contractor working for USAID and is working with AEC to design, implement, and evaluate a comprehensive set of DSM programs. This set of DSM programs, which are at varying stages of implementation, target small flour mills, commercial and residential multi-story building water pumping, municipal water pumping, HT industrial and commercial enterprises, and motor users. This paper focuses on the multi-story building water pumping program (WPP).

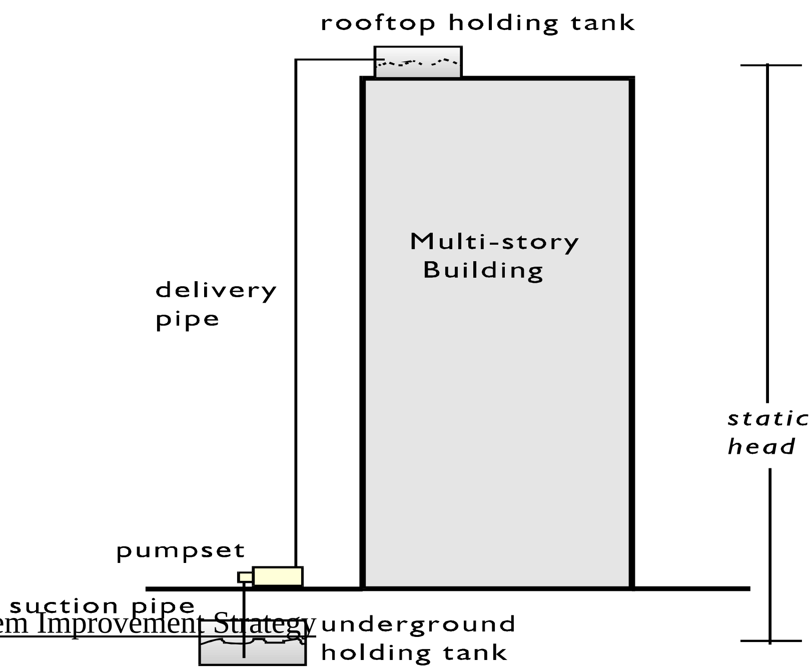
Description of Multi-story Building Water Pumping Systems in Ahmedabad

The multi-story buildings included in this study are dispersed across the city of Ahmedabad. These residential and commercial occupant-owned buildings have from five to eleven floors. In Ahmedabad alone there are an estimated 4,000 such buildings. The majority were built over the last ten years. Each building provides residences for anywhere from 100 to 225 people. Typically, a group of building occupants, known as the building association, manages the building's common areas and infrastructure facilities. Among the building's facilities, water pumping requires about 65% of facility electricity use. Elevators, common-area lighting, and others consume the balance.

All pumping systems have a similar design (as shown in *Figure 1*). The majority of the city's buildings are supplied by the city water system, operated by the Ahmedabad Municipal Corporation (AMC). AMC delivers water to underground holding tanks twice daily in the morning from 6:00 a.m. to 8:00 a.m., and in the early evening between 6 p.m. and 7 p.m[1]. Typically, each building has its own underground holding tank. The underground tanks range in volume from 10 to 22.5 m^3.

After AMC supplies water to a given region, each building's pumping system is activated and water is pumped from the underground holding tank to the rooftop tank, using either a submersible pump or a standard monoblock pumpset. Building water pumps operate from five to ten hours a day, depending on the capacity of the pump and the requirements of the building residents. The roof top tank typically has a capacity ranging from 7.5 to 17.5 m^3. When a monoblock pump is used, a suction pipe runs from the underground tank to the pump, which is typically positioned a few feet above the holding tank (as shown in *Figure 1*). The pumps have rated capacities of 5, 7.5, 10, 12.5 or 15 hp.

Figure 1

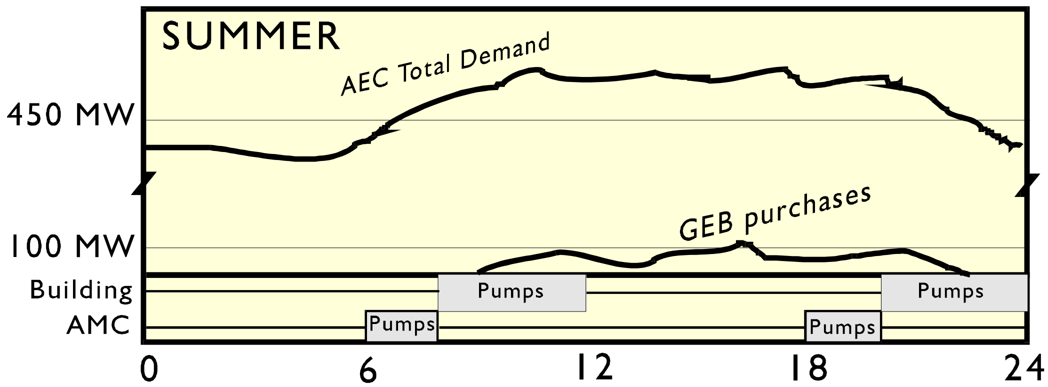


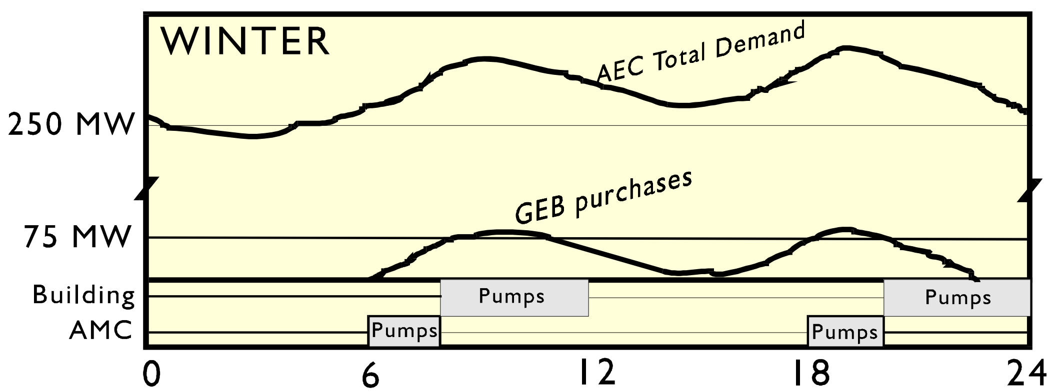
Pumping System Improvement Strategy

[1] Buildings having their own wells use submersible pumps, which typically operated between 5:30 a.m. to 9:30 a.m., 12:00 noon to 2:00 p.m., and 5:30 p.m. to 9:00 p.m.

Schematics of typical Summer and Winter day demand, and power purchase (from GEB) curves are shown in *Figure 2*. Also shown are the approximate periods when AMC supply and building pumping systems operate. The timing of water supply and building pumping are fixed to meet morning and evening water demand. Under these conditions, the best strategy is to reduce building pumpset capacity, so that pumps run longer, thereby reducing and flattening the peak demand. To reduce the customer's costs, it is also important that the efficiency of the pumping system be improved. This is the general strategy taken by AEC's WPP.

Figure 2





Survey of Multistory Building Pumping System Characteristics in Ahmedabad

The AEC DSM Cell team completed a survey of the water pumping systems at 75 multi-story buildings across Ahmedabad, to better understand their energy-using characteristics and physical infrastructure. Currently, the typical multi-story building occupant requires 3.3 kWh per month for water pumping (assuming they use 225 liters of water/day). The survey also revealed the following characteristics of their pumping systems:

	average	range
Head (meters)	52	23 to 91
Power demand (kW)	7	3 to 14

Pumping rate (LPS[2])	4	1.2 to 12.2
Flow velocity (meters/second)	2	0.5 to 6
Pump horsepower (HP)	9	5 to 15

The Pumpset

Pumpsets used in building water pumping systems are typically selected based on their initial purchase cost. Pumpset efficiency is not often a consideration, thus pumpset are typically inefficient. As a matter of habit, pumpsets are commonly oversized significantly . By installing new, smaller energy-efficient pumpsets, both electricity consumption and demand can be decreased.

The Delivery and Suction Pipes

The delivery pipe is typically made of a galvanized iron pipe with an inner diameter of 37, 50, 65 or 75 mm. The suction pipe is made of galvanized iron and most commonly has an inner diameter of 37 or 50 mm. By changing to a larger diameter, typically a 75-mm polyvinyl chloride (PVC) pipe, both the surface friction of the pipe material and pipe friction are reduced. For example, when a 50-mm galvanized iron pipe is replaced by a 75-mm PVC pipe, the coefficient of surface friction drops from 0.01 to 0.005, and the pipe's frictional losses are reduced by 33% (if the flow rate of the water in the pipe remains constant[3]). As old pipes with internal deposits of salts (e.g., calcium), corrosion, or sand are replaced with new pipes, losses are also reduced. Also, the PVC pipes are less susceptible to corrosion and deposition, thereby increasing their useful life.

Right-angle bends are fairly common in plumbing systems. Bends greater or less than 90^o are rarely used. For the pumping systems investigated to date, there have between four and fifteen right-angle bends. Each of these bends causes turbulence and increases losses in the delivery pipe. Ideally, with plumbing system replacement, the number of bends should be minimized. Yet, for most piping configurations audited there is no opportunity to reduce the number of bends.

The Foot Valve

A new foot valve can be installed on the suction pipe. The foot valve keeps the suction pipe and the pump casing full of water (so that the pump does not require priming). New foot valves open completely, while older valves generally only opened partially (older foot valves may also leak — thereby slowly draining the rooftop tank). With new foot valves, friction losses are reduced by about 4%.

Pumping System Efficiency Optimization

The preceding discussion of pumping system efficiency opportunities is presented in a simplified manner. The efficiency of a given pumping system is dependent on numerous factors, including the pumpset capacity, the pumpset efficiency, flow rate, static head, piping system layout, pipe diameter, pipe material, and pumpset operation. Each of these factors plays an important role in the efficiency of

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[2] Or liters per second.

[3] Flow velocity decreases as the diameter of the pipe is increased, further reducing pipe friction losses. This is because pipe friction is a function of both pipe diameter and water velocity. Also, recall that pumpset capacity can be reduced, further reducing the velocity of the water in the pipe. Flow rates can commonly be reduced as the building pumping system transports water from one storage tank to another. Only rarely, in the early evening or morning when occupant water demand is high, might water demand equal or exceed the pumping system's water supply.

the system. To maximize the pumping system efficiency, the technical as well as operational parameters must be optimized. In this paper, we focus on the relatively simple technical measures.

Having identified the energy efficiency and demand reduction measures, it became clear to the staff of AEC's DSM Cell that further development of the WPP was warranted. The DSM Cell staff members developed the implementation strategy (see below) for the pilot program. The pilot program is currently be implemented. About fifteen pumping systems have been modified to date. The results from the first three pumping system modifications were available when this paper was prepared and are presented here.

Program Implementation

Currently the program is being implemented as follows:
1. Multistory buildings are selected based on the number of stories, and their location[4].
2. AEC's DSM staff make the initial contact with building association secretaries.
3. Each building's "energy index" (see *Text Box 1*) is determined for preliminary screening.

Text Box 1

Determining the Energy Index

The energy index is a measure of the power required to lift 100,000 liters of water one meter by a given pumping system. To determine the energy index, the field technician need only measure the average power input, the static head, and the hourly flow rate of the pumping system. The energy index is determined using the formula:

$$EI = (100{,}000 * Pa)/(Hs * F) \qquad (1)$$

where
- EI = Energy Index (unitless)
- Pa = Average power input (kW)
- Hs = Static head (meters)
- F = Flow rate (liters/hour)

The larger the energy index, the greater the potential for pumping system efficiency improvements. The table below describes the pumping system efficiency potential based on the energy index.

Energy Index	Efficiency	Potential for Efficiency Improvements
0.5 - 0.7	55% - 40%	none
0.71 - .9	39% - 30%	minor
0.91 - 1.2	29% - 23%	moderate
1.21 - 1.5	22% - 19%	very good
greater than 1.51	less than 18%	excellent

The 75 representative buildings audited by the AEC team had an energy index averaging 1.5 and ranging from 0.5 to 4.1.

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[4] The demonstration sites were dispersed across Ahmedabad so that more people would be aware of the program.

4. A detailed pumping system energy audit is completed to determine the system efficiency of buildings with a high energy index (i.e., greater than 1.5)[5].
5. For these buildings, their pumping system is redesigned to maximize demand and efficiency improvements while providing dependable service.
6. The design modifications are presented to the building association for approval.
7. The system is modified as per the design.
8. Electricity use and demand are monitored, and the improvements are evaluated.

Typical Pumping System Modifications

When pumpsets are initially installed at buildings, they are specified based on non-engineering and rule-of-thumb practices of the building contractor, rather than any techno-economic analysis. In every case, the existing pumpset has been replaced by a smaller 5-hp pumpset, while meeting water requirements of the building occupants. Experience to date has been that 75-mm delivery and suction PVC pipe is the optimal pipe diameter when considering cost, friction losses, and maintenances needs. Also, most foot valves are in a degraded state and require replacement.

Pumping System Efficiency Audits

Pumping efficiencies were determined for the 75 multi-story buildings without any pumping system modifications. The results of the audits are presented below.

	average value	range of values from audited sites
Friction Head/Static Head[6]	23%	1% to 53%
Plumbing System Efficiency	70%	41% to 96%
Pumpset Efficiency	32%	7% to 62%
Overall System Efficiency	21%	6.7% to 32%

For a pumping system, a pumpset efficiency of 40% to 45% and a plumbing system efficiency of 90%, resulting in an overall system efficiency of about 40%, are considered optimal. Yet, when an existing pumping system is modified, a 40% efficiency is not obtainable. A more realistic efficiency target is 30%. Thus, for the average pumping system in Ahmedabad, AEC hopes to improve overall system efficiency by 50% (i.e., from 21% to 30%).

Preliminary Results: Pumping System Modifications

Tables 1 – 3 describe the results of the pumping system improvements at the first three buildings (all apartment buildings) before and after the improvements were made. The three buildings are each nine or ten stories tall, with 250 to 650 occupants.

[5] Yet, the team was able to identify cost-effective (i.e., payback period less than two years) energy-savings potential at every site surveyed.

[6] Static head is the distance between the inlet and outlet of the underground and the rooftop holding tanks. The friction head is the “apparent” head required to overcome resistance to flow in the pipes, fittings, bends, inlets, outlets, etc.

Table 1 Existing Pumping System Characterizations

	hourly flow rate (LPS)	motor size (Hp)	average power input (KW)	energy index	pumpset[7] efficiency	piping efficiency	system efficiency
Ishita Apartments: C Block	1.67	10	6.7	2.35	19%	64%	12%
Kothawala Apartments	5.05	12.5	8.22	1.16	n/a	n/a	23%
Kirtisagar Apartments	4.2	10	8.4	1.38	38%	51%	19%

In each case, the pumpsets were inefficient and had oversized motors. Similarly, the piping systems were fairly inefficient. The results and the impacts of the pumping system modifications are described in *Tables 2* and *3.* Note that the pumping system at the Kothawala apartment building, with an efficiency of 23%, is most representative of the average multi-story building pumping system in Ahmedabad.

Table 2 Results of Pumping System Modifications

	Energy Index	System Efficiency	Savings
Ishita Apartments: C Block[8]			
50-mm galvanized iron suction pipe was replaced by 75-mm PVC pipe, and the foot valve was replaced	2.15	13%	8%
40-mm galvanized iron delivery pipe was replaced by 75-mm PVC pipe	1.35	20%	43%
The 10-hp pumpset was replaced by 5-hp energy-efficient monoblock	0.82	33%	65%
Kothawala Apartments			
50-mm galvanized iron suction pipe was replaced by 75-mm PVC pipe, the foot valve was replaced, and the 12.5-hp pumpset was replaced by 5-hp energy efficient monoblock[9].	0.9	29%	20%
Kirtisagar Apartments			
65-mm galvanized iron suction pipe was replaced by 75-mm PVC pipe, foot valve was replaced, 50-mm galvanized iron delivery pipe was replaced by 75-mm PVC pipe, and the 10-hp pumpset was replaced by 5-hp energy-efficient monoblock.	0.85	30%	38%

---

[7] All plumbing system efficiencies were estimated based on standard methodologies described in the literature. The methodology requires that the pumping system auditor measures the diameter, length, and number of right bends in the delivery and suction pipes; static head; time-averaged pump power input; and the time-averaged water flow rate.

[8] The index, efficiency and savings values for Ishita are cumulative, that is the energy index for replacing the delivery pipe, includes the improvements resulting from replacing the suction pipe.

[9] Note that the delivery pipe was not replaced.

Table 3 Impacts of Pumping System Modifications

	water flow rate (LPS)	pumpset operation (hours/day)	pumpset size (hp)	monthly energy use (kWh)	demand (KW)
Ishita Apartment Complex: C Block					
before	1.67	9	10	1850	6.7
after	2.7	6	5	650	3.8
change	+62%	-30%	-50%	-65%	-43%
Kothawala Apartment Complex					
before	5.05	8	12.5	1900	8.2
after	3.08	13	5	1500	4.0
change	-39%	+38%	-60%	-21%	-51%
Kirtisagar Apartment Complex					
before	4.2	9	10	2295	8.5
after	3.9	10	5	1420	4.6
change	-7%	+11%	-50%	-38%	-45%

In each case, electricity demand and energy use decreased sharply, while water flow rates were brought to approximately 3 to 4 liters per second (LPS). In two instances, pumpset operational periods increased by about 50%.

AEC's Role

Considering that the program has a payback period to the customer of less than two years, little incentive should be required to promote the program. In fact after the work was completed at the Ishita Apartments C Block (at AEC's cost), the building association made similar investments, using their own capital, at buildings A and B.

Yet, the high first costs of energy efficiency projects remains a serious barrier in India. As AEC, and other India utilities are not yet able to include DSM capital costs in their rate base, they are looking for external funding resources. AEC is currently developing a loan mechanism, more specifically a revolving loan fund, which would provide short-term credit to qualified building associations for pumping system optimization programs similar to those described above. AEC feels that the loan fund is required for the success of this, as well as other, DSM programs.

Providing pumping system improvement information to building associations is critical to the success of this program. Currently, AEC is relying on demonstrations, seminars, and advertising to publicize the program to building associations and others. AEC has already had a few free workshops for interested individuals (including building managers, building contractors, and engineering consulting firms). The seminars have been very well attended and generated a lot of interest and good publicity for AEC. Also, AEC is developing the capacities of DSM allies to carry out and support the program. Allies include local engineering contractors, plumbers, and the suppliers of pumpsets and pipes.

Program Impacts

AEC Impacts
There are approximately 4,000 building water pumping systems in Ahmedabad, having a total demand of about 20 MW and accounting for 50 million kWh of annual sales. Using estimates of 40% demand and 20% energy savings in 50% of Ahmedabad's multi-story buildings, a total savings of 4 MW and 5 million kWh could be generated. With an effective loan fund in place, we estimate that these goals could be obtained within five years.

AEC's cost of new generation, transmission, and distribution is $US 1,700 per kW of new base-load capacity (this is AEC's avoided cost). If the WPP's costs are less than $US 6.8 million to reduce demand by 4 MW, then it is more cost-effective than adding the equivalent amount of new supply-side resources[10].

The approximate costs to replace the pumpset, all suction and delivery pipes, and the foot valve are as follows: (5 hp) pumpset, $US 285: all piping and the foot valve, $US 285; capacitor, $US 45; installation, $US 90; system testing, $US 30; and the initial survey, $US 15; — for a total cost of $US 750 and total capital cost of $US 615. This cost does not include AEC's administrative or energy audit instrument and specialized metering costs. Nor does the cost estimate include the salvage value of the pumpset and the galvanized iron piping (both of which are generally still operable).

The full cost, including AEC's instrumentation and administrative costs, to modify a pumping system has not exceeded $US 1,000. Thus to modify pumping systems at 2,000 buildings, an investment of not more than $US 2 million is required. This is substantially less than the marginal cost of new power generation (i.e., $US 6.8 million). If the loan fund is properly designed and managed, it alone should be profitable. In other words, AEC should be able to avoid the cost of adding 5 MW of new generation capacity, while operating the loan fund on a for-profit basis.

The non-monetary benefits which accrue to AEC are as important to AEC as the monetary benefits. Examples of non-monetary benefits include the following:

- Improving the AEC's reputation among its customers, stockholders, regulators, and competitors.
- Reducing customer animosity against AEC (perhaps reducing theft of power).
- Investigating new business areas which could become profit centers (including energy consultancy services such as performance contracting).
- Collecting load research information to better serve customers and design tariffs.

Customer Impacts
For each kWh and kW saved, the multi-story building customer's bills are reduced by about $US 0.04/kWh and $US 0.55/kW month. For the average multi-story building, electricity bills are reduced by $US 445/year, and the project has a simple payback period of 1.7 years. The simple payback period for the capital costs, alone, is 1.4 years. The net savings accruing to building owners across AEC's service territory is about $US 0.9 million per year, or $US 13.5 million if the pumping system improvements have a fifteen-year life.

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[10] This is an overly simplified statement, as new generation would have a longer life than the savings resulting from the WPP. It also assumes that on-peak load factors for each option are the same. On the other hand, some benefits have been ignored as well, such as avoiding the cost of unserved energy, improving the technical knowledge and abilities of program allies, and reducing detrimental environmental impacts.

National Impacts
India has an urban population of approximately 250 million people, compared to 3.5 million in the city of Ahmedabad. If a similar proportion of urban individuals live in multi-story buildings across India, and if the pumping systems have a similar design and operate during on-peak periods, then the pumping system improvements could result in demand and energy savings of about 290 MW and 360 million kWh, respectively.

Conclusions

This paper shows the vast savings potential and cost-effectiveness of energy efficiency improvements available through DSM for one end-use in India. Our experience indicates that there is similar potential in many other end-use categories across all customer sectors in India. The value of DSM in India is enhanced by the relatively high electricity rates, a serious and growing electricity demand gap, high capital costs for supply-side options, relatively inexpensive material costs, inexpensive (yet skilled) labor, and a booming financial sector. Similar DSM potential is thought to reside throughout most developing countries in Asia.

The WPP is only one of several areas where AEC is targeting its DSM activities, yet the savings potential is significant. Our estimates indicate that if the program were implemented across India, power plant capacity requirements could be reduced by about 300 MW. This program reduces customer's bills and is beneficial to the utility, as purchases of imported power can be reduced, sales can be shifted to customers with a higher profit margin, and power plant construction can be delayed. In addition, replacing traditional supply-side options with DSM options cleans up the environment.

The WPP provides an excellent approach and design for other Indian and Asian utilities to adopt for their initial DSM programs. The water pumping program uses locally available technologies and skills, as well as a bottom-up approach — two important characteristics of successful DSM programs in the developing world. A utility's first DSM program should also target a specific area, produce quick results, be cost-effective, and be relatively easy for the utility to administer and implement. Again the WPP has each of these characteristics.

The project began with research activities to ensure that the concept was realistic and to demonstrate to AEC management that DSM makes sense. The project's initial results demonstrate that the DSM concept is viable in India. At AEC, top level commitment to DSM has continued to grow. Over the next year the program will gradually be scaled up and implemented city-wide. Meanwhile, the capabilities of the AEC DSM team continue to grow. The AEC team will transfer their new insights and confidence to other DSM program areas.

Utility-supported DSM is also expected to develop new areas of business for domestic engineering firms, contractors, and suppliers. It is important to energize these trade allies. Similarly, it is important to show customers that energy efficiency, as opposed to accepting shortages or demanding new capacity additions, can be a viable means of overcoming power shortages. It is also an excellent public relations activity during a period when customers are facing power cuts, tariff hikes, and deteriorating environmental quality.

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APPENDIX 6 - PRC MEETING HANDOUT MATERIALS

EMCAT UPDATE
SEPTEMBER 1996

STATUS:

DSM:

RMA and AEC have been jointly developing a seminar on motors for September 27-28, 1996. The conference will feature energy efficiency and cost savings available from motor changes along with presentations and exhibits on motors and motor rewinding. RMA staff have been working closely with USDOE Motor Challenge staff in identifying materials that will be of interest to the conference. RMA staff developed economic analysis software to analyze motor replacements in India.

RMA has been working with the staff of the Taj Palace Hotel in Delhi to present a case study at the motor seminar. RMA facilitated a high-efficiency motor replacement for the Taj Palace, and the staff is collecting data on its energy consumption. A member of the hotel staff will make a presentation on this case study at the motor seminar.

The multistory water pumping project at AEC is ongoing. RMA has worked with the International Institute of Energy Conservation (IIEC) in identifying someone to assist AEC in developing a revolving loan fund to support the large-scale implementation of this project. Dan Goldberger, representing IIEC, will be in Ahmedabad to work with AEC the week of September 23-28, 1996.

Dr. Hameed Nezhad worked with the International Institute of Education in assessing the need for DSM in Gujarat. Meetings were held with representatives of the Surat Electricity Company and the Gujarat Electricity Board.

RMA has been coordinating with the Electric Power Research Institute (EPRI) in determining whether assistance can be provided to AEC. EPRI provides assistance to electric utilities (by membership) within the U.S., and they are now starting to work internationally to conserve energy.

LPD:

Surveys were conducted at four textile plants in July/August, 1996. Mr. Lewis Price, Jr., assisted Bombay Textile Research Association (BTRA) in visiting each site, working with the plant operating staff, and discussing energy saving opportunities in the facilities. Mr. Price has forwarded a draft copy of his report, which will be edited and then forwarded to the Indian consultant for their review and comments. The consultant comments will be utilized in finalizing the report.

Mini-steel and rolling mills are the next industrial sector to be surveyed. IDBI coordinated a tentative survey schedule, but the preferred U.S. consultant was not available for the specified dates. Coordination of this schedule and consultant selection is still under way. IDBI has selected Metallurgical & Engineering Consultants (MECON) as the Indian consultant.

ESCO:

There were no activities scheduled under the ESCO subtask for this quarter. During the next quarter, RMA will be querying the Indian firms that have started ESCO efforts to learn of their progress and difficulties in establishing this type of service. This information will be forwarded to USAID for future use in working with ESCOs.

EAIP:

The second round of equipment procurement was completed and the equipment shipped to India. Previous equipment requests that were placed on a waiting list have been ordered. The equipment budget will essentially be exhausted with these orders. Equipment which was purchased during the first year of the contract and used for training purposes will be offered to Indian firms at a reduced rate.

Remaining activities include a follow-up survey to be sent to all equipment purchasers, which is intended to assess the impact of providing audit equipment through this program.

TRAINING/DISSEMINATION:

RMA staff have been preparing for the CII Energy Summit '96, held in Madras on September 11-14, 1996. Charlie Fafard, Hameed Nezhad, and Niels Wolter will all be making presentations. (Niels will be giving a presentation planned for a DOE-Motor Challenge representative, who will be unable to attend the seminar). Hameed's presentation will focus on DSM work at AEC, while Charlie's presentation will address energy controls and instrumentation.

Hameed Nezhad and Niels Wolter will also make presentations at the DA/DSM conference held in Delhi on September 17-19, 1996. Their presentations will focus on DSM work at AEC under the EMCAT project.

On September 27-28, 1996, Charlie Fafard, Hameed Nezhad, and Niels Wolter will assist AEC in conducting a motor seminar in Ahmedabad. The seminar will focus on energy- efficient motors and rewinding motors. RMA staff will make presentations and host an evening discussion session.

Hameed Nezhad will also make a presentation at a TERI conference scheduled for September 10, 1996. This conference will focus on DSM efforts at AEC.

RMA is planning an "end of the contract" seminar for January 16-18, 1997, in Delhi. The purpose of the seminar would be to highlight the activities undertaken in the project and to encourage implementation of more energy efficiency measures. The seminar is tentatively planned for the Hyatt Hotel, and ASSOCHAM will coordinate the program. The first two days are intended to cover the EMCAT program's experiences with utility DSM demonstrations, energy conservation surveys conducted in India's energy intensive industries, and the role of Energy Service Companies (ESCOs) in identifying and implementing energy conservation opportunities in India. The third day is planned as a policy session intended to identify future areas for assistance in implementing energy efficiency programs.

APPENDIX 7 - QUESTIONS AND CONCLUSIONS FROM D. GOLDBERGER REGARDING AEC WATER PUMP PROGRAM FINANCING

No electronic Version

APPENDIX 8 - MOTOR ECONOMICS FORMS

MOTOR EFFICIENCY AND MOTOR ECONOMICS WORKSHEETS

ATTACHED ARE CALCULATION SHEETS FOR DETERMINING:
1. THE EFFICIENCY OF AN OPERATING ELECTRIC MOTOR
2. THE PAYBACK PERIOD FOR PURCHASING AN EFFICIENT MOTOR INSTEAD OF AN INEFFICIENT MOTOR
3. THE PAYBACK PERIOD FOR REPLACING A MOTOR RATHER THAN REWINDING THE MOTOR

DEVELOPED BY
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MADISON, WISCONSIN USA

FOR THE:
AHMEDABAD ELECTRICITY COMPANY LTD.
MOTOR SEMINAR
SEPTEMBER, 1996
AHMEDABAD, INDIA

WORK SPONSORED BY:
THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

UNDER THE
ENERGY MANAGEMENT CONSULTATION AND TRAINING PROJECT (EMCAT)
FOR INDIA

1. DETERMINING THE EFFICIENCY OF AN OPERATING MOTOR: THE SLIP METHOD

THIS METHOD IS NOT ACCURATE FOR DETERMINING THE EFFICIENCY OF A REWOUND MOTOR.
THE ACCURACY OF THIS METHOD IS + OR - 2% OR 3%

STEP ONE: COLLECT THE FOLLOWING INFORMATION

1. DESCRIPTIVE INFORMATION

MOTOR AUDIT COMPLETED BY: ______________________
DATE: ____
CLIENT: _______________________________________
MOTOR MAKE AND MODEL: _________________________
MOTOR ID NUMBER: ______________________________

STEP TWO: COLLECT THE FOLLOWING MOTOR DATA

A. NUMBER OF POLES ON THE MOTOR: _____________
B. FREQUENCY OF THE POWER SUPPLY: _____________ HERTZ
C. NAME PLATE MOTOR SPEED: __________________ RPM
D. NAME PLATE MOTOR POWER: __________________KW

STEP THREE: MEASURE THE FOLLOW MOTOR CHARACTERISTICS

TAKE THE MEASUREMENTS FROM THE MOTOR RUNNING AT ITS NORMAL OPERATING CONDITIONS.
TO MAKE THESE MEASUREMENTS THE MOTOR AUDITOR WILL REQUIRE:

- TACHOMETER
- MULTIMETER
- POWER FACTOR METER

E. OPERATING VOLTAGE: __________ VOLTS
F. OPERATING AMPERAGE: __________ AMPS
G. ACTUAL SPEED: _________ RPM
H. POWER FACTOR: ________ (EXPRESSED AS A FRACTION)

STEP FOUR: DETERMINE THE MOTOR'S INPUT POWER

I. MOTOR INPUT POWER EQUALS:

________VOLTS * ________AMPS * _______ (POWER FACTOR) * 1.732 / 1000 = ________KW
(E) (F) (H) (I)

STEP FIVE: DETERMINE THE MOTOR'S SYNCHRONOUS SPEED

J. SYNCHRONOUS SPEED EQUALS:

60 RPM/HERTZ * 2 * ______ HERTZ / ______ = ________ RPM
(B) (A) (J)

STEP SIX: DETERMINE THE MOTOR'S PERCENTAGE SLIP

K. PERCENT SLIP EQUALS:

(______RPM - ______RPM) / ______RPM = ________ (FRACTION)
(J) (G) (J) (K)

STEP SEVEN: DETERMINE THE MOTOR'S SLIP

L. MOTOR SLIP EQUALS:

_______ RPM - _______RPM = _______RPM
(J) (G) (L)

STEP EIGHT: DETERMINE THE MOTOR'S LOAD

M. MOTOR LOAD IS ESTIMATED BY THE FORMULA:

______RPM / (______ RPM - _______ RPM) = _______ (FRACTION)
(L) (J) (C) (M)

STEP EIGHT: DETERMINE THE MOTOR'S APPROXIMATE OUTPUT

N. MOTOR OUTPUT IS ESTIMATED BY THE FORMULA:

_______ * ________KW = _______KW
(M) (D) (N)

STEP NINE: DETERMINE MOTOR'S APPROXIMATE EFFICIENCY

O. MOTOR EFFICIENCY IS ESTIMATED BY THE FORMULA:

_______KW / ______KW = _______(FRACTION)
(N) (I) (O)

2. PAYBACK PERIOD ANALYSIS: FOR COMPARING TWO NEW MOTORS OF DIFFERING EFFICIENCY

THIS ANALYSIS ASSUMES THAT THE MOTORS WOULD BE REWOUND USING THE BEST PRACTICES AND MATERIALS. THUS REWINDING WOULD NOT SIGNIFICANTLY ALTERING THE EFFICIENCY DIFFERENTIAL BETWEEN THE TWO MOTORS.

STEP ONE: COLLECT THE FOLLOWING INFORMATION

1. DESCRIPTIVE INFORMATION

MOTOR ANALYST: ______________________

DATE: ______________________

CLIENT: ______________________

2. MOTOR DATA FOR MORE EFFICIENT MOTOR

TYPE: ______________________________

ENCLOSURE TYPE: ______________________

MANUFACTURER: ______________________

MOTOR ID NUMBER: ____________________

A. SIZE: _______ (KW INPUT)

B. LOAD: _______(FRACTION)

C. USE: _______(HOURS/YEAR)

D. EFFICIENCY AT LOAD: _______(FRACTION)

E. MOTOR PRICE: _______ (RS)

F. ANTICIPATED LIFE: _______ YEARS

3. MOTOR DATA FOR LESS EFFICIENT MOTOR

TYPE: ______________________________

ENCLOSURE TYPE: ______________________

MANUFACTURER: ________________________

MOTOR ID NUMBER: ____________________

G. SIZE: _______ (KW INPUT)

H. LOAD: _______(FRACTION)

I. USE: _______(HOURS/YEAR)

J. EFFICIENCY AT LOAD: _______(FRACTION)

K. MOTOR PRICE: ________ (RS)

4. AEC TARIFF DATA

RATE CLASS: ____________________

L. AVERAGE ENERGY CHARGE: _______(RS/KWH)

M. AVERAGE ANNUAL DEMAND CHARGE: ________ (RS/KW MONTH)

STEP TWO: DETERMINE THE ANNUAL ELECTRICITY USE FOR EACH MOTOR

N. FOR THE EFFICIENT MOTOR: ANNUAL ELECTRICITY USE EQUALS:

_____KW * _____ LOAD * _____ HOURS/YEAR / _____ EFFICIENCY = ______ KWH/YEAR
(A) (B) (C) (D) (N)

O. FOR THE INEFFICIENT MOTOR: ANNUAL ELECTRICITY USE EQUALS:

_____KW * _____ LOAD * _____ HOURS/YEAR / _____ EFFICIENCY = ______ KWH/YEAR
(G) (H) (I) (J) (O)

STEP THREE: DETERMINE THE ANNUAL ENERGY SAVINGS

P. ANNUAL ENERGY SAVINGS EQUALS:

________ KWH/YEAR - ________ KWH/YEAR = ________ KWH SAVED/YEAR
(O) (N) (P)

STEP FOUR: DETERMINE THE VALUE OF THE ANNUAL ENERGY SAVINGS

Q. ANNUAL ENERGY SAVINGS (IN RUPEES) EQUALS:

________ KWH SAVED/YEAR * ________ RS/KWH = ________ RUPEES SAVED /YEAR
(P) (L) (Q)

STEP FIVE: DETERMINE THE ADDITIONAL COST OF THE EFFICIENT MOTOR INVESTMENT

R. MOTOR INVESTMENT EQUALS:

_______ RS - ________ RS = _______ RS
(E) (K) (R)

STEP SIX: DETERMINE THE SIMPLE PAYBACK PERIOD

S. THE SIMPLE PAYBACK PERIOD FOR THE MOTOR INVESTMENT EQUALS:

_______RS / ________ RS SAVED/YEAR = ________ YEARS
(R) (Q) (S)

STEP SEVEN: DETERMINE THE SIMPLE RATE OF RETURN

T. THE SIMPLE RATE OF RETURN FOR THE MOTOR INVESTMENT (WITH AN INTEREST RATE OF ZERO) EQUALS:

1 / _______ YEARS = ________
(S) (T)

STEP EIGHT: DETERMINE LIFE CYCLE SAVINGS OF MOTOR INVESTMENT

U. LIFE CYCLE SAVINGS RESULTING FROM THE MOTOR INVESTMENT EQUALS:

_______ RS SAVED / YEAR * _______ YEARS = _______ RS SAVED
(Q) (F) (U)

3. PAYBACK PERIOD ANALYSIS: PURCHASING A NEW MOTOR OR REWINDING AN EXISTING MOTOR

FOR A MOTOR THAT HAS BEEN REWOUND, ITS EFFICIENCY IS TYPICALLY 2% TO 4% LESS THAN THE NAMEPLATE EFFICIENCY.

STEP ONE: COLLECT THE FOLLOWING INFORMATION

1. DESCRIPTIVE INFORMATION

MOTOR ANALYST: ______________________

DATE: ______________________

CLIENT: ______________________

2. EXISTING MOTOR DATA

TYPE: ______________________________

ENCLOSURE TYPE: ______________________

MANUFACTURER: ______________________

MOTOR ID NUMBER: ____________________

A. SIZE: _______ (KW INPUT)

B. LOAD: _______(FRACTION)

C. USE: _______(HOURS/YEAR)

D. EFFICIENCY AT LOAD: _______(FRACTION)

E. REWINDING PRICE: _______(RS)

F. ESTIMATED SALVAGE VALUE: _______ (RS)

3. NEW MOTOR DATA

TYPE: ______________________________

ENCLOSURE TYPE: ______________________

MANUFACTURER: ________________________

MOTOR ID NUMBER: ____________________

G. SIZE: _______ (KW INPUT)

H. LOAD: _______(FRACTION)

I. USE: _______(HOURS/YEAR)

J. EFFICIENCY AT LOAD: _______(FRACTION)

K. NEW MOTOR PRICE: ________ (RS)

4. AEC TARIFF DATA

RATE CLASS: ____________________

L. AVERAGE ENERGY CHARGE: _______(RS/KWH)

M. AVERAGE ANNUAL DEMAND CHARGE: ________ (RS/KW MONTH)

STEP TWO: DETERMINE THE ANNUAL ELECTRICITY USE FOR EACH MOTOR

N. FOR THE EXISTING MOTOR: ANNUAL ELECTRICITY USE EQUALS:

_____KW * _____ LOAD * _____ HOURS/YEAR / _____ EFFICIENCY = ______ KWH/YEAR
(A) (B) (C) (D) (N)

O. FOR THE NEW MOTOR: ANNUAL ELECTRICITY USE EQUALS:

_____KW * _____ LOAD * _____ HOURS/YEAR / _____ EFFICIENCY = ______ KWH/YEAR
(G) (H) (I) (J) (O)

STEP THREE: DETERMINE THE ANNUAL ENERGY SAVINGS

P. ANNUAL ENERGY SAVINGS EQUALS:

________ KWH/YEAR - ________ KWH/YEAR = ________ KWH SAVED/YEAR
(N) (O) (P)

STEP FOUR: DETERMINE THE VALUE OF THE ANNUAL ENERGY SAVINGS

Q. ANNUAL ENERGY SAVINGS (IN RUPEES) EQUALS:

________ KWH SAVED/YEAR * ________ RS/KWH = ________ RUPEES SAVED /YEAR
(P) (L) (Q)

STEP FIVE - ONLY IF THE MOTOR IS DOWNSIZED: DETERMINE THE KW SAVINGS

IF THE MOTOR IS NOT DOWN SIZED THAN THE DEMAND SAVINGS (S) EQUALS ZERO.

R. WHEN A MOTOR IS DOWNSIZED THE DEMAND SAVINGS EQUAL:

(_______ KW * _______ / _______) - (_______ KW * _______ / _______) = _______ KW
(A) (B) (D) (G) (H) (J) (R)

S. THE ANNUAL DEMAND SAVINGS IN RUPEES EQUALS:

________ KW * _________ RS/KW MONTH * 12 MONTHS/YEAR = _______ RS SAVED/YEAR
(R) (M) (S)

STEP SIX: DETERMINE THE NET ANNUAL SAVINGS

T. THE NET ANNUAL SAVINGS IN RUPEES EQUALS:

________ RS SAVED/YEAR + ________ RS SAVED/YEAR = ________RS SAVED/YEAR
(Q) (S) (T)

STEP SEVEN: DETERMINE THE COST OF THE MOTOR INVESTMENT

U. MOTOR INVESTMENT EQUALS:

_______ RS - ________ RS - ________ RS = _______ RS
(K) (E) (F) (U)

STEP EIGHT: DETERMINE THE SIMPLE PAYBACK PERIOD

V. THE SIMPLE PAYBACK PERIOD FOR THE MOTOR INVESTMENT EQUALS:

_______RS / ________ RS SAVED/YEAR = ________ YEARS
(U) (T) (V)

STEP NINE: DETERMINE THE SIMPLE RATE OF RETURN

W. THE SIMPLE RATE OF RETURN FOR THE MOTOR INVESTMENT (WITH AN INTEREST RATE OF ZERO) EQUALS:

1 / _______ YEARS = ________
(V) (W)

APPENDIX 9 - AEC TRAINING CENTER PROPOSAL

No electronic version

APPENDIX 10 - SURVEY & LIST OF THOSE ATTENDING MOTOR ALLY SESSION