U.S. Department of Transportation
Urban Mass Transportation Administration

UMTA-PA-06-0083-86-1

ENERGY MANAGEMENT GUIDELINES
FOR
RAIL TRANSIT SYSTEMS
EXECUTIVE SUMMARY

SEPTEMBER 1986

UMTA Technical Assistance Program

U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

Headquarters

400 Seventh St., S.W.
Washington, D.C. 20590

MAY 18 1987

Dear Colleague:

The Urban Mass Transportation Administration (UMTA), in cooperation with transit authorities, sponsored the STARS (Subsystems Technology Application to Rail Systems) Program in 1979 to reduce costs as well as improve the reliability and maintainability of rail transit systems.

Under the STARS Energy Reduction Projects, operational strategies and design guidelines for energy cost reduction and improved energy efficiency were developed. The Rail Systems Center of Carnegie Mellon University conducted many of these projects in recent years. These strategies and guidelines are now incorporated into the enclosed three volumes of Energy Management Guidelines for Rail Transit Systems.

We hope that this information will help to reduce the overall energy consumption of transit systems.

Sincerely,

Ronald D. Kangas
STARS Program Manager

Fred L. Sing.

Fred L. Sing
UMTA Project Manager

ENERGY MANAGEMENT GUIDELINES
FOR
RAIL TRANSIT SYSTEMS
EXECUTIVE SUMMARY

by
Richard A. Uher
Onkar N. Sharma
RAIL SYSTEMS CENTER
Mellon Institute
Carnegie-Mellon University
Pittsburgh, PA 15213

SEPTEMBER 1986
FINAL REPORT

Document is available to the U.S. public through the
National Technical Information Service,
Springfield, Virginia 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Systems Engineering
Washington, D.C. 20590

Technical Report Documentation Page

1. Report No. UMTA-PA-06-0083-86-1	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle "Energy Management Guidelines for Rail Transit Systems" Executive Summary	5. Report Date September 1986
	6. Performing Organization Code
7. Author(s) Richard A. Uher, Onkar N. Sharma	8. Performing Organization Report No.
9. Performing Organization Name and Address Rail Systems Center, Mellon Institute Carnegie-Mellon University 4400 Fifth Avenue Pittsburgh, PA 15213	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. PA-06-0083
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration 400 Seventh Street, S.W. Washington, D. C. 20590	13. Type of Report and Period Covered Final Report 7/9/84-10/30/86
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The cost of electricity is a significant portion of the operating costs of rail transit systems. The impact of increasing energy costs is felt by those systems presently in operation and will be felt by those in the planning or construction phases. Because of the number of nuclear power plants coming on line in areas served by transit, the influence of electricity costs on operating and design policies of rail transit authorities is expected to grow in future years.

Concerned by rising energy costs, managers of several rail transit authorities have established energy management programs. The objectives of these programs are energy cost reduction and improved energy efficiency. Energy management is a process of understanding a system's energy requirements, with the goals of reduced energy cost and increased energy efficiency. Both goals enhance rail transit productivity. The bottom line is lower electric bills for the transit authority.

As a rule, energy management can foster its largest payoff when it is initiated during the design and construction phase of a rail transit system. The high dollar savings occur because low energy cost technology and operating practices can be engineered into the system at the outset. However, changes in technology and operations of present transit systems can also reduce the electric bill. Reduction of energy cost can be achieved through energy conservation, load management, and power rate intervention. These guidelines describe the tools and methodologies for assessing energy conservation strategies and power rate structure modifications.

17. Key Words Rail Transit Systems Energy Management Power Rate Structure	18. Distribution Statement Report is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 12	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply by	To Find	Symbol
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t

VOLUME

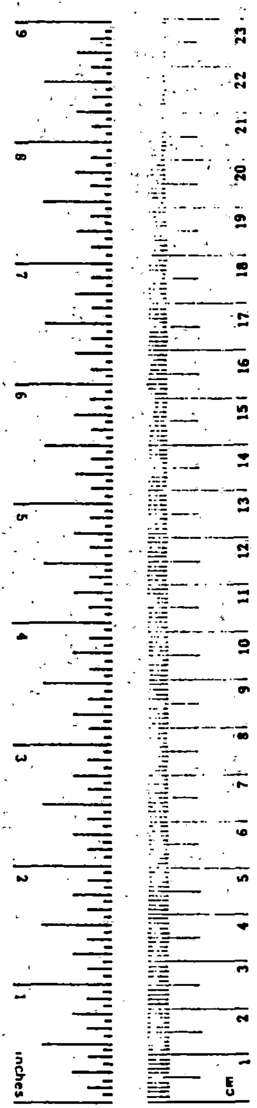
Symbol	When You Know	Multiply by	To Find	Symbol
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

---

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	

MASS (weight)

Symbol	When You Know	Multiply by	To Find	Symbol
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	

VOLUME

Symbol	When You Know	Multiply by	To Find	Symbol
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

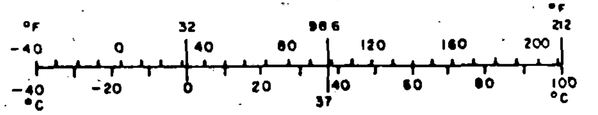


Table of Contents

1. INTRODUCTION

The cost of electricity is a significant portion of the operating costs of rail transit systems. The impact of increasing energy costs is felt by those systems presently in operation and and will be felt by those in the planning or construction phases. Because of the number of nuclear power plants coming on line in areas served by transit, the influence of electricity costs on operating and design policies of rail transit authorities is expected to grow in future years.

Concerned by rising energy costs, managers of several rail transit authorities have established energy management programs. The objectives of these programs are energy cost reduction and improved energy efficiency. Energy management is a process of understanding a system's energy requirements, with the goals of reduced energy cost and increased energy efficiency. Both goals enhance rail transit productivity. The bottom line is lower electric bills for the transit authority.

Energy management research and development for rail transit systems began at the Rail Systems Center (RSC) at Carnegie-Mellon University in 1976. The effort was established to help rail transit authorities manage energy within their organizations. The output of this work is the tools and methodologies for assessing energy conservation strategies and power rate structure modifications.

As a rule, energy management can foster its largest payoff when it is initiated during the design and construction phase of a rail transit system. The high dollar savings occur because low energy cost technology and operating practices can be engineered into the system at the outset. However, changes in technology and operations of present transit systems can also reduce the electric bill. Reduction of energy cost can be achieved through energy conservation, load management, and power rate intervention.

2. ENERGY COST AND EFFICIENCY

The factors that determine electricity cost in rail transit are related to variables of system design and operating practices (referred to as the energy use pattern), and the power rate structure of the electric utilities that serve the system. The energy use pattern is controllable within limits by transit management. The power rate structure, which sets the schedule of charges for electricity for energy use, power demand, and facilities is a matter of negotiations between the transit authority and the electric utilities subject to rate making jurisdiction of the public utility commissions.

The cost of electricity on rail transit systems is made up of facilities, power demand and energy use components. The facilities charges are generally fixed and may partially be funded by the transit systems' contributions-in-aid of construction. The energy consumption and power demand components result from operating the transit system. Energy consumption is the actual use of power integrated over time and it is measured by electric meters in units of kilowatt-hours (kWh). Power demand represents the generation, transmission and distribution facilities shared by transit with other customers or groups of customers of fhe electric utility serving the transit system. Power demand is measured and recorded by the meters and computed using a complex mathematical formula, which is usually different for every rail transit system. Power demand has units of kilowatts (kW).

It is the marriage of the power rate structure with the energy use pattern which determines energy cost, and in order to effect energy cost reduction, both aspects must be addressed by transit management.

The true measure of rail transit energy efficiency is related to the movement of people. The index most commonly used is the watt-hour per passenger-mile. This is a productivity index, for it relates mission oriented output (passenger-miles) to energy input (watt-hours). The index includes marketing effectiveness as well, since passenger-miles depends on how the system is used by its customers.

Energy management performance indices represent measures which can be used by transit authorities to determine the effectiveness of energy management strategies and/or gauge the energy productivity of the transit system.

A useful index which is reported by many rail transit systems is the kilowatthour per car-mile. There are two major problems with the reporting of this index. First, energy on some systems includes both traction and support components, while on other systems only the traction component is included. Secondly, kilowatt-hours per car-mile varies with the types of trains being run, the routes on which they run and the time of day and day of week on which they operate.

All indices, which are reported, are based on "average" properties of the transit system and are most useful when comparing the effects of energy conservation strategies with other types of operation.

2.1 ENERGY CONSUMPTION RELATED DESIGN AND OPERATING PARAMETERS

The design and operating parameters which influence energy use, power demand and ultimately energy cost can be grouped into six broad categories:

1. General transportation system characteristics such as passenger volumes, headways, station dwell times, speed, accelerating and braking rates and sizes of trains,
2. Right of way characteristics such as miles of track, number of stations, station spacing, grades, speed restrictions and curves,
3. Power transmission and distribution system characteristics such as impedances, voltage ranges, type of transmission and distribution networks and substation equipment.
4. Vehicle characteristics such as empty weight, train resistance characteristics, auxiliary power required and rotational weight.
5. Vehicle propulsion and braking system type and characteristics.
6. Support power requirements.

3. RAIL SYSTEM DESIGN AND CONSTRUCTION

Rail system design and construction refers both to new rail systems or to additions to or extensive modifications of old rail systems. Design and construction of a rail system is usually divided into five phases, all of which generally overlap:

1. Planning
2. Design
3. Procurement and Construction
4. Testing
5. Initial Revenue Operation

There are activities associated with reduction of energy cost and improvement of energy efficiency in each of the five phases. During phases 1-3, analyses are conducted to determine the energy cost consequences of major planning, design, procurement and construction decisions. These costs must be included in the overall cost-effectiveness evaluations as part of the decision making process. It is also during this time (phases 1-3) that major energy conservation strategies are designed into the system, provided that these strategies are also cost-effective. During phases 4-5, verification of the energy cost and efficiency model of the rail system is conducted. What generally results from the verification process, is a fine tuning of the model, so that it can be used during full revenue operation of the system.

The energy management activities appropriate to each of the five phases of rail system design and construction are discussed in the following subsections.

3.1 PLANNING PHASE

During the planning phase of a rail system, an energy management plan is assembled. This plan contains an outline of all of the tasks necessary to integrate energy cost reduction and improved energy efficiency into the design, procurement and construction of the rail system and subsequent verification of this integration. The following issues are addressed in the plan:

1. Identification of analytical studies to be undertaken during design, which may have a significant energy cost component.

2. Preliminary discussions with the electric utilities which will provide power to the rail system, to determine the range of options of power rate structure available.

3. Management controls to assure that short term design decisions, which have a major energy cost or efficiency impact, are considered. This may include appointment of an energy management officer.

The analytical studies undertaken during the design phase should include the investigation of cost-effective energy conservation and load management strategies.

3.2 DESIGN PHASE

During this phase of the design and construction process, energy cost and efficiency trade-off studies are conducted. The use of the Energy Management Model (EMM) or similar simulation tools for those studies involving traction energy is highly recommended. Studies should be conducted in the following areas.

1. Route Selection - Although route selection is usually initiated during the planning stage of the design and construction, it is truly a part of design. There is an energy cost component to route selection, which has not generally been considered in weighing alternatives. Topography and route directness can have an important influence on energy cost during subsequent revenue operation. If the energy cost component of alternative routes is estimated and included among the other cost considerations in the alternative route analysis work, a more complete picture is obtained before a decision on the final route is made.

2. Station Locations - There can be significant energy cost implications in the location of passenger stations. The term location refers both to the vertical (above/at/below grade) and the geographical. Stations located far below the surface require energy for lighting, escalators, elevators and environmental control. Also, stations located deeper underground than adjacent stations could cause more traction energy to be expended because of adverse grades negotiated by trains in the ingress and egress to the station. Displacement of the station from the general direct route will also have energy cost implications. These costs are estimated using train performance simulation. The change in support energy required as alternative vertical station locations are considered should also be estimated to complete the analysis.

3. Track Network - The track network refers to the number of parallel tracks, including turn backs and sidings, along the route. Selection of the track network can significantly affect both energy cost and efficiency. The use of turnback tracks at intermediate stations allows the flexibility of better passenger loading during both peak and off-peak hours. Likewise, regions of three or four parallel tracks or sidings allow running of local and express service to optimize passenger loading. In addition to specific energy cost and efficiency components, selection of the track network has an effect on overall transit productivity.

4. Passenger Station Accommodations - Accommodations and services for passengers in station areas will use energy. The energy cost is recurring over the lifetime of the station. Design of passenger stations for modern

rail transit has not considered the energy cost component. Control of selected support systems, such as Lighting, Air Conditioning, Heating, Escalators and Elevators can allow portions of the system to be switched off at selected critical times, either when demand is reaching its maximum or when not required.

5. Power Transmission and Distribution - Many considerations affect energy cost in the selection of the power transmission and distribution system's network configuration and components. These considerations are:

   a. Physical layout

   b. Inverter/Energy storage substations(R & D area)

   c. Circuit conductivity

   d. Nominal Voltage and Voltage tolerances

   e. Power factor

   f. Circuit monitoring

6. Preliminary Rate Structure Review - It is during the early portion of the design phase that a preliminary evaluation of the power rate structure should be conducted. All of the electric utilities which could provide power to the rail system should be identified. Likewise, all of the public utility commissions, which have jurisdiction over rate and service matters should also be listed. There are several steps in the rate structure evaluation process.

   a. Determine into which customer class the utilities intend to put the rail system. If a railway customer classification is already recognized within the jurisdiction, then it is likely that the new service would be grouped into that class. If such a class does not exist, then it is likely that the utility will want to put the service into one of the existing commercial/industrial customer classes. This may not be appropriate in terms of the rate based on the utilities' cost to serve the rail system as a customer.

   b. Review of the specific rate that the utilities intend to charge the rail system. This review should be conducted to determine rate fairness to the transit system and for the purposes of determining the cost of energy for various scenarios of rail equipment selection and operational strategies, which may be investigated during the design process. The rate should reflect customer and load characteristics of the rail system. It should be just, reasonable, non-discriminatory, and based on the cost of providing service.

   c. Conduct a tradeoff study on the ownership of the excess or special transmission lines from the utilities' substations to the feeds to the rail transit substations. It is a general rule that when the transit authority owns these lines, the meters are placed at the utility's substation and all power delivered to the transit substations, which feed from the utility substation, is recorded on a single meter.

   d. Meetings should be held with the electric utilities which will serve the system. These initial meetings will set the tone for subsequent rate negotiations.

7. Vehicles - The vehicles to be used to make up the train consists which are used for revenue service are an important consideration in assessment of energy consumption. There are several ways that the rail vehicle influences energy consumption. One way is through the physical characteristics, principally weight and physical dimensions. Selection of propulsion and braking subsystems also has a large influence on energy consumption while the trains are running. The auxiliary power requirement on-board the car influences traction energy since that power must be delivered to the car via the traction power distribution system (third rail or trolley). Finally, characteristics of the car or fleet that can indirectly affect energy consumption are grouped under operational flexibility. These characteristics generally refer to the ability to match car-miles to passenger-miles using the minimum number of car-miles. Such things as quick uncouple/couple operations and the ability to use cars as head ends and in interiors of trains provide this operational flexibility.

8. Train Control - Train control may be manual or automatic (ATC). In the new heavy rail systems, train control is automatic. In the new light rail systems and older heavy and light rail systems which are being modernized, train control is usually manual. There are two general considerations in the design of train control systems, which will influence both power demand and energy consumption. These are train interference and train performance.

   a. Train interference. Until recently, most of the concern in the train interference area has been to maintain capacity and reduce delay time. Because of reduction of subsidies to transit authorities, reducing operational cost is also important, and energy cost is one of the easiest of operational costs to reduce.

   b. Train performance. Generally, transit authorities use their equipment to minimize the running time between stations, subject to speed restrictions, grades, traffic interference, program stop requirements and other operational policies. This minimum run time does not result in minimum energy consumption. Strategies of train running which result in run times greater than the minimum are known as performance modification strategies. Performance modification strategies to reduce energy consumption are not new. Several kinds have been implemented in the past on rail transit systems. These include acceleration and deceleration reduction, speed reduction, coasting and optimum performance reduction. The last strategy refers to reducing performance such that their is maximum reduction of energy per running time increase. In all cases, running time increase is kept to a minimum so that capacity of the system is not influenced.

9. Planned System Operation - During the design phase, a system operating plan is developed. The plan usually contains several alternatives for future operation, beginning with initial revenue operation and continuing

for several years. It is the basis for vehicle, train control and power distribution equipment procurement. Both train performance and operation are specified and are used as the basis for estimating the energy use pattern, which is subsequently used for electric utility rate negotiation. Predicted passenger flows are no sacred cows. In fact, they are probably one of the weakest knowns in the system. Energy cost will be least when schedules are developed to best match car-miles to passenger-miles without crowding. Ultimately, this matching can only be done under actual revenue operating conditions. It is desirable, not only from an energy use but also from an overall transit productivity perspective, to optimize passenger load factor (passenger-miles/car-miles).>

3.3 PROCUREMENT AND CONSTRUCTION PHASE

During this phase of the design and construction process, the results of the energy cost tradeoff studies are incorporated into procurement and construction decisions. Energy efficiency, when appropriate, is incorporated into the specification for the vehicles, train control, power distribution and passenger station equipment. There is an important rule which should be followed here: IF A METHOD DOES NOT EXIST FOR PROVING THAT A SPECIFICATION HAS BEEN MET, THEN DO NOT MAKE THE SPECIFICATION.

The model which were used for the energy cost tradeoff studies should remain active to help evaluate the bids submitted by the suppliers during this stage. This model should be made available to the serious bidders, especially if the same model will be used to evaluate the bids.

Test plans should be developed to evaluate the energy use of the equipment and systems. Suppliers should also have copies of these test plans before the bid. The test plans should clearly specify the methodology and conditions of the test.

Since energy use patterns of the alternative scenarios of rail system operations have been developed as part of the system operating plan, serious negotiations with the electric utilities who will supply power can continue. These negotiations will include interim rates during prototype testing and startup of revenue operation, when system power requirements will be unpredictable. Requirements for power demand monitoring should also be discussed at this time.

There are four major areas in which energy use can be specified either covertly or overtly in the supply. These areas are: vehicles, train control, power distribution and support equipment.

Test plans should be produced to determine energy related characteristics of the vehicle, train control, power transmission and distribution system, support equipment power and any monitoring equipment.

Test operations on the new or addition to the rail system will produce an energy use pattern substantially different from that which will be seen during revenue operation. The electric bill for test operations could be quite high relative to the actual use if some arrangements are not made beforehand to alert the utility of the pattern. During the initial negotiations with the utility the rates during this phase of design and construction should be discussed separately from the revenue operation rate structure.

3.4 TEST OPERATIONS

The results of the energy related tests will result in some modification of the energy related input parameters into the model used to estimate energy use patterns for alternative train operation scenarios under future revenue operations. If these modification are substantial, the energy use patterns for these scenarios should be reestimated. These reestimates could influence decisions that were made during the design phase.

The energy use patterns predicted for revenue operations should now be the best estimates available for discussion with the electric utilities. If these are the basis for cost of service determination by the utility, the rates for initial revenue operation will be finally set on these predictions.

3.5 INITIAL REVENUE OPERATION

An energy audit should be conducted after about two years of revenue operation. The results of the energy audit should be compared with the predicted energy use patterns. Changes which have occurred in the train operation scenarios because of experience obtained in revenue operation together with model changes, which were mandated by the verification process, require updating of the energy use pattern forecasts. These should be carried out at this time.

Rate intervention will still occur on those issues which have not been resolved in the past. Solid energy use patterns are now available for true cost of service analysis by the utility. These should be conducted in line with the next rate hike request.

4. RAIL SYSTEM OPERATION

The application of energy cost reduction to rail transit systems which are presently operating is somewhat different from those in the design and construction phase. There are two steps:

1. Energy management study, and
2. Implementation of energy cost reduction.

The energy management study has four phases:

1. Energy audit.
2. Simulation and Verification of Normal Operation.
3. Power Rate Structure Evaluation.
4. Identification of Energy Cost Reduction Opportunities.

4.1 ENERGY MANAGEMENT STUDY

The energy management study is the beginning of any energy management program applied to systems already in operation. It is here that the components of energy cost, obtained by the marriage of the energy use pattern and the power rate structure are understood. The costs and benefits realizable by application of energy conservation and load management strategies are also predicted. All of this is accomplished in four stages.

1. Energy Audit - Through the use of an audit procedure, the actual energy use pattern of the rail system is established. The detail to which this can be accomplished depends on the detail of data available. If the data are available, this audit should take the form of a detailed computer analysis of metering information (which can be obtained from the electric utilities serving the system) at each power delivery point over successive demand intervals over a long period of time (at least a year or more), and a detailed estimate of energy end use at each meter. The audit must include traction energy, used to run the trains and provide auxiliary support power aboard them, and support energy, used to provide support services.

2. Simulation and Verification of Normal Operation - In order to provide a base for reduction of electric power use caused by application of energy conservation techniques, it is necessary to estimate the energy use pattern by simulation. The support and traction power which do not depend on train operation are treated as background power, which may have ambient and time of day variation, while the traction power which results from train operation is estimated using the EMM or similar tool. The verification procedure is the comparison of the estimates of the traction

energy use pattern obtained through simulation, with the results obtained in the energy audit. The level of detail of this comparison depends on the detail achieved in the energy audit.

3. Power Rate Structure Evaluation - The basic regulatory principle on which the power rate structure should be evaluated is that the rail transit system be required to pay no more for their electricity than the cost to the utility to serve it. The evaluation begins by reviewing the history of power rate structure at the transit system. It includes reviewing the original negotiations and/or master agreement and subsequent rate increases that had been implemented for various components of the tariff. In order to complete this comprehensive review process, cooperation and assistance of the utility providing electric service is crucial. Once the review process has been completed, the transit authority should seek to resolve unfair rate structures and issues, through direct negotiations with the utility or intervention in formal rate proceedings, before the public utility commission. All of the issues may not be resolved in the context of a single rate proceeding. Utility rate making is a continuous problem and each rate proceeding presents the transit management with an opportunity and a challenge to reduce its power cost.

4. Identification of Energy Cost Reduction Opportunities - This stage of the energy management study is the final one. The energy cost savings of energy conservation and load management strategies are determined along with the costs associated with implementing them. Savings associated with rate intervention, either by negotiating with the electric utilities or by presenting a case to the regulatory agency, are also estimated along with the costs of the action. A plan for implementing those actions which are identified as cost-effective is also included. Evaluation of the power rate structure leads to an estimated cost savings, should the issues identified in the evaluation be resolved. The estimates here are necessarily much softer than those made on the operations side. The degree to which rate relief can be realized is always uncertain. Since any rate relief achieved by the transit authority shifts the burden to other customers of the electric utilities, there is an inducement for them to oppose the case. Commissions look on customers who do not intervene as satisfied with their rate structure. All of these things must be carefully considered before attempting rate intervention.

4.2 IMPLEMENTATION OF ENERGY COST REDUCTION

Completion of the energy management study, outlined in the previous section, implies a decision point for transit management on which strategies to select for implementation. All of the theoretical estimates of cost and benefit are now available.

1. Prototype Operation and Validation - It is important to minimize the technical and financial risk of applying the selected conservation strategies. A low cost experiment should be conducted during which both the actual energy savings and performance changes can be measured under actual operating conditions. The results should be compared with the simulated case.

2. Full Implementation and Monitoring - The prototype operation and validation step should reduce the technical risk for implementing energy cost reduction on a wider basis. However, the program does not end here. Continued monitoring of the energy cost savings is still required, together with any system performance changes which result from the program. It is at this stage of the program that the negotiation capability of the transit authority with the electric utilities must be strongest, since the reduction of revenue to the utilities because of the program will be felt. Changes in the power rate structure may bring other opportunities to reduce energy cost as well. Thus, the energy management study should be updated from time to time, typically on a five year basis. If the original study were conducted properly, updating should not be difficult.

3. Rate Intervention - If the transit authority decides to proceed with rate intervention, the first step is to meet with the utility to negotiate issues which can be settled outside of regulatory hearings. The remainder of the tasks may be conducted before and during the next rate proceedings:

    a. Select a local law firm who has some experience in rate proceedings. Since part of the intervention will be an educational process of the regulatory commissioners, a law firm which can ease this process is most appropriate.

    b. Review and analyze the utility's rate increase proposal. This review should be based on the cost to serve principle and be considered in the light of the other issues to be addressed at the rate proceeding.