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MASTER

BATTERY STORAGE ON THE CUSTOMER SIDE OF THE METER ASSESSMENT

Final Report

By
F. Jere Bates
John E. Clifford
Mary L. Duchi
Thomas R. Martineau
John C. Skelton

February 25, 1981

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Battelle
Columbus Division
Columbus, Ohio

U. S. DEPARTMENT OF ENERGY

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EXECUTIVE SUMMARY

This report presents the approach used in and the findings of this study designed to assess battery storage on the customer-side of the meter. Recognizing the importance of evaluating customer-side battery storage, the U.S. Department of Energy sponsored this research with the primary objectives of:

- Determining the feasibility of customer-owned battery storage and the potential applicability of utilization by various electricity customers based on an evaluation of technical, economic and institutional issues
- Identifying electricity customers who may subsequently participate in a battery storage demonstration with DOE.

The research was conducted following a typical energy system decision-making process. The sequential steps of this process are to:

- Identify the project objectives and thrust
- Select the appropriate energy system for evaluation
- Determine the energy system's cost and performance parameters
- Identify and evaluate important nontechnical factors (regulatory, institutional and environmental)
- Determine the economic viability of the energy system
- Conduct a market assessment of the energy system
- Summarize the findings and recommendations.

To accomplish the project objectives, the study involved an evaluation of factors which have a bearing on customer siting, ownership and operation of battery storage systems. These factors were found to vary significantly from utility-side systems. Consequently, the research was directed toward evaluating the issues of battery system design; the economics of battery storage for electricity customers; institutional and environmental concerns for battery users; and market potential on the customer-side of the meter.

The selection of a baseline system for evaluation was founded on the systems' availability for near-term demonstration and subsequent commercialization. Therefore, lead-acid batteries were chosen for baseline evaluation. To assure a comprehensive analysis of customer-side viability, DOE battery storage system goals were also chosen for inclusion in the viability analysis.

Battery system cost and performance parameters were calculated for the baseline system and identified for DOE goals. To allow for the evaluation of various size customer loads, four widely varying battery storage system sizes were evaluated. System component costs for the batteries, power conditioner and balance-of-plant were estimated. The resulting baseline system costs for the four systems are:

Power kW	Energy kWh	System Cost $\$/kWh_{ac}$
20,000	100,000	140
1,000	5,000	162
40	200	194
2	10	241

The calculated baseline system efficiency was estimated at 71 percent. To permit a comprehensive analysis of customer-side opportunities for battery storage, equations were developed to allow these base costs to vary as the customer required battery discharge period varied. The DOE system cost goals employed are \$65 per kWh_{ac} and .65 efficiency.

Nontechnical factors of significance to customer-side battery storage were identified and evaluated. Research quickly identified the importance of the electric rates of potential customer-side battery storage customer. The evaluation of electric rates is complicated by the widely varying rate structures and schedules presently in place; the wide differences in the changeable nature of the regulatory environment; and the fact that each utility has its own generation mix, customer mix, rate derivation methodology, etc., all of which influence battery storage viability. Three electric rate factors were found to be most significant. First, the relative level of demand charges within electric utilities' rate schedules and second, the duration of the battery discharge period, as determined by the customers load shape and the utility rate structure, dominate the benefits associated with the electricity cost reduction potential. Regulatory uncertainty, the third factor, is a potential barrier because a potential customer cannot be sure of the expected savings from installing a battery storage system when electric rate structures and schedules are subject to frequent change. This is a significant risk that many potential customers may be unwilling to accept.

Other nontechnical factors of an environmental and institutional nature were identified. These factors will not restrict the diffusion of battery storage systems on the customer side of the meter, if they are given appropriate and timely attention. The most important of these factors are:

- Determining the applicability of tax incentives
- Development of appropriate measures for dealing with hazards
- Identification and resolution of local use restrictions
- Widespread dissemination of information to foster customer acceptance and positive attitudes within financial institutions and the insurance industry.

The economic viability analysis found the baseline battery storage system (cost estimates for the year 1987 at commercialization levels of production) to be viable for some customers in electric utilities with large rate differentials associated with present rate schedules. Economic viability is impacted significantly by the level of demand charges (in both traditional and time-of-day rate structures), the duration of the battery system discharge period, and the cost of the battery storage system. Achievement of the DOE cost and performance goals for battery storage systems will significantly improve economic viability. Real electric price increases are likely to impact demand charges and thereby favorably impacting economic viability.

The market potential for demonstration customers appears to be greatest for moderate size applications among the commercial and industrial customer classes. The major factors influencing this potential are diffusion potential, receptivity, potential for demand charge or time-of-day savings, and the potential for short discharge periods. Willingness to participate in a demonstration program appears to be greatest among the industrial classes. Potential demonstration customers have been identified who appear to have the most viable applications and are interested in discussing a battery storage system demonstration with DOE.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS

Page

LIST OF TABLES

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS

Page

LIST OF FIGURES

TABLE OF CONTENTS
(Continued)

Page

CHAPTER I. INTRODUCTION

BACKGROUND

One of the primary energy goals of the United States is to reduce the consumption of scarce fuels (oil and natural gas) within all feasible segments of our economy. Two general approaches being employed to meet this goal are direct reduction in energy consumed through conservation in many forms, and the shifting of energy consumption from scarce fuels to other more plentiful energy sources (including coal and nuclear fuels, and solar). Within the electric utility industry energy conservation is being pursued in many programs (e.g. utility induced direct load control, and user initiated through increased insulation, more energy efficient equipment etc.). Shifting of fuels consumed (oil to coal) within feasible generating plants is an example within the utility industry of fuel switching from scarce fuels to more plentiful fuels.

Within this industry there are many companies that generally use coal and nuclear for base load generation and scarce fuels for peak load generation. Where this fuel use mode of operation exists, plentiful fuels can be substituted for scarce fuels through a flattening of the load curve. (This assumes sufficient base load generation exists to absorb the shifted load). Battery storage is one approach that could be employed to affect this load flattening or shift. The load shift could occur when battery charging takes place during the off-peak or low demand on the utility period,and the battery discharge is done during the on-peak or high demand on the utility period (Figure I-1).

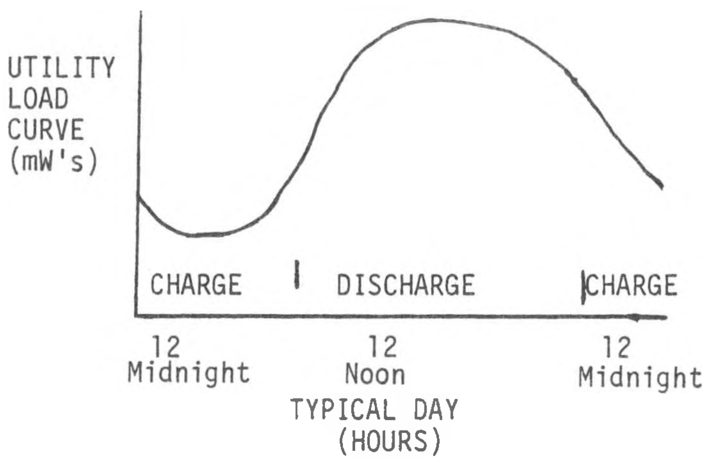


FIGURE I-1. BATTERY STORAGE LOAD SHIFT POTENTIAL - DAILY LOAD CURVE

This shift from scarce to more plentiful energy sources can result whether the battery storage is on the utility-side or the customer-side of the meter. Evaluation of utility-side load-leveling battery storage has been performed in many Department of Energy (DOE) and Electric Power Research Institute (EPRI) studies beginning in 1972. These prior studies were reviewed on this project for pertinent information and are cited in later Chapters of this report. This research project is concerned with assessing the viability of customer-side battery storage from the perspective of overall customer-side and individual customer class viability.

PROJECT OBJECTIVES AND APPROACH

There are two primary objectives of this research. They are to:

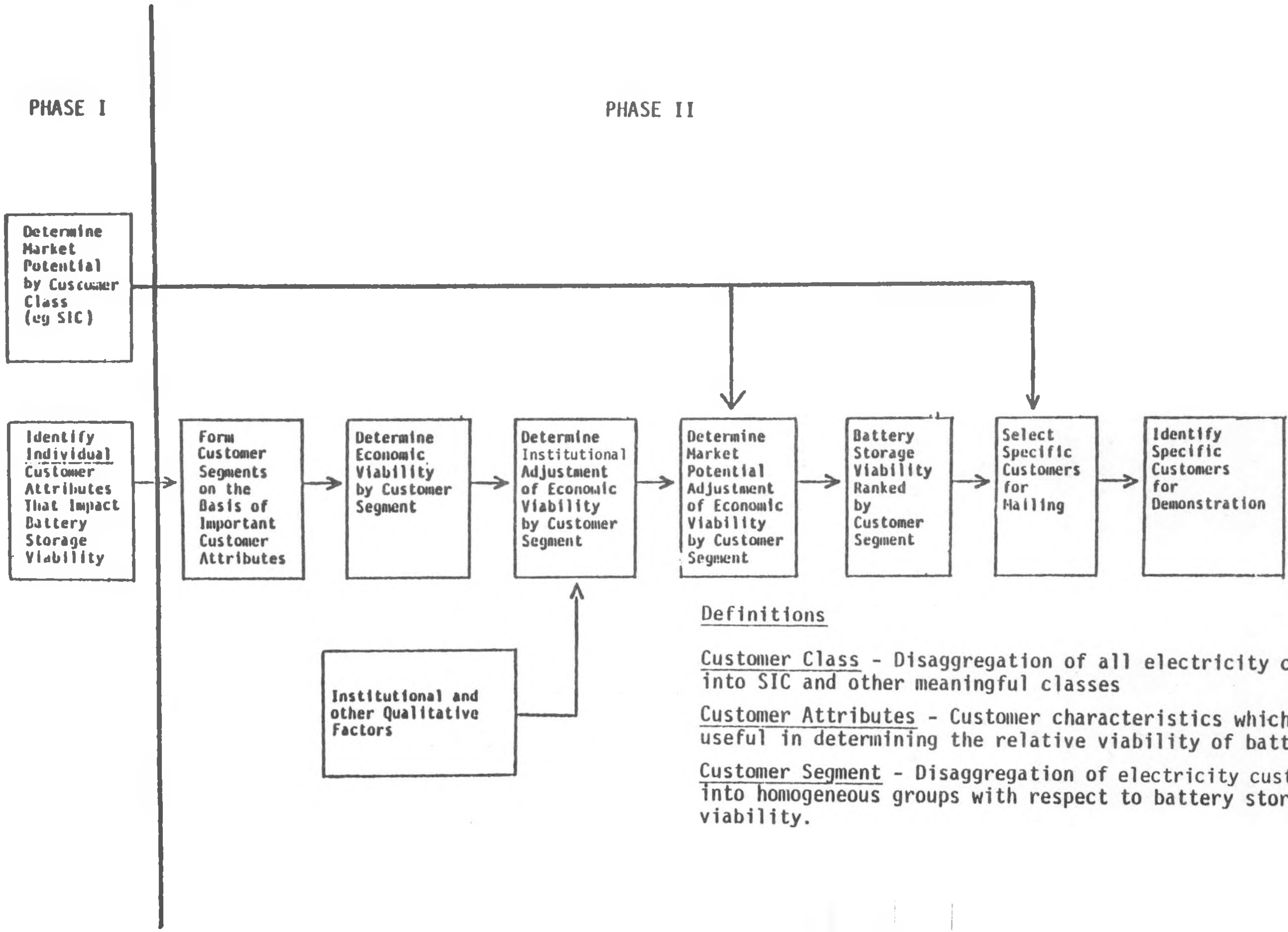
- Determine the feasibility of customer-owned battery storage and the potential extent of utilization by various electricity customers based on an evaluation of technical, economic, and institutional issues
- Identify electricity customers, who may subsequently participate in a battery storage demonstration with DOE.

Stated in a more concise manner, the overall study objective is to identify electricity customers:

- For whom battery storage is potentially justified
- Who represent a significant potential for widespread implementation and scarce fuels conservation
- Who may subsequently participate in a battery storage system demonstration with DOE.

These objectives require a scope that integrates the technical, economic, and institutional issues evaluation by electric customer classes including their implementation potential and willingness of individual electric customers to consider a demonstration facility.

The project approach to meeting these objectives is presented in Figure I-2. The first phase of this project identified electricity customer attributes that could impact battery storage viability and determined, by customer class, baseline data and characteristics that impact viability and widespread implementation. The initial Phase II activity entailed an identification of customer segments which are homogeneous groups with respect to battery storage viability, as determined by the important electricity customer attributes of Phase I. Using respresentative battery system costs and typical



Definitions

Customer Class - Disaggregation of all electricity consumers into SIC and other meaningful classes

Customer Attributes - Customer characteristics which are useful in determining the relative viability of battery storage

Customer Segment - Disaggregation of electricity customers into homogeneous groups with respect to battery storage viability.

FIGURE I-2. BATTERY STORAGE PROJECT FLOW economic benefits of employing a battery system, an initial economic evaluation was conducted. This initial evaluation was modified by pertinent institutional and market potential factors to determine the overall viability of battery storage by customer segment. Customer segment viability evaluation was then linked to the electricity customer classes to determine where viability exists, and the potential for widespread implementation. Finally, customers within the viable customer classes were contacted and screened for demonstration customer potential.

STUDY SCOPE

The thrust of this study is a thorough evaluation of customer side-of-meter battery storage issues. This thrust precludes a rehashing of utility-side issues and a direct comparison of customer-side with utility-side storage. However, the present study was approached by asking the positive question: "What is different and advantagous about customer-owned battery storage compared to utility-owned storage?" The answers to this question defined the issues and the thrust of this study. Thus, the major project effort is focused on the important issues in customer-owned battery storage that have not previously been analyzed in detail. Therefore, instead of a very detailed battery system comparison, as has previously been completed, an appropriate battery system for customer-side, near-term demonstration and subsequent commercialization has been chosen and evaluated in sufficient depth and clarity to form a solid technology base for the customer-side regulatory, institutional, economic and market potential evaluations.

Battery Storage System

The difference in thrust between this study and previous research is illustrated in Figure I-3. Previous studies viewed the battery storage system on the utility side of the meter which normally has implied utility siting, ownership, and operation. This is shown as the dashed line in the Figure. This Battelle research considers battery storage on the customer side of the meter including customer siting, ownership and operation. Before

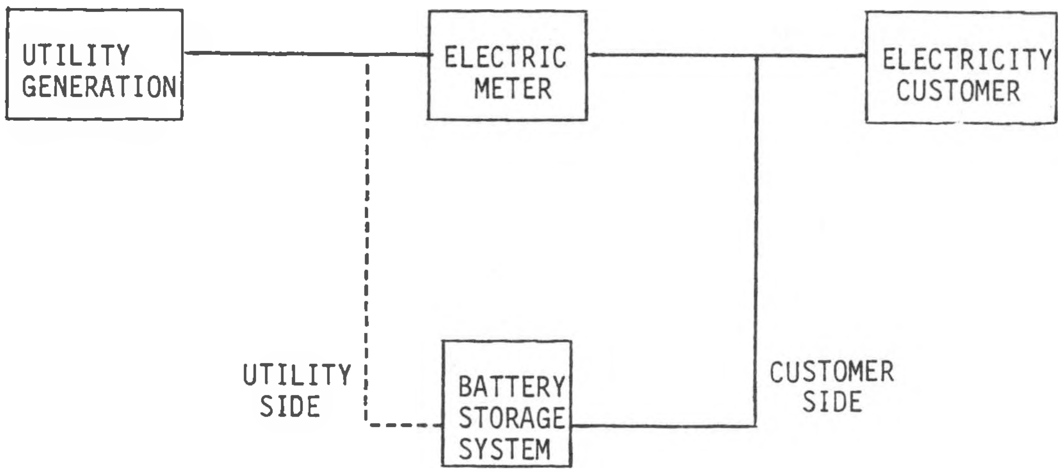


FIGURE I-3. RESEARCH THRUST ON THE CUSTOMER-SIDE-OF-THE METER discussing the implications of this difference in the next section, it is important to note that the primary components of a battery storage system are the batteries, a power conditioner and balance of plant (e.g., building, electrical connections, and land). (See Chapter II for an elaboration.)

As a base for this study, the type of battery storage system to be evaluated was determined. Of primary consideration was the system's availability for near-term demonstration and subsequent commercialization. The system characteristics had to be compatible with the intended demonstration; namely customer-side of the meter storage for load leveling. Therefore, the choice of batteries for a base system is lead-acid. These batteries are available with sufficient cycle life and are proven. Recognizing the potential near-term availability of zinc-chloride batteries, a sensitivity analysis of battery system viability for this system was also conducted. Finally, a view of long-term future, customer-side viability was prepared using DOE battery storage goals. (Choice of batteries is discussed in depth in Chapter II.)

Overview of Customer Side Issues

Electric customer ownership, siting and operation of battery systems requires the evaluation of many different issues from those relevant to utility ownership. The following sections briefly address the major issues with a complete evaluation contained in subsequent Chapters of this report.

Battery System Design Issues

Utility-side of the meter studies have generally considered batteries with relatively short discharge periods of three to five hours. The discharge periods were of this duration because of the fit with their intended use: an alternative to peak load generation.

On the customer-side of the meter, however, the potential duration of discharge is considerably longer for most electricity customers. The rate structures generally faced by electricity customers, coupled with their own load shapes, require batteries with discharge periods running from a few to 14 hours. This is the case for many current rate structures with demand charges, and for emerging time-of-day rate structures with 8 to 14 hour on-peak periods. Customer-side storage system designs must meet these requirements.

Economic Evaluation Issues

A very important issue is the approach used in preparing an economic evaluation of battery storage systems. Because utility-side battery storage system applications are viewed from the perspective of an alternative to conventional peak load generation, all components are designed to the normal three to five hour peak period (discharge period for batteries). This is typical of the operation mode of conventional peak load generation such as combustion turbines. The economic evaluation is conducted using typical utility parameters such as fixed charge components (e.g., utility cost of capital, discount rates and taxing structures); mode of operation and maintenance; and cost of fuel (utility incremental cost of off-peak power). This approach to the economic evaluation of electric customer ownership of battery storage systems is clearly not appropriate for this study.

The electric customer is generally concerned with system cost vs. the benefits of the system (i.e., What is the life cycle cost of the system vs. the savings derived from using the system rather than maintaining the status quo-total dependence on electric grid power?). The rate structure faced by the electric customer is the primary determining factor in evaluating expected savings. Rate structure concerns include:

- Length of customers' maximum or near maximum use of electricity (demand charge related)
- Length (in hours) of the on-peak period set by the utility in combination with the customers electricity usage pattern (time-of-day rates)
- Months of the year the utility has time-of-day rates in place
- The magnitude of the demand charge or the on-peak/off-peak differential
- Potential future changes in or elimination of rate structures assumed for evaluation purposes.

In addition, the economic evaluation must consider factors such as the customers' load shape changes during the year (i.e., Is battery storage needed throughout the year or only during some seasons?), and various quantifiable institutional factors that could impact viability (e.g., cost-of-capital, siting costs, and environmental costs).

Thus the economic evaluation is conducted from an entirely different perspective than that prepared for utility ownership.

Institutional Issues

Customer-side systems are faced with institutional issues that are either of no concern to utilities or are taken for granted as a normal part of their operations. The difference in institutional concerns generally focuses on siting and risk-related issues. Typical of the customer-side institutional issues studied are:

- Risk of the technology and associated impact on the cost and availability of capital and insurance
- Environmental and safety concerns of siting in or near electricity customer facility
- Building code and zoning restrictions.

These and other institutional issues are addressed and factored into the viability analysis of this study.

Market Potential Issues

Customer-side of the meter market potential assessments are vastly different from utility-side evaluations, which typically have been prepared on the basis of an economic comparison with competing peak load generation. The customer-side evaluation also is concerned with an economic evaluation, but on the basis of a discounted cash flow approach which involves the calculation of the incremental cash flows associated with each year in the life of the battery storage investment. Market potential, besides economic assessment, also is influenced by post demonstration diffusion potential within various customer classes, by the amount of electricity consumed in the viable customer classes, and by the geographic location of customers with respect to utility characteristics.

REPORT ORGANIZATION

The report is organized along the lines of frequently used decision-making processes employed when selecting an energy source. The general flow of this process and the organization of this report is displayed in Figure I-4. "Energy System Decision-Making Process".

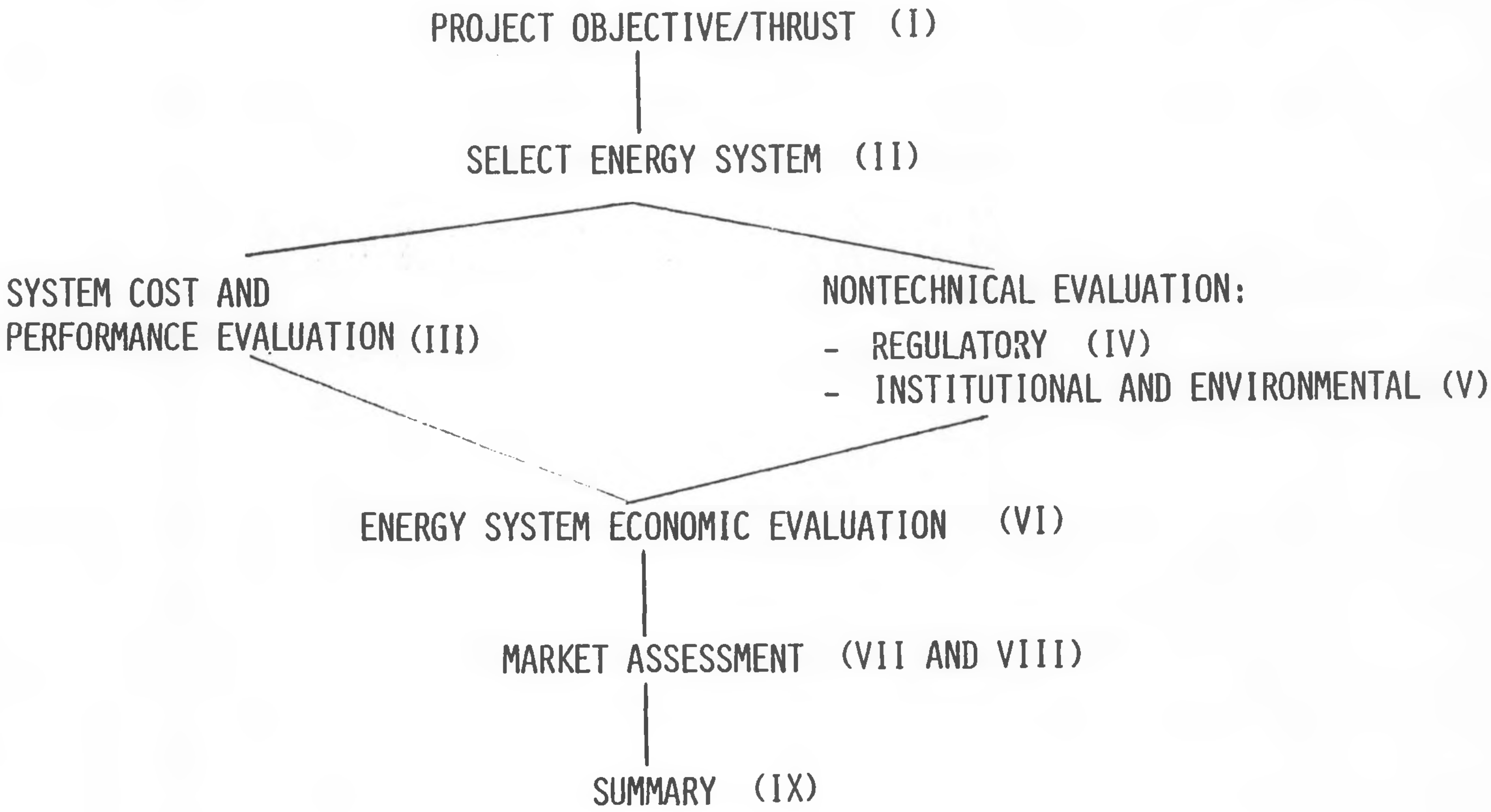


FIGURE I-4. ENERGY SYSTEM DECISION–MAKING PROCESS
(Roman numerals indicate associated report chapters)

CHAPTER II. BATTERY ENERGY STORAGE SYSTEM DESCRIPTION

BATTERY ENERGY STORAGE TECHNOLOGY

Introduction

An electric energy storage system can be considered a "black box" that is connected to the electric utility lines as shown in Figure II-1. During off-peak hours, electricity from the utility lines is stored in the energy storage system (charging mode of operation). During on-peak hours, electricity from the energy storage system is returned to the utility lines and/or directly to the electrical load of the consumer (discharging mode of operation). Of the many possible energy storage systems, battery energy storage is distinctive in that electrical energy is stored by conversion of electrical energy to chemical energy and later released by reconversion of chemical energy to electrical energy. Since the electrochemical conversion requires direct current (dc), an essential component of the battery energy storage system is a power conditioning subsystem to convert electric utility supplied alternating current to direct current (i.e., operation as a rectifier). For the special case of direct current loads, the output of the battery during discharge could be directly connected to the load. For the more general case, the direct current output of the battery is returned to the power conditioning subsystem and converted back to alternating current (i.e., operation as an inverter).

Battery Subsystem

The three principal elements of a battery energy storage system are the:

- Battery subsystem (B)
- Power conditioning subsystem (PC)
- Balance of plant (BOP).

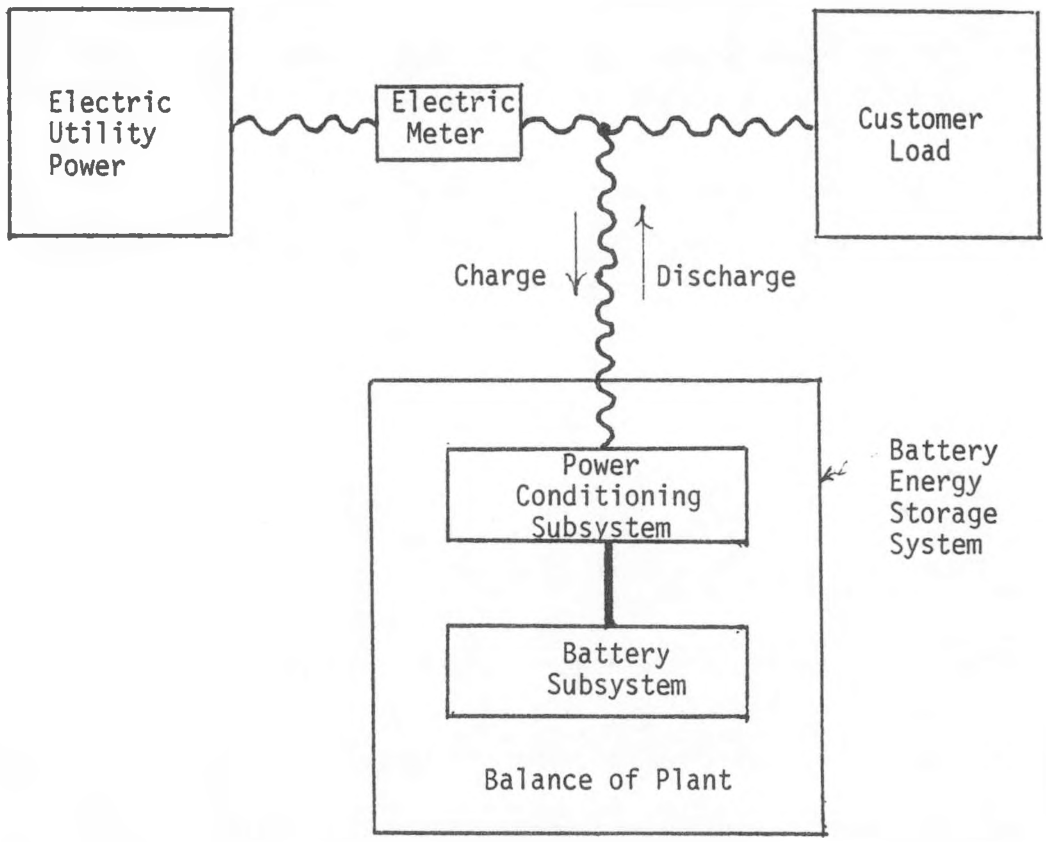


FIGURE II-1. SCHEMATIC OF BATTERY ENERGY STORAGE SYSTEM

The relative importance of the three principal elements to the total cost of the battery energy storage system depends on many factors such as energy storage capacity. For preliminary discussion, a 100 MWh 5-hour discharge battery plant (baseline system described later in Chapter III of this report) might have a cost distribution as shown in Table II-1.

Generally, the purchase price of the battery subsystem (F.O.B.) represents the major cost element. Depending on battery type, the battery is also the major contributor to balance of plant costs. The power conditioning subsystem is practically independent of the battery type.

Power Conditioning Subsystem

The term "power conditioning subsystem" is used in this report to include everything associated with electrical ac-dc-ac conversion. A typical breakdown of components is shown in Table II-2 for one type of power conditioning subsystem[(1)].

Balance of Plant

"Balance of plant" (BOP) is a term used to cover all components of the total system not included in either the power conditioning subsystem or the battery subsystem. As a minimum, BOP includes the site. Depending on the particular battery system, BOP may include foundation, weatherproof enclosure, electrical connections, and any ancillary equipment (e.g., for cooling, ventilation, battery-handling, electrical control, instrumentation, safety).

For the purpose of this project, the battery (cells or modules) subsystem and power conditioning subsystem were considered to be truck transportable items that were purchased from the factory (i.e., costs are F.O.B. the factory). Thus, the cost of transportation and installation was included in the balance of plant costs.

II-(1) Conceptual Design of Electric Balance of Plant For Advanced Battery Energy Storage Facility, United Technologies Corporation, ANL-80-16 (January, 1980).

TABLE II-1. TYPICAL DISTRIBUTION OF BATTERY ENERGY STORAGE SYSTEM COSTS*

Total Energy Storage System (100%)
Battery Subsystem (56%)
Power Conditioning Subsystem (14%)
Balance of Plant (30%)

*Baseline 20MW, 100 MWh System.

TABLE II-2. TYPICAL DISTRIBUTION OF POWER CONDITIONING SUBSYSTEM COSTS*

Power Conditioning Subsystem			(100%)
Power Conditioner		(95.4%)	
Converter	(71.3%)		
Three-phase Bridges			
Low Voltage Magnetics			
Output Transformer			
AC Isolator			
Miscellaneous Components			
AC Interconnect Equipment	(3.3%)		
DC Interconnect Equipment	(20.8%)		
Auxiliary Power System		(4.6%)	
Uninterruptible Power Source	(0.6%)		
Auxiliary Diesel Generator	(0.3%)		
Other	(3.7%)		

*Percentage distribution of costs in parentheses based on costs in Reference II-1.

Battery Terminology

The terms cell, submodule, module, battery, and battery plant (or system) are used in the description of large energy storage systems and the terminology depends on the type of battery. Other terms used are "rated capacity", "depth of discharge", and "cycle life". It is also important to appreciate that any battery-type can be optimized for a particular application. A simplified example based on a lead-acid battery will help to clarify the terminology.

The most familiar example of a storage battery is the lead-acid battery used in automobiles and referred to as the SLI-type (for starting, lighting, and ignition). The typical 12-volt battery contains six cells connected in series internally (nominal 2 volts/cell open circuit). A cell is defined by the smallest integral of voltage for the electrochemical couple. Each cell contains a number of positive and negative electrodes in an electrolyte of aqueous sulfuric acid that are connected electrically in parallel. The electrodes (lead alloy grid plus the active material, predominantly lead dioxide at the positive and lead at the negative in the charged state) are referred to as plates (e.g., a 5-plate cell contains two positive plates interspersed between three negative plates with separators between plates). Capacity in ampere-hours increases in proportion to the number of plates (e.g., positives) connected in parallel electrically. The important factor in cell design is the total plate area per cell (e.g., number of positive plates times the geometric area per plate). Ideally, as in the lead-acid case, the electrolyte of one cell does not interconnect with the electrolyte of other cells, so there are no shunt current losses from cell to cell. Any number of cells can be connected electrically in various series and parallel combinations to achieve a desired system voltage and current capacity (ampere-hours) or energy capacity (kilowatt-hours). For example, if two 12-volt SLI "batteries" were connected in series electrically to produce 24-volts, or in parallel to double the capacity at 12-volts, each "battery" of six cells could be referred to as a module. A module is the smallest building block of a battery plant and the module may be a single large cell in the case of large lead-acid battery plants.

Cells are rated by the manufacturer in terms of the specified time of discharge with discharge voltage above a particular discharge "cut-off" voltage (or recommended discharge termination voltage) when discharged at a constant current. For example, a cell rated at C = 100 ampere-hours at the 5-hour rate has a rated discharge current of $\frac{C}{5}$ or 20 amperes.

With reference to the lead-acid cell, the actual capacity for a new cell may be higher (e.g., 125 ampere-hours) but the manufacturer "derates" the cell in order to assure that the rated capacity can be achieved after a specified number of cycles. In effect, the initial (e.g., first 10 cycles) depth of discharge in the above example would be 80 percent (i.e., $\frac{100 \text{ ampere-hours}}{125 \text{ ampere-hours}}$). If data and experience indicated that such a derating will allow long cycle life (e.g., 2000 cycles or 8-10 year life), the increased initial cost of the cell (25 percent more because of derating) is usually considered to be an economical tradeoff for load leveling batteries.

The above discussion relative to rating and derating is typical of a lead-acid battery (and other battery types in which the active materials are contained within the cell during charge and discharge) which can be classified as conventional. However, some types of battery can be classified as unconventional, and cycle life does not depend on depth of discharge.

For any particular battery type, the specific design depends on the intended application. For example, the lead-acid type includes the familiar SLI-type which is designed primarily for short (high current) discharges in automobile starting and shallow depth-of-discharge (percentage of available capacity in ampere-hours removed). Motive-power batteries (as used in fork lifts) are designed for repetitive daily deep discharges with long cycle life (a cycle is one complete discharge followed by recharge). Stationary batteries (as used by telephone companies for back-up power) are designed to "float" on the electric line at full charge with occasional deep discharge. Stationary batteries, as the name implies, are not subjected to vibration and are usually constructed with light plastic cases. In contrast, motive-power batteries are usually designed with a more rugged case and special separators to favor retention of the active material on the grids. Shedding of active material from the positive electrode is a cycle life-limiting factor for deep discharge lead-acid batteries and is a function of the depth of discharge and cell operating temperature.

The two principal applications of advanced battery research, development and demonstration (RD&D) are directed toward electric vehicle use and large size electric utility load leveling use. For the commercially available lead-acid battery technology, there are distinctions made in terms of state-of-the-art (SOA) battery which could be designed and built with today's technology and an improved state-of-the-art (ISOA) battery which will result from current R&D (1-2 years) and future R&D over the next 5-8 years. The principal thrust of research on lead-acid batteries for electric vehicles is to reduce weight whereas the principal thrust of research for load-leveling applications is to increase cycle life. The load-leveling application requires compromise with features borrowed from several types of lead-acid battery: low-cost plastic case from stationary battery design, separator design from the motive power battery for deep discharge cycle life, and possibly pasted plates (for positive as well as negative) from SLI design for low manufacturing cost.

It is important to note that the advanced batteries that are the subject of intensive R&D support by government and industry are being developed with both the electric vehicle application and the electric utility load leveling application as potential markets. In fact, the potential for application in both markets was one factor in selection of the battery types to be developed.

Types of Batteries

From a functional viewpoint, there are many potential battery systems that fit the "black-box" definition of an energy storage system shown previously in Figure II-1. Table II-3 shows some typical examples of electrochemical energy storage systems organized in the two broad categories of chemical batteries and hydrogen systems consistent with the usual U.S. terminology.[2] The somewhat arbitrary categorization of batteries and hydrogen systems appears to have originated in early assessment studies in 1974,[3] and the term "battery" usually implies the types listed under "chemical batteries". However, all of the examples in Table II-3 are "battery" systems in the sense that electrical energy is converted to chemical energy which is stored and later reconverted to electric energy.

The first four examples in Table II-3 are batteries that have received significant funding for R&D as load-leveling batteries (and as electric vehicle batteries, too). The lead-acid, lithium-metal sulfide, and sodium-sulfur types can be considered conventional in cell design. The zinc-chloride battery is classified as unconventional since the active materials are stored outside the cell as an aqueous solution in the discharged state and as a solid inside the cell (zinc) and as a solid (chlorine hydrate) outside the cell in the charged state. The redox battery (being developed for photovoltaic battery storage) stores the active materials as an aqueous solution outside the cell in both the charged and discharged state.

The nickel-hydrogen battery is a recent consideration for load leveling and has been added to Table II-3 to illustrate the problem of categorization as either chemical batteries or hydrogen systems.

II-(2) Clifford, J. E. and Brooman, E. W., "Development of the Water Battery for Energy Storage", First National Seminar on Electrochemical Systems: Batteries and Fuel Cells", Federal University of Ceara, Brazil (March, 1980).

II-(3) An Assessment of Energy Storage Systems Suitable for Use by Electric Utilities, Public Service Electric & Gas Co., EPRI EM-264 (July, 1976).

TABLE II-3. TYPICAL EXAMPLES OF ELECTROCHEMICAL ENERGY STORAGE SYSTEMS CONSIDERED FOR ELECTRIC UTILITY USE

CHEMICAL BATTERIES

Conventional Design

- Lead-acid
- Lithium-metal sulfide
- Sodium-sulfur

Unconventional Design

- Zinc-chloride (zinc chlorine hydrate)
- Redox
- Nickel-hydrogen

HYDROGEN SYSTEMS

Irreversible (multiple devices)

- Commercial alkaline electrolyzer/gas turbine
- Advanced alkaline electrolyzer/alkaline fuel cell
- Advanced SPE electrolyzer/phosphoric acid fuel cell

Reversible (single devices)

- Hydrogen-chlorine
- Hydrogen-bromine
- Hydrogen-oxygen
    - Regenerative fuel cell
    - Water battery (reversible electrolyzer)

Mature Plants vs Demonstration Plants

An assumption was made that for large battery systems (100 MWh) the commercialization time schedule would follow the pattern of batteries now being developed for electric utility load-leveling.

Step 1. Development and testing of basic building block (cell or module)

Step 2. Establish production facility for manufacture of cell or module

Step 3. Test of battery (of cells or modules) of significant size (e.g., BEST* facility; ~5 MWh)

Step 4. Demonstration program (e.g., SBEED**)

Step 5. Commercial, semi-mature technology based on economic production rates.

For the purposes of this program a minimum of two years lead time was assumed for a Demonstration Plant (1982) and another five years for a Commercially Mature Plant (1987).

The definition of commercial status depends on the technology involved. For a standard method of estimating the cost of advanced batteries, EPRI studies[(4)] use 2500 MWh (i.e., 25 battery plants of 100 MWh each).

Although lead-acid batteries were used in the BEST facility, the purpose was to check out the facility. Lead-acid batteries for load leveling are currently at Step 4 in the SBEED program where a large lead-acid battery demonstration plant will be built and operated by an electric utility over the next 5-8 years.

The zinc-chloride battery technology is currently at Step 2 with modules being built at a pilot plant for testing in the BEST facility (Step 3) in 1982.

Lithium-metal sulfide and sodium-sulfur batteries are near to Step 1 for load leveling application and scheduled for the BEST facility in the 1982-1985 period.

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* Battery Energy Storage Test Facility

** Storage Battery Electric Energy Demonstration

II-(4) Interim Cost Estimates for Advanced Battery Systems, A. D. Little, EPRI EM-742, (July, 1978).

Typical Customer Applications

For electric utility applications, the economic size range is usually considered to be 10 MW-20 MW for use at utility substations. For this study of customer-side-of-the-meter battery storage, it was necessary to investigate a wide range of battery sizes for various types of customers. Four examples were selected as shown in Table II-4 to span a range of sizes (power or energy) and voltages at which the electricity would be delivered from the battery system. Example 1 is the baseline system selected.

BASELINE SYSTEM SELECTION

The lead-acid battery was selected for the baseline system because the technology is well-established. There is consensus among battery manufacturers that a lead-acid battery with a useful life of 2000 deep discharge cycles can be produced at reasonable cost using state-of-the-art technology. A large battery system (100 MWh, 20MW) was selected for the baseline to utilize the extensive data available on cost and performance of lead-acid batteries that were developed from 1974 to 1976 in prior studies of electric utility load-leveling batteries.(5) A 100-MWh battery (5-hour rate) has become a standard size for costing studies(4) that also assume a standard battery manufacturing facility producing 25 batteries per year (annual output of 2500 MWh). While 3-, 4-, 5-, and 10-hour batteries have been used in various studies, the 5-hour battery (e.g., 20 MW of constant power output for 5 hours) appears to be typical. A charging period of 7-10 hours is also typically used.

II-(5) Lead-Acid Batteries for Utility Application; Workshop II, EPRI EM-399-SR March, 1977.

II-(4) Ibid

TABLE II-4. EXAMPLES OF REPRESENTATIVE BATTERY SYSTEM SIZE AND VOLTAGE FOR A RANGE OF CUSTOMER APPLICATIONS

Example	Power, kW	Energy, kWh	Line Voltage (volts ac)	Possible Customer Application
1	20,000	100,000	∿15,000	large industrial
2	1,000	5,000	∿15,000	small industrial
3	40	200	∿440	small commercial
4	2	10	∿220	small residential

Another reason, for selecting the lead-acid battery for the baseline system is the availability of consistent data on cell design and performance,[(6)] and plant layout for determining balance of plant costs.[(7)]

The baseline system is not necessarily the preferred battery type or size. However, it is a frame of references for making comparisons. The zinc-chloride battery system is compared with the lead-acid battery later in this Chapter relative to size and efficiency, and is compared on a cost basis in Chapter III.

LEAD-ACID BATTERY

Baseline Cell Design

The baseline lead-acid cell is based on a tublular positive plate (pasted negative plate) design for cells supplied for U.S. Navy submarine batteries. The ESB cell (designated VLL 45) was used as the basic unit in the design of a 20 MW, 100 MWH battery plant[(6)] and the cell dimensions indicated on Figure II-2 were used in a more detailed plant layout[(7)].

The weight of the cell is 1587 lb (without electrolyte)[(6)], and the packaged shipping weight is 2183 lb[(6)]. The cells are given a formation charge at the site. The specified sulfuric acid electrolyte (S.G. 1.280) for operation adds 515 lb to the cell weight for a total of 2102 lb[(6)]. Accessories (e.g., intercell connectors) add to the weight and a value of 2211 lb[(7)] is the assembled weight.

The rated capacity of the ESB cell[(6)] to achieve 2000 cycles is 9756 ampere-hours at the 5-hour rate which is 1951 amperes. At an average cell voltage on discharge of 1.873 volts above the cut-off voltage of 1.65 volts/cell, the energy is 18.27 kWh cell. Thus, 5472 cells are required for a 100 MWh plant.

II-(6) Design and Cost Study for State-of-the-Art Lead-Acid Load Leveling and Peaking Batteries, ESB, Incorporated, EPRI EM-375 (February, 1977).

II-(7) Engineering Study of a 20 MW Lead-Acid Battery Energy Storage Demonstration Plan, Bechtel Corporation, ERDA Contract E(04-3)-1205, CONS/1205-1 (October, 1976).

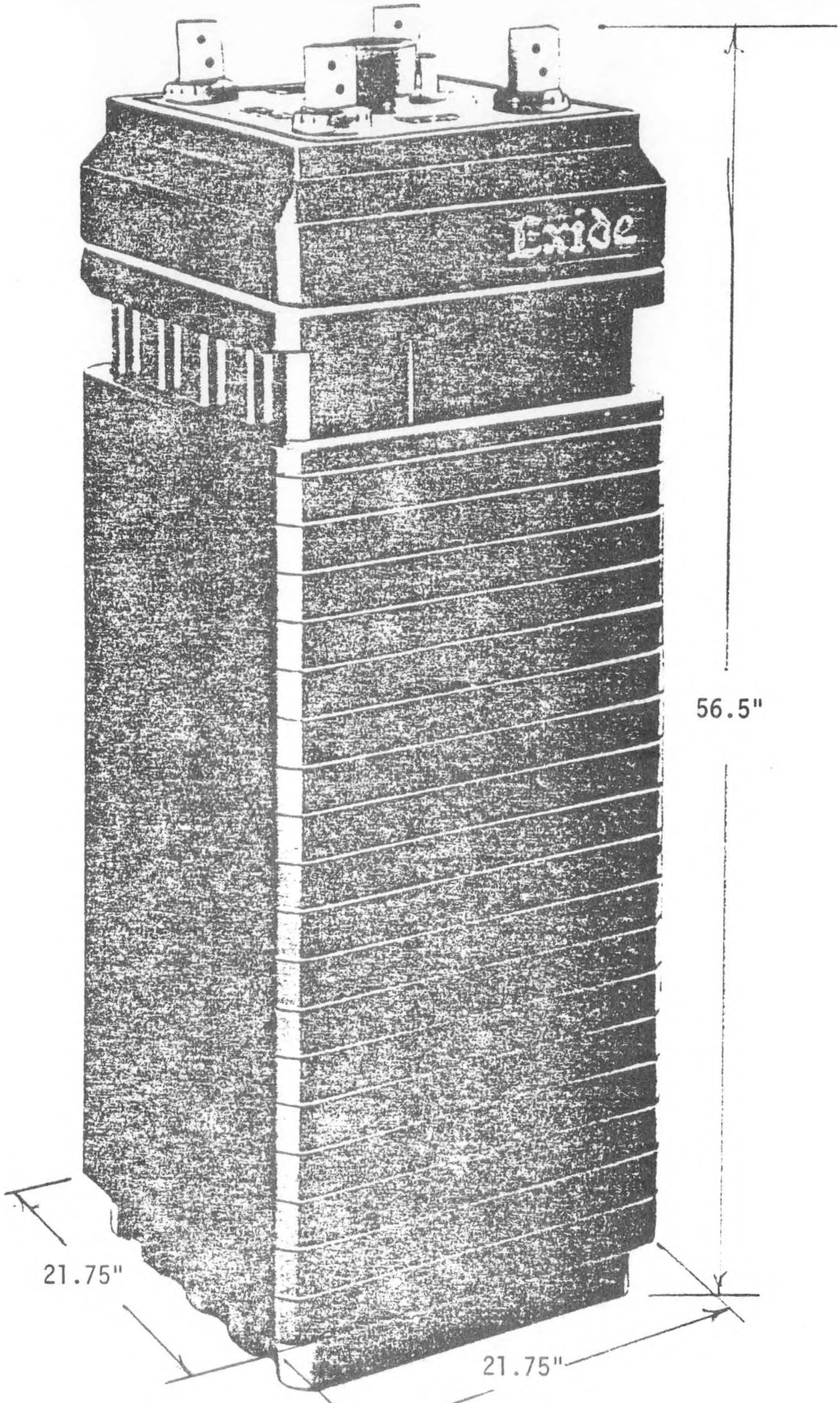


FIGURE II-2. BASELINE LEAD-ACID CELL [FROM REFERENCE II-(6)]

Baseline Battery Plant Layout

Figure II-3 shows the plant layout for the baseline system. There are 5472 lead-acid cells arranged in 6 parallel strings. Each string contains 912 series connected cells. The cells in each string are arranged in 12 rows (76 cells/row) as shown in Figure II-4.

The single layer configuration results in a large plant area. An alternative plant layout is a tiered configuration of cells as shown in Figure II-5. Although the battery plant area is reduced to about 1/3, the plant costs are about the same.

Table II-5 shows the building area and site area for various assumed plants (size and voltage) assuming single layer cells (a three-tier configuration would require less area).

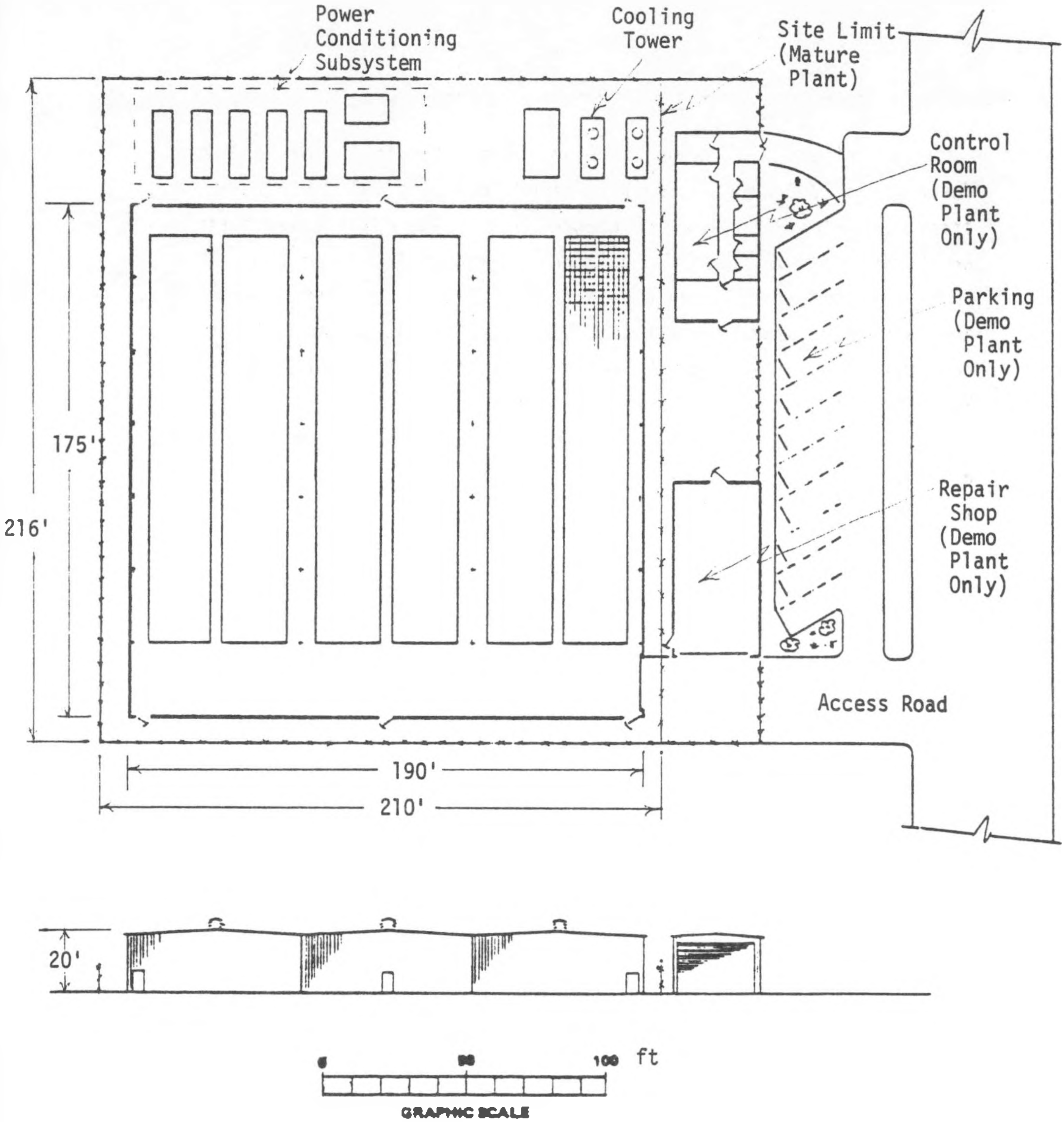


FIGURE II-3. BASELINE BATTERY PLANT LAYOUT
[FROM REFERENCE II-(7)]

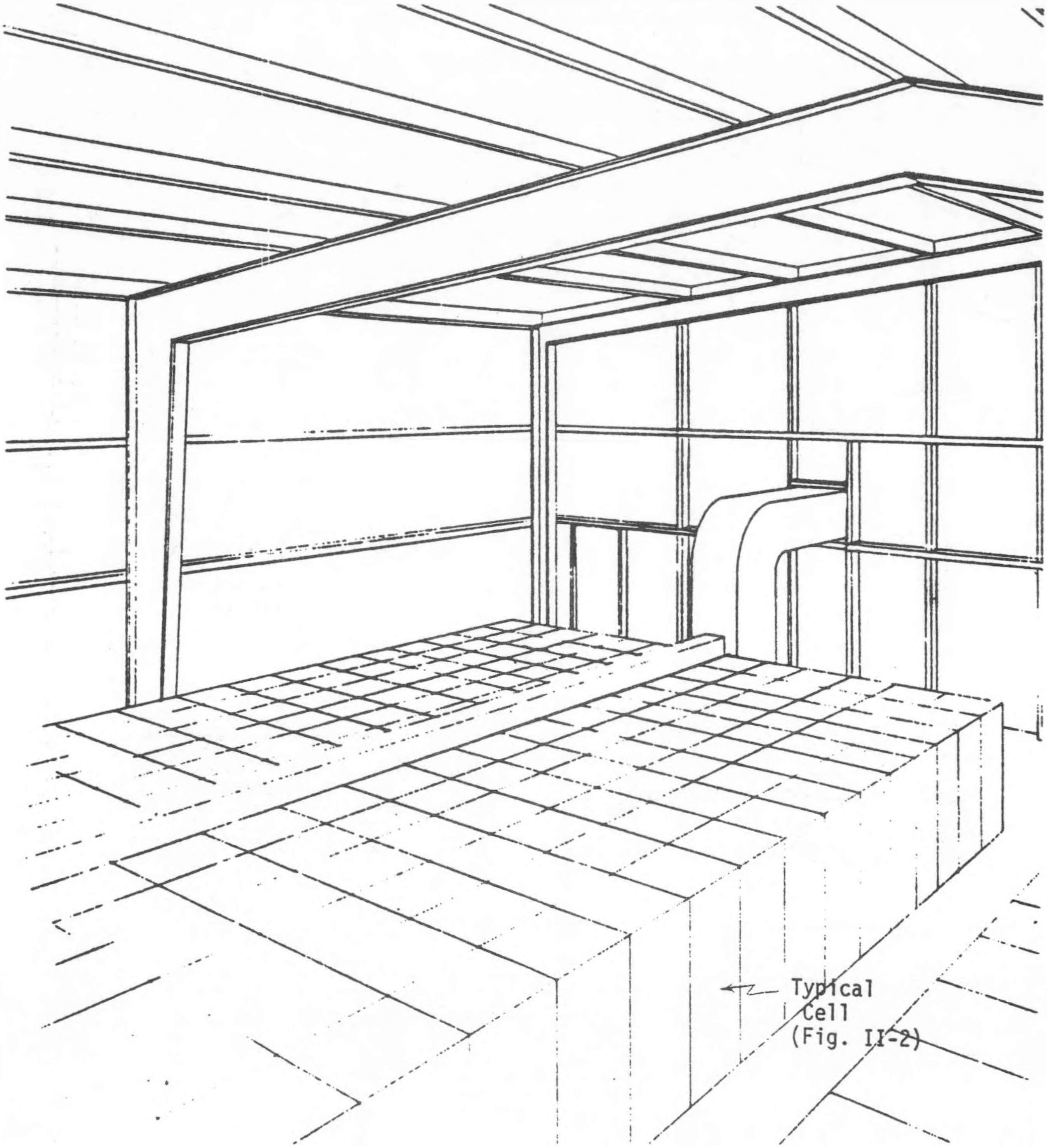


FIGURE II-4. SKETCH OF BASELINE BATTERY STRING SHOWING SINGLE LAYER CELL LAYOUT [FROM REFERENCE II-(7)]

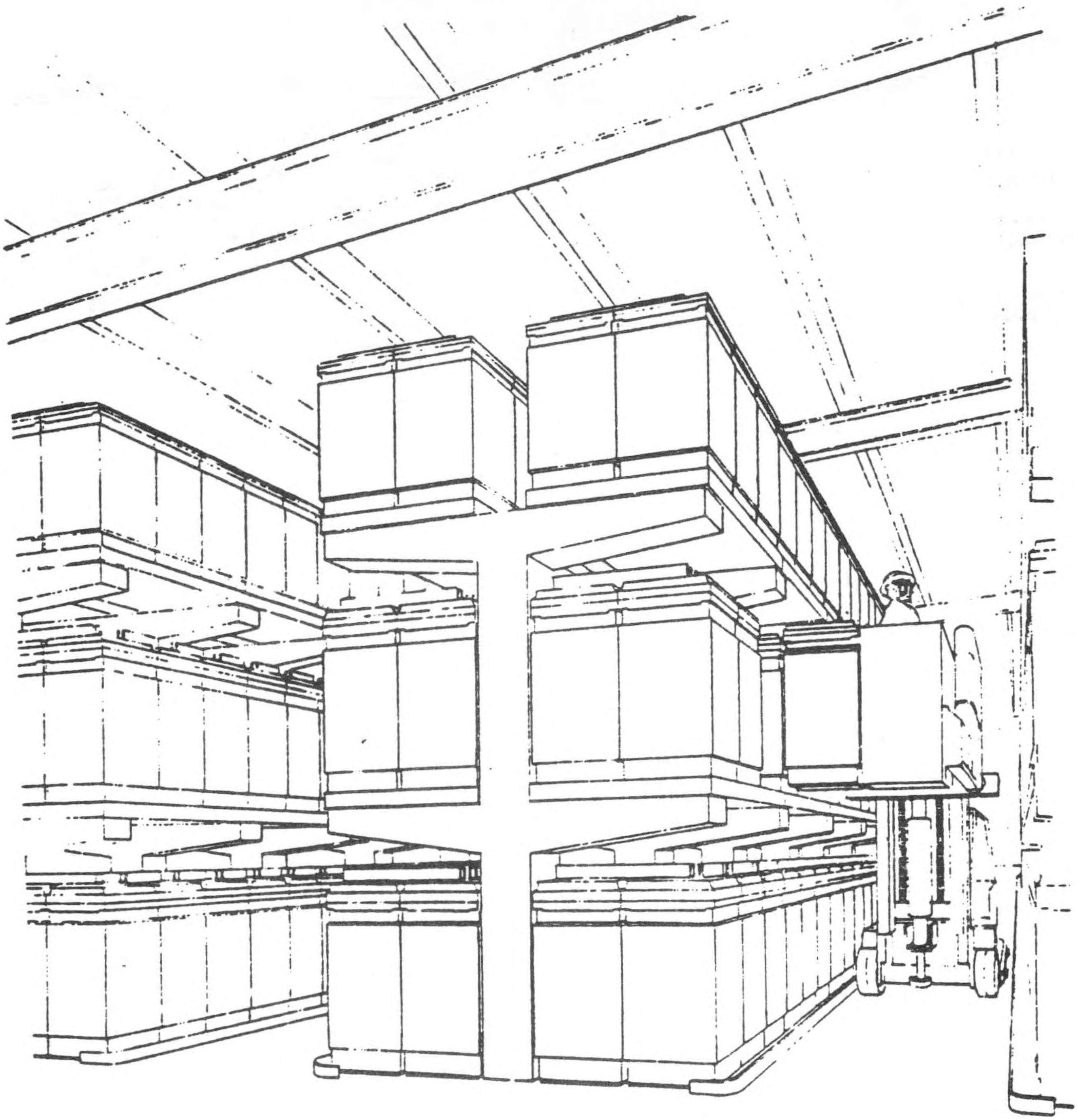


FIGURE II-5. SKETCH OF ALTERNATIVE 3-CELL TIERED CONFIGURATION [FROM REFERENCE II-(7)]

TABLE II-5. SUMMARY OF TYPICAL BATTERY PLANT[a] LAYOUTS FOR SINGLE LAYER CONFIGURATION

Power kW	Energy kWh	Voltage DC	Voltage AC	Area Ft.^{2} Bldg	Area Ft.^{2} Site	Floor Loading Lb./Ft.^{2} Cell	Floor Loading Lb./Ft.^{2} String	Floor Loading Lb./Ft.^{2} Bldg
20,000[b]	100,000	1,505	15,000	33,235	45,410[c]	982[d]	673[e]	364[f]
1,000	5,000	1,505	15,000	6,394[g]	11,071[g]	402	255	95
40	200	297	440	1,283[h]	3,463[h]	200	132	19
2	10	165	220	(i)	(i)	(i)	(i)	(i)

(a) Assumes single layer of lead-acid cells on floor of building arranged in 6 parallel strings for constant reliability and 2000 cycles with each cell discharged at 5-hour rate at an average voltage of 1.873 volts/cell above cutoff voltage of 1.65 volts/cell.

(b) Baseline power conditioning subsystem of two 10 MW converters plus transformer and ac/dc breakers for outdoor use in an area of 2400 ft^2 for 20 MW.

(c) Enclosed site includes power conditioning subsystem plus water treatment, cooling towers, and site controller with 10 feet all around to protective fence.

(d) Based on cell weight of 2211 lb on cell bearing surface of 18 inches by 18 inches.

(e) Based on area occupied by one cell in string of 21.75 inches by 21.75 inches.

(f) Total weight of 5472 cells divided by building floor area.

(g) Basic cell size reduced to 8 x 8 x 20 inches high with weight of 110 lb/cell and 912 cells/string.

(h) Basic cell size reduced to 5 x 5 x 12 inches high with weight of 22 lb/cell. String dimensions are 5.4 ft x 6 ft, 180 cells/string. For cells in 3-tiers, building area reduced to 550 ft^2 and site area reduced to 1470 ft^2.

(i) Basic cell size reduced to 2 x 2 x 5 inches high with weight of 2.4 lb/cell. With 84 cells/string and 6-tier stacking, total battery system including power conditioner could be packaged in a cabinet 2.5 x 2.5 x 4 ft high.

ZINC-CHLORIDE BATTERY

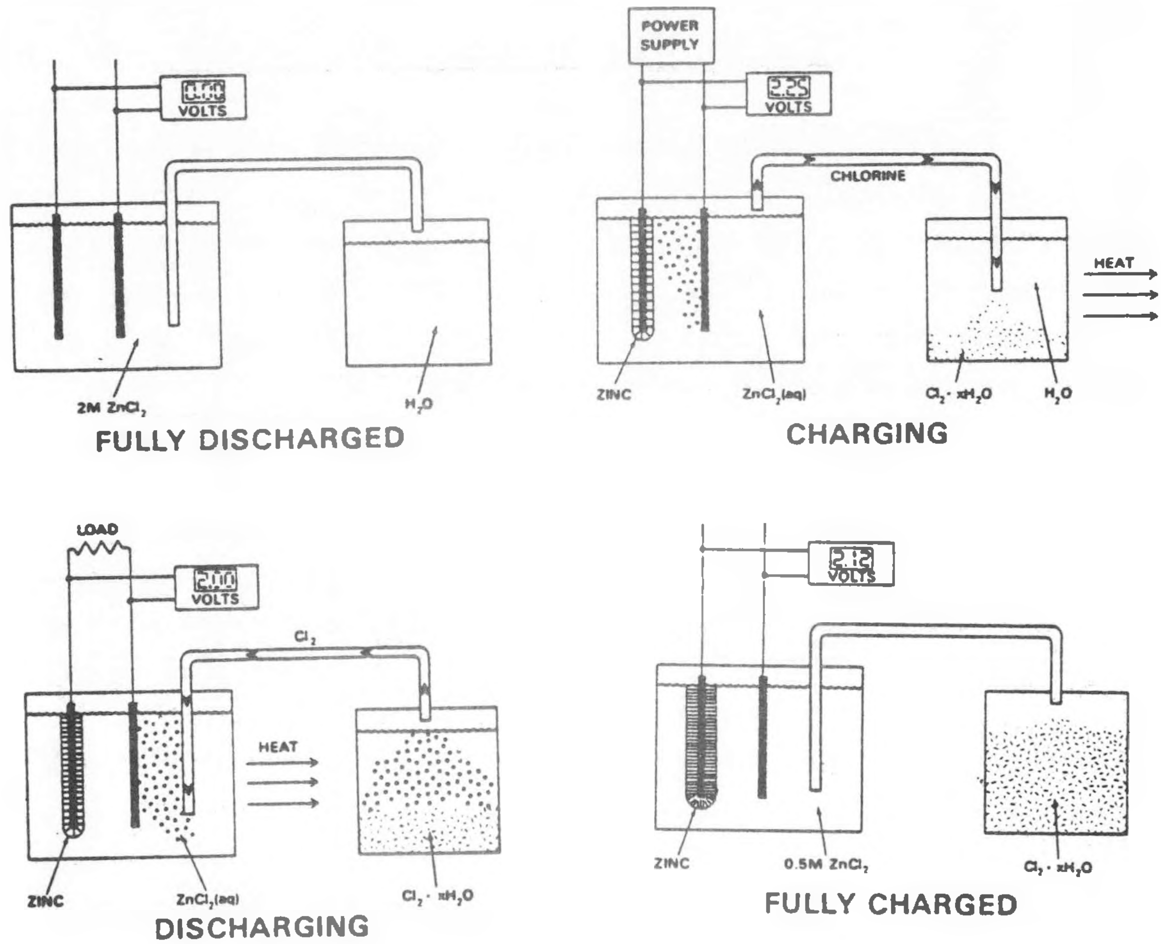
General Description

The zinc-chloride battery for load leveling has been developed by Energy Development Associates (EDA), a subsidiary of Gulf and Western Corporation. The most recent report(8) reviews the status of development begun in 1974 and directed towards electric utility applications. The same technology (in different battery configurations) is also being developed for use in electric vehicles.

The zinc-chloride battery is unconventional (relative to the lead-acid battery) in design and operation. As shown in Figure II-6, the active material is an aqueous solution of zinc chloride ($ZnCl_2$) in the discharged state. In the charged state, one of the active materials, chlorine gas (Cl_2), is stored external to the cell in the form of chlorine hydrate ($Cl_2 \cdot XH_2O$) which is a pale yellow, solid formed in water below 50°F (9.6°C). Thus, the system is sometimes referred to as the zinc-chlorine hydrate battery (charged state) or zinc-chlorine battery (with reference to the state of the active materials at the electrodes during charge and discharge).

Because no separator is used between the zinc electrode (zinc on graphite) and the chlorine electrode (porous graphite) in the cell, the reaction of dissolved chlorine with zinc during charge and discharge can reduce the coulombic (current) efficiency (η_I) during charge and discharge. The near-term electrochemical energy efficiency goal is 75 percent (i.e. $\eta_V \eta_I = 0.75$). With an optimistic assumption of converter efficiency (98 percent each way), the battery/power conditioner efficiency goal is 72 percent [i.e. $\eta_V \cdot \eta_I \cdot \eta_r \cdot \eta_i = (0.75)(0.98)(0.98) = 0.72$], which is about the same as for a lead-acid battery. The total battery plant efficiency goal is 65 percent ($\eta_T^* = 0.65$) when auxiliary component energy is included as shown in Figure II-7.

II-8 Development of the Zinc-Chloride Battery for Utility Applications, Energy Development Associates, EPRI EM-1417 (May, 1980).



$$ZnCl_2\ (aq) = Zn(s) + Cl_2\ (aq)$$

$$Cl_2\ (aq) + xH_2O = Cl_2 . xH_2O(s)$$

FIGURE II-6. SCHEMATIC OF ZINC-CHLORIDE CELL OPERATION [FROM REFERENCE II-(8)]

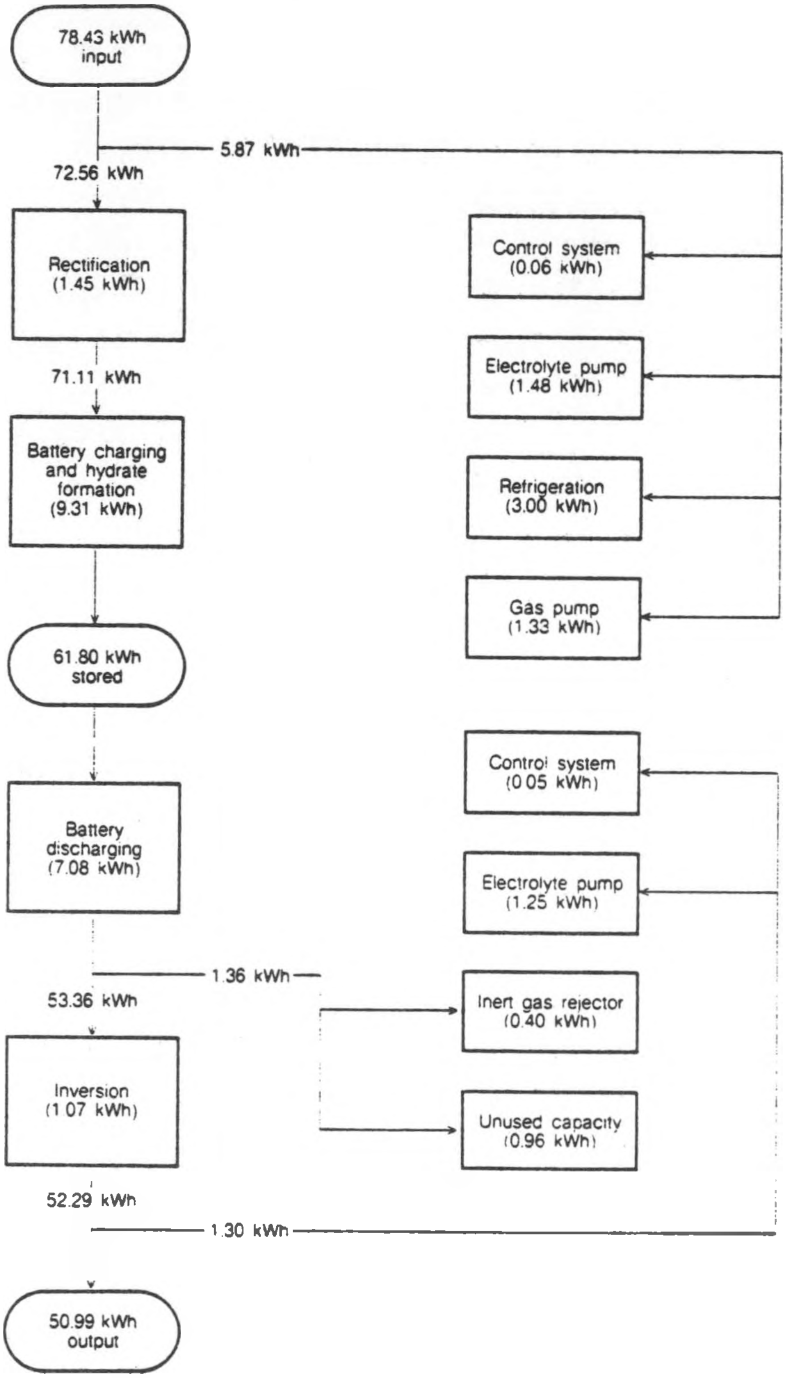


FIGURE II-7. ENERGY FLOW DIAGRAM FOR ZINC-CHLORIDE BATTERY SYSTEM [FROM REFERENCE II-(8)]

Plant Layout

Figure II-8 shows an artist rendition of a 100-MWh zinc-chloride battery plant at a utility substation. The modules are arranged in three-tiers (20 modules/tier, 60 modules per 3-tier rack, and two racks per string) with 120 modules connected in series in a string and four strings in parallel per 5 MW converter for each 25 MWh battery unit. Thus, for the total battery plant of 4 units, there are a total of 1920 modules arranged in 16 parallel strings with a minimum discharge voltage of 2352 volts.

The basic unit for the zinc-chloride battery is the self-contained nominal 53.4 kWh module shown in Figure II-9 which has dimensions of 44 by 44 by 60 inches high. Within the "stack" section of the module, the cells are connected in series/parallel arrangement such that the open circuit voltage of the module is 21.2 volts. For the 5-hour discharge (7-hour charge) module, the current is 544 amperes and the discharge voltage is 19.6 volts; for charge at 544 amperes, the charge voltage is 22.2 volts per module.

Comparison with Baseline System

Figure II-10 shows a site plan and elevation view for the zinc-chloride battery plant. The fenced in area of a site would be 31,500 ft^2 to 54,625 ft^2 for 10-ft and 50-ft fence clearance from the module racks, respectively, depending on the clearance required for safety. If the modules only were in a building, the building area would be about 23,500 ft^2 (exclusive of power conditioner and other auxiliaries). This is a larger area than the comparable 3-tier lead acid battery building of about 18,000 ft^2. Thus, the zinc-chloride battery plant is not as compact as the lead-acid battery plant. This can be visualized by a comparison in which four lead acid cells (21.75 by 21.75 X 56.5 inches each) are considered as a module. The energy density footprint of the lead-acid "module" (44 by 44 by 56.5 inches high) is 5.4 $kWh/ft.^2$. The energy density footprint of the zinc-chloride module (44 X 44 X 60

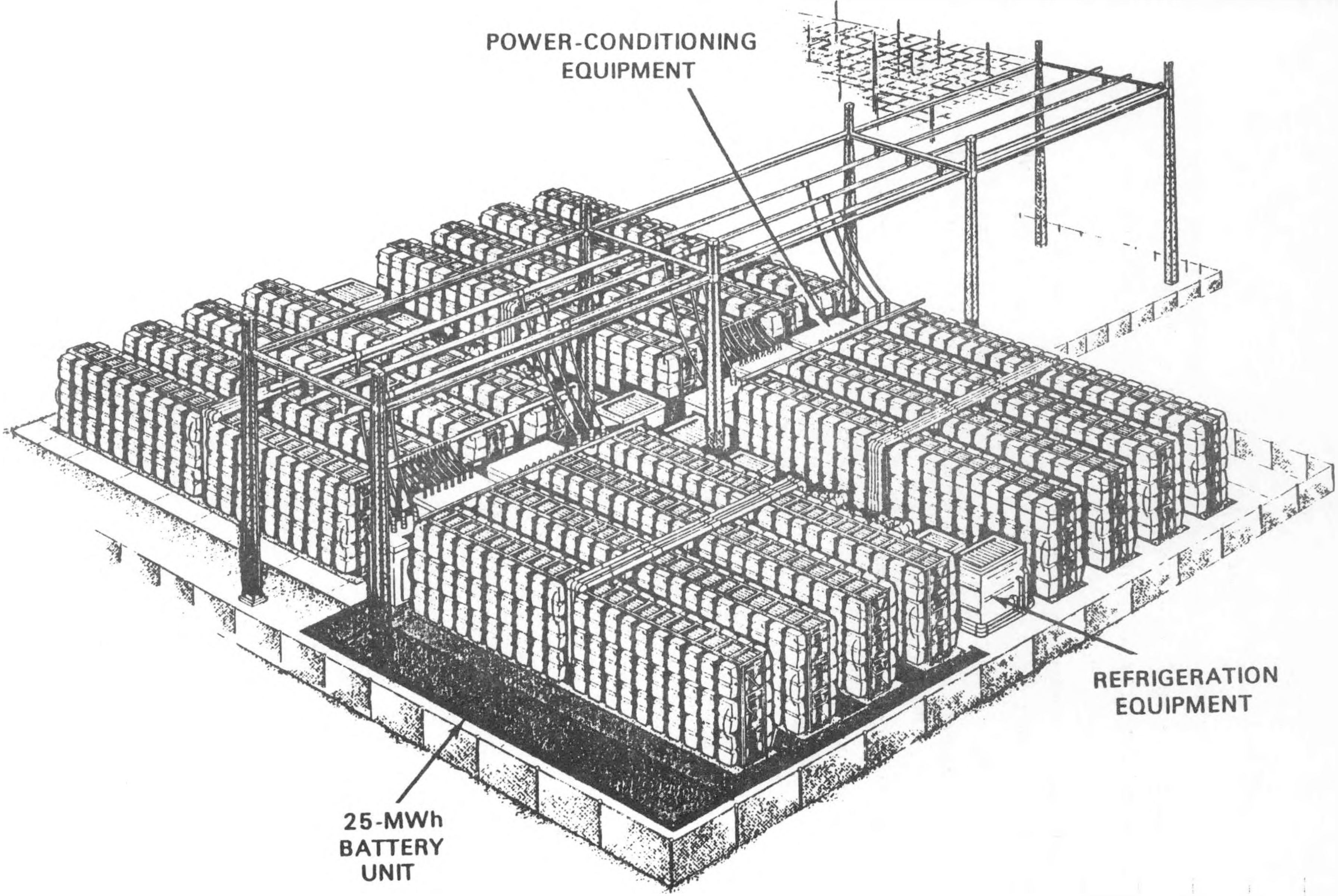


FIGURE II-8. ARTIST'S RENDITION OF 100 MWh ZINC-CHLORIDE BATTERY PLANT
[FROM REFERENCE II-(8)]

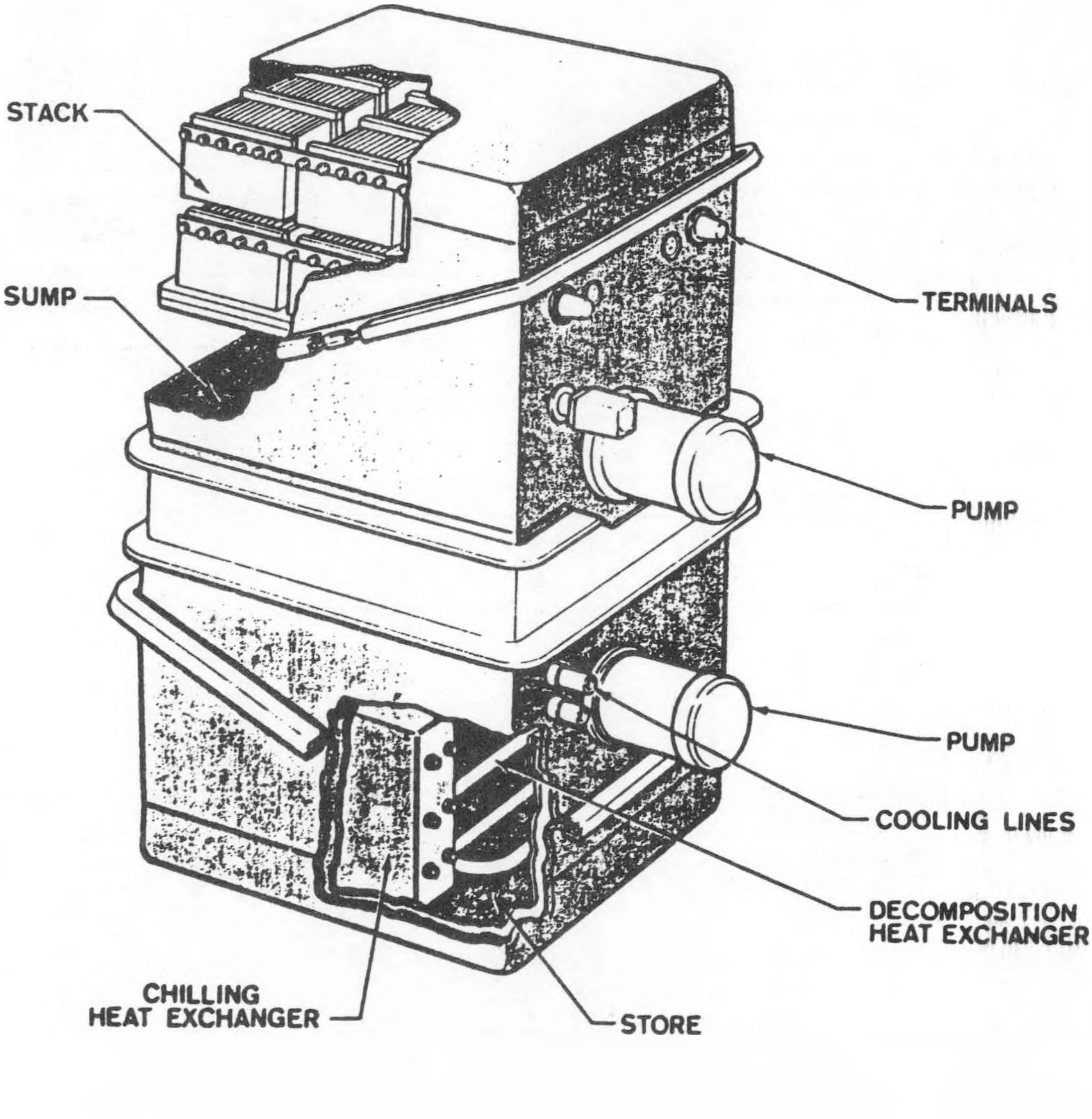


FIGURE II-9. SKETCH OF ZINC-CHLORIDE MODULE FOR LOAD LEVELING [FROM REFERENCE II-(8)]

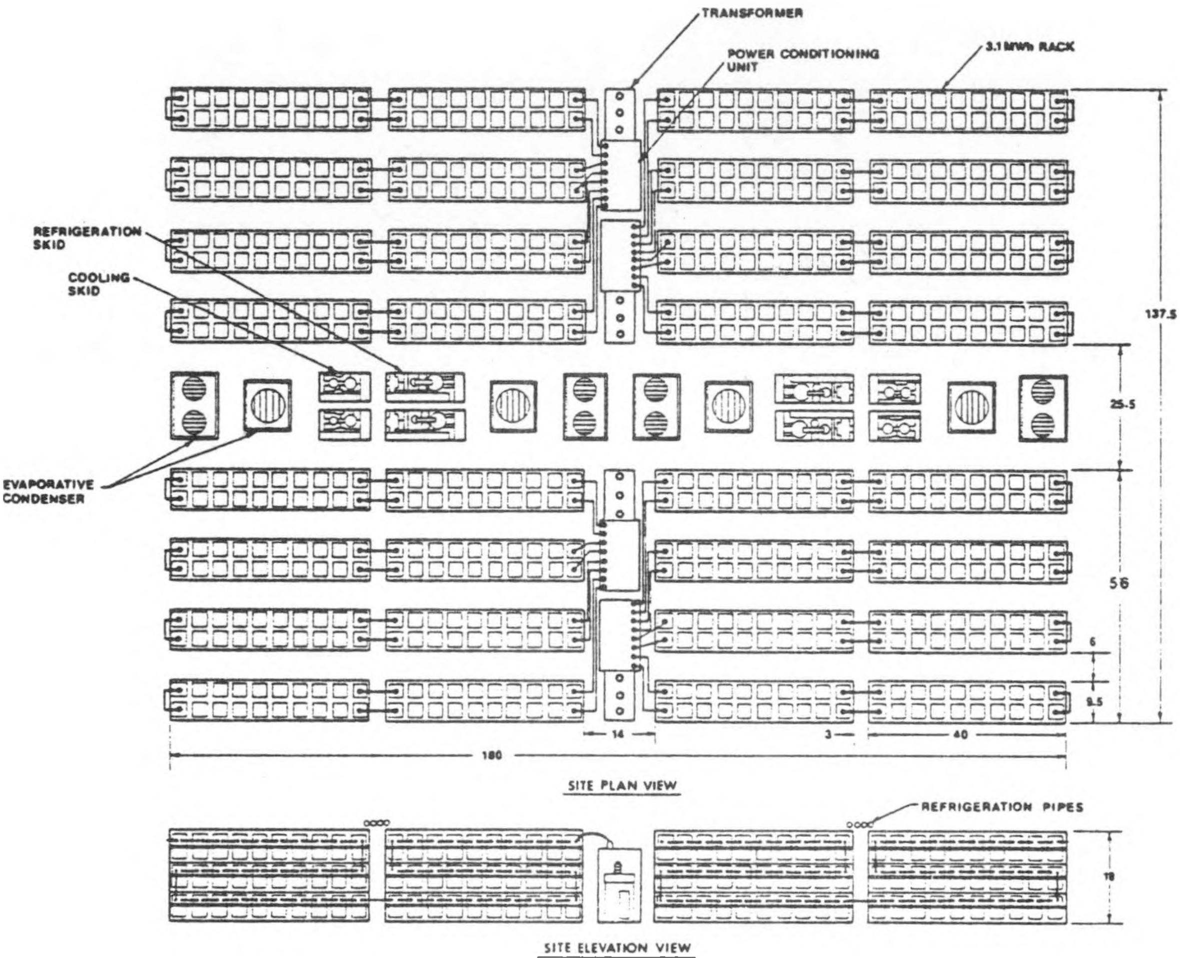


FIGURE II-10. PLAN AND ELEVATION LAYOUT OF 100 MWh
ZINC-CHLORIDE BATTERY PLANT
[FROM REFERENCE II-(8)]

inches high) is 4 kWh/ft.^{2}. The latter weighs about 2200 lbs compared. to 8400 lbs for the former. However, the minimum basic unit to be handled in each case weighs about one ton.

The above comparison of the lead-acid battery and the zinc-chloride battery is summarized in Table II-6. At the present time, the zinc-chloride battery does not offer advantages with regard to energy density or efficiency compared to the state-of-the-art lead-acid battery which has a fairly confident life of 2000 cycles. Thus, the principal advantage of the zinc-chloride battery must lie in lower projected costs which are discussed at the end of Chapter III.

TABLE II-6. COMPARISON OF BATTERY TYPES

Battery Type	Lead-Acid	Zinc-Chloride
Cells per Module	4	10
Module rating, kWh	73.1	53.4
Module weight, lb	8800	2200
Height, inches	56	60
Length, inches	44	44
Width, inches	44	44
Energy Density, kWh/ft.^{2}	5.4	4.0
Efficiency goals, percent		
Coulombic (η_I)	93	85 (76)*
Voltage (η_V)	85	88 (85)
Electrochemical (η_e)	79	75 (65)
Battery/Conditioner (η_T)	71	72 (59)
Total System (η_T^*)	69	65 (53)

* Commercial Goal (BEST Battery Goal)

CHAPTER III. BATTERY SYSTEM COST AND PERFORMANCE ANALYSIS

LEAD-ACID BATTERY

Baseline System

Battery System Description

The baseline battery system described in Table III-1 is similar to designs for use by electric utilities at substations.

The battery plant layout was defined in detail in the Bechtel Corporation study[1] of balance-of-plant costs (specifically, 5-hour design, sealed-cell - single layer configuration.)

The representative lead-acid cell used as the basis for the battery plant layout was defined in detail in the ESB study.[2]

Cost Basis

All cost data in this report are in mid-1980$ (except where specifically designated by a year). Cost data for battery systems have been estimated at various times from 1972 to 1980. In order to adjust these costs to 1980 dollars, the overall Gross National Product (GNP) deflator has been used on this project as a measure of inflation. The GNP index values used are shown in Table III-2. For example, 1976 cost data were inflated to 1980 by a factor of 1.347.

III-(1) Engineering Study of a 20 MW Lead-Acid Battery Energy Storage Demonstration Plant, Bechtel Corporation, ERDA Contract E (04-3)-1205, CONS/1205-1 (October, 1976).

III-(2) Design and Cost Study for State-of-the-Art Lead-Acid Load Leveling and Peaking Batteries, ESB, Incorporated, EPRI EM-375 (February, 1977).

TABLE III-1: BASELINE BATTERY SYSTEM

Type:	Lead-Acid
Energy:	100 MWh
Charge:	7-hour + 2-3 hour taper
Design Rate:	5-hour discharge
Voltage:	1505 volts dc (minimum)
Power:	20 MW (constant)
Life:	2000 cycles
Cost Status:	Mature Plant (25 per year)

TABLE III-2: ASSUMED INFLATION FACTOR

Year	GNP Index	Inflation Factor
1972	100	1.803
1973	105.8	1.704
1974	116.0	1.554
1975	127.2	1.417
1976	133.8	1.347
1977	141.6	1.273
1978	152.1	1.185
1979	165.5	1.089
1980(mid)	180.3(est.)	1.000

All unit costs for power (\$/kW) or energy (\$/kWh) in this report are based on ac output from the power conditioner in the discharge mode, except where specifically noted by subscript. Most battery cost data in the literature are based on battery output (kWh_{dc}). Thus, a one-way inverter efficiency of 95% (η_I=0.95) was assumed in converting to an ac basis. For example, \$95/kWh_{dc} = \$100/kWh_{ac}).

Cost data for the power conditioning subsystem are on the same basis as described above in this report. The cost data from the principal reference[3] were found to be reasonably consistent with current cost data[4], when corrected for inflation.

Baseline System Costs

Capital Cost. The baseline system cost equation is

$$C_T = \frac{C_1}{t_d} + \frac{C_2}{t_d} + C_3 + C_4 \qquad (1)$$

where

C_T = total specific cost of battery system, \$/$kWhr_{ac}$

C_1 = power conditioner cost, \$/kW_{ac}

C_2 = power related balance of plant cost, \$/kW_{ac}

C_3 = baseline battery cost, \$/kWh_{ac}

C_4 = energy related balance of plant cost, \$/kWh_{ac}

t_d = rated discharge time, hours

III-(3) AC/DC Power Conditioning and Control Equipment For Advanced Conversion and Storage Technology, Westinghouse Electric Corporation, EPRI EM-271 (August, 1975).

III-(4) Conceptual Design of Electric Balance of Plant For Advanced Battery Energy Storage Facility, United Technologies Corporation, ANL-80-16 (January, 1980).

For the baseline system (5-hour battery), the specific cost constants in Equation (1) are:

$$C_1 = \$100/\mathrm{kW}$$

$$C_2 = \$\ 40/\mathrm{kW}$$

$$C_3 = \$\ 78/\mathrm{kWh}$$

$$C_4 = \$\ 34/\mathrm{kWh}$$

Therefore, the total specific cost per unit of output energy of the battery system is:

$$C_T = \frac{100}{5} + \frac{40}{5} + 78 + 34 = \$140/\mathrm{kWh} \qquad (1A)$$

Equation (1) can be rewritten to show the total specific cost per unit of output power:

$$C_T \bullet t_d = C_1 + C_3 \bullet t_d + \left[C_2 + C_4 \bullet t_d\right] \qquad (2)$$

$$C_T \bullet t_d = 100 + 390 + [40 + 170] = \$700/\mathrm{kW} \qquad (2A)$$

The bracketed term is the balance of plant cost of \$210/kW or \$42/kWh for the baseline system.

<u>Cost and Performance Summary</u>. The baseline cost data and associated efficiency are summarized in Table III-3. For the assumptions used, the cost data are believed to be accurate within 10 percent. The objective has been to provide a specific combination of data that is internally consistent in recognition that all of the values in Table III-3 and specifications in Table III-1 are interdependent. The effect of independent design variables and assumptions on cost is discussed in more detail in the following sections of this chapter.

TABLE III-3 BASELINE COST AND PERFORMANCE SUMMARY

Baseline Design: t_d=5 hours (See Table III-1)

Specific Cost Constants for Equation (1)

C_1 = \$100/kW

C_2 = \$ 40/kW

C_3 = \$ 78/kWh (34¢/lb Pb)

C_4 = \$ 34/kWh

C_T = \$140/kWh

$(C_T)(t_d)$ = \$700/kW

C_3* = \$ 52/kWh (34¢/lb Pb)

Operation and Maintenance Cost

O_m = \$0.005/kWh

Efficiency (exclusive of ancillary energy)

η_T = 0.7135 (~71% ±1%)

<u>Replacement Battery Cost</u>. Since the SOA lead-acid battery has a finite cycle life (2000 cycles) or years of useful cyclic operation (~6-10 years) that is less than other components of the plant, it will be replaced one or more times during the plant life of 20-30 years. The cost of the replacement battery is less than the original cost by the salvage and reuse credit (lead and other materials and components). Using credit data for the ESB battery[(2)] and adding the cost of roundtrip transportation plus reinstallation, the cost of the replacement battery is estimated to be 2/3 of the original battery (FOB) cost: $C_3^* = 2/3(C_3) =$ \$52/kWh. The salvage value of the cells was estimated as the reuse credit less one-way transportation back to the factory or 39 percent of the original battery (FOB) cost.*

<u>Effect of Lead Cost</u>. The price of lead is a significant factor in the cost of lead acid batteries. The reference [(2)] battery costs used were based on a lead cost of \$0.25/lb (1976). In 1980\$, the value of C_3 = \$78/ kWh is based on a lead cost of approximately \$0.34/lb.

The effect of lead cost (in \$/lb Pb) on battery cost (FOB) is

$$C_3 = 50.60 + 80.75\ (\$/\text{lb Pb}) \qquad (3)$$

and on replacement battery cost (installed) is

$$C_3^* = \left[50.60 + 80.75\ (\$/\text{lb Pb})\right] 2/3 \qquad (4)$$

III-(2) ibid

* The salvage and reuse credits consist of about \$26/kWh for metals (80 percent recovery of lead, antimony, and terminal copper) and about \$8/kWh for reuse of purchased parts (95 percent reuse of jar, cover and hoops). The salvage value could be as low as 29 percent if limited to metal recovery. The assumptions regarding salvage value over the system life have little effect (<3 percent) on the present value of the battery system.

Operation and Maintenance Cost. The operation and maintenance cost (O_m) was estimated to be \$0.005/kWh for the baseline system. For purposes of this study, the value of O_m includes the estimated cost of electricity to operate the ancillary components in the baseline battery system. This was done so that the total battery system efficiency could be limited by definition to the product of battery electrochemical efficiency and the two-way converter efficiency as shown below:

$$O_T = \frac{F_\rho}{\eta_T} + O_m = \frac{F_\rho}{\eta_T^*} + M_o \qquad (5)$$

$$O_m = X + M_o \qquad (6)$$

$$X = F_\rho \frac{\eta_T - \eta_T^*}{(\eta_T)(\eta_T^*)} \qquad (7)$$

where

O_T = total operating cost, \$/ kWh

F_ρ = off-peak electric power cost, \$/ kWh

η_T = total battery/converter efficiency

η_T^* = total system efficiency

O_m = total operation and maintenance cost, \$/ kWh

X = cost of electricity for ancillary power, \$/ kWh

M_o = other cost of operation and maintenance, \$/ kWh

For the lead-acid battery system, assuming $\eta_T = 0.7135$ and $\eta_T^* = 0.6985$ with $F_\rho = 0.02$ in Equation (7), $X = 0.0006$ and $M_o = 0.0044$ from Equation (6). Thus, the Equivalence in equation (5) for total operating cost is:

$$O_T = 0.0330 = \frac{0.02}{0.7135} + 0.005 = \frac{0.02}{0.6985} + 0.0044 \qquad (5A)$$

The above example is believed to be representative of the baseline system with water cooling for thermal control (a large factor in ancillary energy) which can reduce lead-acid battery system efficiency (η_T) by 1 to 3 percent. The inclusion of ancillary energy in total system efficiency (η_T^*) can reduce the efficiency from <1 to 10 percent depending on the battery type and operating temperature.

Efficiency

As noted previously, the total battery system energy efficiency has been defined for this project to exclude use in ancillary components. With this qualification, the total round-trip energy efficiency (η_T) is defined below:

$$\eta_T = \frac{\text{kWh ac output}}{\text{kWh ac input}} \qquad (8)$$

$$\eta_T = \eta_v \bullet \eta_I \bullet \eta_r \bullet \eta_i \qquad (9)$$

where

η_T = battery storage system efficiency

η_v = voltage efficiency

η_I = current efficiency (coulombic efficiency)

η_r = converter efficiency in rectification mode

η_i = converter efficiency in inverter mode.

Converter efficiencies depend on the type of converter, percent of rated load operation, (end of charge voltage/end of discharge voltage), and other factors in the design. Generally, converter efficiencies are in the range of 0.9 to 0.98 over 25-100 percent of rated load (η_r and η_i may not be equal). Typical values used for estimates are $\eta_r = \eta_i = 0.95$.

The voltage efficiency and current efficiency are more easily defined for systems that operate at constant power for charge and discharge. However, the lead-acid battery and other batteries that require special charging profiles and periodic cell equalization charge are more difficult to describe. The specific charging procedure specified by the battery manufacturer is related to the rated cycle life. For the ESB cell[(2)] used in the baseline system, the specified charging procedure is:

- Constant current charge for 7 hours to 2.32 volts/cell (86 percent of rated amperes-hours)
- Constant voltage charge at 2.32 volts/cell for 2 hours (taper charge) to return 103 percent of daily discharge in ampere-hours
- Weekly equalization charge at 2.65 volts per cell and low finishing current (essentially constant power) for 120 percent of daily discharge in ampere-hours over 5 hours.

In lieu of weekly equalization, calculations were based on a daily charge cycle of 7-hour constant current, 2-hour taper and 1-hour equalization (total of 10 hours for charging).

For the specified charging cycle, the current efficiency is $\eta_I = 0.9337$.

Since the charging voltage is not constant over the total charge period of 10 hours, an equivalent average charging voltage was calculated:

$$V_c = 2.13 + \frac{0.5740}{t_c} \qquad (10)$$

where

V_c = equivalent average charge voltage, volts

t_c = time for initial <u>constant current</u> charge, hours.

III-(2) ibid

The average discharge voltage would be approximated as follows:

$$V_d = 1.959 - \frac{0.4312}{t_d} \tag{11}$$

where t_d = time for constant power discharge.

Therefore, for the baseline conditions

$$\eta_v = \frac{V_d}{V_c} = \frac{1.959 - \frac{0.4312}{5}}{2.130 + \frac{0.5740}{7}} = 0.8467 \tag{12}$$

Substitution of values in Equation (9), yields total efficiency of about 71 percent (rounded):

$$\eta_T = (0.8467)(0.9337)(0.95)(0.95) = 0.7135 \tag{13}$$

Figure III-1 summarizes the calculated efficiency (η_T) for various discharge periods, (t_d), and possible constant current charge periods, (t_c), that might be available in the rate schedule.

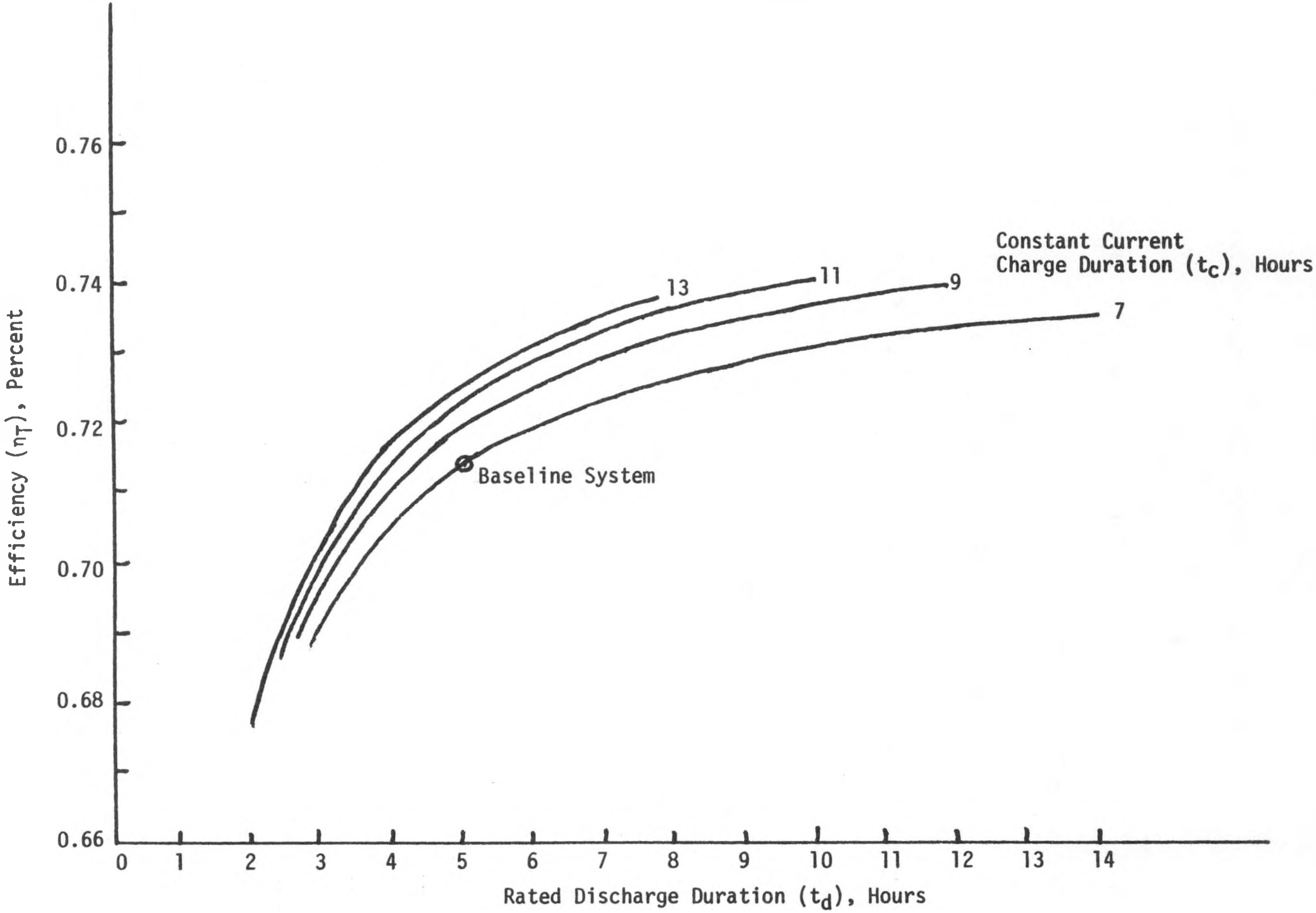


FIGURE III-1. EFFICIENCY AS A FUNCTION OF RATED DISCHARGE DURATION FOR VARIOUS CHARGE DURATIONS

General Battery Cost Equation

A general cost equation that is broadly applicable to most battery systems is shown below in terms of $/kWh$_{ac}$ output:

$$C_T = C_1 \ (F_1)(F_2)(F_3) + C_2 \ (F_4) + C_3 \ (F_5)(F_6) \ + C_4 \qquad (14)$$

where

F_1 = power conditioner voltage factor

F_2 = power conditioner size factor

F_3 = power conditioner charge rate factor, hour^{-1}

F_4 = power related balance of plant discharge rate factor, hour^{-1}

F_5 = battery size factor

and F_6 = battery discharge rate factor.

Equations for calculating the various factors are as follows:

$$F_1 = 0.79 + \frac{316}{V_m} \qquad (15)$$

$$F_2 = \left[\frac{20{,}000}{P_d}\right]^{0.028} \qquad (16)$$

$$F_3 = \frac{1}{t_d} \qquad \text{for} \quad \frac{P_c\ (\eta_r)(\eta_i)}{P_d} \leq 1 \qquad (17A)$$

or

$$F_3 = \frac{1\ \ (P_c)(\eta_r)(\eta_i)}{(t_d)(P_d)} \qquad \text{for} \quad \frac{P_c\ (\eta_r)(\eta_i)}{P_d} > 1 \qquad (17B)$$

$$F_4 = \frac{1}{t_d} \qquad (18)$$

$$F_5 = \left[\frac{100{,}000\ \ V_m}{(P_d)(t_d)(1505)}\right]^{0.075} \qquad (19)$$

$$F_6 = 1 - x\,(t_d - 5) \quad \text{where } x = 0.0088576 \text{ for } t_d > 5 \tag{20}$$

$$F_6 = 1 + x\,(5 - t_d) \quad \text{where } x = 0.045267 \text{ for } t_d < 5 \tag{21}$$

where V_m = minimum battery voltage, volts d_c

P_d = maximum discharge power output, kW ac

P_c = maximum charge power, kW ac

t_d = rated discharge time, hours

η_r = power conditioner efficiency in rectifier mode (ac to dc)

η_i = power conditioner efficiency in inverter mode (dc to ac).

For the lead-acid battery, the ratio of maximum charge power to maximum discharge power (on an ac basis) can be calculated as follows:

$$\frac{P_c}{P_d} = \frac{(t_d)(E_1)(V_T)}{(t_c)(V_c)(\eta_r)(\eta_i)} \tag{22}$$

where t_c = time for initial constant current charge, hours

E_1 = fraction of charge input at constant current

V_T = voltage for taper charge, volts

V_d = average cell voltage during discharge, volts

Combining Equations (22) and (17B), the factor (F_3) for the lead-acid battery is:

$$F_3 = \frac{(E_I)(V_T)}{(t_c)(V_d)} \quad \text{for } \frac{P_c\,(\eta_r)(\eta_i)}{P_d} \geq 1 \tag{23}$$

Equations (22) and (23) can be simplified by assuming typical values for η_r and η_i, and values for E_I and V_T prescribed for charging the lead-acid battery as follows:

$\eta_r = 0.95$

$\eta_i = 0.95$

$E_I = 0.861$

$V_T = 2.32$ volts

$$\frac{P_c\ (\eta_r)(\eta_i)}{P_d} = \frac{t_d\ (2.00)}{(t_c)(V_d)} \tag{24}$$

$$F_3 = \frac{2.00}{(t_c)(V_d)} \quad \text{for} \quad \frac{P_c\ (\eta_r)(\eta_i)}{P_d} \geqq 1 \tag{25}$$

Using Equation (11) for the average discharge voltage (V_d), the ratio of charge to discharge power (on an ac basis) in Equation (22) can be simplified for the lead-acid battery as follows:

$$\frac{P_c}{P_d} = \frac{t_d}{0.885\ t_c - \frac{0.195}{t_d}} \tag{26}$$

The criterion for calculating F_3 by Equations (17B), (23), or (25), for the lead-acid battery is calculated as follows:

$$\frac{P_c\ (\eta_r)(\eta_i)}{P_d} = \frac{t_d\ (0.9025)}{0.885\ t_c - \frac{0.195}{t_d}} \tag{27}$$

By substitution of Equation (27) in Equation (17B), the factor F_3 can be calculated for particular charge and discharge times as follows:

$$F_3 = \frac{1}{0.981\ t_c - \frac{0.216}{t_d}} \quad \text{for} \quad \frac{P_c\ (\eta_r)(\eta_i)}{P_d} \geqq 1 \tag{28}$$

Using the above equations, the specific cost ($/kWh) and capital investment ($) were calculated for four examples covering possible applications as shown in Table III-4.

The specific energy cost ($/kWh) from Table III-4 versus system size (kWh or kW for 5-hour discharge) is shown on the log-log plot of Figure III-2.

Figure III-3 shows the change in total specific cost (C_T) for the 20 MW system as a function of rated discharge time (t_d) for various constant current charge times (t_c).

TABLE III-4. SUMMARY OF COST CALCULATIONS FOR FOUR SPECIFIC EXAMPLES*

Example*					Specific Cost,**$/kWh					Cost,**$				
No	Power kW	Energy kWh	Volts		Power		Energy		System Total	Power		Energy		System Total
			DC	AC	PC	BOP_{PC}	B	BOP_B		PC	BOP_{PC}	B	BOP_B	
1	20,000	100,000	1,505	15,000	20	8	78	34	140	2×10^6	0.8×10^6	7.8×10^6	3.4×10^6	14×10^6
2	1,000	5,000	1,505	15,000	22	8	98	34	162	1.1×10^5	0.4×10^5	4.8×10^5	1.7×10^5	8.1×10^5
3	40	200	297	440	42	8	110	34	194	8.3×10^3	1.6×10^3	22.0×10^3	6.8×10^3	38.7×10^3
4	2	10	139	220	69	8	130	34	241	690	80	1,300	340	2,410

* Examples were selected to cover a range of battery energy capacities (or power for 5-hour battery) and ac voltages typical of large industrial (baseline), small industrial, commercial, and small residential customers; also minimum dc battery voltages were assumed.

** Rounded off.

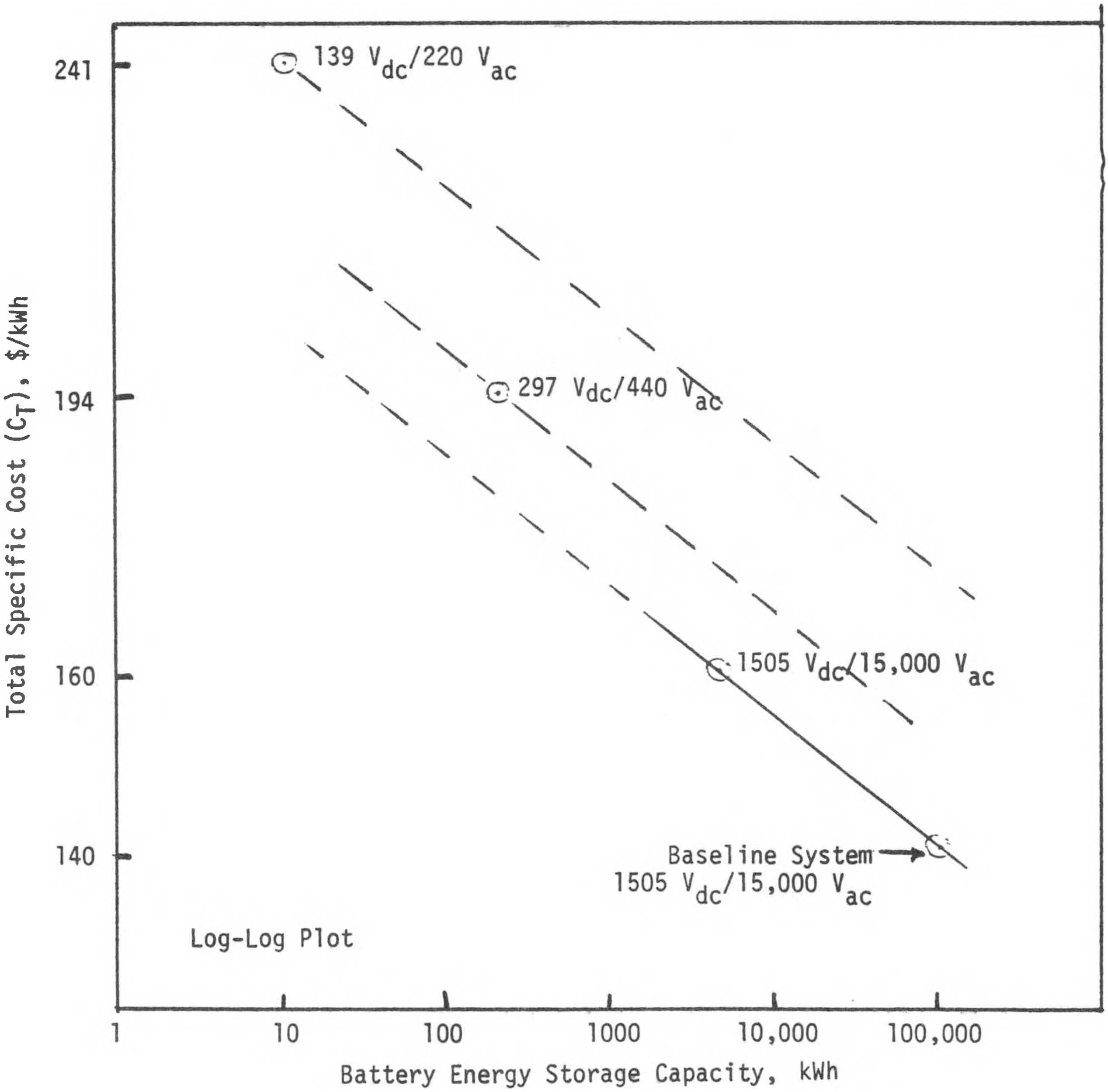


FIGURE III-2. TOTAL SPECIFIC COST AS A FUNCTION OF BATTERY SIZE AND VOLTAGE

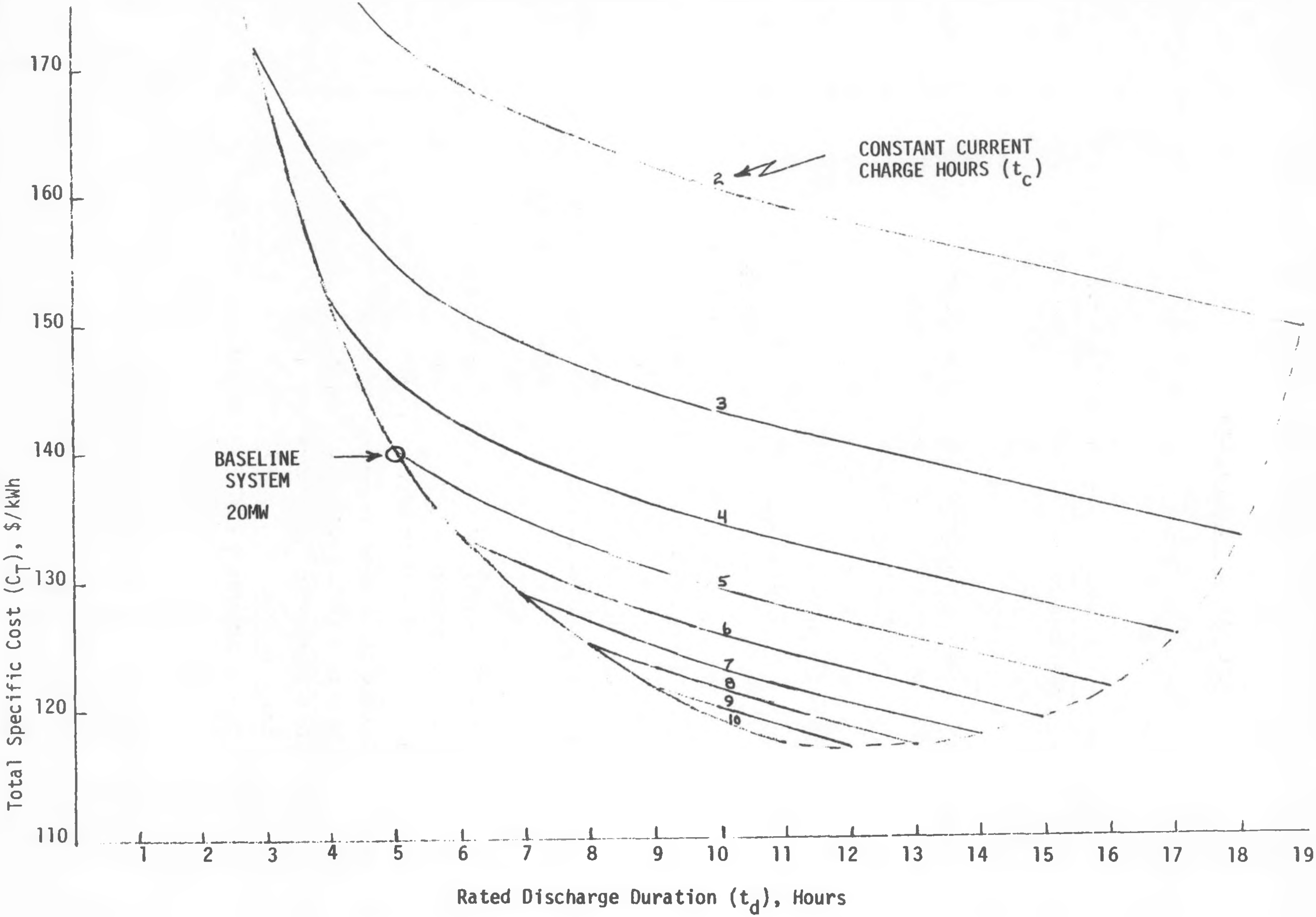


FIGURE III-3. TOTAL SPECIFIC COST AS A FUNCTION OF RATED DISCHARGE DURATION FOR VARIOUS CHARGE DURATIONS

Discussion of Cost Factors

Assumptions

With respect to the lead-acid battery there are two important assumptions implicit in the form of Equation (14) which modifies the baseline system cost Equation (1):

Assumption (1) The minimum cycle life of 2000 cycles specified for the baseline battery cost (C_3) is maintained for all battery system sizes and rated discharge rates.

Assumption (2) The reliability of the baseline battery system, which is characterized by six parallel strings, is not reduced (i.e., all size battery systems are assumed to be composed of six parallel strings).

The implications of making these two assumptions are discussed below.

Cycle Life. The assumption regarding cycle life is implicit in Equation (1) (the baseline cost) where the baseline battery cost (C_3) refers to a battery of cells specifically designed for a 5-hour discharge (i.e., cells derated to achieve a minimum of 2000 cycles by reducing the initial depth of discharge to 83 percent). Cycle life at a specified temperature is inversely related to depth of discharge. In the study by ESB[(2)] a 2000-cycle battery of cells designed for a 3-hour discharge (20 MW, 60 MWhr) was shown to cost slightly more than a 5-hour battery of cells (20 MW, 100 MWhr); conversely a 10-hour cell was shown to cost

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III-(2) ibid.

less. The latter data were used for factor F_6 to modify the battery cost (C_3) for any hour rating (t_d). A linear cost relationship was assumed between 5-hour and 3-hour or less cells in Equation (21) and between 5-hour and 10-hour or more cells in Equation (20).

Thus, all battery systems costs according to Equation (14) are based on a minimum of 2000 cycles regardless of the value of the rated discharge time (t_d).

Reliability. The assumption regarding reliability is based on an inherent reliability for the baseline battery system composed of six parallel strings. The specific battery cost (C_3) is associated with this 6-string reliability. For example, if the capacity of the battery system were reduced from 100 MWhr to 50 MWhr by eliminating three strings, the system reliability would be reduced although the specific battery cost would remain the same. Thus, all sizes of battery systems were designed with six parallel strings. Therefore, smaller cells are required to reduce capacity (holding string voltage constant) with an increase in specific cost for scale-down of cell size according to factor F_5 in Equation (19).

Reliability of the battery system is important when rate schedules include demand charges. The baseline system reliability is not known quantitatively because no data were found on cell failure rates to calculate string failure rates. However, a failure in one string would result in loss of only 1/6 of the battery capacity (i.e., battery could be operated at 83% of rating using 5 strings). Alternatively, the power on the remaining 5 strings could be increased 20 percent. In the early stages of battery cycle life, a 20 percent increase in power would be equivalent to an increase in cell depth of discharge to 100 percent. In the later stages of battery cycle life, either the power level would need to be reduced to 83 percent for the same discharge duration or the time of discharge would need to be reduced 83 percent (e.g., from 5 to 4.17 hours) at rated power.

For a particular cell failure rate, the string reliability is inversely related to the number of cells in the series string. Thus, if the baseline system were reduced in capacity from 100 MWhr to 50 MWhr by eliminating one-half of the 912 series cells in each of the six strings, the string reliability would be increased with no change in specific battery cost. However, the converter cost increases as battery (or string) voltage is reduced.

For battery voltages less than the baseline voltage of 1505 volts, the system reliability would not decrease. Thus, the assumption regarding reliability is valid. However, for very low battery voltages, the system reliability may be higher than necessary by also retaining six parallel strings. Fewer strings (with adequate system reliability) would allow larger cell size and reduced cost. Thus, the small systems (e.g., Example No. 4 in Table III-4) may be overdesigned for reliability, particularly if there are no demand charges in the rate schedule.

Minimum Battery Voltage

Effect on Power Conditioner Cost. The specific power conditioner cost increases as the minimum battery voltage decreases. The minimum voltage output (V_m) of the battery depends on the cell cut-off voltage on discharge (e.g., 1.65 volts/cell times 912 series connected cells per string equals 1505 volts), and also is the input dc voltage to the converter. Figure III-3 shows the effect of minimum voltage on the relative power conditioner cost (F_1) derived from data in the Westinghouse study[3] of converters.

For Examples No. 3 and No. 4 in Table III-3, the minimum dc voltage (V_m) was selected in increments of 19.8 volts (i.e., 1.65 volts/cell times 12 cells/row in each string) such that the maximum dc voltage, which was in increments of 31.8 volts (2.65 volts/cell times 12 cells/ row), would be close to the required ac voltage (440 or 220 volts ac).

III-(3) ibid

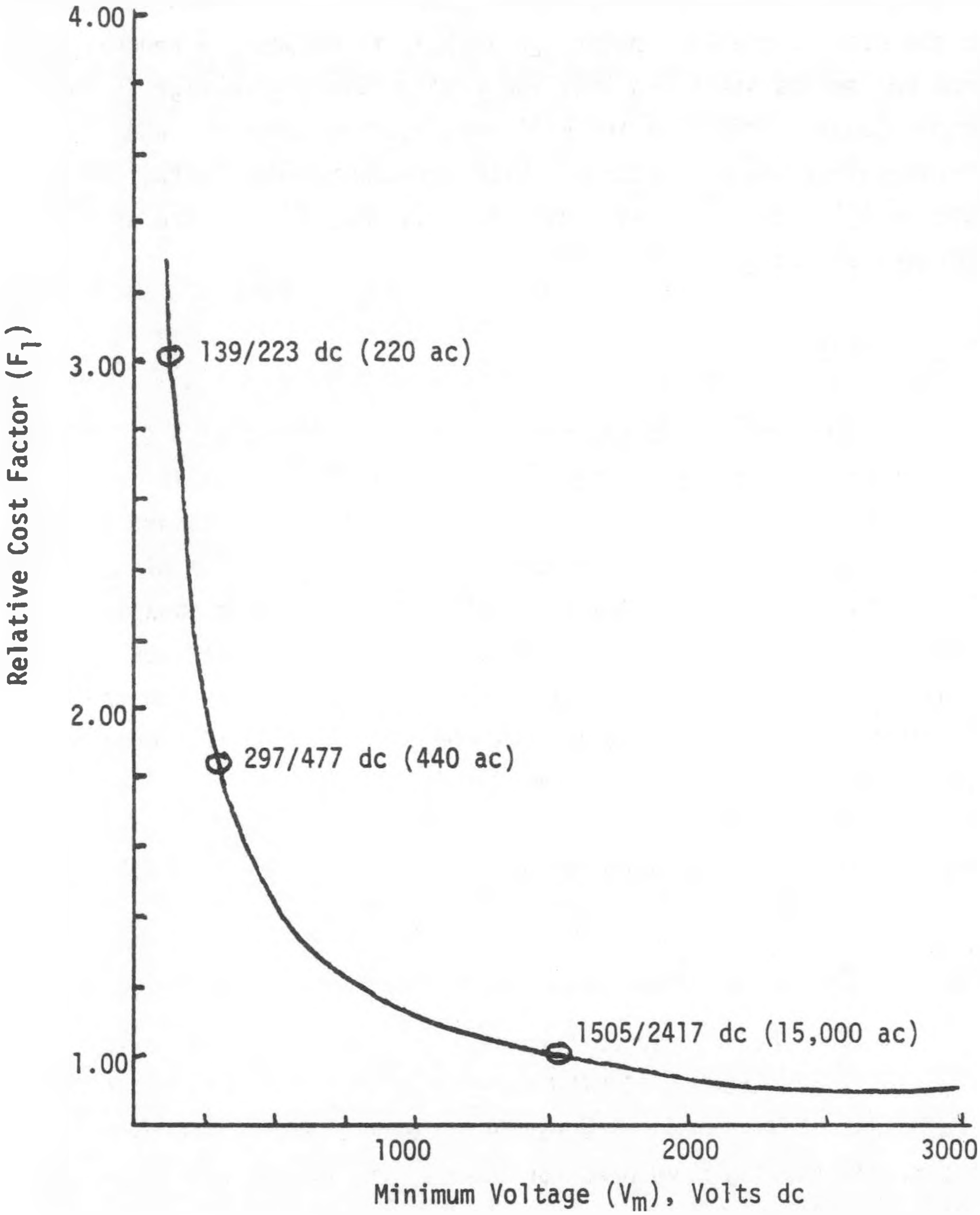

FIGURE III-4. EFFECT OF MINIMUM BATTERY VOLTAGE ON THE RELATIVE COST OF THE POWER CONDITIONER [FROM DATA IN REFERENCE III-(3)]

Effect on Battery Cost. The minimum battery voltage also affects the specific battery cost in factor F_5. As shown in Equation (19), if the battery energy capacity $[(P)\ (t_d)]$ is reduced by removal of cells from the series string so that the minimum battery voltage is reduced proportionally, the baseline cell size does not change. When V_m is reduced as low as practical (with consideration of effect on converter cost in F_1), it is necessary to reduce the basic cell size with consequent increase in cost factor F_5.

Battery Size

The scaling factor for cell size (exponent of 0.075 in equation 19) was based on the estimate that the specific cost would double for a 5-order of magnitude reduction in cell capacity (9756 ampere hours/cell to 0.97 ampere-hour/cell). Actually, the battery of Example No. 4 in Table III-3 consisted of 504 cells of 10.6 ampere-hour capacity each. Cell capacity reduction was visualized as a reduction in total cell area (number of plates/cell and area per plate) with current density constant so that electrochemical performance did not change. The specific cost of the lead active materials and grid was assumed to be the same for all sizes. The inactive materials (e.g., plastic cell case) and cost of cell assembly were assumed to be proportionately larger for the smaller cell sizes.*

Power Conditioner Size

The scaling factor (exponent of 0.028 in Equation 16) was based on an estimate of $350/kW for a 7 kW (220 volt ac) converter [i.e., $(F_1)\ (F_2) = 3.5$]. The estimate corresponds to the present cost of converters being developed for residential photovoltaic systems. The R&D goal is $200/kW.

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* Separate scaling factors for salvage and reuse credits for replacement batteries were not used. The effect on present value of the total battery system cost was estimated to be well within the range of values covered in the sensitivity analyses in Chapter VI.

Charge/Discharge Cycle

The factor F_3 (Equations 17A or 17B) depends on the charge/discharge cycle and whether the power conditioner needs to be sized to the discharge power (Equation 17A) or the charge power (Equation 17B). Also, equation (17) reflects that all of the charging of the lead-acid battery is not at constant power. The time available for the initial constant current charge is 24 hours minus 2 hours constant voltage (taper charge) and minus a daily average of 1 hour equalizing charge per week and minus the on-peak period of the rate schedule (t_n) or $21-t_n = t_c$.

For the baseline system where t_n = 14 hours or t_c = 7 hours for initial constant current charge, and the rated discharge time is t_d = 5 hours, Equation (27) shows that the maximum power occurs on discharge $\left[\frac{P_c(n_r)(n_i)}{P_d} = 0.73 \leqq 1\right]$. Thus, factor F_3 is calculated by equation 17A. For t_c = 7 hours, the maximum charge power equals the maximum discharge power when the rated discharge time is equal to about 7 hours. For discharge times from about 7 hours to a maximum of 14 hours (i.e. $t_c + t_d$ = 21 hours), factor F_3 is calculated by Equation (17B) since maximum power occurs during charge. However, for a particular charge time (t_c), total system cost decreases as t_d increases as shown in Figure III-3.

Balance of Plant

The apportionment of balance of plant costs between power related costs (C_2) and energy related cost (C_4) was estimated in the engineering plant design[1]. The value of C_2 includes converter installation and other fixed costs that do not vary with discharge capacity of the battery. Except for very short discharge times, the cost associated with C_2 are not a large portion of the total system costs in $/kWh.

In contrast, the term C_4 is essentially a constant in Equation (14). C_4 amounts to about 30 percent of the total battery related costs ($C_3 + C_4$). While the value of C_4 appears large, it should be remembered that it is based on a new site and building. Many times in the literature the term "installed cost" is used to distinguish from "factory cost" or "FOB cost". For conventional generating equipment the assumption is often made that installation is at an existing facility. However, for a new site, there is a "balance of plant" cost estimated by Burns & McDonnell(5) of about $90/kW for a 3-MW high-speed diesel to $180/kW for a 5-MW low-speed diesel generator. These values can be roughly compared to the $210/kW for total balance of plant for the baseline lead-acid battery system.

No scaling factor for size was used for the balance of plant costs C_4 or C_2. The large baseline system involved more expensive field labor. The use of less expensive factory labor for the smaller battery systems to be shipped as complete truck transportable systems was assumed to compensate for any economy of scale for larger battery systems.

The cost of land was not specifically included in the Bechtel study(1) estimates because it is site-specific. It was estimated on this project that land costs are relatively small compared to building costs and would not significantly impact the results within the accuracy of the engineering estimates.

The typical 20 percent contingency used in the engineering estimates(1) for a mature plant was assumed to be related to the uncertainty in the low cost for the converter assumed. Based on a higher estimate for power conditioner cost used on this project, which includes dc breakers and an auxiliary power system, the contingency was not included for a mature plant. However, the mature plant cost estimate came out about the same in 1980 dollars.

III-(5) An assessment of the Fuel Cell's Role in Small Utilities, Burns & McDonnell Engineering Company, EPRI EM-696 Final Report, Volume I p 3-8 (February, 1978).

III-(1) Ibid.

Demonstration Plant Cost Estimates

Demonstration plant cost estimates were estimated relative to the mature plant cost estimates for the baseline system as shown in Table III-5. For the demonstration plant, a 20 percent contingency was added to the balance of plant costs. Because lead-acid battery plants exist for producing a state-of-the-art (SOA) battery, the battery costs were increased 50 percent to reflect the lower production rate and present lack of a plant specifically dedicated to the large cell sizes required. Assuming about a 2-year lead time for the demonstration plant (i.e., 1982), it is estimated that the converter would be the pacing item. Although converters have been built for fuel cell demonstration plants and could be modified for use in battery systems, further R & D will be needed to reduce costs. It is estimated that the SOA power conditioning system for the demonstration plant would be about 2-fold higher than projected for a mature plant.

OTHER BATTERY SYSTEMS

Zinc-Chloride Battery

The zinc-chloride system has been developed sufficiently for future testing in the BEST* facility. Battery modules are currently being built for the BEST facility at a pilot plant. The system is sufficiently developed for possible consideration in a near-term demonstration plant. A principal uncertainty at the present time is manufacturing costs. The most recent study report(6) by EDA contains their estimates of costs as follows:

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*Battery Energy Storage Test

III-(6) Development of the Zinc-Chloride Battery for Utility Applications, Energy Development Associates, EPRI EM-1417 (May, 1980).

TABLE III-5. DEMONSTRATION PLANT COST ESTIMATES COMPARED TO MATURE PLANT COSTS FOR THE BASELINE SYSTEM

Mature Plant	Demonstration Plant
C_1 = \$100/kW	C' = \$200/kW
C_2 = \$40/kW	C_2' = \$48/kW
C_3 = \$78/kWh	C_3' = \$117/kWh
C_4 = \$34/kWh	C_4' = \$41/ kWh
C_T = \$140/kWh	C_T' = \$208/kWh
$C_T t_d$ = \$700/kW	$C_T' t_d$ = \$1038/kW

$$\text{Zinc Chloride System Cost*} = \frac{\$175/\text{kW}}{5\,\text{Hour}} + \frac{\$100}{\text{kWh}} = \frac{\$135}{\text{kWh}}$$

The auxiliaries include the converter and all other costs except the module target cost of \$100/kWh. The latter is expected to fall between the minimum of \$47/kWh and the permissible maximum of \$100/kWh (calculated by EDA to be competitive). The target efficiency is $\eta_T = 0.75$ and $\eta_T^* = 0.65$ (including energy of auxiliary equipment). Cycle life is projected to be at least 2000 cycles (but has not yet been demonstrated).

Advanced Technology Goals

Advanced technology goals for battery systems have been established with reference to competitive generation systems available to electric utilities. The breakeven cost for batteries changes over time with different assumptions for conventional systems (e.g., cost of fuel). The most typical guideline values were established in 1976 by EPRI and government agencies involved in battery development[7]. For the baseline system these cost goals in 1980 dollars are:

$$G_T = \frac{G_1}{t_d} + \left[G_3 + \frac{G_2}{t_d} + G_4\right] \qquad (27)$$

$$G_T = \frac{100}{5} + [\ 45\ ] = \$65/\text{kWh ac} \qquad (28)$$

$$(G_T)(t_d) = \$325/\text{kW}$$

Equation (27) is similar to Equation (1) except the symbol (G) is used for cost goals. The above goals are predicated on the following additional assumptions:[7]

Operation and Maintenance Cost (M_o) = \$0.014/kWh
System Efficiency (η_T^*) = 0.65
Battery Life = 10 years (i.e., 2000 cycles)

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*May be on a dc basis.

III-(7) Birk, J. R. and Yao, N. P., "Batteries for Utility Applications: Progress and Problems", Load Leveling, ECS Symposium Volume 77-4, pp 229-250, (October, 1977).

A number of advanced battery systems under development are reported to have projected costs (G_3) that could achieve the goal of \$45/kWh in Equation (28) (e.g., zinc-chloride, lithium-metal sulfide, sodium-sulfur)[8]. However, the balance of plant cost goals $G_2/t_d + G_4$ would have to be negligible which seems unlikely. Efficiency goals are attainable. Life cycle goals (2000 cycles) may be difficult to meet with a cost effective battery.

In contrast, the goals for an advanced lead-acid battery are to increase cycle life from 2000 to 4000 cycles at no increase in battery cost.

III-(8) Interim Cost Estimates for Advanced Battery Systems, Arthur D. Little, Inc., EPRI EM-742 (July, 1978).

CHAPTER IV. REGULATORY ISSUES AND ELECTRIC RATES

INTRODUCTION

The electric rate picture in the United States is very complex and generalizations about it are difficult to make. The picture is clouded by a number of factors. First, there is no uniformity among rate schedules throughout the country. Utilities even within the same state will employ different rate structures, utilize different generation technologies, and serve very different customer mixes. It is also difficult to make generalizations about electric rates because of the detailed nature of some rate schedules which specify a rate contingent upon several complex stipulations. The situation is further compounded by the highly politicized nature of the regulatory process. In some states the regulatory commissions are elected, while in others, they are appointed. Some states are characterized as being pro-consumer, while others are pro-business. A final factor in the picture is the rapid change the entire energy arena is undergoing. Future electric rate structures and schedules are difficult to project in the face of new regulations, technology advances, and uncertain fuel supplies.

In this study, the first step in assessing the impact of electric rates on battery storage viability was to define the basic formats and characteristics of rate schedules. Then a framework evaluating the different rate schedules on a common basis was derived. The final step involved cataloging existing rates and identifying future electric rate trends.

RATE SCHEDULE FORMATS

There are four components common to most rate schedules: the demand charge, the energy charge, the fuel adjustment clause, and the customer charge. Demand charges are essentially a capital utilization charge and are calculated on a $/kW-month basis. Residential rates do not typically include a demand charge component because of the low power levels involved coupled with the additional metering costs to measure them.

Energy charges and fuel adjustment clauses recover the variable costs of utility operating, maintenance, and fuel expenses and are calculated on a ¢/kWh basis. Customer charges recover customer processing costs and hook-up expenses and are calculated on a $/month basis.

Historically, the regulatory process has focused upon: 1) determining the revenue requirement needed by the utility to cover expenses and to earn a fair rate of return on the utility's invested capital; and 2) allocating this revenue requirement to the various customer classes based on some notion of cost responsibility. Based on voltage levels, utility customers are categorized into different customer classes, typically residential, commercial, and industrial. Once the allocation has been achieved, a utility is frequently allowed some freedom in allocating the customer class revenue requirements among the four cost components; in assigning detailed specifications set in the rate schedule; and, more generally, in deciding the form that the rate schedule might take. This rate schedule form is termed the rate structure.

This study focused upon three rate structure forms:

- Traditional - standard rate schedules with no time differentiated aspects
- Semi-time-of-day - time differentiated definition for the billing demand
- Time-of-day - time differentiated demand and/or energy charges.

These three forms represent the vast majority of existing rate schedules and more importantly, represent the rate structure forms which are compatible with and hold potential for the battery storage systems addressed in this study. Other rate structure forms such as seasonal, interruptible, and stand-by rates are less common and are related only indirectly to battery storage feasibility. These other forms will be assessed in a later section of this Chapter.

Traditional rate structures are defined as the typical demand charge/energy charge rate schedules which make no distinction as to the hour, day, or month consumption took place. These rate schedules represent a majority of the schedules in effect today. Because there are no reduced prices in these schedules for nighttime consumption, the primary potential for battery storage under such rates rests is load smoothing. Naturally, the higher the demand charge and the lower the energy charge, the greater the potential benefit accruing to battery storage.

Semi-time-of-day rate schedules usually take the form of a rider to the traditional rate schedule. This rider offers a reduction in off-peak or nighttime use by counting off-peak demand at a lower rate than on-peak demand. For example, a firm served by a utility offering a 50% semi-time-of-day rate schedule and taking power at 90 kW during the nighttime and at 50 kW during the daytime, would be billed for the 50 kW demand.

Time-of-day rates are rate schedules which offer a time-dependent pricing scheme whereby charges for daytime use of electricity are significantly greater than charges for nighttime consumption. The rationale behind time-of-day rates is two-fold. First, during the daytime, or when the demand for electricity is greatest, the utility is forced to use its least efficient production units. These units frequently utilize scarce and expensive fuels such as petroleum and natural gas. Second, emphasis on daytime consumption will necessitate continued expansion in new electric generation and transmission facilities to meet higher peak loads. The utility companies must pass the costs of such added facilities on to their customers. Time-of-day pricing holds that since nighttime production costs are less than daytime production costs, nighttime prices should be less than daytime prices. Thus, with a battery storage system, a customer can purchase and store power during periods when electric rates are their lowest and discharge and consume power from the batteries when rates are high.

Adoption of time-of-day rates are in part motivated by the passage of the Public Utilities Regulatory Policy Act (PURPA) which is part of the National Energy Act of 1978. The stated purposes of PURPA are to encourage:

1) Conservation of energy supplied by electric utilities

2) Efficient use of facilities and resources by electric utilities

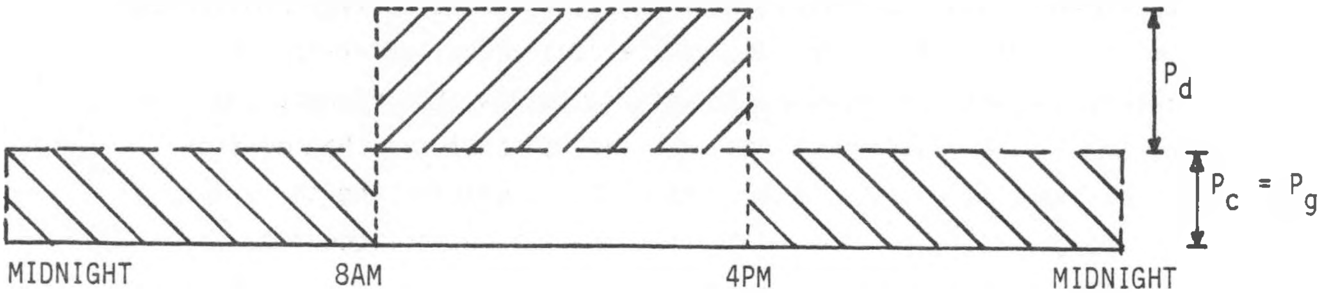
3) Equitable rates to electric consumers.

PURPA focuses upon the issue of appropriate rate structure forms - i.e., the process of translating the customer class revenue requirement into the actual rate schedule. PURPA requires state public utility commissions to consider the rate making standard of setting rates to reflect the costs of providing electric service to electric consumers at different times of the day unless such rates are deemed not cost-effective. The Act itself has no legal embodiment, but it does serve to illustrate the shift away from traditional rate structures to structures which more accurately reflect the cost to serve.

RATE SCHEDULE EVALUATION METHODOLOGY

In order to put the widely varying rate structures and rate schedules on a common reporting basis, a single measure termed the "rate differential" was derived. The rate differential represents the potential reduction in electricity costs per kWh of battery output. Because of the demand charge element found in many rate schedules, rate differentials are calculated for a series of discharge period durations. Modeling of rate schedules in a systematic fashion is based on the assumption that the battery will discharge at a constant rate of power. This means that the battery user will still draw power from the utility grid to supply small random fluctuations in its loadshape. To clarify the manner in which rate differentials are calculated and interpreted, examples will be discussed for each of the three rate structures under consideration: traditional, time-differential billable demand definitions, and time-of-day.

In the battery system application under traditional rate structures, battery storage is used to level loads so that the billable demand is reduced. Depicted below is an application utilizing a battery system with an eight hour discharge period:



Input load to the battery

Output load from the battery

Load taken from the grid, but not stored

Customer demand on the grid without battery storage

Customer demand on the grid with battery storage

P_c = Maximum battery charging power level

P_d = Maximum battery discharging power level

P_g = Maximum power level taken from the grid, but not stored

Here the battery is discharged during the firm's operating hours and charged during the other sixteen hours. With a battery system the firm's load factor for power supplied by the utility grid has increased from 33 percent to 100 percent. Since the goal of load leveling is to minimize the billable demand, and consequently the associated demand charges, the battery input level will equal the power level taken from the grid during operating hours. Therefore, the input power level (P_c) will equal the grid power level (P_g).

The rate differential, or the potential reduction in electricity costs per kWh of battery output, is the sum of two components: the demand charge savings plus the energy charge savings. The demand charge savings per unit of output energy would be equal to the reduction in monthly demand charges spread over the number of hours of discharge in a month. The energy charge savings per unit of output energy would be equal to the energy rate less the product of the energy rate and the amount of energy input to the battery system for each unit of energy output. Under traditional rate structures, the energy charge savings will actually be negative and will represent the cost associated with the additional charging required to compensate for the battery system efficiency. Under time-of-day rate structures this savings will be positive if the price of the off-peak energy used to charge the battery is significantly less than the on-peak price of the energy it is replacing. The following equations show the derivation of the rate differential.

Demand charge savings (\$ per kWh) = $\dfrac{D_p}{t_d \cdot d \cdot w}$

D_p = demand charge \$/kW-month

t_d = time for constant power discharge, hours

d = number of cycles per week = 5

w = average number of weeks per month less holidays = (50 working weeks per year)/(12 months per year) = 4.166

$d \cdot w$ = number of cycles per month.

$$\text{Energy charge savings (\$ per kWh)} = E - \left(\frac{C_f}{C_p}\right) \cdot E$$

$$= E - \frac{E}{n_t} \quad . \qquad (2)$$

E = energy charge, $/kWh

C_p = total electricity discharged by the battery, kWh

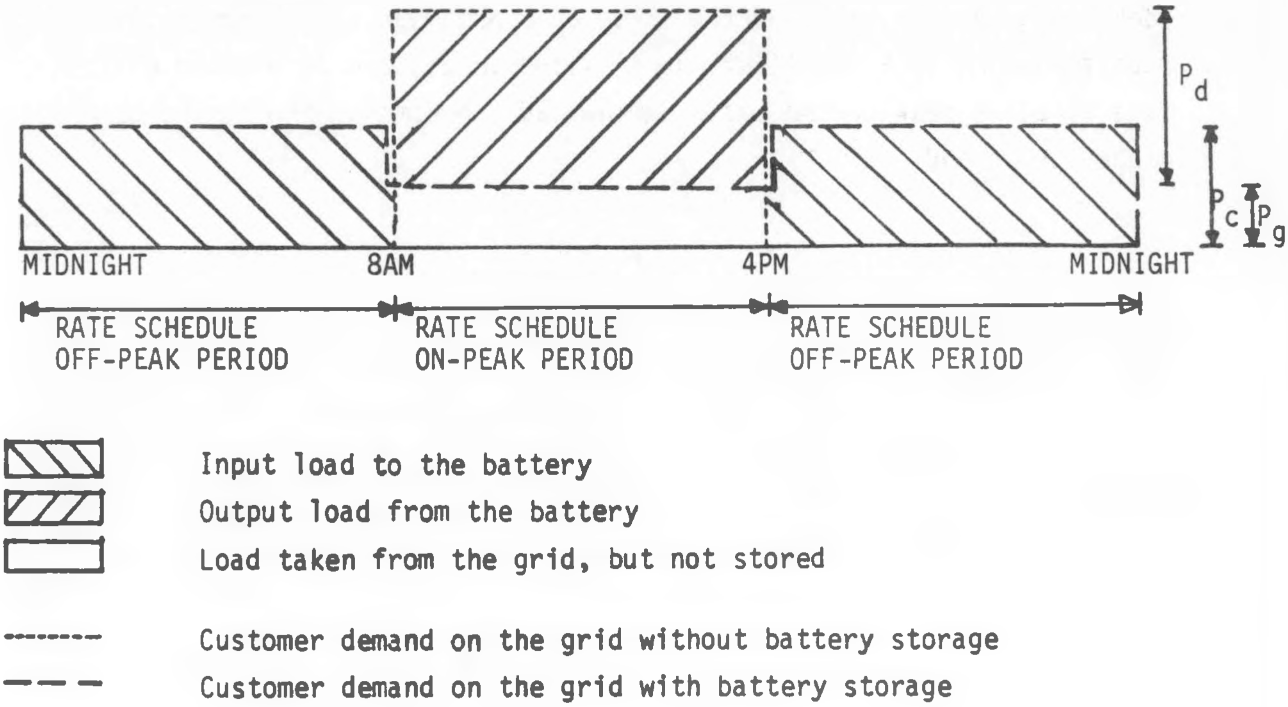
C_f = total electricity drawn from the utility grid = C_p/n_t, kWh

n_t = total system efficiency

$$\text{Rate differential} = \left[\frac{D_p}{t_d \cdot d \cdot w}\right] + \left[E - \frac{E}{n_t}\right] \qquad (3)$$

The battery system size would be based on the required battery output which in this case example is equal to the product of the output power level and the discharge period ($=P_d \cdot 8$). Total electricity cost reduction is equal to the product of the rate differential and the required battery output. Extension of the analysis to other discharge periods is straightforward. A six-hour discharge period would represent a firm with a load factor of 25 percent - i.e., 6/24ths. On a kWh unit basis, the calculated rate differential would be higher than in the eight-hour case because the demand charge savings ($/kW) resulting from the reduced billable demand could be recovered in a shorter discharge period.

The second rate structure form, semi-time-of-day or rate schedules with time-differentiated billable demand definitions, reflects a slightly different use of battery storage systems. Depicted below is an application with an eight-hour discharge period. For illustrative purposes, assume that the rate schedule peak period is defined to be the same period as the battery discharge period. Assume also that demands occurring in the off-peak period will be billed at 50 percent of their actual level.



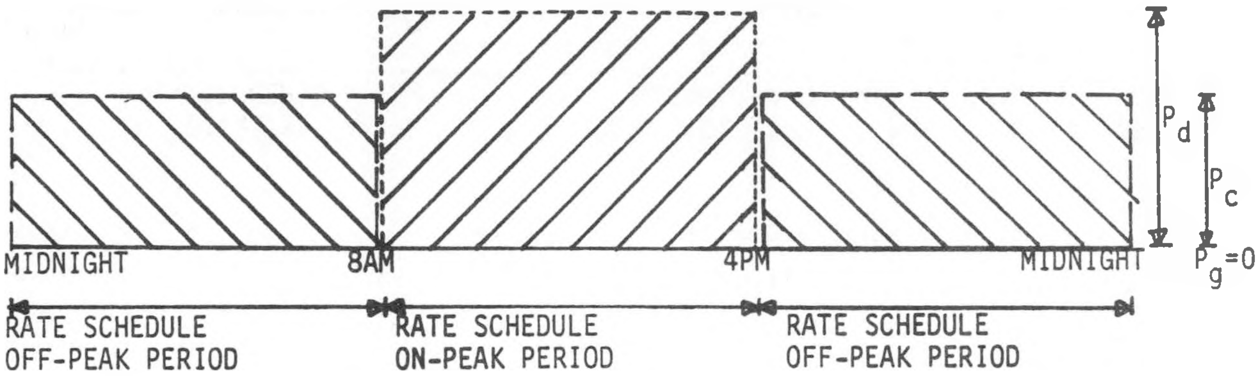
P_c = Maximum battery charging power level

P_d = Maximum battery discharging power level

P_g = Maximum power level taken from the grid, but not stored

All other things being equal the time differentiated billable demand definition will result in a slightly larger battery system than under a traditional rate structure because the off-peak load can reach twice the level of the on-peak demand without increasing the billing demand. The ratio of the input load to the battery and the electrical load taken from the grid (P_c/P_g) will reflect the rate at which off-peak demand is included as billable demand - i.e., 50 percent. Calculation of the rate differential under semi-time-of-day rate structures is the same as under traditional rate structures.

The time-of-day application will utilize battery systems to shift much more consumption away from the on-peak periods to the off-peak periods than either of two previous rate structures. Off-peak demand levels in the time-of-day battery system are charged at the separate off-peak demand charge rate and thus are not linked to on-peak demand levels. Depicted below is an application utilizing an eight-hour battery with the rate schedule peak period again defined as the same period as the battery discharge period:



Input load to the battery

Output load from the battery

Load taken from the grid, but not stored

-------- Customer demand on the grid without battery storage

— — — Customer demand on the grid with battery storage

P_c = Maximum battery charging power level

P_d = Maximum battery discharging power level

P_g = Maximum power level taken from the grid, but not stored

Calculating the rate differential for time-of-day rate schedules will be slightly different in order to reflect on-peak and off-peak demand and energy charges. The first step will be to determine the load during the charge period required to produce one kilowatt of power during the discharge period. The charging and discharging power levels are different to the extent that the charging and discharging periods are different. For example, in a time-of-day application with a peak period duration of 14 hours, only about 7 hours would remain to charge the system. Thus the charging power level would be roughly twice that during discharge. On an ac basis the maximum input power level for an output power level of one kilowatt equals P_c/P_d. This ratio multiplied by the off-peak demand charge and then subtracted from the on-peak demand charge results in the monthly demand charge savings per kilowatt output. The ratio of charge to discharge power (on an ac basis) was derived in Equation (26) from Chapter III and can be calculated as follows:

$$\frac{P_c}{P_d} = \frac{t}{0.885 \cdot t_c - \frac{0.195}{t_d}} \qquad (4)$$

The demand charge savings per unit of output energy would be equal to the reduction in monthly demand charges spread over the number of hours of discharge in a month. The energy charge savings per unit of output energy would be equal to the on-peak electric price less the product of the off-peak electric price and the amount of energy input to the battery system for each unit of energy output.

$$\text{Demand charge savings (\$ per kWh)} = \frac{[(D_p) - \frac{P_c}{P_d} \cdot (D_f)]}{t_d \cdot d \cdot w} \qquad (5)$$

D_p = on-peak demand charge \$/kW-month

D_f = off-peak demand charge \$/kW-month

t_d = time for constant power discharge, hours

d = number of cycles per week = number of days in a week in the peak period

w = average number of weeks per month less holidays = (50 working weeks per year)/(12 months per year) = 4.166

$$\text{Energy charge savings (\$ per kWh)} = E_p - \frac{C_f}{C_p} \cdot E_f \qquad (6)$$

$$= E_p - \left(\frac{C_p}{C_p \cdot \eta_t}\right) \cdot E_f$$

$$= E_p - \frac{E_f}{\eta_t}$$

E_p = on-peak energy rate, \$/kWh

E_f = off-peak energy rate, \$/kWh

C_p = energy consumption during the peak, kWh

C_f = energy consumption during the off-peak = C_p/η_t

η_t = total system efficiency

$$\text{Rate differential} = \frac{D_p - \left[\dfrac{t_d}{(.885 \cdot t_c) - (\frac{.195}{t_d})}\right] \cdot (D_f)}{t_d \cdot d \cdot w} + \left(E_p - \frac{E_f}{\eta}\right) \qquad (7)$$

The rate differential equations (3) and (7) for the three rate structure forms are very similar. In fact, the principal differences disappear when it is noted that the off-peak demand charge in a time-of-day rate tends to be small and often zero.

As a numerical example to demonstrate the calculations, suppose the primary light and power rate schedule from Consolidated Edison is evaluated. First, this schedule (noted SC9 in Table IV-1) represents a traditional rate structure form (load leveling). The demand charge is approximately \$10/kW, and the energy charge including fuel adjustment is \$.04 per kWh. Assume that the potential battery user requires a system with a discharge period of five hours and that $\eta_t = .72$. Assume also that the battery is to discharge an average of 20.8 cycles per month. Therefore,

$$\text{Rate differential } (\$/\text{kWh}) = \frac{10}{20.8 \cdot 5} + .04 - \frac{.04}{.72}$$

$$= .082$$

Rate differentials for various combinations of demand and energy charges are shown in Table IV-1. The ranges for the demand charges and energy charges were selected so that the vast majority of existing rate schedules would be encompassed. Assuming that the off-peak demand charge component is close to zero, rate differentials for time-of-day schedules can also be incorporated by adjusting the energy charge component to reflect the off-peak energy charge. That is, the traditional rate schedule energy charge savings implicit in the table would be subtracted from the rate differential and the time-of-day rate schedule energy charge savings added in its place.

Several observations can be made on the basis of a review of Table IV-1:

- In Chapter VI (Economic Evaluation) it will be determined that the rate differential necessary to recover the life-

TABLE IV-1. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - TRADITIONAL RATE SCHEDULES ($/kWh)

Demand Charges ($/kW)	Discharge Period (hours)	Energy Charges		
		(1¢/kWh)	(3¢/kWh)	(5¢/kWh)
10	12	.036	.029	.021
10	8	.056	.049	.041
10	5	.093	.086	.078
10	3	.156	.149	.141
10	2	.238	.231	.223
6	12	.020	.013	.005
6	8	.032	.025	.017
6	5	.054	.047	.039
6	3	.092	.085	.077
6	2	.141	.134	.126
2	12	.004	(.002)	(.011)
2	8	.008	.001	(.007)
2	5	.015	.008	.000
2	3	.028	.021	.013
2	2	.044	.032	.029

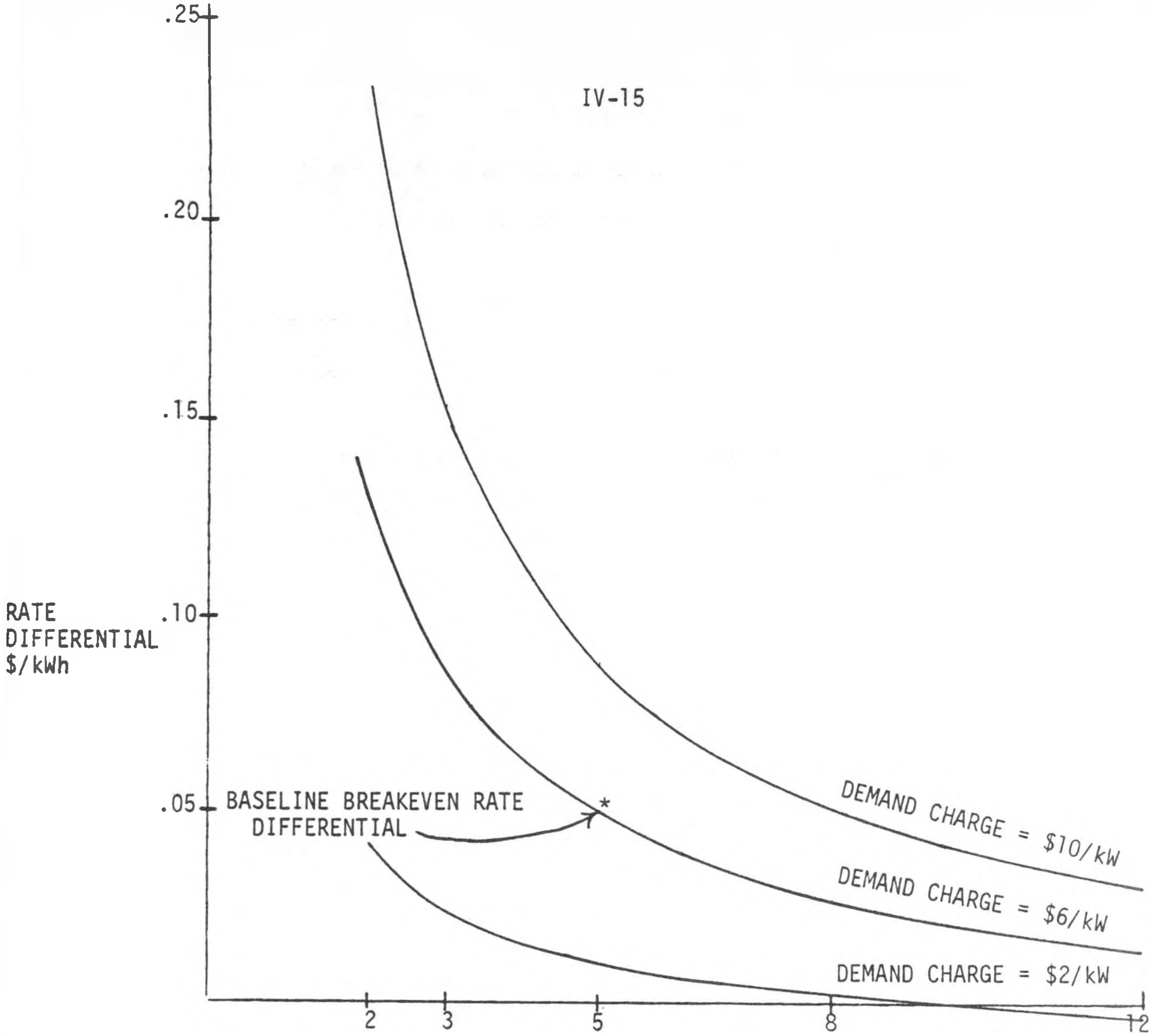
cycle costs of the base case battery system is $.053/kWh. Some of the rate differentials included in the table exceed this breakeven differential, while others fall below it. In any case, it is apparent that the rate schedule used to evaluate battery storage system viability can have a significant impact on the conclusion of that evaluation.

- The range of demand charges (from $2/kW to $10/kW) has a significant impact on the rate differential -- a factor of 9.0 (=.036/.004) for the case of a discharge period of 12 hours and an energy charge of 1¢/kWh.

- The range of discharge periods (from 2 hours to 12 hours) similarly has a significant impact on the rate differential -- a factor of 6.6 (=.238/.036) for the case of a demand charge of $10/kW and an energy charge of 1¢/kWh.

- The range of energy charges (from 1¢/kWh to 5¢/kWh) has the least impact of the three parameters on the rate differential -- a factor of 1.7 (=.036/.021) for the case of a demand charge of $10/kW and a discharge period of 12 hours.

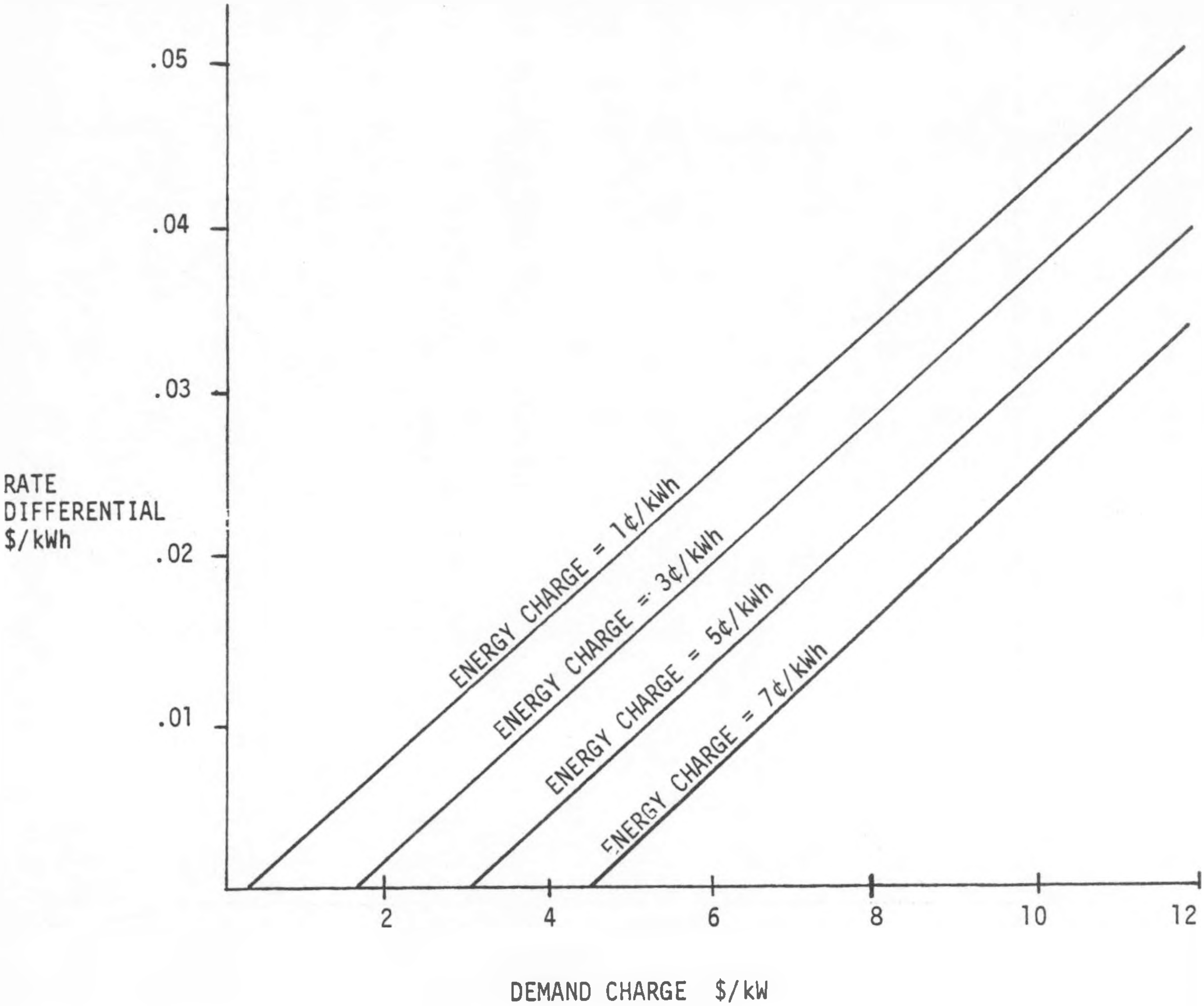
Figures IV-1 through IV-6 graphically portray the various combinations of demand charges, energy charges, and discharge periods. These curves indicate clearly the benefits of identifying utilities with large demand charge levels and customers with short discharge period requirements.



DISCHARGE PERIOD HOURS

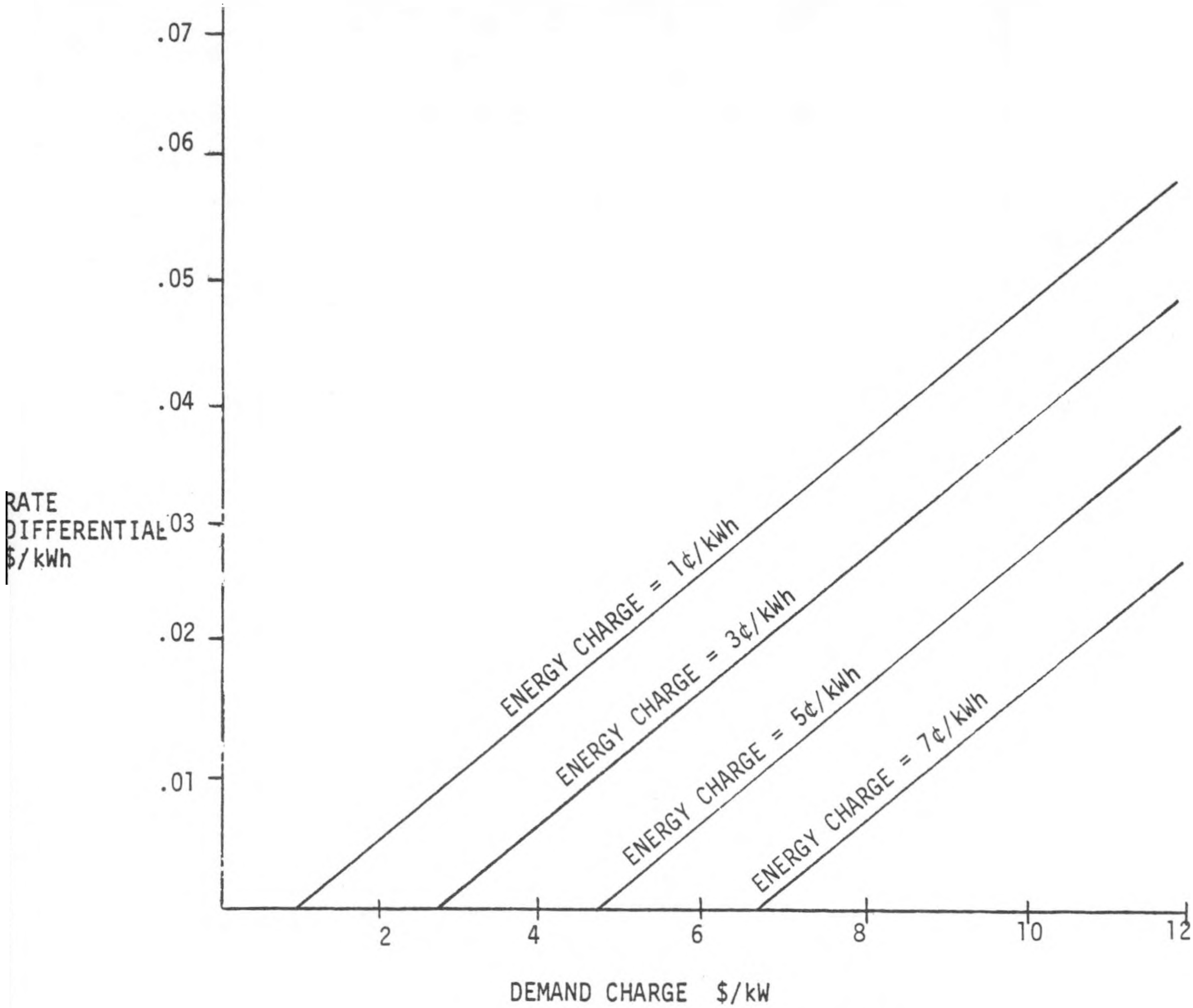
ASSUMES ENERGY CHARGE = 3¢/kWh

FIGURE IV-1. PLOT OF ALTERNATIVE TRADITIONAL RATE SCHEDULES AND THE BREAKEVEN RATE DIFFERENTIAL FOR THE BASE CASE



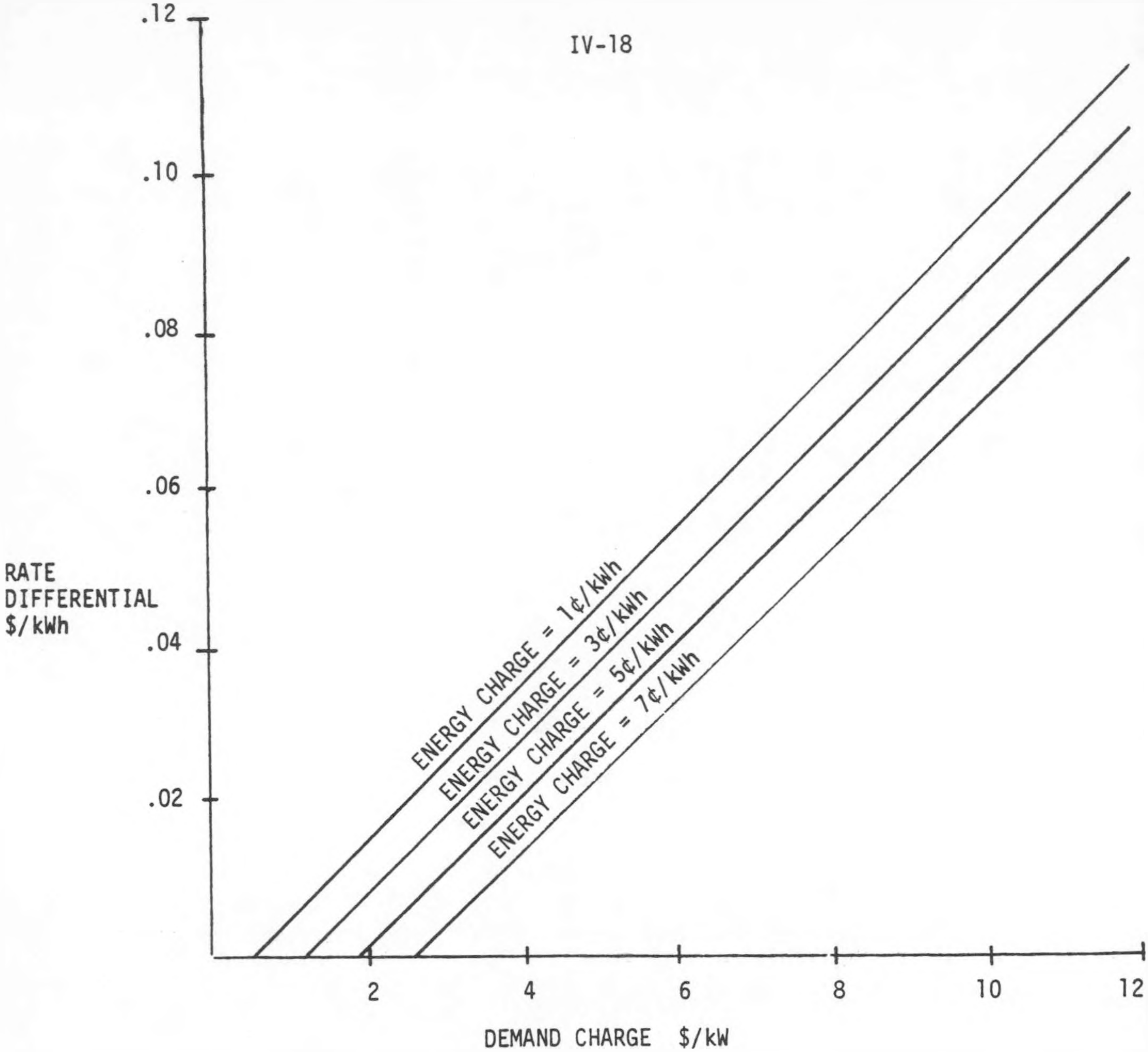
ASSUMES DISCHARGE PERIOD = 12 HOURS

FIGURE IV-2. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - 12-HOUR DISCHARGE PERIOD



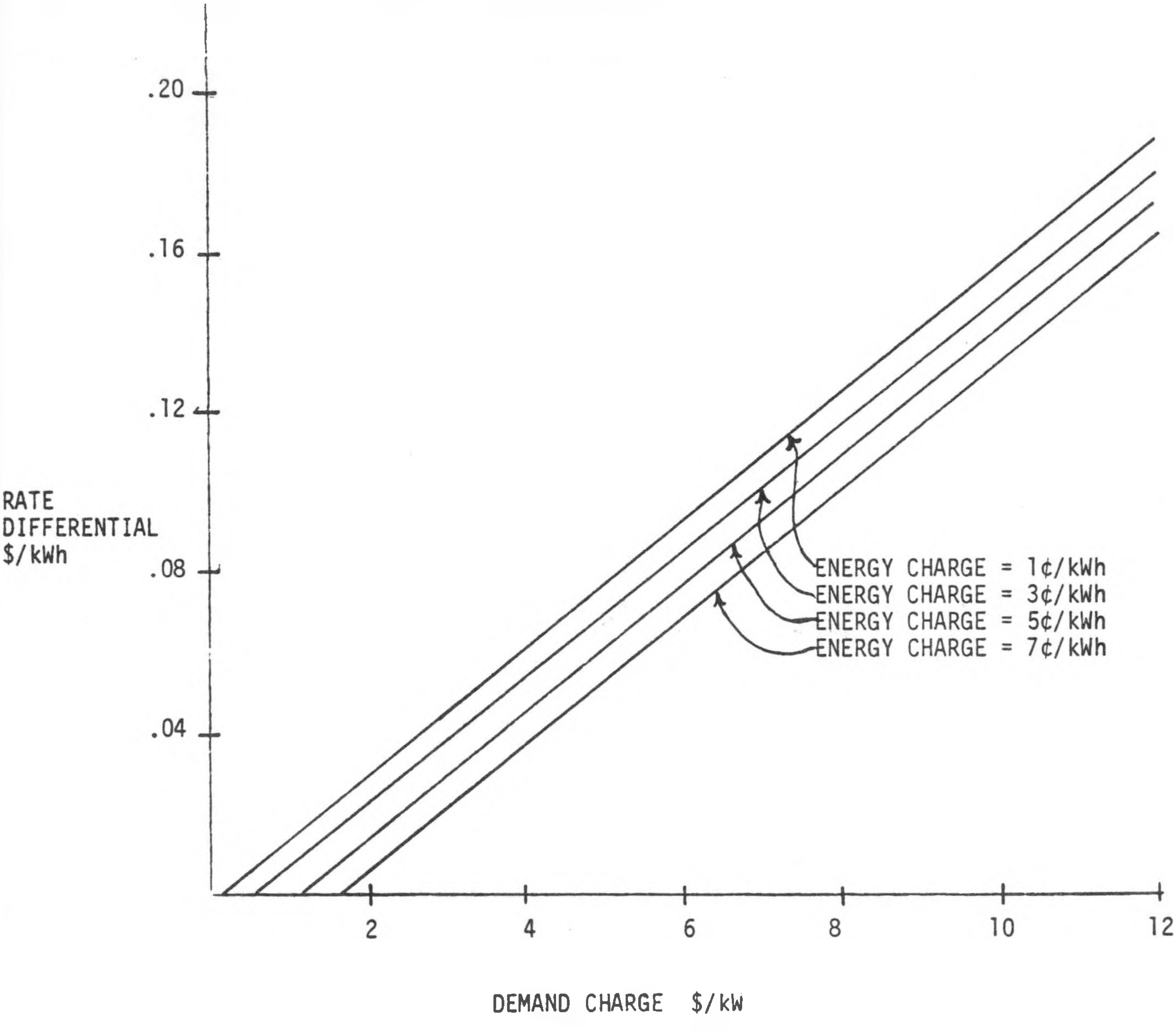
ASSUMES DISCHARGE PERIOD = 8 HOURS

FIGURE IV-3. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - 8-HOUR DISCHARGE PERIOD



ASSUMES DISCHARGE PERIOD = 5 HOURS

FIGURE IV-4. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - 5-HOUR DISCHARGE PERIOD



ASSUMES DISCHARGE PERIOD = 3 HOURS

FIGURE IV-5. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - 3-HOUR DISCHARGE PERIOD

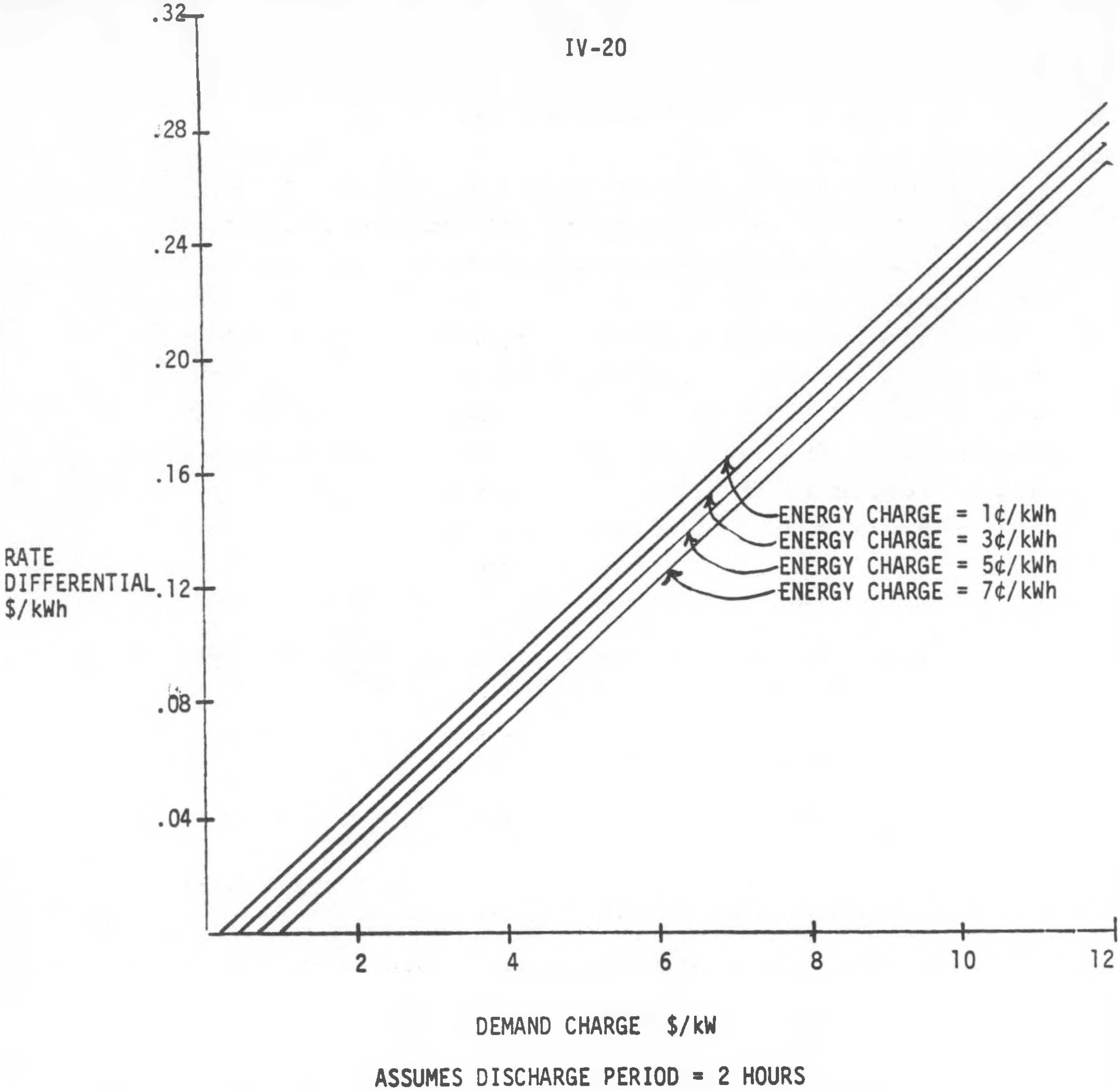


FIGURE IV-6. RATE DIFFERENTIALS FOR ALTERNATIVE COMBINATIONS OF DEMAND AND ENERGY CHARGES - 2-HOUR DISCHARGE PERIOD

PRESENT RATE SCHEDULES

The investigation of existing rate schedules is important from a number of perspectives. First, it provides benchmarks of the potential electricity cost reduction using battery systems. These benchmarks can then be compared with the life-cycle costs of providing the battery system to establish their relative viability. Second, it provides insight into the format and characteristics of rate schedules and into how battery systems could be incorporated and evaluated under various utility rate structure forms. Finally, it pinpoints which utility service areas hold the greatest potential for battery storage systems along with an indication of the degree to which subsidies must be provided to make an economically viable demonstration project. Several categories of rate schedules were investigated and they include:

- Most favorable traditional rate schedules for customers in the 20000kW classification (Table IV-2)
- Most favorable traditional rate schedules for customers in the 1000kW classification (Table IV-3)
- Most favorable traditional rate schedules for customers in the 40kW classification (Table IV-4)
- Most favorable rate schedules with a time-differentiated billable demand definition (Table IV-5)
- Existing Traditional Rate Schedules (Table IV-6)
- Existing Time-of-Day Rate Schedules - Residential (Table IV-7)
- Existing Time-of-Day Rate Schedules - Commercial and Industrial (Table IV-8).

Naturally, the use of "favorable" relates to those utilities which hold the greatest potential for battery storage systems. Because of the constraints posed by the detailed nature of the rate schedules and by the unusual formats of some rate schedules, the data presented in the tables represent approximations. For example, the demand charges and energy charges were rounded off to the nearest \$/kW and ¢/kWh, respectively. In order to incorporate the seasonality associated with some rate schedules, it was assumed that the customer utilized a constant amount of electricity throughout the year. Adjustments to reflect declining block rates were made on the basis of a 33-1/3 percent load factor for the 40kW system application, a 60 percent load factor for the 1000kW system application, and a 90 percent load factor for the 20000 kW application. These load factors are typical for customers requiring the associated size battery system. The rate schedules were obtained from the National Electric Rate Book[(1)], and many were updated to reflect any recent changes. Note also that energy charges include both the energy charge and the fuel adjustment clause.

Traditional and Semi-Time-of-Day Rate Schedules

Review of Table IV-2 indicates that the three best utility service areas for battery storage applications at the 20000 kW level are Carolina Power and Light (GLFS-3), Minnesota Power and Light (74), and Indianapolis Power and Light (HL). These rate schedules all have high demand charges and low energy charges. The rate schedules appearing on this list generally represent the Northeast, Midwest, and Southern Atlantic regions. A later section of this Chapter will address the relationship between characteristics of the utility and its rate schedules. An example of such relationships would be the correlation between a significant amount of hydroelectric capability and low electric rates. Thus, none of the utilities appearing on the list have hydroelectric capability in excess of 10 percent of their generation capacity. As such, utilities serving the Northwest will typically hold little potential for battery storage viability.

For a discharge period of five hours, 9 of the 24 utilities listed have rate differentials exceeding the breakeven rate differential of $.053/kWh for the base case battery system. All of the utilities listed exceed the $.053/kWh hurdle for the shorter discharge periods of three and two hours. Note again the large impact increasing demand charge levels and decreasing discharge periods have on the calculated rate differential.

IV-(1) National Electric Rate Book published continuously by the Energy Information Administration of the United States Department of Energy.

TABLE IV-2. MOST FAVORABLE TRADITIONAL RATE SCHEDULES — 20,000 kW CLASS

Utilities	Rate Designation	Demand Charge ($/kW)	Energy Charge (¢/kWh)	Rate Differentials for Alternative Discharge Periods ($/kWh) 12 Hours	8 Hours	5 Hours	3 Hours	2 Hours
San Diego Gas & Electric Company	A-6	6	4	0.009	0.021	0.043	0.081	0.130
Central Illinois Public Service Company	9B	10	2	0.032	0.052	0.089	0.152	0.234
Indianapolis Power and Light Company	HL	11	1	0.040	0.062	0.102	0.172	0.262
Indianapolis Power and Light Company	SL	5	1	0.016	0.026	0.044	0.076	0.117
Iowa Electric Light and Power Company	LGS	7	2	0.020	0.034	0.060	0.104	0.161
Consumers Power Company (Michigan)	D	5	2	0.012	0.022	0.040	0.072	0.113
Detroit Edison Company	D-4	6	3	0.013	0.025	0.047	0.085	0.134
Upper Peninsula Power Company (Michigan)	WP-1	5	2	0.012	0.022	0.040	0.072	0.113
Minnesota Power and Light Company	74	12	1	0.044	0.068	0.111	0.188	0.286
Northern States Power Company (Minnesota)	DK-025	5	2	0.012	0.022	0.040	0.072	0.113
Otter Tail Power Company (Minnesota)	C-02M	5	2	0.012	0.022	0.040	0.072	0.113
Missouri Power and Light Company	IS	5	2	0.012	0.022	0.040	0.072	0.113
Public Service of New Jersey	LPL	5	3	0.009	0.019	0.037	0.069	0.110
Central Hudson Gas & Electric Corporation	SC-3	11	3	0.033	0.055	0.095	.0165	0.255
Consolidated Edison Company of New York	SC-9	10	4	0.025	0.045	0.082	0.146	0.227
Carolina Power and Light Company	GLFS-3	13	1	0.048	0.074	0.124	0.208	0.314
Toledo Edison Company	PV-43	5	2	0.012	0.022	0.040	0.072	0.113
South Carolina Electric and Gas Company	23	5	1	0.016	0.026	0.044	0.076	0.117
Houston Lighting and Power Company	LOS-3	5	1	0.016	0.026	0.044	0.076	0.117
Central Vermont Public Service Corporation	4	7	1	0.024	0.038	0.064	0.108	0.165
Green Mountain Power Company	14	5	1	0.016	0.026	0.044	0.076	0.117
Appalachian Power Company	LCP	8	2	0.024	0.040	0.069	0.120	0.185
Wisconsin Power and Light Company	CP-4	5	2	0.012	0.022	0.040	0.072	0.113

Table IV-3 records the most favorable traditional rate schedules for the next smaller class--1000kW. As indicated by the rate designation column, many of the rate schedules appearing on this list are the same ones included in the list for the 20000kW class. That is, the same rate schedule would be applicable to both customer sizes. If the costs to serve vary significantly as to customer size and electrical requirements, the utility will offer more than a single rate schedule in the industrial customer class.

Even though the same rate schedule may appear in both lists, it may be assigned different rate differentials. This difference is due to the declining blocks many utilities have incorporated. That is, the average rates of the very largest customers (20000kW) are relatively unaffected by the possibly high demand charge levels in effect for the first 100kW increments of the declining block. In the case of Indianapolis Power and Light, for example, rate schedule "SL" was assigned a $5/kW demand charge level for the 20000kW customer, but a $7/kW demand charge level for the 1000kW customer.

In general, utilities with favorable rate schedules for one customer size will also have them for other customer sizes. For example, Central Illinois Public Service Company has rate schedule "9B" for the largest class and "9" for the smaller class. This correlation between the rate schedules can be traced to the fact that rates are formulated on the basis of the utility's cost to serve. For example, a system dominated by recent nuclear generation capacity additions will tend to formulate rate schedules which can be characterized by the inordinant demand charges required to recover the large capital investments associated with nuclear facilities.

At the eight hour discharge level, the utilities exhibiting the most favorable traditional rate schedules for the 1000kW class include Central Hudson Gas and Electric Corp. (SC-3), Appalachian Power Co. (LCP), and Central Vermont Public Service Corp. (4). In the most favorable traditional rate schedules for the 40kW class (Table IV-4), Iowa Electric Light and Power (GS) and Central Vermont Public Service Corp. (2) were estimated to have the highest rate differentials for an eight-hour discharge period.

TABLE IV-3. MOST FAVORABLE TRADITIONAL RATE SCHEDULES — 1000 kW CLASS

Utilities	Rate Designation	Demand Charge ($/kW)	Energy Charge (¢/kWh)	Rate Differentials for Alternative Discharge Periods ($/kWh) 12 Hours	8 Hours	5 Hours	3 Hours	2 Hours
Central Illinois Public Service Company	9	6	3	0.013	0.025	0.047	0.085	0.134
Indianapolis Power and Light Company	SL	7	2	0.020	0.034	0.060	0.104	0.161
Iowa Electric Light and Power Company	LGS	7	2	0.020	0.034	0.060	.0104	0.161
Consumers Power Company (Michigan)	D	6	2	0.016	0.028	0.050	0.088	0.137
Detroit Edison Company	D-4	6	3	0.013	0.025	0.047	0.085	0.134
Upper Peninsula Company (Michigan)	P-1	6	2	0.016	0.028	0.050	0.088	0.137
Minnesota Power and Light Company	55	5	3	0.009	0.019	0.037	0.068	0.110
Northern States Power Company (Minnesota)	DK-025	5	2	0.012	0.022	0.040	0.072	0.113
Otter Tail Power Company (Minnesota)	C-02M	5	2	0.012	0.022	0.040	0.072	0.113
Missouri Power and Light Company	18	5	2	0.012	0.022	0.040	0.072	0.113
Public Service of New Jersey	LPL	6	3	0.013	0.025	0.047	0.085	0.134
Central Hudson Gas & Electric Corporation	SC-3	11	3	0.033	0.055	0.095	0.165	0.255
Rochester Gas & Electric Company	SC-3	5	2	0.012	0.022	0.040	0.072	0.113
Toledo Edison Company	PV-43	5	2	0.012	0.022	0.040	0.072	0.113
South Carolina Electric & Gas	20	6	1	0.020	0.032	0.054	0.092	0.141
Central Power and Light (Texas)	32	5	2	0.012	0.022	0.040	0.072	0.113
Houston Lighting and Power	LOS-3	5	1	0.016	0.026	0.044	0.076	0.117
Central Vermont Public Service Corporation	4	7	1	0.024	0.038	0.064	0.108	0.165
Green Mountain Power Company	14	5	1	0.016	0.026	0.044	0.076	0.117
Appalachian Power Company	LCP	9	2	0.028	0.046.	0.079	0.136	0.210
Virginia Electric Power Company	6	5	2	0.012	0.022	0.040	0.072	0.113
Wisconsin Power and Light	CP-4	5	2	0.012	0.022	0.040	0.072	0.113

TABLE IV-4. MOST FAVORABLE TRADITIONAL RATE SCHEDULES — 40 kW CLASS

Utilities	Rate Designation	Demand Charge ($/kW)	Energy Charge (¢/kWh)	Rate Differentials for Alternative Discharge Periods ($/kWh) 12 Hours	8 Hours	5 Hours	3 Hours	2 Hours
Florida Power Corporation	CI-ID	5	3	0.009	0.019	0.037	0.069	0.110
Iowa Electric Light and Power	GS	8	2	0.024	0.040	0.069	0.120	0.185
Potomac Electric Power Company	GS	5	5	0.001	0.011	0.058	0.061	0.102
Boston Edison Company	G-2	5	3	0.009	0.019	0.037	0.069	0.110
Lansing, Board of Water (Michigan)	4	5	2	0.012	0.022	0.040	0.072	0.113
Public Service of New Jersey	GLP	7	5	0.009	0.023	0.049	0.093	0.150
UGI Corporation	GS-2	6	3	0.013	0.025	0.047	0.085	0.134
Central Vermont Public Service Corporation (Wisconsin)	2	7	1	0.024	0.038	0.064	0.108	0.165
Virginia Electric Power Company	5	6	4	0.009	0.021	0.043	0.081	0.130
Lake Superior District Power Company	CG-1	5	3	0.009	0.019	0.037	0.069	0.110

Table IV-5 records the rate schedules listed in the previous three tables that, in addition, have a time-differentiated billable demand definition. As indicated in an earlier section of this Chapter, such definitions do not affect the rate differential calculation but do enable larger loads to be shifted to the off-peak hours. In the case of Indianapolis Power and Light Co. (SL), off-peak loads could increase to a level twice that of the on-peak load without increasing the billable demand.

An inventory of rate schedules for each of the customer sizes and for most of the major utilities in the country is presented in Table IV-6. Several observations of the information can be made:

- The majority of traditional rate schedules in the country have demand charge levels in the range of \$2-\$4. The rate differentials associated with these rate schedules would fall below the required breakeven rate differential associated with the base case battery system except in the very shortest of discharge periods. Discussion later in this Chapter and in the Economics Evaluation (Chapter VI) will address the issues of what demand charge levels might be in the future and of what reductions could be expected in the baseline battery system costs.

- Although there are some regional trends in the data due to similarities in utility characteristics, there are many cases of wide variations between utilities in the same state with respect to (1) the underlying relative rate level and (2) the relative contribution of demand charges and energy charges. An example of the first case would be Central Power and Light (32) which has demand charges and energy charges of \$5/kW and 2¢/kWh, respectively, and Dallas Power and Light (IPS) which has charges of \$2/kW and 1¢/kWh, respectively. An example of the second case would be Indianapolis Power and Light (SL) with charges of \$7/kW and 2¢/kWh and Northern Indiana Public Service Co. (724) with charges of \$3/kW and 4¢/kWh.

TABLE IV-5. MOST FAVORABLE RATE SCHEDULES WITH A TIME DIFFERENTIATED BILLABLE DEMAND DEFINITION

Utilities	Rate Designation	Demand Charge ($/kW)	Energy Charge (¢/kWh)	Off-Peak Load as a Proportion On-Peak Load	On-Peak Time Period
		40 kW Class			
Boston Edison Company	G-2	5	3	30%	9 AM – 12 PM, Weekdays
		1000 kW Class			
Indianapolis Power & Light Company	SL	7	2	50%	6 AM – 10 PM, Weekdays
Iowa Electric Light and Power Company	LGS	7	2	50%	7 AM – 7 PM, Weekdays
Consumers Power (Michigan)	D	6	2	33%	9 AM – 9 PM, Weekdays
Detroit Edison Company	D-4	6	3	33%	9 AM – 11 PM, Weekdays
Minnesota Power and Light Company	55	5	3	33%	9 AM – 9 PM, Weekdays
Public Service of New Jersey	LPL	6	3	50%(1)	8 AM – 8 PM, Weekdays
Houston Lighting and Power Company	LOS-3	5	1	60%	8 AM – 10 PM, Weekdays
Central Vermont Public Service	4	7	1	50%	6 Hours, Weekdays
		20,000 kW Class			
Central Illinois Public Service Company	9B	10	2	70%	
Indianapolis Power & Light Company	HL	11	0	50%	6 AM – 10 PM, Weekdays
Indianapolis Power & Light Company	SL	5	1	50%	6 AM – 10 PM, Weekdays
Jowa Electric Light and Power Company	LGS	7	2	50%	7 AM – 7 PM, Weekdays
Consumers Power (Michigan)	D	5	2	33%	9 AM – 9 PM, Weekdays
Detroit Edison Company	D-4	6	3	33%	9 AM – 11 PM, Weekdays
Upper Peninsula Power Company	WP-1	5	2	60%	7 AM – 8 PM, Weekdays
Public Service of New Jersey	LPL	5	3	50%(1)	8 AM – 8 PM, Weekdays
Houston Lighting and Power	LOS-3	5	1	60%	8 AM – 10 PM, Weekdays
Central Vermont Public Service	4	7	1	50%	6 Hours, Weekdays

(1) In addition to the 50%, there is a 1¢/kWh reduction in the energy charge.

TABLE IV-6. EXISTING TRADITIONAL RATE SCHEDULES

	40 kW System Size			1000 kW System Size			20,000 kW System Size		
Utility	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)
Alabama Power Company	LPS	–	4	LPM	3	3	LPL	2	2
Alaska Electric Light & Power Company	21	–	4	41	–	4	41	–	4
Arizona Public Service Company	E-32-1	3	4	E-139	2	4	E-139	2	4
Tucson Gas & Electric Company	10	–	6	12	2	4	13	2	3
Arkansas-Missouri Power Company	GS-1	3	3	GS-3	2	2	P-1	2	2
Arkansas Power & Light Company	G7	3	3	G-5	2	3	P-1	2	2
Burbank Public Service Department	L-2	–	5	PC-1	2	3	PC-1	2	3
C P National	A-122	–	4	P-140	–	5	P-140	–	5
Glendale, City of	L-2	–	6	PC-1	2	4	PC-1	2	4
Los Angeles, Deptartment	A-1	2	5	A-1	2	4	A-1	2	4
Pacific Gas & Electric Company	A-1	–	7	A-12	2	5	A-12	2	5
Pacific Power & Light Company	A-32	1	7	A-36	2	4	A-36	2	4
Sacramento Municipal Utility	27	2	4	27	2	4	27	2	4
San Diego Gas & Electric Company	A-5	3	1	A-5	3	4	A-6 (TOD)	6	4
Sierra Pacific Power Company	A-1	–	6	A-2	3	3	A-3	3	3
Southern California Edison Company	A-1	1	5	A-1	1	5	TOO-8	2	1
Central Telephone & Utilities Corporation	GS-1	4	4	IS-1	2	3	IS-1	2	2
Colorado Springs Department	E2-C	–	4	E8-L	3	2	E8-L	3	2
Public Service Company of Colorado	GCL-1	–	4	GLP	4	1	CLP	3	1
Connecticut Light & Power Company	30	3	3	35	3	3	35	3	3
Hartford Electric Company	22	4	3	50	3	3	50	3	3
United Illuminating Company	GS	3	4	LP	2	3	LP	2	3
Delmarva Power & Light Company	GS	2	3	GS	3	3	GS	2	3
Florida Power Corporation	CI-ID	5	3	CI-ID	3	3	CI-ID	2	3
Florida Power & Light Company	GS	–	5	GSD	2	3	GSD	2	3
Gulf Power Company	41	2	3	LP	2	2	PX	4	1
Jacksonville Electric Company	20	2	6	30	1	4	40	1	3
Lakeland, Department of Electric	B	–	4	–	–	–	–	–	–
Orlando Utilities Comm	D	2	3	D	2	3	D	2	3
Tallahassee, City of	G	–	5	GD	2	3	GD	2	3
Tampa Electric Company	25	–	5	36	3	3	36	3	3
Georgia Power Company	GS-ND	–	6	PL-1	1	4	PL-1	1	4
Savannah Electric & Power Company	B-12	1	5	D-11	2	4	D-11	2	4
Hawaiian Electric Company, Incorporated	G	1	8	P	3	4	P	3	4
Idaho Power Company	11	2	3	19	2	1	19	2	1
Central Illinois Light Company	13	1	6	21	4	3	23	3	3
Central Illinois Public Service Company	24	–	6	9	6	3	9B	10	2
Commonwealth Edison Company	6	4	6	6L	4	3	6L	3	3
Illinois Power Company	SC-10	–	4	SC-21	3	2	SC-21	3	2

TABLE IV-6. (Continued)

Utility	40 kW System Size Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	1000 kW System Size Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	20,000 kW System Size Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)
Mt. Carmel Public Utility Company	SH-3	–	7	SH-6	2	5	SH-6	2	5
Indianapolis Power & Light Company	SS	–	4	SL	7	2	HL	11	0
							SL	5	1
Northern Indiana Public Service Company	721	–	7	724	3	4	724	3	3
Public Service Company of Indiana, Inc.	GS	–	5	PPL	3	3	PPL	3	3
Southern Indiana Gas & Electric Company	GS	2	4	IP	2	3	IP	2	3
Interstate Power Company	260	2	5	440	2	4	440	2	4
Iowa Electric Light & Power Company	GS	8	2	GS	7	2	LGS	7	7
Iowa-Illinois Gas & Electric Company	22	–	4	42	3	3	41	3	2
Iowa Public Service Company	10	–	6	14	–	4	14	–	4
Iowa Southern Utilities Company	46	3	4	01	3	2	06	2	2
Central Kansas Power Company, Incorporated	SGS-1	–	5	PGS-2	2	3	PGS-2	2	3
Central Telephone & Utilities Corporation	GS-1	3	5	IS	3	3	IS	2	3
Empire District Electric Company	CB	–	4	GP	3	2	GP	3	2
Kansas City Power & Light Company	2-41	–	6	2-42	3	3	2-54	2	2
Kansas Gas & Electric Company	GS-278	–	6	LLP-278	3	2	HLF	4	2
Kansas Power & Light Company	GB-77	–	4	LP-77	1	2	LP-77	1	2
Kentucky Power Company	GS	1	4	L-P	2	2	L-P	2	2
Kentucky Utilities Company	GS-1	–	5	LP	2	3	HLF	4	2
Louisville Gas & Electric Company	GS	–	4	LP	3	3	LP	3	3
Central Louisiana Electric Company, Inc.	GS	–	5	LGS	2	2	LIS	2	2
Lafayette Utility System	C-1	3	4	C-1	3	3	C-1	3	3
Louisiana Gas & Electric									
Louisiana Power & Light Company	GS-IH	2	2	LGS-2	2	2	LGS-7	1	2
New Orleans Public Service, Inc.	LE-2	3	3	LE-2	3	3	LE-2	2	2
Bangor Hydro-Electric Company	B-1	–	5	D-4	2	2	D-3	3	2
Central Maine Power Company	GS-1	4	3	GS-2	2	3	GS-3	2	2
Maine Public Service Company	C	–	4	E	3	1	E	3	1
Baltimore Gas & Electric Company	G	3	5	G	3	3	G	3	2
Potomac Edison Company	C	1	3	PH	4	1	PP	3	0
Potomac Electric Power Company	GS	5	5	GS	4	4	GS	3	4
Boston Edison Company	G-2	5	3	G-2	4	3	G-2	4	3
Cambridge Electric Light Company	SC-2	2	5	SC-7	2	4	SC-7	2	4
Fitchburg Gas & Electric Light Company	B	3	6	D	3	4	D	3	3
Holyoke Water Power Company	89-E	–	5	91-E	–	5	91-E	–	4
Nantucket Electric Company	C	3	7	LG	3	6	G	3	5
New Bedford Gas & Edison Light Company	E-4	2	6	E-7	2	5	E-7	2	5
Western Massachusetts Electric Company	20	4	4	35	3	3	35	3	3
Alpena Power Company	SP	4	3	SP	3	2	SP	3	2
Consumers Power Company	B	–	6	D	6	2	D	5	2
Detroit Edison Company	D-3	–	5	D-4	6	3	D-4	6	3
Edison Sault Electric Company	G-1	–	5	L-G	3	3	L-G	2	3

TABLE IV-6. (Continued)

Utility	40 kW System Size			1000 kW System Size			20,000 kW System Size		
	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)
Lansing, Board of Water	4	5	2	5	3	2	5	3	2
Upper Peninsula Power Company	C-21	5	—	P-1	6	2	WP-1	5	2
Austin Utilities	CP	—	6	CP	—	5	CP	—	4
Minnesota Power & Light Company	25	3	6	55	5	3	74	12	1
Northern States Power Company	DC	3	3	DK-025	5	2	DK-025	5	2
Otter Tail Power Company	G-01M	—	6	C-02M	5	2	C-02M	5	2
Mississippi Power Company	GS-2	3	3	LGS-2	2	2	LGS-2	2	2
Mississippi Power & Light Company	GS-231	—	4	B-21	2	3	C-12	2	3
Independence Power	GS-1	—	6	LGS-1	3	4	LP=1	2	3
Missouri Power & Light Company	GS-1	—	5	IS	5	2	IS	5	2
Missouri Public Service Company	100	—	4	200	2	2	210	2	2
Missouri Utilities Company	GES-1	3	3	GS-1	3	2	GS-1	3	2
St. Joseph Light & Power Company	B-SJ	—	6	LP-SJ	3	2	LP	2	2
Springfield, City Utility	GL	—	5	LP	4	3	LP	4	3
Union Electric Company	3-(M)	—	5	9-(M)	—	4	9-(M)	—	4
Montana Power Company	GS-77	1	2	GS-77	1	1	GS-77	1	1
Nevada Power Company	GS	—	3	LGS-1	3	2	LGS-1	3	2
Public Service Company of New Hampshire	G	3	4	GV	4	2	GV	4	2
Atlantic City Electric Company	AGS	—	6	AGS	—	5	GAS	—	5
Jersey Central Power & Light Company	GS	3	5	GS	4	3	GS	4	3
Public Service Company of New Jersey	GLP	7	5	LPL	6	3	LPL	5	3
New Mexico Electric Service Company	301	3	4	305	2	3	305	2	3
Public Service Company of New Mexico	SP	—	5	LP	3	2	LTP	3	2
Central Hudson Gas & Electric Corporation	SC2	3	5	SCE (TOD)	11	3	SC 3 (TOD)	11	3
Consolidated Edison Company of New York	SC2	—	9	SC9	10	4	SC9	10	4
Long Island Lighting Company	SC2	—	6	SC9 (TOD)	84	3	SC9	84	3
New York State Electric & Gas Corporation	SC-2-PCS-115	4	5	SC-3-PSC-115	4	3	SC-3-PSC-115	4	3
Niagara Mohawk Power Corporation	SC-2-PSC-207	4	3	SC-3-PSC-207	4	2	SC-3-PSC-207	4	2
Orange & Rockland Utilities, Incorporated	SC-2	4	5	SC-3	4	2	SC-3	4	2
Rochester Gas & Electric Corporation	SC-7	4	2	SC-3	5	2	SC-3	4	2
Carolina Power & Light Company	SGS-3	—	2	GS-3	4	2	GLFS-3	13	1
Duke Power Company	G	—	4	I	—	4		—	3
Montana-Dakota Utilities Company	20-N-6A	—	6	38-N-4A	3	2	38-N-4A	3	2
Cincinnati Gas & Electric Company	GS-A	3	4	PSL	3	2	PSL	3	2
Cleveland Electric Illuminating Company	LC	4	3	LI	4	2	LI	4	2
Columbus & Southern Ohio Electric Company	G-S-2	3	3	G-S-2	3	3	G-S-2	3	3
Dayton Power & Light Company	GS	3	3	LP	4	2	LP	4	2
Ohio Edison Company	29	4	5	33	4	3	33	4	3
Toledo Edison Company	GS-16	4	5	PV-43	5	2	PV-43	5	2
Okalhama Gas & Electric Company	C-1	—	3	PL-1	2	2	PL-1	2	2
Public Service Company of Oklahomas	GS	—	5	LPL	2	2	LPL	2	2
Eugene Water & Electric	G-1	2	1	E-2	2	1	E-2	2	1

TABLE IV-6. (Continued)

Utility	40 kW System Size			1000 kW System Size			20,000 kW System Size		
	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)	Rate Designation	Demand Charge ($/kW)	Energy Charge ($/kWh)
Portland General Electric Company	32	3	1	83	2	1	83	2	1
Duquesne Light Company	GS	–	5	GL	3	2	GL	3	3
Metropolitan Edison Company	GPL-2	3	4	LP	3	2	LP	3	2
Pennsylvania Electric Company	GM	3	4	LP	3	2	LP	3	2
Pennsylvania Power Company	GS	1	4	GL	3	2	LP	2	2
Pennsylvania Power & Light Company	GS-1	–	5	LP-4	3	2	LP-4	3	2
Philadelphia Electric Company	GS	4	4	PD	3	3	PD	3	3
UGI Corporation	GS-2	6	3	LP	3	2			1
West Penn Power Company	C	–	3	PH	3	2	PP	3	2
Narragansett Electric Company	C-2	–	6	H	2	4	H	2	4
Newport Electric Corporation	GS	–	5	GP	2	3	LP	3	3
South Carolina Electric & Gas Company	9	–	4	20	6	1	23	5	1
South Carolina Public	GS-78	1	3	L-78	2	2	L-78	2	2
Black Hills Power & Light Company	GS-8	3	4	GL-7	3	2	IC-8	3	1
Northwestern Public Service Company	21	–	6	34	4	2	34	4	2
Kingsport Power Company	CS-9	–	6	CIP-13	–	3	CIP-13	–	3
Tennessee Valley Authority	GS-2	–	3	GS-3	2	2	GS-3	2	1
Austin, Electric Utility	GS	–	3	LGS	4	1	PS	4	1
Bryan, City of	SC	–	3	LP-2	2	1	LP-2	2	1
Central Power & Light Company	21	–	6	32	5	2	44	4	2
Community Public Service Company	SE-39	–	3	SE-55	3	1	SE-12	3	1
Dallas Power & Light Company	G	2	3	IPS	2	1	IPS	2	1
El Paso Electric Company	02	–	3	25	4	1	20	3	1
Garland Power & Light	GS-L	2	1	HTS	1	1	HTS	1	1
Gulf States Utilities Company	GS	–	5	LGS	–	3	LPS	2	1
Houston Lighting & Power Company	MGS-1	1	4	LOS-3	5	1	LOS-3	5	1
Lobboch Power & Light	C	–	3	C	–	3	C	–	3
San Antonia, City Public	PC	–	4	LCP	2	3	LLP	2	3
Southwestern Electric Power Company	ATC-1	–	4	LP	2	3	LP	2	2
Southwestern Public Service Company	3100.15	–	6	4106.6	2	3	4106.6	2	3
Texas Electric Service Company	C	1	3	LGS	4	2	LGS	4	2
Texas Power & Light Company	GS-S	–	4	LP-20	4	2	GSL	2	3
West Texas Utilities Company	SC	–	4	LPL-2A	2	3	LP-1	2	2
Utah Power & Light Company	3	@	11	8	4	2	8	4	2
Central Vermont Public Service Corporation	2	7	1	4	7	1	4	7	1
Citizens Utilities Company	SC-2	–	4	SC-3	2	2	SC-3	2	2
Green Mountain Power Company	06	–	4	14	5	1	14	5	1
Appalachian Power Company	SGS	2	3	LCP	9	2	LCP	8	2
Danville, Water, Gas Department									
Vepco	5	6	4	6	5	2	6	5	2
Puget Sound Power & Light Company	24	2	2	31	2	2	49	2	1
Seattle, Department of Light	44	–	2	60	1	1	65	1	1

TABLE IV-6. (Continued)

Utility	40 kW System Size Rate Designation	40 kW Demand Charge ($/kW)	40 kW Energy Charge ($/kWh)	1000 kW System Size Rate Designation	1000 kW Demand Charge ($/kW)	1000 kW Energy Charge ($/kWh)	20,000 kW System Size Rate Designation	20,000 kW Demand Charge ($/kW)	20,000 kW Energy Charge ($/kWh)
Tocoma, Light Division	D-1	1	1	CP	1	1	CP	1	1
Washingotn Water Power Company	11	2	2	23	1	1	25	—	1
Monongahela Power Company	B	—	5	D	4	2	K	4	1
Lake Superior District Power Company	CG-1	5	3	CG-1	4	3	CG-1	3	3
Madison Gas & Electric Company	CG-1	4	3	CG-1	4	3	CG-1	4	3
Northwestern Wisconsin Electric Company									
Wisconsin Electric Power Company	CG-1	—	4	CP-1	4	2	CP-1	4	1
Wisconsin Power & Light Company	CG-1	—	4	CP-4	5	2	CP-4	5	2
Wisconsin Public Service Corporation	CG-1	3	4	CP-1	4	2	CP-1	4	2
Cheyenne Light, Fuel, & Power Company	GCL-1	—	3	LCP	3	1	LCP	3	1

Time-of-Day Rate Schedules

Motivated in part by the adoption of the Public Utilities Regulatory Policy Act (PURPA), the time-of-day rate making standard has been receiving an increasing amount of attention. Five years ago, few time-of-day rate schedules were in effect. But since that time, interest has grown to the extent that now at least one utility in twenty-four different states has adopted some form of time-of-day rate. In addition, there are numerous proposals presently before state commissions seeking time-of-day rate schedules.

Residential and commercial/industrial time-of-day rate schedules presently in use are listed in Tables IV-7 and IV-8, respectively. Only non-experimental rates were included because it was felt that experimental rates could have been formulated with the objective of studying the relationships between price and electricity consumption patterns and not with the idea of accurately portraying the utility's cost to serve.

The general format of time-of-day rates currently in use is fairly uniform. Several characteristics stand out in reviewing the complete list of time-of-day rates:

- Most peak period durations are in the range of ten to twelve hours.
- Most peak periods apply only during the weekdays.
- Most peak periods apply to some extent during each month of the year.
- Many off-peak demand charges are minimal or non-existent.
- Since the residential rate schedules do not contain demand charge components, the rate differential is independent of the discharge period.
- Much of the on-peak to off-peak differential associated with commercial and industrial rates is captured in the on-peak/off-peak differences in the demand charges and not in the energy charges.

TABLE IV-7. EXISTING TIME-OF-DAY RATES — RESIDENTIAL SCHEDULES

Utility	Rate Designation	Peak Hours	Peak Days	Peak Months	On-Peak Energy Change ($/kWh)	Off-Peak Energy Change ($/kWh)	Rate Differential ($/kWh)
Connecticut Light & Power Company	7	8 AM – 8 PM	Weekdays	All Year	0.056	0.026	0.020
Hartford Electric Light Company	7	8 AM – 8 PM	Weekdays	All Year	0.062	0.026	0.026
Boston Edison Company	P	11 AM – 5 PM	Weekdays	July-Oct	0.159	0.011	0.064
		9 AM – 11 AM; 5 PM – 9 PM	Weekdays	July-Oct	0.057		
		9 AM – 9 PM	Weekdays	Nov-June	0.043		
Massachusetts Electric Company	A-30	8 AM – 8 PM	Weekdays	July-Oct	0.064	0.013	0.045
		8 AM – 8 PM	Weekdays	Nov-June	0.057		
Western Massachusetts Electric Company	6	8 AM – 8 PM	Weekdays	All Year	0.050	0.013	0.032
Montana — Dakota Utilities	16-M-2	10 AM – 10 PM	Weekdays	All Year	0.074	0.018	0.049
Public Services of New Hampshire	D-OTOD	7 AM – 10 PM	Weekdays	All Year	0.069	0.036	0.019
Dayton Power and Light Company	Request Pending	11 AM – 9 PM	Weekdays	June-Aug	0.057	0.007	0.043
		7 AM – 9 PM	Weekdays	Mar-May, Sept-Nov	0.045		
Ohio Power Company	RS	7 AM – 11 PM	Weekdays	All Year	0.030	0.015	0.019
Central Vermont Public Service Company	11	7 Hours	Weekdays	Jan-Apr	0.139	0.025	0.026

TABLE IV-8. EXISTING TIME-OF-DAY RATES – COMMERCIAL AND INDUSTRIAL SCHEDULES

Utility	Rate Designation	Customer Class	Peak Hours	Peak Days	Peak Months	On-Peak Demand Charge ($/kW)	Off-Peak Demand Charge ($/kWh)	On-Peak Energy Charge ($/kWh)	Off-Peak Energy Charge ($/kWh)	Rate Differential ($/kWh) Discharge Period: 12 Hours	8 Hours	6 Hours	3 Hours	2 Hours
San Diego Gas & Electric Company	A-6	20,000 kW	10 AM – 5 PM	All Week	May Sept	6.41	0	0.008	0.002	–	–	0.054	0.092	0.141
			5 PM – 9 PM	All Week	May-Sept	0	0	0.004	0.002					
			10 AM – 5 PM	All Week	Oct-Apr	0	0	0.004	0.002					
			5 PM – 9 PM	All Week	Oct-Apr	6.41	0	0.008	0.002					
Southern California Edison Company	TOU-8	20,000 kW	12 PM – 6 PM	Weekdays	May-Oct	5.05	0	0.005	0.002	–	–	0.039	0.064	0.097
			5 PM – 10 PM	Weekdays	Nov-Apr	5.05	0	0.005	0.002					
			8 AM – 12 PM 6 PM – 10 PM	Weekdays	May-Oct	0.65	0	0.004	0.002					
			8 AM – 5 PM	Weekdays	Nov-Apr	0.65	0	0.004	0.002					
Connecticut Light & Power Company	27	40 kW	9 AM – 8 PM	All Week	All Year	4.80	0	0.043	0.026	0.024	0.034	0.053	0.095	0.125
Hartford Electric Light Company	27	40 kW	9 AM – 8 PM	All Week	All Year	4.80	0	0.043	0.026	0.074	0.034	0.053	0.085	0.126
Boston Edison Company	T-1	40 kW	11 AM – 5 PM	Weekdays	June-Oct	5.41	30% of billable demand	0.055	0.027	0.021	0.029	0.044	0.068	0.102
			9 AM – 11 AM	Weekdays	June-Oct	5.42		0.041	0.027					
			5 PM – 10 PM	Weekdays	June-Oct	5.42		0.041	0.027					
			9 AM – 10 PM	Weekdays	Nov-May	5.42		0.039	0.026					
Massachusetts Electric Company	C-30	40 kW	8 AM – 8 PM	Weekdays	Nov-June	–	–	0.063	0.013	0.048	0.048	0.048	0.048	0.048
					July-Oct	–	–	0.071	0.013					
Massachusetts Electric Company	G-30	40 kW	8 AM – 8 PM	Weekdays	Nov-June	2.30	0	0.032	0.013	0.022	0.026	0.033	0.046	0.062
					July-Oct	2.30	0	0.035	0.013					
Western Massachusetts Electric Company	27	40 kW	8 AM – 8 PM	Weekdays	All Year	5.50	0	0.030	0.011	0.037	0.048	0.067	0.103	0.146
Consumers Power Company (MI)	13, 14	1,000 kW,	5 PM – 9 PM	Weekdays	Oct-Feb	5.37	0.40	0.017	0.015	–	–	0.044	01076	0.117
		20,000 kW	10 AM – 5 PM	Weekdays	Mar-Sept	5.37		0.017	0.015					
Detroit Edison Company	D6, D6.1	1,000 kW,	5 PM – 9 PM	Weekdays	Oct-Feb	5.37	0.40	0.017	0.015	–	–	0.044	0.076	0.117
		20,000 kW	10 AM – 5 PM	Weekdays	Mar-Sept	5.37	0.40	0.017	0.015					

TABLE IV -8. (Continued)

Utility	Rate Designation	Customer Class	Peak Hours	Peak Days	Peak Months	On-Peak Demand Charge ($/kW)	Off-Peak Demand Charge ($/kW)	On-Peak Energy Charge ($/kWh)	Off-Peak Energy Charge ($/kWh)	Rate Differential ($/kWh) Discharge Period 12 Hours	8 Hours	5 Hours	3 Hours	2 Hours
Public Service Electric and Gas Company (NJ)	HTS	20,000 kW	8 AM – 10 PM	Weekdays	All Year	4.91	0	0.028	0.022	0.025	0.035	0.053	0.085	0.126
Central Hudson Gas & Electric Company	SC3	1,000 kW, 20,000 kW	8 AM – 10 PM	Weekdays	June-Feb	10.86	1.65	0.018	0.018	0.032	0.050	0.083	0.140	0.214
Long Island Lighting	SC-2MRP	1,000 kW, 20,000 kW	10 AM – 10 PM	Weekdays	June-Sept	8.46	0	0.036	0.021	0.020	0.028	0.043	0.068	0.101
			7 AM – 10 AM, 10 PM – 12 PM		June-Sept	2.13	0.030	0.036						
			7 AM – 12 PM		Oct-May	2.13	0.030	0.036						
Carolina Power & Light (NC)	LGS-TS-9	1,000 kW, 20,000 kW	10 AM – 10 PM	Weekdays	July-Oct	8.05	1.95	0.022	0.014	0.027	0.039	0.061	0.099	0.148
			6 AM – 1 PM, 4 PM – 9 PM		Nov-June	8.05	1.95	0.022						
Dayton Power and Light	Request Pending	1,000 kW, 20,000 kW	11 AM – 9 PM	Weekdays	June-Aug	4.66	0	0.008	0.001					
			7 AM – 9 PM		Mar-May, Sept-Nov	4.66	0	0.005	0.001	0.016	0.026	0.044	0.076	0.117
			7 AM – 9 PM		Jan-Dec	4.66	0	0.001	0.002					
Philadelphia Electric	PD	20,000 kW	7 AM – 7 PM	Weekdays	All Year	2.43	1.29	0.018	0.018	(0.004)	0.000	0.002	0.008	0.024
Central Vermont Public Service	12	40 kW	7 Hours	All Week	All Year	10.53	5.27	0.030	0.020	–	–	0.052	0.084	0.125

- Most of the time-of-day rate schedules have been adopted by states in the Northeast or Midwest region.

- Many pricing schemes do not seem to offer much incentive to switch consumption patterns.

The first three characteristics can be grouped together as attributes of the peak period. Each holds important implications for the operation and viability of battery storage systems. The peak period duration defines the upper limit of the required discharge period. Under traditional and semi-time-of-day rate structure forms, companies with large, flat loadshapes have no opportunity or incentive to shift loads. Under time-of-day rate schedules with peak periods of eight hours or less, a high load factor firm could have ample incentive to shift consumption because it could recover the on-peak demand charge with a discharge period of eight hours or less. Assuming that off-peak demand charges are minimal, the length of the peak period does not have a great impact on the calculation of the associated rate differential. However, it does have an impact on the amount of battery storage that could be installed for two reasons. First, with short time-of-day periods (five to eight hours) the range of firms that could take advantage of battery storage is not limited to firms with single shift operations or widely fluctuating loadshapes, but is open to nearly every firm in the service area. Second, firms can economically shift a greater portion of their consumption under time-of-day rates with low off-peak demand charges. Under traditional rate structures nighttime demand levels are constrained by the typically higher demand charges set by the traditional rate schedules.

Several early versions of time-of-day pricing incorporated peak periods of four hours or less. These utilities generally found that customer loads increased significantly just beyond the boundaries of the peak period, thus creating even sharper peaks than what existed prior to the time-of-day rate. Some utilities have adopted peak periods in excess of 14 hours. This strategy eliminates customers with flat loadshapes as potential customers of battery storage and significantly reduces battery storage viability in those service areas with time-of-day rate schedules incorporating a large off-peak demand charge.

The number of days and months in the peak period also affects battery viability by determining the utilization of the battery system. For example, if the peak period only lasts during the summer months, there may be no economically viable use for the battery system during the remainder of the year. This could have substantial impact on the overall feasibility of batteries in terms of a return on investment. On the other hand, a peak period in effect only during the weekdays is more favorable to battery storage than one lasting through the entire seven days. All other things being equal, the rate differentials for the two rate schedules will be the same, but the five-day application requires fewer battery cycles per month to achieve the same rate differential.

The most favorable residential time-of-day rate schedules are found in the service areas of Boston Edison Co., Montana-Dakota Utilities, and Massachusetts Electric Co. The most favorable commercial and industrial time-of-day rate schedules for discharge periods of eight hours are found in the service areas of Central Hudson Gas and Electric Co., Western Massachusetts Electric Co., and Massachusetts Electric Co.

The fact that many existing time-of-day rate schedules fail to offer much incentive for off-peak power use points out one of the significant issues involved with time-of-day pricing or with any new standard. In their extensive studies on rate design for the Electric Power Research Institute, Ebasco Services and National Economic Research Associates[(2)] have derived time-of-day rates with more severe on-peak/off-peak differentials than what has been applied in practice. It is entirely reasonable to believe that many of the existing time-of-day rates were derived on a very conservative basis. Indeed, historically one of the main objectives of utility pricing regulation has been to maintain continuity in rates.

In order to link the present situation for time-of-day rate schedules with what might occur in the future, a series of projections were developed to show which utilities theoretically have the greatest potential

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IV-(2) Electric Power Research Institute, <u>Electric Utility Rate Design Study</u> 1976-77.

for time-of-day rates favorable to battery storage. Essentially, the more severe the on-peak/off-peak differential, the more favorable the rate schedule is to battery storage.

Developing specific time-of-day rate schedules for each utility service area is a costly and detailed effort - far beyond the scope of this study. On the other hand, a few factors important in determining the relative on-peak/off-peak differential can be identified and were used to select the most promising service areas. These factors are listed in Table IV-9 and include:

- Hourly load variations
- Seasonal variations
- Petroleum and natural gas dependence
- Hydroelectric dependence.

The most important characteristic is the hourly load shape variability associated with the utility's demand for power. High daytime loads coupled with low nighttime demands often force the utility to make use of inefficient equipment configurations. The load factor summarizes in a single measure the relative utilization of production capacity. The load factor is the ratio of average annual demand divided by annual peak demand. In order to factor out seasonality, average monthly load factors were used instead of the annual load factor figure. A low average monthly load factor indicates significant variations in daily loads. Note in Table IV-2 that the hourly load variation is scaled 1 to 5 on the following basis (coupled with small subjective adjustments based on a review of the utility's hourly load shapes):

Scale	Description
5	Average monthly load factor ≤ .65
4	.65 < Average monthly load factor ≤ .70
3	.70 < Average monthly load factor ≤ .75
2	.75 < Average monthly load factor ≤ .80
1	.80 < Average monthly load factor

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
ALABAMA						
Alabama Power Co.	3	1	3	3		2
ALASKA						
Alaska Electric Light & Power Co.	3	5	3	1		1
ARIZONA						
Arizona Public Service Co.	3	1	3	5		2
Tucson Gas & Electric Co.	3	3	1	5		3
ARKANSAS						
Arkansas-Missouri Power Co.	3	5	1	5		3
Arkansas Power & Light Co.	3	1	5	5		2
CALIFORNIA						
CP National	4	1	-	-	A	3
Burbank Public Service Dept.	5	3	1	5	A	4
Glendale, City of	5	1	1	5	A	2
Los Angeles, Dept.	4	3	1	4	A	3
Pacific Gas & Electric Co.	3	3	1	2	A	2
Pacific Power & Light Co.	3	3	3	3	A	3
Sacramento Municipal Utility	5	1	1	4	A	2
San Diego Gas & Electric Co.	4	5	1	5	A	3
Sierra Pacific Power Co.	2	5	1	5	A	2
Southern California Edison Co.	3	3	1	4	A	2
COLORADO						
Central Telephone & Utilities Corp.	3	5	1	5		3
Colorado Springs Dept.	5	-	3	5		4
Public Service Co. of Colorado	3	5	5	5		4
CONNECTICUT						
Connecticut Light & Power Co. The	4	5	1	4	A	4
Hartford Electric Co., The	4	5	1	5	A	4
United Illuminating Co., The	4	5	1	5	A	4
DELAWARE						
Delmarva Power & Light Co.	2	5	5	5		2

"5" denotes a rating favorable to battery storage
"A" denotes states in which a great deal of time-of-day activity has been undertaken
"B" denotes states in which time-of-day pricing has been vetoed by the state commission

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
FLORIDA						
Florida Power Corp.	5	3	5	5		4
Florida Power & Light Co.	4	5	1	5		4
Gulf Power	4	3	3	5		4
Jacksonville Electric	4	3	1	5		4
Lakeland, Dept. of Electric	5	3	1	5		4
Orlando Utilities Comm.	5	3	1	5		4
Tallahassee, City of	5	3	1	5		4
GEORGIA						
Georgia Power Co.	3	3	3	5		3
Savannah Electric & Power Co.	3	3	5	5		3
HAWAII						
Hawaiian Electric Co., Inc.	3	5	1	5	B	1
IDAHO						
Idaho Power Co.	4	1	3	1		1
ILLINOIS						
Central Illinois Light Co.	4	3	3	5		4
Central Illinois Public Service Co.	3	3	3	5		3
Commonwealth Edison Co.	4	1	5	5		3
Illinois Power Co.	3	1	3	5		2
Mt. Carmel Public Utility Co.	4	1	-	-		3
INDIANA						
Indianapolis Power & Light Co.	4	3	3	5		4
Northern Indiana Public Service Co.	1	5	3	5		1
Public Service Co. of Indiana, Inc.	3	5	3	5		4
Southern Indiana Gas & Electric Co.	4	1	3	5		2
IOWA						
Interstate Power Co.	3	5	5	5		3
Iowa Electric Light & Power Co.	4	5	3	5		4
Iowa-Illinois Gas & Electric Co.	3	1	5	5		2
Iowa Public Service Co.	4	3	3	5		4
Iowa Southern Utilities Co.	4	3	3	5		4

"5" denotes a rating favorable to battery storage
"A" denotes states in which a great deal of time-of-day activity has been undertaken
"B" denotes states in which time-of-day pricing has been vetoed by the state commission

TABLE IV-5. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
KANSAS						
Central Kansas Power Co., Inc.	3	1	1	5		2
Central Telephone & Utilities Corp.	5	1	3	5		3
Empire District Electric Co. The	4	3	3	5		4
Kansas City Power & Light Co.	4	1	3	5		3
Kansas Gas & Electric Co.	3	1	1	5		2
Kansas Power & Light Co., The	4	1	5	5		3
KENTUCKY						
Kentucky Power Co.	3	5	3	5		3
Kentucky Utilities Co.	4	5	3	5		4
Louisville Gas & Electric Co.	3	1	3	5		2
LOUISIANA						
Central Louisiana Electric Co., Inc.	3	1	1	5		2
Lafayette Utility System	5	3	1	5		3
Louisiana Power & Light Co.	2	3	1	5		2
New Orleans Public Service, Inc.	3	3	1	5		2
MAINE						
Bangor Hydro-Electric Co.	1	3	5	1		1
Central Maine Power Co.	3	3	5	1		1
Maine Public Service Co.	4	3	5	1		1
MARYLAND						
Baltimore Gas & Electric Co.	3	1	5	5		2
Potomac Edison Co., the	3	3	3	3		3
Potomac Electric Power Co.	4	1	5	5		3
MASSACHUSETTS						
Boston Edison Co.	4	5	5	5	A	5
Cambridge Electric Light Co.	4	3	3	5	A	4
Fitchburg Gas & Electric Light Co.	3	5	1	5	A	4
Holyoke Water Power Co.	5	5	1	2	A	4
Nantucket Electric Co.	5	1	1	5	A	3
New Bedford Gas & Edison Light Co.	4	5	1	5	A	4
Western Massachusetts Electric Co.	3	5	1	4	A	3

"5" denotes a rating favorable to battery storage
"A" denotes states in which a great deal of time-of-day activity has been undertaken
"B" denotes states in which time-of-day pricing has been vetoed by the state commission

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
NEW MEXICO						
New Mexico Electric Service Co.	1	5	1	5		1
Public Service Co. of New Mexico	3	5	5	5		3
NEW YORK						
Central Hudson Gas & Electric Corp.	3	5	1	5	A	3
Consolidated Edison Co. of New York	4	1	5	5	A	3
Long Island Lighting Co.	4	1	1	5	A	3
New York State Electric & Gas Corp.	3	5	3	5	A	3
Niagara Mohawk Power Corp.	3	5	-	-	A	3
Orange & Rockland Utilities, Inc.	4	1	5	1	A	3
Rochester Gas & Electric Corp.	4	5	3	5	A	4
NORTH CAROLINA						
Carolina Power & Light Co.	4	5	3	5		4
Duke Power Co.	4	5	3	5		4
NORTH DAKOTA						
Montana-Dakota Utilities Co.	4	3	3	5		4
OHIO						
Cincinnati Gas & Electric Co., The	3	1	3	5		2
Cleveland Electric Illuminating Co.	3	5	3	5		3
Columbus & Southern Ohio Electric Co.	4	1	3	5		3
Dayton Power & Light Co., The	4	5	3	5		4
Ohio Edison Co.	3	5	3	5		3
Toledo Edison Co., The	3	5	3	5		5
OKLAHOMA						
Okalhoma Gas & Electric Co.	4	1	1	5		3
Public Service Co. of Oklahomas	4	1	1	5		3
OREGON						
Eugene Water & Elec.	4	1	3	1		1
Portland General Electric Co.	3	1	3	2		1

"5" denotes a rating favorable to battery storage
"A" denotes states in which a great deal of time-of-day activity has been undertaken

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
MICHIGAN						
Alpena Power Co.	4	5	-	-		4
Consumers Power Co.	3	5	-	5		3
Detroit Edison Co., The	3	5	-	5		3
Detroit Public Lighting	3	5	-	-		3
Edison Sault Electric Co.	2	5	-	-		2
Lansing, Board of Water	3	5	-	-		3
Upper Peninsula Power Co.	1	5	3	2		1
MINNESOTA						
Austin Utilities	5	1	5	5		4
Minnesota Power & Light Co.	1	5	3	3		1
Northern States Power Co.	4	1	3	5		3
Otter Tail Power Co.	3	3	3	5		3
MISSISSIPPI						
Mississippi Power Co.	3	3	5	5		3
Mississippi Power & Light Co.	4	1	1	5		3
MISSOURI						
Independence Power	5	1	5	5		4
Missouri Power & Light Co.	4	3	1	5		3
Missouri Public Service Co.	4	1	3	5		3
Missouri Utilities Co.	4	1	1	5		3
St. Joseph Light & Power Co.	4	3	5	5		4
Springfield, City Utility	5	1	5	5		4
Union Electric Co.	3	1	3	5		2
MONTANA						
Montana Power Co., The	2	3	3	1		1
NEVADA						
Nevada Power Co.	2	3	3	1		1
NEW HAMPSHIRE						
Public Service Co. of New Hampshire	4	3	5	4		4
NEW JERSEY						
Atlantic City Electric Co.	4	1	5	5		3
Jersey Central Power & Light Co.	4	3	5	5		4
Public Service of New Jersey						

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
PENNSYLVANIA						
Duquesne Light Co.	3	5	3	5		3
Metropolitan Edison Co.	3	5	3	5		3
Pennsylvania Electric Co.	3	5	3	-		3
Pennsylvania Power Co.	3	3	5	5		3
Pennsylvania Power & Light Co.	3	3	5	5		3
Philadelphia Electric Co.	-	3	5	4		3
UGI Corporation	4	1	3	5		3
West Penn Power Co.	2	5	3	5		2
RHODE ISLAND						
Narragansett Electric Co., The	5	5	3	5		5
Newport Electric Corp.	3	5	1	5		3
SOUTH CAROLINA						
South Carolina Electric & Gas Co.	3	3	5	5		3
South Carolina Public	4	3	3	3		4
SOUTH DAKOTA						
Black Hills Power & Light Co.	1	5	3	5		1
Northwestern Public Service Co.	5	1	5	5		4
TENNESSEE						
Kingsport Power Co.	2	5	3	5		2
Tennessee Valley Authority						
TEXAS						
Austin, Electric Utility	-	1	1	5		2
Bryan, City of	5	3	1	5		4
Central Power & light Co.	3	3	1	5		3
Community Public Service Co.	-	-	-	-		-
Dallas Power & Light Co.	4	1	1	5		3
El Paso Electric Co.	3	1	5	1		1
Garland Power & Light	5	1	1	5		4
Gulf States Utilities Co.	2	3	1	5		2
Houston Lighting & Power Co.	2	3	1	5		2
Lubboch Power & Light	4	1	1	5		3
San Antonio, City Public	4	1	5	5		3
Southwestern Electric Power Co.	3	1	5	5		2
Southwestern Public Service Co.	2	1	3	5		1
Texas Electric Service Co.	3	3	1	5		3
Texas Power & Light Co.	3	1	5	5		2

TABLE IV-9. UTILITY CHARACTERISTICS RELATED TO T-O-D RATES
(RELATIVE VALUES)

Utilities	Hourly Load Variations	Seasonal Variations	Petroleum Natural Gas Dependence	Hydro Electric Dependence	Other Utility Characteristics	Overall Rating
TEXAS (Cont.)						
West Texas Utilities Co.	3	1	1	5		2
UTAH						
Utah Power & Light Co.	2	3	3	5		2
VERMONT						
Central Vermont Public Service Corp.	3	3	3	1	A	1
Citizens Utilities Co.	2	3	3	1	A	1
Green Mountain Power Co.	-	1	3	1	A	1
VIRGINIA						
Appalachian Power Co.	4	5	3	5		4
Danville, Water, Gas Dept.	5	3	5	1		2
Virginia Electric & Power Co.	4	3	5	5		4
WASHINGTON						
Puget Sound Power & Light Co.	4	1	5	1		1
Seattle, Dept. of Light	3	3	3	1		1
Tacoma, Light Division	2	3	3	1		1
Washington Water Power Co., The	2	1	3	1		1
WEST VIRGINIA						
Monongahela Power Co.	2	5	3	5		2
WISCONSIN						
Lake Superior District Power Co.	3	5	5	2	A	3
Madison Gas & Electric Co.	4	1	5	5	A	3
Wisconsin Electric Power Co.	3	5	3	5	A	3
Wisconsin Power & Light Co.	3	5	3	5	A	3
Wisconsin Public Service Corp.	3	5	3	5	A	3
WYOMING						
Cheyenne Light, Fuel, & Power Co.	3	5	-	-		3

"5" denotes a rating favorable to battery storage
"A" denotes states in which a great deal of time-of-day activity has been undertaken
"B" denotes states in which time-of-day pricing has been vetoed by the state commission

The second factor listed in Table IV-9 is seasonal variation. A large amount of seasonal variation can be unfavorable to battery storage because it could result in time-of-day peak rates which are in effect for only a portion of the year. The consequences of this aspect have been discussed earlier. Seasonality is measured in terms of the number of monthly peaks exceeding 80 percent of the annual peak. This definition is related to the amount of production that is associated with peak generation units and to the designation of what months are responsible for creating the need for such units. In the Table:

Scale	Description	
5	9 to 12	Monthly peaks exceeding 80 percent of the annual peak
3	6 to 8	Monthly peaks exceeding 80 percent of the annual peak
1	1 to 5	Monthly peaks exceeding 80 percent of the annual peak.

The third column, petroleum and natural gas dependence, in Table IV-9 incorporates two factors. First, a very high proportion of scarce fuel utilization often indicates a lack of available inexpensive base load capacity for off-peak battery charging. Second, a very small proportion of scarce fuel utilization indicates a relatively insignificant potential for limiting the use of scarce fuels - a national conservation priority. Thus the following somewhat discontinuous rating scale applies:

Scale	Description
5	11-69 percent of the utility's total output is petroleum or natural gas (kWh basis)
3	0-10 percent of the utility's total output is petroleum or natural gas (kWh basis)
1	70-100 percent of the utility's total output is petroleum or natural gas (kWh basis).

The availability of hydroelectric power can reduce the typical costs associated with supplying a power demand characterized by wide variations. Hydroelectric generation usually allows utilities to efficiently store energy until the time it is needed. Other types of conventional electricity generation units can only produce to meet an immediate demand. Since the hourly peaks associated with utilities typically do not amount to more than 25 percent of the utility's total production, hydroelectric capability in excess of roughly 30 percent of the utility's total capability just about precludes the necessity of time-of-day pricing to smooth the load shape. The ratings for hydroelectric dependence are given below.

Rating	Description
5	0-5 percent of the utility's total output is hydroelectric (kWh basis)
4	6-10 percent of the utility's total output is hydroelectric (kWh basis)
3	11-20 percent of the utility's total output is hydroelectric (kWh basis)
2	21-30 percent of the utility's total output is hydroelectric (kWh basis)
1	31-100 percent of the utility's total output is hydroelectric (kWh basis).

The factors which are grouped together under the column titled other utility characteristics represent other influences on time-of-day:

Rating	Description
A	States in which a great deal of time-of-day pricing activity has been undertaken
B	States in which time-of-day pricing has been vetoed by the state commission.

The overall rating was based on the rules presented below. Note that an overall rating of "5" indicates a utility with characteristics potentially favorable to battery storage systems, while a rating of "1" would indicate unfavorable characteristics.

- A "1" under the hydroelectric column resulted in an overall rating of "1" because of the availability of hydroelectric power to supply inexpensive peak power.
- A "B" under the "other factors" column resulted in an overall rating of "1" because the state commission had ruled out any further consideration to time-of-day pricing.
- In the remaining cases, the rating under the hourly variation column dominated with adjustments in the downward direction only in recognition of low ratings for the other four factors.

It should be clearly stated that this utility evaluation system serves as an approximation in the screening of utility service areas potentially favorable to battery storage. The evaluation only takes into account the factors described above. Other possibly important factors, such as pumped-hydro storage capacity, were not included in this preliminary study. This is to say that a few utilities could receive a high overall rating based on the described factors, but a reduced rating if other factors such as pumped-hydro storage capacity had been included.

The relative availability of interruptible or load management rates is another factor that could influence the degree to which a utility can offer rate schedules favorable to battery storage. If the interruptible rates offered by a utility are taken on a large scale by industrial customers, then the utility has in effect gained a great deal of control over its periods of high peak demand. This reduces the need for a large emphasis on time-of-day rates or other rates favorable to battery storage viability. This factor was not included in the analysis because of the relative difficulty in obtaining interruptible rate levels and associated customer demands. In general, the utility evaluation system used in this study includes those factors which were the most assessed as being the most important and widespread in determining utility service area viability.

Results from the time-of-day projections are recorded in Figure IV-1. Many of the utilities rated highly in the projections also appear in the list of utilities offering the rate schedules most favorable to battery storage. The results of these projections can be used to reduce the range of potential customers by limiting the search to utilities scoring "3" or above.

Other Rate Structures

The other three rate structure forms that could be considered (seasonal, interruptible, and stand-by) are related only indirectly to battery storage feasibility. Seasonal rates offer electric prices differentiated by the month in which consumption occurs. Because lead-acid batteries are not long-term storage devices, potential benefits associated with seasonal rates cannot be realized by such systems. In fact, the utility characteristics that lead to offering large seasonal incentives are the same ones that were rated unfavorably with respect to battery storage viability in the time-of-day projections discussed in the previous section.

A review of interruptible rates indicate that such power contracts typically offer a 20 to 30 percent reduction in electricity costs in exchange for the right to interrupt power delivery for a prescribed amount of time. Because the battery system capital costs far outweigh the potential savings, interruptible rates were not analyzed in detail. For example, assume that the firm's average electricity costs were 4¢/kWh, the interruptible discount was 30 percent, and the level and duration of the potential interruptions required a battery equal in size and performance to the baseline battery system. The rate differential associated with such a situation would be roughly $.012/kWh (i.e., 30 percent of 4¢/kWh) or far below the breakeven rate differential of $.053/kWh.

Stand-by rates are an important consideration in evaluation energy systems which have a low level of reliability. As indicated in the discussion of battery performance and costs, this study has incorporated baseline design with six parallel strings. It is assumed that the reliability of such a system will not fall much below the reliability of the electric power grid. For this reason, stand-by rates were not analyzed in detail in this report.

Utilities with an Overall Rating of 5:

Boston Edison

Utilities with an Overall Rating of 4:

Connecticut Light and Power	Kentucky Utilities
Carolina Power and Light	Rochester Gas and Electric
Montana - Dakota Utilities	Duke Power Company
Public Service of Colorado	Dayton Power and Light
Iowa Electric Light and Power	Appalachian Power

FIGURE IV-7: THEORETICAL RANKING OF UTILITIES WITH CHARACTERISTICS FAVORABLE TO BATTERY STORAGE VIABILITY

TRENDS IN ELECTRIC RATES AND IN THE REGULATORY ENVIRONMENT

Considerable attention has been given to existing rate schedules. As mentioned earlier, the objectives of this investigation were to:

- Provide benchmarks of the potential electricity cost reduction using battery systems; these benchmarks could then be compared with the life-cycle costs of providing the battery system.
- Determine the basic characteristics and formats of rate schedules
- Demonstrate how battery systems could be incorporated and evaluated under various utility rate structure forms
- Pinpoint which utility service areas hold the greatest potential for battery storage systems
- Indicate the degree to which subsidies must be provided to make an economically viable demonstration project.

These objectives and the conclusions associated with them, serve as the basis and model for projecting the future viability of battery storage. Most of the objectives will be addressed in terms of their meaning to future electric rates and their impact on battery storage viability. The discussions in this section are not meant to be comprehensive, but serve only to highlight briefly some of the apparent trends in rate schedules and the regulatory environment.

Under the baseline assumptions (i.e., 1987 commercialization capital cost estimates), battery system storage is viable for selected utilities for discharge periods less than eight hours. In the Economic Evaluation (Chapter VI) the results will show that market penetration could increase substantially if the DOE technology development goals could be met. Battery storage market penetration could also increase if rate differentials associated with the electricity rate schedules increase (1980$) beyond those calculated in this Chapter. This situation could occur for three reasons. First, according to the Energy Information Administration[(3)],

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IV-(3) Energy Information Administration, Annual Report to Congress - 1979, Vol III, U.S. Government Printing Office, Washington (1979), Table 4.4, P 94.

electricity prices are expected to increase annually over the next 15 years at a rate of 2.1 percent in real terms (i.e., discounting inflation). It is, of course, uncertain how this increase might be allocated between the demand charge and the energy charge. On the other hand, the relative proportions are important to battery storage viability because higher demand charges favor battery storage, while higher energy charges are unfavorable. One assumption might be that the escalation rates for each component are the same. This assumption is not unrealistic when it is noted that both components have strong factors suggesting their increase. The increase in demand charges are supported by increases in construction costs including the additional expenses to implement environmental and safety systems. The increases in energy charges are supported by the rapid increase in fuel prices. If the relative increase in real terms is indeed roughly equivalent, the net impact on battery storage viability is positive for most cases. Recall from previous discussions that the demand charge component has greater impact in most cases than the energy charge component in determing rate differentials. In the case of a 100 percent increase in the demand charge component from $4/kW to $8/kW, and in the energy charge component from 2¢/kWh to 4¢/kWh, the rate differential for a discharge period of eight hours increases from .016 to .033. Additional combinations can be analyzed using the curves presented in Figures IV-2 through IV-6.

A second factor supporting the conclusion that rate differentials will be increasing in real terms over time is the movement on the part of public utility commissions away from average, embedded, and historical cost pricing to marginal and replacement cost pricing. This shift is encouraged by stipulations in PURPA which state that rate schedules should be derived in a manner that is consistent with the cost to serve. To the economist, this declaration means marginal cost pricing or the incremental cost to produce one additional unit of output. Under marginal cost pricing, rates could approximate the capital and operating costs associated with a new peaking unit. Present rate derivations are typically based on the accounting and average costs associated with the cost to serve. For example, the capital costs of a hydro-electric unit constructed forty years ago would be rolled into the rate base, at book value with all the other units, to determine an average capacity or demand charge. It is apparent that rates based on the costs of a new peaking unit could be substantially greater than those based on a hydroelectric facility built forty years ago.

A third and final indicator that rate differentials could be higher than those included in this study is the fact that many of the rate schedules utilized in this study were issued in 1978. Although there is no way to verify the changes which have occurred since that time except by contacting every utility in the study, it is probably safe to assume that the rate differentials calculated in this study could be increased by 10-15 percent in order to bring the rate schedules in line with the frame of reference used in this study, i.e., 1980$.

The basic characteristics and formats of rate schedules could change substantially. The adoption of PURPA will encourage the use of time-of-day rates and may serve to standardize some of the basic formats as rate schedules and structures are given increased scrutiny. It is not expected that these changes will substantially impact battery storage viability. As discussed earlier, the adoption of time-of-day rates does not affect the rate differential as much as they might increase the range of potential customers and the size of any single application.

The utility characteristics which were incorporated in establishing the list of utilities with the greatest likelihood of holding potential for battery storage and which motivated the derivation of the existing rate schedules favorable to battery storage do not change rapidly over a short period of time. Therefore, it is expected that the most favorable utilities identified will remain so in the future. Other utilities could be added as the need to increase capacity with expensive generation facilities becomes critical. On the other hand, since the rise of marginal cost pricing has the tendency to de-emphasize local service area characteristics, increased use of that approach could blur the boundaries between favorable and unfavorable rate schedules.

REGULATORY UNCERTAINTY

A final word should be mentioned concerning what might be one of the major barriers to widespread application of battery systems. Batteries are a capital intensive technology relying on large potential savings accruing in future years to compensate for the initial capital outlays. Because of the uncertainty pervading the regulatory environment and of the rapid changes taking place throughout the entire energy arena, discussions held with firms have indicated evidence of a strong hesitation to undertake any major energy-related investment in which the basic parameters could change so quickly with such a great impact. Suppose, for example, that a large electric customer with a flat load shape installed a battery system to take advantage of time-of-day rates offered by its utility. Assume also that the investment was made viable due to the short six-hour peak period incorporated in the time-of-day schedule. Should the utility decide to switch to a 14-hour peak period, the potential savings could be halved and the viability of the investment reversed. For many applications, some sort of long-term agreement between the potential customer and the utility will be mandatory before the customer can justify making the investment.

CONCLUSIONS

The investigation of the effects of rate schedules and the regulatory environment on battery storage viability is complicated by the fact that any assessment is utility-specific or even rate schedule-specific. There are few generalizations that can be made across all utilities. Each utility has its own generation mix, customer mix, rate derivation methodology, declining blocks, and detailed rate schedule specifications.

Present rate structure forms include six basic types: traditional, time-of-day, semi-time-of-day, seasonal, interruptible, and stand-by. The last three forms are only indirectly related to battery storage and, as such, hold no potential viability for battery systems. Traditional rate schedules hold potential for battery systems through load smoothing. Semi-time-of-day rates (i.e., traditional rates with a time-differentiated definition for billable demand) offer the advantage or additional opportunity to shift loads to the nighttime without increasing the billable demand. Time-of-day schedules offer even more opportunity to shift loads to the nighttime since they are constrained only by the off-peak demand charges which are typically low.

In order to evaluate and compare the rate schedules presently in use, on a common reporting basis, a rate differential was derived to interrelate energy charges and demand charges and to represent other potential reduction in electricity costs per kWh of output.

Results indicated for all three rate structures that demand charge levels and the discharge period duration had the largest impacts on the calculation of the rate differential. Energy charges had less impact over the ranges that were typical for all three parameters. Although the economic viability of battery systems will be assessed in Chapter VI, preliminary results indicate that a demand charge of $4/kW coupled with a 3-hour discharge period, a demand charge of $7/kW coupled with a 5-hour discharge period, or a demand charge of $12/kW coupled with an 8-hour discharge period all represent viable applications of battery storage.

Tables IV-2 through IV-8 record the utilities with the most favorable rate schedules. In general, the utilities with such rate schedules are located in the Northeast or Midwest.

Rate differentials should be reaching even higher levels over time because of the underlying increase in electricity prices and because of the increased utilization of marginal cost pricing.

One of the major barriers that would prevent any widespread penetration of battery storage systems is regulatory uncertainty. Long-term contracts may be necessary so that the potential customer can justify the investment.

CHAPTER V. INSTITUTIONAL AND ENVIRONMENTAL EVALUATION

IDENTIFICATION OF PERTINENT INSTITUTIONAL AND ENVIRONMENTAL FACTORS

The overall objective of the U.S. Department of Energy in studying battery storage on the customer side of the meter is to develop low-cost reliable battery systems capable of being used to reduce peak demand on electric utilities. Assessment of potential applications and resulting demonstration programs will help stimulate the creation of industrial and commercial capacity to produce and distribute these systems while at the same time, stimulating the demand for battery storage systems by the customer. An important part of achieving the overall objective of the program is the identification and resolution of non-technical issues that are instrumental in assuring consumer acceptance of the systems; these issues are addressed in this report as the institutional and environmental factors pertinent to the implementation of battery storage systems.

In the component design and manufacturing; system design and siting; installation, operation and maintenance phases of battery systems, there are numerous technical considerations which must and are being addressed. However, there are many other non-technical considerations that must be investigated as well. The objective of this Chapter is to identify and discuss approaches for dealing with the institutional and environmental issues associated with the operation of battery storage systems on the customer side of the meter. Specifically, the following institutional and environmental factors have been studied in meeting this objective:

- Required Return on Investment. Business and industry will perform financial analyses when evaluating the worth of an investment in battery storage systems. Return on investment (ROI) is a recognized tool used in investment analysis. Factors that impact ROI, taxes and tax incentives, for example, are examined and the ROI of the market sectors under considerations for demonstration of a battery storage system are evaluated to determine the extent to which they present a barrier to battery storage on the customer side of the meter.

- Capital Availability/Cost of Capital. The availability of capital for the purchase of battery systems is an issue that could potentially impact the acceptance of the systems by residential, commercial, and industrial users. The cost of capital for investment in the systems will depend on the attitudes of lenders which is also discussed in this Chapter.

- Insurability. Many insurers will be unfamiliar with the risks and hazards associated with battery storage systems and, because of this lack of experience, may be hesitant or express some uncertainty when insurance coverage is required of them. Insurability is of concern as it may be a prerequisite for acquiring financing as well as being a protection to those in the distribution chain of battery systems and the user. The insurance industry's attitude will also affect the outlook of potential users of battery storage systems.

- Ability To Handle Hazardous and Explosive Materials. Potential safety and environmental hazards could become important obstacles to the use of battery storage systems by prospective user groups. For example, dangerous conditions could develop from the release of toxic gases during battery recharging or the accidental spillage of chemical compounds and acids. The effect of environmental and safety hazards on the feasibility of battery storage on the customer side of the meter is examined herein.

- Safety and Environmental Control Requirements. Given their potentially dangerous characteristics, battery storage systems should be located in areas having limited access in order to lessen the possibility of personal injury or property damage. The need for this type of caution is explored and the effect on possible user groups discussed.

- Applicability of Use Restrictions. Provisions of zoning ordinances and other laws enacted by local governments in the interest of public health, safety, and general welfare could potentially be a significant institutional constraint to the installation, operation, and maintenance of battery storage systems by individual user groups.

- Potential for Building Code Restrictions. Lack of uniformity among building codes and the lack of specific reference to battery storage systems may result in the development of barriers to battery storage at the local level. This issue and its ramifications are addressed in detail.

In the discussion that follows, those institutional and environmental factors that have been quantified for the analysis of economic feasibility are addressed first. Quantification is addressed in terms of the effect each of the factors has on the economic analysis. Those factors that are quantified are also addressed in qualitative terms so that all information available is included in the analysis of the factor, not only those terms that are quantifiable. Next the institutional factors that are not quantified are addressed, because although they may not have an impact on the analysis of economic feasibility, they may still have an effect on the way in which the demonstration, or future commercialization and actual implementation should proceed.

The institutional and environmental factors introduced above and addressed in this report suggest action on the part of the U.S. Department of Energy and other actors involved in the demonstration and subsequent introduction of battery storage on the customer side of the meter. As part of the detailed discussion of the factors that follows, activities for ameliorating institutional and environmental concerns will also be presented.

EVALUATION OF THE QUANTIFIABLE FACTORS AND THEIR IMPACT ON ECONOMICS OF BATTERY STORAGE CUSTOMER CLASSES

Required Return on Investment

The purchase of a battery storage system by a business will likely be evaluated as would any other investment decision. More sophisticated investment analysis takes into account the time value of money, making it appropriate to evaluate the investment based on the firm's required rate of return. Others may examine the investment decision in terms of its payback period (i.e., the number of years it takes the firm to recover its original investment). The firm will compare battery storage systems with other uses of funds in determining the appropriate investment strategy. In other words, battery systems will be competing with other investment options of the firm.

Individuals (residential applications) are perceived to be primarily interested in the payback of this type of investment. Because the average owner-occupied home mortgage runs only six or seven years (according to estimates of the U.S. League of Savings Associations), if payback is the primary concern of residential buyers of battery storage systems, the payback period must be shorter than the mortgage's life.[1] Hopefully, many homeowners will evaluate battery storage systems, and other energy-saving devices, based not only on their payback but also on the added value these systems may add to their property, which can potentially be recaptured at resale.

The concern about the expected financial return of battery storage systems is addressed in this report through the economic analysis of the systems in prototypical applications. For comparative purposes, the required return on investment (ROI) of market sectors, in terms of the percentage rate of return received by the owners on their investment, has been determined and is presented in the economic evaluation. The ROI of each sector can be compared with the discount rates used in the sensitivity analysis to determine the economic attractiveness of battery storage systems to potential customers.

A factor which may impact the return on investment of battery storage, and hence the economic feasibility of the systems, is taxation. Tax incentives have arisen at the Federal, state, and local levels with the intent of encouraging the commercialization of solar and other new energy technologies. The incentives typically decrease the cost to the consumer, either through reduction of the initial cost, or the life-cycle cost of the product.

Tax credits provided through Federal legislation can play an important role in encouraging the adoption of new technologies. As part of the National Energy Act, the Energy Tax Act of 1978 became law November 9, 1978. The main purpose of the Energy Tax Act is to provide tax incentives for the production and conservation of energy. In doing so, the Act provides for an income tax credit of 15 percent of the first $2000 of residential energy conservation expenditures. Because battery storage systems are not specifically mentioned in the legislation, if they are to be eligible for this tax credit, the Secretary of the Department of Energy must make a determination specifying that battery storage systems increase the energy efficiency of the dwelling.

The business version of the energy investment tax credit is found under Title III. In general, the energy credit is in addition to the regular 10 percent investment credit to the extent that the energy property also qualifies as regular investment credit property under existing law.

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[1] Kraemer, Sandy F., Solar Law, Shepard's Inc., Colorado Springs (1978).

The credit is equal to 10 percent of the qualified investment in energy property. Energy property means property which is:

- Alternative energy property
- Solar wind energy property
- Specially defined energy property
- Recycling equipment
- Shale oil equipment, or
- Equipment for producing natural gas from geopressured brine.

Batteries may qualify as "specially designed energy property", but the Secretary of DOE would have to make such a determination. Should they qualify, batteries would have to be installed in connection with an industrial or commercial facility.

The traditional investment tax credit available to business is presently set at 10 percent of the eligible investment and is limited to the income tax liability shown, or $25,000 plus 60 percent of the tax liability in excess of $25,000, whichever is less. To qualify the property must:

- Be depreciable
- Have a useful life over 3 years
- Be tangible personal property or other tangible property
- Be placed in service in a trade or business or for production of income by an individual during the years.

Tangible personal property does not include air conditioners or space heating units. Generally, central heating and air conditioning systems, plumbing, wiring, etc., are structural components of a building and do not qualify as tangible personal property.

Structural components include all components (whether in or adjacent to the building) of a central air conditioning or heating system, including motors, compressors, pipes and ducts; plumbing and plumbing fixtures, electric wiring and lighting fixtures; and other components relating to the operation and maintenance of a building.

Buildings and structural components do not qualify as investment credit property. The term building does not include a structure which is essentially an item of machinery or equipment; or a structure which houses property used as an integral part of furnishing electrical energy services if the use of the structure clearly can be expected to be replaced when the property it virtually houses is replaced.

The IRS Office in Cincinnati, Ohio, interprets the policy to indicate that as long as the batteries are movable, even with fork lift, they are eligible for credit.

Even before the Federal government passed the National Energy Act in 1978, many states had already legislated tax incentives to encourage conservation. As the states have acted independently, there is a great deal of variety in the specifics of much of the legislation; however, incentives typically result in a reduction of the purchaser's income tax, property tax, or sales tax payments. Although some state legislation may not currently be specifically applicable to battery storage systems, the attitudes of legislators toward encouraging new energy technologies is an indication of the response that may be exhibited when the availability and potential of battery storage systems on the customer side of the meter is known.

As was stated earlier, tax incentives can improve the economic feasibility of battery storage systems to residential, commercial, institutional, and industrial users. The investment tax credit has been entered into the economic analysis; however, the applicability of many of these incentives will have to be determined, and should be pursued before commercialization is attempted.

Capital Availability/Cost of Capital

Capital Availability

The availability of capital, and its cost to the borrower, depend, to a great extent, on the credit-worthiness of the borrower and on the risk involved in the investment as perceived by the lender. The financial community that will provide the capital necessary for the purchase of battery storage systems may consist of commercial banks, savings and loan associations, investment bankers, and insurance companies. These institutions are perceived as conservative and skeptical of providing financing where an unusual amount of risk is involved. Should this conservatism and skepticism result in a hesitancy to lend money for the purchase of battery storage systems, these institutions could present a barrier to battery storage on the customer side of the meter.

The attitudes of the financial community toward battery storage will not be developed independently, but will relate to the acceptance of battery storage systems by other institutions as well as by individuals. The advent of a new technology, or a new application of an existing technology, can create a hesitancy on the part of institutions as reactions to the technology are assessed. The insurance industry is an institution that will have a significant impact on the attitudes of the financial community as typically a capital acquisition must be insured for the financial institution to be willing to lend money for investment.

Consumer acceptance is also important to the financial community's attitudes toward battery storage systems; this is especially true in residential and small commercial applications. The importance of consumer acceptance arises because a battery storage system becomes part of the dwelling unit and, as such, impacts the selling price of the property. The financial institution's investment retains its value only so long as the consumer market considers the investment as worthwhile. Should battery storage systems not gain acceptance, the inclusion of one in a residence could detract from the dwelling and even decrease its resale value. Thus, it is important to strive for consumer acceptance of battery storage if the technology can be expected to be implemented.

The importance of general consumer acceptance will, however, vary according to the type of customer considering the purchase of a battery storage system and the time of purchase. For example, in residential applications, marketability of the property, and hence public acceptance of battery storage systems, will be of importance to the financial institution if financing is provided either as part of a construction loan, when the dwelling is being built, or as a mortgage loan at the time of acquisition of the dwelling. Alternatively, the financial condition of the borrower is the primary concern to the financial institution when a home improvement loan is contemplated, as would be the case when a battery storage system is added to an existing structure, on a retrofit basis, for example.

Interviews with representatives of major financial institutions in Colorado, Georgia, Minnesota, Missouri, Nebraska, New York, and Ohio provided evidence that they are even more reluctant to become owners of commercial, institutional, or industrial property through default of the owner than they are to foreclosing on a residential mortgage. This arises because of the lower marketability of the former types of properties. Therefore, of primary importance to the lender in the application of battery storage systems in commercial, institutional, and industrial properties is the financial viability of the structure's occupants, be they the owner or lessees.

At the present time,the financial community lacks information with which to evaluate battery systems. As requests for financing develop, they will likely rely on established standards and codes for battery systems which provide some indication of performance and reliability; however, without experience, uncertainty as to what can be expected of the system may create hesitancy on the part of some leaders to respond to requests for financial assistance.

Financial institutions not only seek experience in the operation of new systems, but also experience in sales and resales of properties that include battery storage systems. Much appraising, or determining of value, is done based on sales of comparable properties. Lacking direct evidence from comparable sales, appraisers are likely to evaluate the property at a price that does not reflect the additional cost of the battery system.

In spite of the reasons for hesitancy on the part of many financial institutions to finance battery systems, it is expected that many will be interested in participating in the growth of the technology. For some the public relations value will be important; others will feel a moral obligation to be involved in energy conservation systems. On the other hand, many will recognize that additional risks do exist, but that by taking action to reduce the risk,they can still prudently make loans for battery storage systems without jeopardizing the assets of their depositors.

Those financial institutions contacted by Battelle indicated that,in an effort to reduce their risk when lending for battery storage systems, they would try to achieve an understanding of the technology through contacts with individuals possessing technical expertise in battery storage, and would investigate the state of the art. Others suggested that they would want assurance that the systems would operate as expected, which might involve contacts with the manufacturer. The existence of codes and standards is important to lenders; however, even if codes and standards relating specifically to battery storage systems do not exist, they may be willing to finance battery storage systems, after an evaluation by the local government having jurisdiction.

In order to assure that financial institutions do not become a barrier to battery storage on the customer side of the meter, there are efforts that are appropriate for U.S. Department of Energy to undertake. First, customer acceptance is essential. This can only be assured through successful demonstration programs and proof of economic viability. Efforts should also be directed to assuring that the quality of components, system design, and installation are high so that early experience with the systems, and potential independent evaluation, result in positive evaluation of the product. The dissemination of information about the product will also be important, as the attitudes of insurers, building officials, and local government authorities will all influence the willingness of financial institutions to provide capital for investment in battery storage systems.

Cost of Capital

The cost of capital to the purchaser of battery storage systems can directly influence the economic viability of the system for the particular user; therefore, that cost is a potential issue of concern in the actual implementation of battery storage on the customer side of the meter. Literature sources occasionally speculate that the cost of capital provided by financial institutions will be higher to the borrower when the use of funds is for investment in new energy technologies. Higher interest charges are viewed as a means of compensating lenders for this risk associated with the unproven technology. Generally, however, the contacts with financial institutions revealed that they would evaluate the loan,and if the determination was made to grant financing, it would be provided at normal rates.

The cost of capital varies for different types of borrowers. The differences in the costs have evolved over time, primarily in response to differences in the level of risk associated with lending to each of the customer classes. Although interest rates fluctuate, sometimes even daily, the cost of capital to borrowers can be analyzed in relative terms by comparing the differences in interest rates among different types of customers. Shown below are relative financing rates for customers, with the rate on U.S. Government long-term bonds providing the base rate.

TABLE V-1. COST OF CAPITAL

Borrower	Annual Rate
Government (U.S.)	Base
Government (State and Local)	- 2.75%
Hospitals, Educational Institutions	
Public	- 2.75%
Private	+ 1.90%
Utilities	+ 0.65%
Large Industry	+ 1.50%
Small Industry/Commercial	+ 1.90%
Residential	
New	+ 1.35%
Retrofit	+ 3.70%

These rates have been estimated based on several discussions with officers of financial institutions. Their usefulness in this study are as factors in the economic analysis. The cost of capital enters into the economic analysis as the discount rate by which cash flows occurring at different points in time for different purchasers of the battery storage system are reconciled.

The cost of capital is not in itself a barrier to the use of battery storage systems on the customer side of the meter. It will, however, impact the economic feasibility of the systems. The use of the cost of capital in the economic analysis is further discussed in Chapter VI.

Insurability

The application of battery technology to the storage of electricity on the customer side of the meter necessitates questioning regarding the stance of the insurance industry in the United States toward this new application of an existing technology (lead-acid), as well as a new technology (zinc-chloride). Identification of industry concerns will provide a point of reference from which the U.S. Department of Energy can work to help ameliorate the concerns of the insurers so that they do not become a barrier to battery storage applications. In addition, estimates of the cost of insurance to users of battery storage will impact on the economic feasibility of the systems; hence, they are discussed in this Chapter.

The purpose in researching insurability is to identify and, where possible, suggest measures for overcoming issues that may be associated with insurance and liability in the application of battery storage on the customer side of the meter. The following objectives were established with the aim of achieving the stated purpose:

- Identify key concerns and design requirements necessary to maximize safety and minimize hazards to persons and property
- Evaluate anticipated attitudes of the insurance industry to requests for insurance of battery storage systems on the customer side of the meter
- Determine requirements for establishing a rate structure for insuring privately owned battery storage systems and estimate the cost of that insurance.

The hazards and perils to which persons and property will be exposed are of key concern to the insurance industry in evaluating the insurability of battery storage systems. Hazards and perils are addressed in detail in the discussions of safety and environmental hazards; however, because of their importance to the insurance issue, they are also briefly reviewed in this section.

Some of the following hazards and perils have been experienced in existing battery storage systems and in experimental applications;

others are anticipated based on knowledge of the systems and processes involved in lead-acid and zinc-chloride battery systems. These hazards are mentioned here as a basis for understanding the risks that may be faced by residential, commercial, and industrial users of battery storage systems:

- Hydrogen concentration build-up may present explosive conditions (lead-acid).
- Handling of acid electrolyte solution could cause personal injury,[i.e., acid burns (lead-acid)].
- Escaped chlorine gas could cause lung damage or death if concentrations are high (zinc-chloride).
- Potential for electrical shock (lead-acid and zinc-chloride).
- Possible acid leakage from system (lead-acid)
- Evolution of toxic gases, such as arsine or stibine (lead-acid).
- Toxic agent, thallium chloride, may be an electrolyte additive; if released in an accident, decontamination would be required (zinc-chloride).

These possible hazards can be protected against by proper design, manufacture, installation, and maintenance. With this attention, the possibility of injury or property damage is remote; however, losses associated with early operation of battery storage systems will be the experience upon which decisions to insure and rates to be charged are based. Thus, it is important that the probability of system failures and accidental injury be reduced by attention to safety even during the early phases of demonstration and commercialization.

The owners of a battery storage system will require insurance to protect themselves in case of accidential injury attributable to the system to persons on their property. The owner will also want to protect his/her own property from damage caused by the battery storage system. Individuals will generally be protected through their homeowner's policy while businesses will be covered by a business liability contract. The ability of property owners to secure this coverage for battery storage systems, and the issues related to such coverage, are of key concern.

The reaction of the insurance industry to requests for property insurance where electricity is supplied through battery storage systems is difficult to anticipate. Lack of experience with the risks involved with system operation will cause special attention to be given by insurance agents and brokers to requests for coverage on property that includes these systems. Although there may be hesitancy on the part of some insurers, it is not expected that securing insurance will be a problem for the owner of a battery storage system.

If a property owner installs a battery storage system, the system will typically be covered under existing policies. However, at the time of renewal of that policy, the insurer may re-evaluate the risk and make a determination whether or not to continue the coverage. At this point, the property owner may face the same circumstances as would an individual desiring coverage for new property which incorporates a battery storage system.

It can be anticipated that insurers will require a well-engineered and soundly constructed system. The existence of standards, and compliance with standards by the manufacturer, will be important, as will installation by a licensed contractor. Individuals who install the systems themselves may expect to have somewhat more difficulty securing insurance; however, inspection and approval after installation will usually prove satisfactory to an insurer.

Placement of the battery storage system will likely enter into the insuring decision. Insurers have indicated that they would be concerned that the battery system be isolated so that leakage of chemicals would not cause damage to property or other unnecessary risks to persons or property.

Most insurers indicated that the insurance rate for a structure with a battery storage system will be no different than it would be without the system. However, there will be a cost to the owner in that the system will add value to the property and thus the insurance premiums will be higher to account for the added value. Although this will likely be the initial reaction of many insurers, experience with the system that follows these initial impressions will be a significant factor in determining both the future attitudes of insurers and the rates that they charge to provide coverage for battery storage systems on the customer side of the meter. The estimated annual cost of insurance, as provided by an insurance industry representative, for the four prototypical systems is shown in the table below.

TABLE V-2. ESTIMATED INSURANCE COSTS

Power (kw)	Application	Cost of Insurance
2	Small Residential	$ 8
40	Large Residential/Small Commercial	$ 300
1,000	Large Commercial/Small Industrial	$ 1,400
20,000	Large Industrial	$14,000

Not only is business liability and homeowner's insurance essential for the acceptance of battery storage systems, but system manufacturers, designers, retailers, and installers must be covered by product liability insurance. Their responsibility is to use reasonable care in the design, manufacture, testing, and distribution of their products; incorporate available safety devices; and furnish adequate warnings and instructions for installation and use. If injury to person or property results from the use of a faulty battery storage system, there may be grounds for legal action in the courts based on the concept of product liability.

A business typically will have financial protection for instances where it is found liable for harm resulting from the use of its product as part of its comprehensive general liability policy. The insurer will evaluate the risk involved in battery storage systems through a technical and legal review and will establish rates for the business based on the risk of the system, or similar products if there are no products that are exactly comparable, and on the level of sales. The existence of standards aids the insurer in evaluating the risk of the product by providing knowledge of the product and how it can be expected to perform. They also provide a defense if injury occurs and the manufacturer or others in the chain of distribution are charged with liability for the injury. However, even should standards not exist for a specific system, the lack of standards should not pose a significant problem,as often a new product, new application, or new technology is evaluated by the insurer under the assumption that standards are not in existence.

A final issue in the discussion of the insurability of battery storage systems on the customer side of the meter is the topic of warranties. Market receptivity, and hence attitudes of the institutional actors, as well as the consumer, depends to a great extent on initial experience with a product. Thus, it is essential that design, manufacture, installation, and service are of such quality as not to give the technology a poor reputation or slow commercialization. Warranties can be used as a tool to protect the consumer and minimize the risk in purchasing a battery storage system. Whether the government should actually mandate warranties is an issue of discussion with respect to many new energy-related technologies now in the demonstration and early introduction stages. Some feel that government-mandated warranties will help protect consumers investing in new technologies, and make them more willing to try a new product. Others feel that warranties should be left to the industry to be used as a marketing tool and mandated warranties could retard innovation in the industry. Regardless, it should be realized that standards and warranties are means of informing the consumer and the involved institutions,and could potentially serve as a means of reassurance in the development and application of battery storage systems on the customer side of the meter.

EVALUATION OF QUALITATIVE FACTORS AND THEIR IMPACT ON BATTERY STORAGE BY CUSTOMER CLASSES

The following paragraphs present a synopsis of four identified battery storage environmental, institutional, and health and safety issues: the ability to handle hazardous materials; the applicability of zoning and other use restrictions; safety and environmental controls; and the relevance of building code regulations. The significance of each of these issues to the commercialization of battery storage systems is discussed in terms of the four defined prototype applications (residential, commercial/large residential, large commercial/small industrial, and large industrial), and in relation to the two battery system types (lead-acid and zinc-chloride) which are being investigated in this study.

In general, if properly designed, installed, and maintained battery systems should evolve into a relatively environmentally benign, publicly acceptable, and safe form of energy storage technology. However, it must be pointed out that this study dealt exclusively with issues from the customer side of the meter, and that there are potentially more significant environmental, institutional, and health and safety issues related to the mining, manufacturing, and other production activities associated with batteries and other battery system components (e.g., wiring, inverters, etc.). The incremental costs associated with these four issues are not expected to appreciably add to the total costs of installing and operating a battery storage system, nor are they likely to be as important as other technological and economic factors in determining the overall rate of commercialization of this technology. The costs have, however, entered into the economic analysis as "balance of plant" costs, as discussed in Chapter III.

Ability To Handle Hazardous Materials

The ability of various prospective user groups to handle potential safety and environmental hazards related to the potential toxic, electrical, and explosive characteristics of battery systems could become an important "public acceptance" obstacle to the adaptation of the battery storage technology. This issue, in part, focuses upon such factors as the general understanding of the technology by personnel from previous experience and training programs, and systems/procedures which may already exist at proposed sites to monitor/control potentially hazardous situations. The key parties-of-interest who must be familiar with the potential hazards and safety issues associated with the battery storage technology include the potential purchasers, installers, and operators of battery storage systems.

Potential types of safety and environmental concerns include, for example, dangerous concentrations of toxic gases (e.g., stibine, arsine, and chlorine compounds) which can be released during battery recharging; fires and explosions which may result from the ignition of flammable gases such as hydrogen; and personal injury which may result from electrical shocks and chemical acid burns.

In general, the range of prospective battery storage user groups varies from those sectors which have little or no understanding of the technology,and no experience or facilities for working with hazardous and explosive materials, to those sectors which have trained/experienced personnel and adequate facilities. For example, prospective users of large battery storage systems who are involved in electrochemical technologies (e.g., electrical utilities and telephone companies) are likely to have trained/experienced personnel on their staff and to have special types of ventilation and monitoring systems in place. These user groups may consider their familiarity with and ability to handle hazardous materials as an asset regarding the adoption of battery storage technologies. On the other hand, the prospective residential and small commercial business sectors are not as likely to be familiar with electrochemical technologies which may initially hinder their willingness to adopt battery storage systems. With respect to the lead-acid and zinc-chloride battery systems under study, no significant differences have been identified between the two systems which may affect the ability of prospective users groups to generally understand the technology and to properly handle potentially hazardous materials.

Because the reputation and rate of commercialization of battery storage technology will, to some extent, be dependent upon the public's understanding of this technology and its safety requirements, potential adversities could perhaps be avoided through comprehensive training programs. Specifically, potential buyers, installers, and operation/maintenance personnel should be instructed through literature, films, workshops, and other similar media as to the basic operation of such battery systems, potential safety hazards, and actions which should be taken in emergency situations. The private manufacturing and contracting industry, in conjunction with appropriate governmental agencies, could possibly provide this information. The establishment of such public education activities should help eliminate "bad experiences" with early battery storage systems and may reduce insurance risks associated with this technology. On the other hand, prospective user groups who are not familiar with the operation and maintenance of battery systems may become "overly alarmed" and biased against battery systems upon hearing of any isolated incidents taken out of context.

In general, facility and personnel training requirements for battery storage systems are likely to be related to the size of the system, with large industrial applications requiring more safety systems and training than small residential and commercial applications. However, for all user groups, the additional incremental costs associated with providing the necessary facility safety improvements and personnel training are expected to comprise only a very small and insignificant portion of the total installation and operation/maintenance costs of a battery storage system.

Applicability of Use Restrictions

Another potential institutional/regulatory obstacle to widespread adoption of battery storage technology deals with the siting of the battery systems. Specifically, various provisions of zoning ordinances, architectural controls, and other regulations enacted by local governments in the interest of public health, safety, and general welfare could potentially affect the placement of battery storage systems by various customer classes. Such laws may place limitations on the construction, location, or style of accessory structures, and may regulate permitted uses within identified use zones. Use restrictions are primarily an issue of concern to potential purchasers of battery systems, contractors who design and install the systems, and representatives of local governmental bodies who enact and enforce such legislation in the interest of public welfare. Potential siting constraints attributed to use restrictions are generally impartial to either the lead-acid or zinc-chloride battery systems that are under consideration in this study.

For the most part, such local regulations are patterned after standard "model" ordinances, and incorporate, to various levels of detail, specific local considerations. Early ordinances developed a hierarchy of use zones in which permitted uses were cumulative in nature with single family residences on large lots being the exclusive, highest use zone. Recent ordinances have addressed compatibility issues by establishing exclusive districts for other uses (e.g., industrial parks). Additionally, architectural and site design specifications are increasingly being used in planned unit developments and other large-scale developments to achieve desired public goals. However, in general, such local ordinances remain less restrictive for industrial use zones and most restrictive for residential use zones.

Examples of the range of provisions in local zoning ordinances used by communities to regulate the design, construction, occupancy, and use of land and buildings which may affect the siting of battery systems include:

- Accessory use limitation - prohibition of out-structures required to house the battery system
- Use regulations - prohibition of energy storage systems in certain zones
- Side and setback restrictions - placement of the system in relation to lot boundaries
- Density or percent of lot area - potential for placement of system to exceed the legal building-to-lot area size ratio
- Aesthetic, historic preservation, or architectural controls - restrictions on the style, materials, design, or color of system components.

An additional provision of zoning laws and other use restrictions which also may become important in the siting of battery systems are procedures for requesting and granting variances. That is, if a proposed battery storage system technically violates a minor provision of a local code, a request for variance can be submitted to the zoning board of appeals to permit the installation of the battery storage system with appropriate modifications designed to achieve conformity.

Also, as is the case with most developing technologies, local ordinances which are prescriptive in nature may not explicitly address particular applications of the new technology, in which case the administrative officials have the authority to interpret whether such systems are in compliance or not. Local officials are likely to grant approval for the installation of this new technology only after they become knowledgeable about the characteristics of battery storage systems and are satisfied with information provided them about the system from various professional and other sources.

Generally, in a limited number of situations, compliance with provisions of local ordinances may initially prohibit and/or place restrictions (thereby resulting in slightly higher installation costs) on the siting of battery storage systems, especially for residential applications. However, in all likelihood, utility, industrial, and commercial applications of battery storage systems will not be prohibited or restricted by local use ordinances. As applications of the battery storage technology become more commonplace and as the technology is demonstrated as a safe and efficient method of energy storage, the number of such restrictions will be lessened and local codes will be modified and/or amended to specifically include provisions for the siting of this technology.

Safety and Environmental Control Requirements

The efficient and safe operation of battery storage systems require the installation and maintenance of various safety and environmental control systems. In some instances the installation of these safety and fire monitoring systems, controlled access systems, ventilation systems, and other protective measures may be viewed as a major obstacle to the purchase of battery storage systems by prospective customer groups.

In general, from an installation perspective, the space required to house a battery storage system with its power converter components ranges in size from approximately a 6' x 6' area for small-scale lead-acid residential applications to over an acre for large-scale utility/industrial facilities. The battery system must be housed within a building so that the temperatures and other environmental factors can be controlled to insure the efficient operation of the system because battery efficiency decreases with temperature extremes. Other building code requirements such as fire walls must also be considered. Given their potentially dangerous characteristics, battery storage systems should also be located in areas having limited access and should have security controls to prevent unauthorized access in order to lessen the possibility of personal injury to curious individuals as well as damage by vandals.

From an operational/maintenance perspective, battery storage systems require ventilation, electrical fusing systems and special fire and safety equipment. Safety system requirements include gas detectors and ventilation systems to detect and prevent the build-up of hazardous levels of toxic and/or explosive gases evolved during recharging cycles; acid-handling equipment such as rubber aprons, gloves, and foot gear; face masks; deluge water showers, eyewash stations, etc.; and electrical/chemical fire and acid spill clean-up equipment. For example, lead-acid battery systems must be designed to prevent electrical shocks, to prevent the isolation of cell modules, and to ventilate potentially explosive concentrations of hydrogen gas and toxic arsine and stibine gases. On the other hand, zinc-chloride battery systems have several unique features (such as a flowing electrolyte) which require special equipment such as tanks, heat exchangers, and pumps. Adequate safety systems for zinc-chloride battery systems must include the detection of chlorine leakages and the prevention of contact from the chemicals with electrical and moving parts. Although zinc-chloride battery storage systems are considered as moderately safe if properly designed, it is possible that zinc-chloride systems may not be feasible for small-scale residential and commercial applications due to safety and environmental considerations.

Environmentally, on the customer side of the meter, battery storage systems constitute a relatively benign energy system with few adverse attributes. No major air or water regulations have been identified as issues which may impede the rate of commercialization of this energy technology. However, in terms of waste disposal, under regulations promulgated by Section 3004, "Standards for Hazardous Waste Treatment, Storage, and Disposal Facilities", of the Resource Conservation and Recovery Act of 1976

(RCRA), wastes characterized as having hazardous properties must be disposed of in "secured" landfills or by some other acceptable method. In general, these RCRA regulations will not likely pose any technical barriers for compliance, but may result in secondary economic costs for compliance in the form of a reduced salvage value for spent lead-acid batteries and increased disposal costs for the zinc-chloride chemical wastes.

In general, for larger size battery storage systems, the installation costs associated with the ventilation, safety, security, etc., systems are normally included as a component of the balance of plant costs. For smaller scale residential/commercial applications these additional expenses will likely be a function of specific insurance and building code requirements. However, these installation costs are likely to comprise only a minor increment of the total cost of the battery storage system. Similarly, routine operation/maintenance costs for safety and environmental control systems are not expected to add significantly to the overall Kw cost of the battery storage system.

Potential for Building Code Restrictions

An important factor in the successful implementation of battery storage will be the support provided by various regulatory agencies and their representatives. For example, building code officials will play a key role in the success of new and retrofit battery system installations in residential, commercial, and industrial buildings because of their responsibility to approve building, and attendant mechanical systems, design and construction techniques. Each building code official is required to interpret whether a given design meets certain prescribed rules of practice in a given geographic location. The basis for his judgement is the local building code and various material and construction standards that have been legally adopted. To achieve an understanding of the issues related to building codes, this task has been designed to review selected model codes and to identify potential problems and constraints that might relate to battery storage in buildings.

The scope of this task involved reviewing the model building codes which included: (1) the Uniform Building Code, (2) the Basic Building Code,

(3) the Standard Building Code, (4) the National Building Code, and (5) the National Electrical Code. The analysis covered residential, commercial/institutional, and industrial building applications with an emphasis on the four prototypical battery systems. Potential and actual problems/constraints were identified relating to structural and electrical design, fire protection, and equipment and system standards.

Building Codes

A building code is a set of regulations designed to ensure that the public health, safety and welfare are protected during the construction and occupancy of buildings. Within the scope of a building code terms are defined; standards are set for materials, equipment, and the assembly of materials and equipment; and provisions are made for the enforcement of permits, inspections and other procedures.

Generally, there are two types of building codes - a specification code and a performance code. Specification codes delineate the kinds of materials and equipment that may be used. Such codes are typically easier to administer than performance codes, but are inflexible in terms of innovation. Performance codes, on the other hand, define the specific functional requirements of various parts of the structure and its appliances and equipment. For example, fire resistance, thermal resistance, structural capacity, and air flow requirements are given. These kinds of codes are flexible and allow for innovation, but also require more trained personnel, time, and funds to administer.

Traditionally, building codes are enacted by local governments pursuant to their police powers. As a result, there are thousands of locally enacted building codes throughout the United States. More recently, however, states have taken a more active role in promulgating and enforcing building codes. In some cases these codes have provided minimum requirements which must be adopted by local governments.

Building codes are enforced by local governments and states through a system of permits and inspections which allow construction to proceed and permit occupancy only when plans and construction practices have been determined to meet the prescribed requirements. Although not all states and municipalities have legally adopted building codes, by far the majority of states and many municipalities have done so. Many of these codes are based upon one of the four model building codes available in the United States. According to a 1970 survey of local building departments, 63 percent of the 191 cities reporting had adopted one of the four model building codes.[3] These model codes are: (1) the Basic Building Code, prepared by the Building Officials Conference of America, and used mostly in the east and midwest; (2) the Standard Building Code, prepared by the Southern Building Code Conference, and used mostly in the south; and (3) the Uniform Building Code, prepared by the International Conference of Building Officials, and used mostly in the west. The fourth model building code is the National Building Code prepared by the American Insurance Association and is used nationally. These organizations also have a separate code for mechanical design and construction. Additionally, numerous standards supplement the basic building codes. The building codes reference these standards in the appendix to the code, and then delineate the conditions under which the standards apply. For example, BOCA's Basic Building Code references over 400 standards.

In order to identify potential building code barriers to battery storage on the customer side of the meter, the four model building codes were analyzed. One of the major issues determined from this review is that none of the model building codes currently incorporate any provisions for battery storage systems. It is expected, however, that due to the characteristics of the battery storage systems under consideration, the specific sections of the codes that would most directly relate to battery storage are: (1) special or explosion hazards, (2) fire resistive construction, (3) ventilation, and (4) electrical. As a result of this lack of provisions for battery storage systems, any proposed battery storage system will be subject to the interpretation of the local or state building code official. Without any provisions in the code that can easily be referenced, the official will have to decide whether the equipment and system meets available recognized design and testing standards and, if not, whether he will deny the permit or require additional testing. Thus, a conservative building

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[3]Kraemer, Sandy, Solar Law, Shepard's Inc., Colorado Springs (1978).

code offical may require costly testing of the system design or of specific materials or components before a building permit would be issued. Because building code officials often lack the technical knowledge to adequately enforce discretionary building code criteria, they may feel compelled to require the submission of expensive engineering tests and details before granting a building permit. As a result, a significant financial barrier could be added to the installation of a battery storage system. If the building's owner or contractor is denied a building permit, the resulting appeal process also raises a significant time and cost barrier.

Another major issue is the lack of uniformity in building codes. If state and local governments continue to develop and promulgate their own energy technology-oriented building codes without benefit of national references, the development and distribution of battery storage systems will be slowed because each manufacturer will be required to meet different standards. It will simply be too costly for many manufacturers to customize their components or system to meet the special requirements of each state or locality. The result is that they could be forced to withdraw their product from the market thus reducing competition and creating the potential for higher cost systems. Our experience is that some individuals involved in energy research, as well as technical writers, have stated that because there is no specific provision for electric storage in building codes, there are no barriers in the codes. It should be made clear that history has proven otherwise. Innovations much less radical than battery storage systems have taken years to achieve acceptance on a broad scale. Much of this can be blamed on the prescriptive characteristic of the majority of the U.S. buildings codes. As a result, a major manufacturer, group of manufacturers, or labor union, who already have a specific material or product accepted under the code, can provide enough resistance to any proposed innovative change to prevent its use even on a limited scale.

A detailed review of the model building codes indicates that there are many sections within the codes that might bear upon the installation of battery storage systems. While many of these sections are not, at present, outright barriers, because battery storage systems are not specifically addressed, implications can be drawn based upon the intent of the code to provide for the protection of public health, safety and welfare. Consequently, they offer potential problems/constraints to the design and installation of battery storage systems. Potential problems or constraints identified in codes, relative to battery storage systems, are presented in Appendix A.

Summary of Institutional and Environmental Evaluation

The analysis of the institutional and environmental issues associated with the demonstration and introduction of battery storage systems on the customer side of the meter has resulted in the identification of selected issues that seem to be of more immediate importance to use of the systems than others considered in this Chapter. These issues are:

- Tax Incentives. There is currently ambiguity in the Energy Tax Act with respect to the applicability of the energy tax credit to battery storage systems. This is also true of state legislation that provides incentives for new energy technologies.

- Consumer Acceptance. Acceptance is vital to the reaction of financial institutions to battery storage systems.

- Information. Consumer acceptance, attitudes of financial institutions and the insurance industry are all founded on the information that is relayed to them, be it in the form of reports on others' experience with the system, or through codes and standards. Positive reaction to battery storage systems by these groups can be encouraged through efforts designed to transmit information regarding the systems.

- Appropriate Measures for Dealing with Hazards. It is anticipated that battery storage systems will present hazards to the user that may not be currently experienced. Codes and standards can incorporate measures to reduce the likelihood of threat to public health, safety and welfare. Design of facilities and personnel training programs to encourage the safe handling of battery storage systems and related components are appropriate.

- Use Restrictions. Local ordinances may, in some instances, initially prohibit and/or place restrictions on the siting of battery storage systems.

These issues are not exhaustive, but rather they are representative of areas that need to be addressed to further the use of battery storage on the customer side of the meter. A successful demonstration program and proof of economic viability, along with attention to the quality of components, system design, and installation, will contribute greatly to alleviating institutional barriers to the use of battery storage that do exist.

CHAPTER VI. ECONOMIC EVALUATION

The economic evaluation brings together the battery costs developed in Chapter III and the potential electric cost savings derived in Chapter IV. The diagram on the next page depicts the relationships between each of these sections. It should be noted that while these two outputs have similar dimensions ($/kWh), the capital cost figure represents a one-time investment, while the rate differential represents a savings that accrues every hour of battery discharge.

The economic evaluation utilizes standard present value analysis to assess the feasibility of battery storage. The measure of economic value is given in terms of a ratio of the present value of system benefits and the present value of system costs. The rate differential which results in an electricity cost reduction equaling the life-cycle costs of a particular battery system (i.e., a benefit to cost ratio = 1) is termed the breakeven rate differential. Conversely, the initial battery system capital cost which results in a life-cycle battery system cost equaling a particular rate differential (i.e., a benefit to cost ratio = 1) is termed the breakeven battery system cost. In general, comparisons are made in terms of the breakeven rate differential. That is, the life-cycle costs of the battery are calculated in terms of the rate differential required to breakeven. This strategy facilitates the determination of which combinations of energy and demand charges and which existing rate schedules would support viable battery storage applications.

Specification of the economic evaluation formula is provided below:

$$\frac{\text{Benefit}}{\text{Cost}}\ \text{Ratio} = \frac{\text{Net present value of the operating savings accumulating throughout the lifetime of the investment}}{\text{Net present value of the capital outlays for the battery system}}$$

$$= \frac{\sum_{i=1}^{2n} (R_{t_d} - O_m) \cdot Y \cdot (1+k)^{-1}}{(1-t) \cdot [C_t + C_p \cdot C_3 \cdot (1+k)^{-n} - C_s \cdot C_3 \cdot (1+k)^{-2n}]} \qquad (1)$$

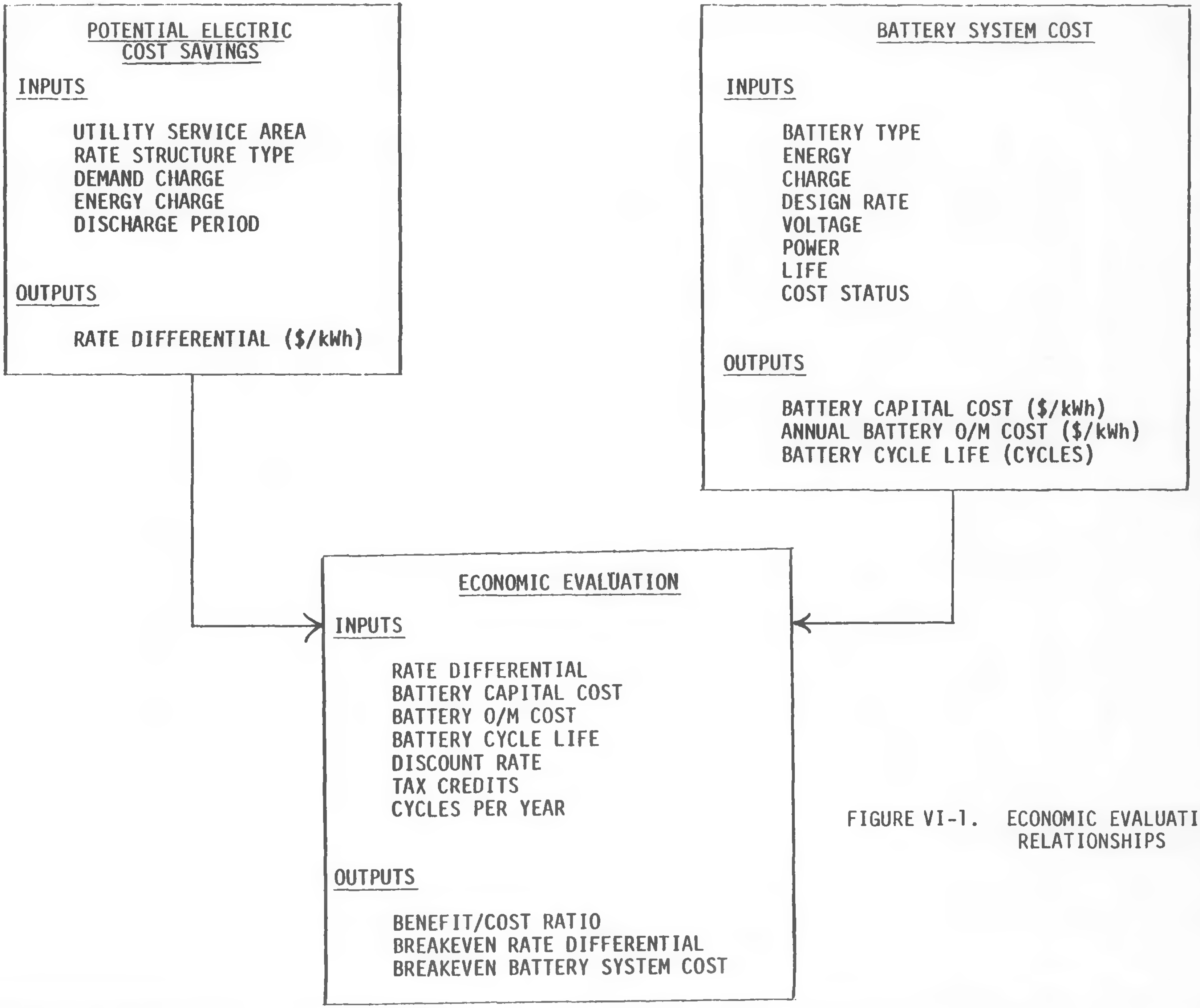


FIGURE VI-1. ECONOMIC EVALUATION RELATIONSHIPS where,

n = battery lifetime in years = lead-acid cycle life divided by the number of cycles per year

R_{t_d} = rate differential for a designated discharge period t_d

O_m = operating and maintenance costs

Y = number of cycles per year

k = discount rate in real terms ≈ the cost of capital less the inflation rate

t = investment tax credit

C_T = total specific cost of battery system, \$/kWh ac

C_R = net replacement cost of a battery as a proportion of the initial battery cost

C_3 = baseline battery cost, \$/kWh ac

C_S = net salvage value of a battery as a proportion of the initial battery cost.

The numerator of the formula encompasses the electric cost reduction less the battery system operating and maintenance costs. The terms inside the brackets of the denominator represent the initial battery system costs, replacement battery costs after the n^{th} year, and battery salvage value after the $2 \cdot n^{th}$ year. Calculating the benefit/cost ratio would involve solving for the left-hand side of the equation. Calculating the breakeven rate differential would involve setting the left-hand side equal to one and solving for R_{t_d}. Calculating the breakeven battery system cost involves setting the left-hand side equal to one and solving for C_T.

The remainder of the Chapter is organized into four sections:

- Base Case Analysis
- Sensitivity Analyses
- Customer Attribute Evaluation
- Conclusions.

BASE CASE ANALYSIS

In this section, the baseline battery system described in earlier chapters will be assessed. In addition, several important parameters will be investigated as to their impact on battery storage viability. These include:

- Changes in battery system size
- Changes in the discharge period
- Changes in the baseline capital costs.

The baseline battery system is essentially a battery for large industrial applications in which a discharge period of five hours is appropriate. As presented in Table III-1 of Chapter III, the principal design features of the baseline battery system include:

Battery Type: Lead-Acid
Energy: 100 mWh
Charge: 7-hour + 2-3 hour taper
Design Rate: 5-hour discharge
Voltage: 1505 Volts dc (minimum)
Power: 20 mW (constant)
Life: 2000 cycles
Cost Status: Mature Plant (25 per year).

As included in Table III-3 of Chapter III, the principal baseline cost and performance data include:

Specific Cost Constants: (1980$)*

C_T = total specific cost of battery system = $\$140/kWh_{ac}$

C_1 = power conditioner cost = $\$100/kW_{ac}$

C_2 = power related balance of plant cost = $\$40/kW_{ac}$

C_3 = baseline battery cost = $\$78/kWh_{ac}$ (P_b - 34¢/lb)

C_4 = energy related balance of plant cost = $\$34/kWh_{ac}$

Operation and Maintenance Cost:

O_m = \$0.005/kWhr

Efficiency (exclusive of ancillary energy):

η_T = 0.7135 ($\sim$71% $\pm$ 1%)

* Cost estimates based on applications for the year 1987 at commercialization levels of production.

In order to complete the specification of the economic evaluation formula (Equation 1), several other assumptions are incorporated in the baseline analysis:

- Investment lifetime = 16 years
- Replacement battery cost = 67% of initial battery cost (from Chapter III); $C_R = .67$
- Salvage value of battery = 39% of initial battery costs (from Chapter III); $C_S = .39$
- Inflation rate = 10%
- Cost of capital = 15%
- Discount rate = i ≈ Cost of capital - Inflation rate = 15% - 10% = 5%
- Investment tax credit = t = 20%
- Cycles per year = Y = 250 (assumes 5 cycles per week, 50 working weeks per year).

Additional cost factors associated with the other three specific system designs (1000 kW, 40 kW, and 2 kW) were adapted from Table III-4 and Equation (14) from Chapter III.

Baseline System Evaluation

Benefit/cost ratios were calculated over a range of rate differentials for the baseline system and for the other three specific system designs. Results from these equations are presented in Table VI-1 and Figure VI-2.

TABLE VI-1. BASE CASE ECONOMIC EVALUATION

		Benefit/Cost Ratios	
System Design	Rate Differential for Benefit/Cost Ratio = 1 (Breakeven)	Rate Differential = $.02/kWh	Rate Differential = $.10/kWh
20,000 kW	.053	.38	1.82
1,000 kW	.061	.33	1.67
40 kW	.074	.27	1.39
2 kW	.093	.22	1.11

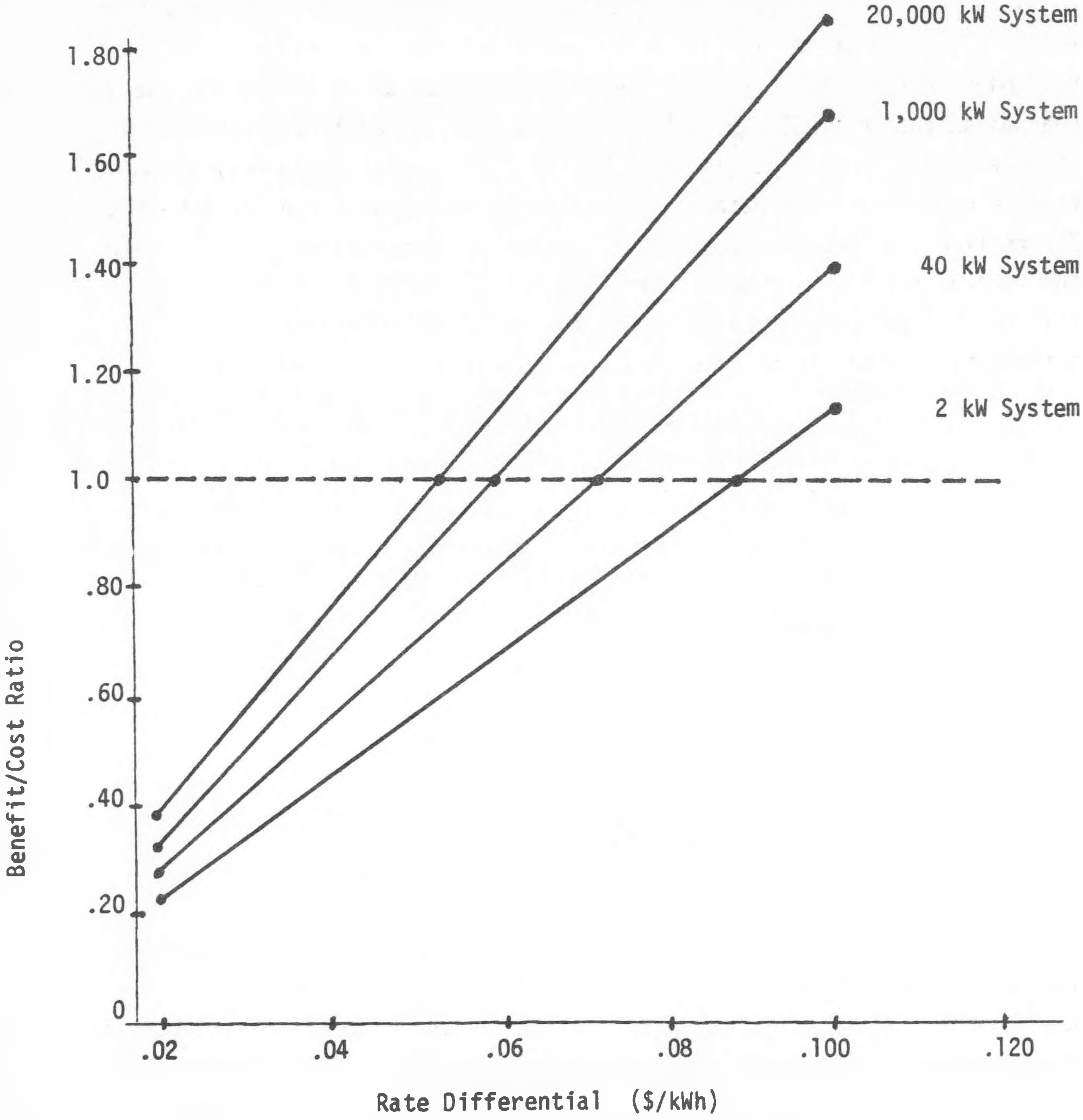


FIGURE VI-2. BASE CASE ECONOMIC EVALUATION

The plot for the baseline case shows that the breakeven rate differential equals $.053/kWh. It may be recalled that Figure IV-4 depicted rate differential calculations for five-hour discharge periods and different combinations of demand charges and energy charges. Any combination of demand and energy charges exceeding $.053/kWh would represent a viable application of battery storage systems under baseline assumptions. For example, the rate differential associated with a $6/kW demand charge and 1¢/kWh energy charge is $.053/kWh. Tables IV-2 and IV-8 from Chapter IV listed the most favorable traditional and time-of-day rate schedules for customers in the 20,000 kW class. Note that for a five-hour discharge period the following utilities had rate differentials equal to or in excess of $.053/kWh:

(Table IV-2: Traditional Rate Schedules)

Central Illinois Public Service Co. - $.089/kWh
Indianapolis Power and Light Co. - $.102/kWh
Iowa Electric Light and Power Co. - $.060/kWh
Minnesota Power and Light Co. - $.111/kWh
Central Hudson Gas and Electric Co. - $.082/kWh
Carolina Power and Light Co. - $.124/kWh
Central Vermont Public Service Corp. - $.064/kWh
Appalachian Power Co. - $.069/kWh

(Table IV-8: Time-of-Day Rate Schedules)

San Diego Gas and Electric Co. - $.054/kWh
Public Service Gas and Electric Co. (NJ) - $.053/kWh
Central Hudson Gas and Electric Co. - $.083/kWh
Carolina Power and Light Co. (NC) - $.061/kWh

Naturally, the market potential is fairly small in this application because of the limited need for such large systems (20,000 kW) with a five-hour discharge. This conclusion is tempered by the information developed in Chapter IV which indicated potential for increases in future utility rate differentials. Such a scenario would increase the number of utilities with rate schedules exceeding a particular breakeven rate differential. Later discussions in this Chapter will address the impact of battery system cost estimates achieving the DOE development goals. These reduced costs would decrease the breakeven rate differential required to recover the life-cycle costs of the battery system. Therefore, while present potential may be limited, future potential could be much greater based on increased electric rates and decreased capital costs.

The other system designs require even higher breakeven rate differentials ranging from \$.061/kWh to \$.093/kWh. Note that these evaluations are only for battery systems with discharge periods of five hours. Battery system costs, including replacement battery costs, battery salvage value, and a 20 percent investment tax credit amount to \$129/kWh, \$150/kWh, \$181/kWh, and \$229/kWh for the 20000 kW, 1000 kW, 40 kW, and 2 kW systems, respectively. The increase of 78 percent in the unit costs between the 20000 kW and the 2 kW systems indicates the substantial economic advantage belonging to the larger systems.

Discharge Period Evaluation

A second important parameter in addition to battery system size is the impact of alternative discharge periods on the viability of battery storage systems. Table VI-2 displays the breakeven rate differentials for discharge periods of 2, 3, 5 (baseline), 8, and 12 hours. Results reflect a gradual decrease in battery system costs on a kWh basis as the discharge period increases. This unit cost decrease is due to a reduction in power conditioning costs on a kWh basis and to savings from scale economies associated with battery systems of larger capacities (i.e., larger discharge periods). It can be recalled from the earlier Chapter on electric rates that the rate differentials associated with alternative rate schedules increase rapidly with decreasing discharge periods. Displayed in Figure VI-3 is the interaction between rate differentials and battery system unit costs which also increase with decreasing discharge periods.

For each of the system sizes, any rate schedule that results in a rate differential falling above the appropriate dashed line represents a viable application of battery storage. The data clearly indicate that, in most cases, the increase in rate differentials for shorter discharge periods outweighs the increase in battery system unit costs. Thus, in general, the shorter the discharge period, the greater the viability of battery storage.

Battery System Cost Evaluation

Three battery cost scenarios were evaluated in order to establish relative battery storage viability under the best of situations and in a less favorable situation. These scenarios are based on:

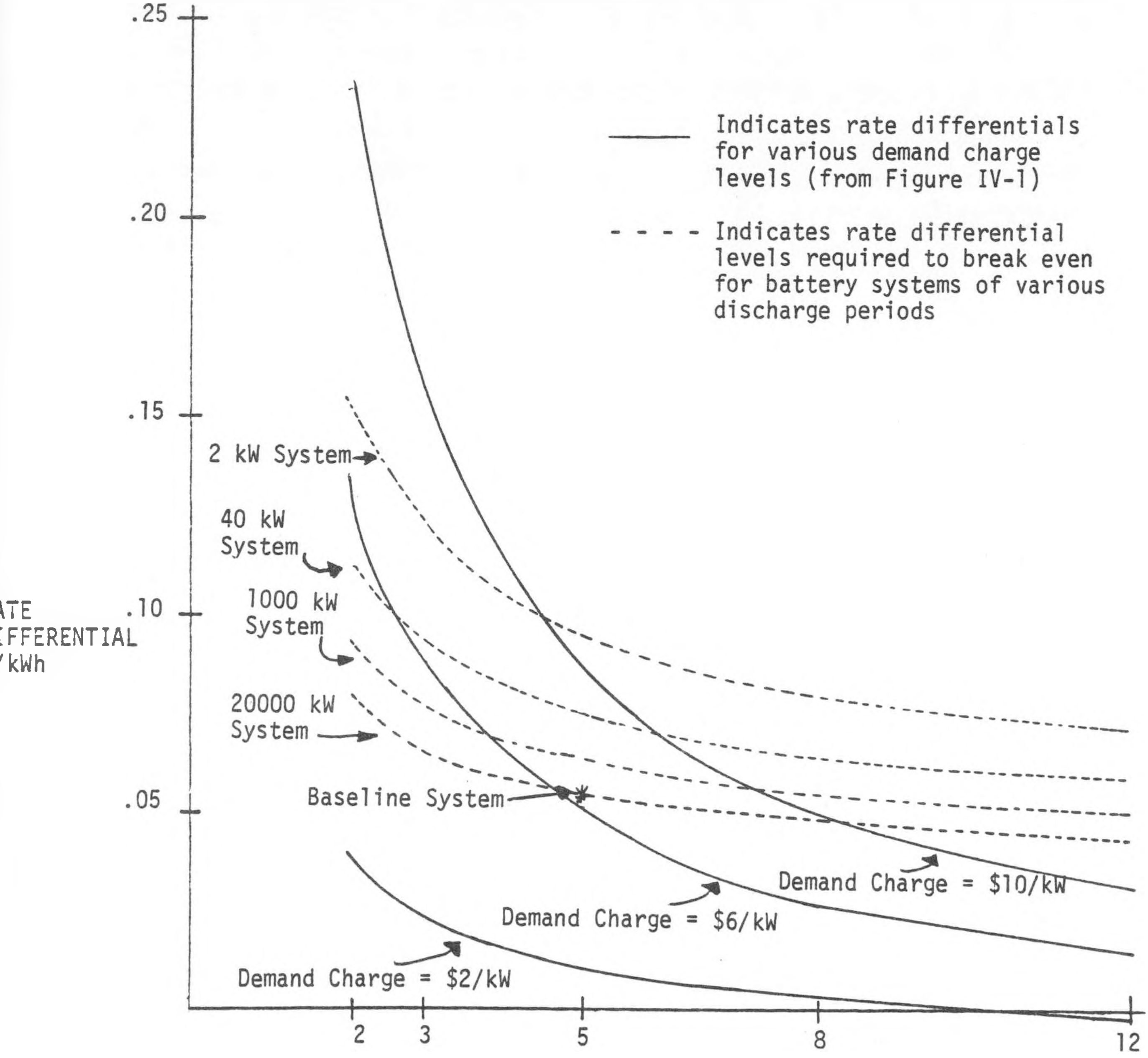
- DOE development goals for advanced battery systems as (listed in Chapter III)
- Development goals for advanced lead-acid battery systems (cycle life of 4000 cycles)
- Demonstration project cost estimates based on a 1982 installation (listed in Chapter III).

TABLE VI-2. REQUIRED BREAKEVEN RATE DIFFERENTIALS FOR DIFFERENT SIZED BATTERY SYSTEMS AND FOR DIFFERENT DISCHARGE PERIODS ($/kWh)*

Battery System Size (kW)	Battery System Discharge (Hours)				
	2	3	5	8	12
20,000	.076	.064	.053**	.047	.042
1,000	.086	.072	.061	.054	.048
40	.110	.090	.074	.063	.057
2	.152	.120	.093	.079	.069

* Assumes that the charging power level is less than the discharging power level.

** Baseline results.



DISCHARGE PERIOD
HOURS

ASSUMES ENERGY CHARGES = 3¢/kWh*

FIGURE VI-3. ECONOMIC EVALUATION OF ALTERNATIVE BATTERY STORAGE SYSTEMS

* This level of energy charge is selected because it represents the most typical energy charge. It can be recalled that small changes in energy charge levels do not have a large impact on battery storage viability.

Results for each of these scenarios are presented in Table VI-3 and in Figure VI-4. The technology goal scenario would substantially increase the range of viable applications for battery storage. Doubling the cycle life from 2000 cycles to 4000 cycles, reduces the breakeven rate differential by some 20 percent. Demonstration costs increase the required breakeven rate differentials by nearly 50 percent. In short, each of these scenarios represents significant impacts on battery storage viability and points to the importance of obtaining accurate capital cost estimates.

TABLE VI-3. BATTERY SYSTEM COST EVALUATION

Battery Cost Scenario	Breakeven Rate Differentials for Alternative System Designs			
	20,000 kW	1,000 kW	40 kW	2 kW
Base Case (Commercialization in 1987)	.053	.061	.074	.093
Development Goals	.023	.026	.034	.047
Demonstration in 1982	.078	.089	.110	.142
Double Cycle Life to 4000	.043	.047	.057	.073

Breakeven battery system costs for a 1000 kW system have been calculated for a number of demand charge levels and discharge periods. The calculations are similar to those represented in Figure VI-3 with the exception that the results are displayed in terms of breakeven battery system costs instead of breakeven rate differentials. The 1000 kW system was selected as the evaluation basis because it is felt that the 1000 kW design is a better representation of the system size that firms will adopt. These results are displayed in Table VI-4 and in Figure VI-5.

The 1987 commercialization capital cost estimates for a 1000 kW, 5-hour battery system are $162/kWh. Comparing this figure with the 5-hour curve in Figure VI-3 shows that the breakeven demand charge level is somewhere between $6/kW and $8/kW. In order to be viable in utilities with $2/kW demand charge levels, capital costs for 1000 kW system would have to be reduced to

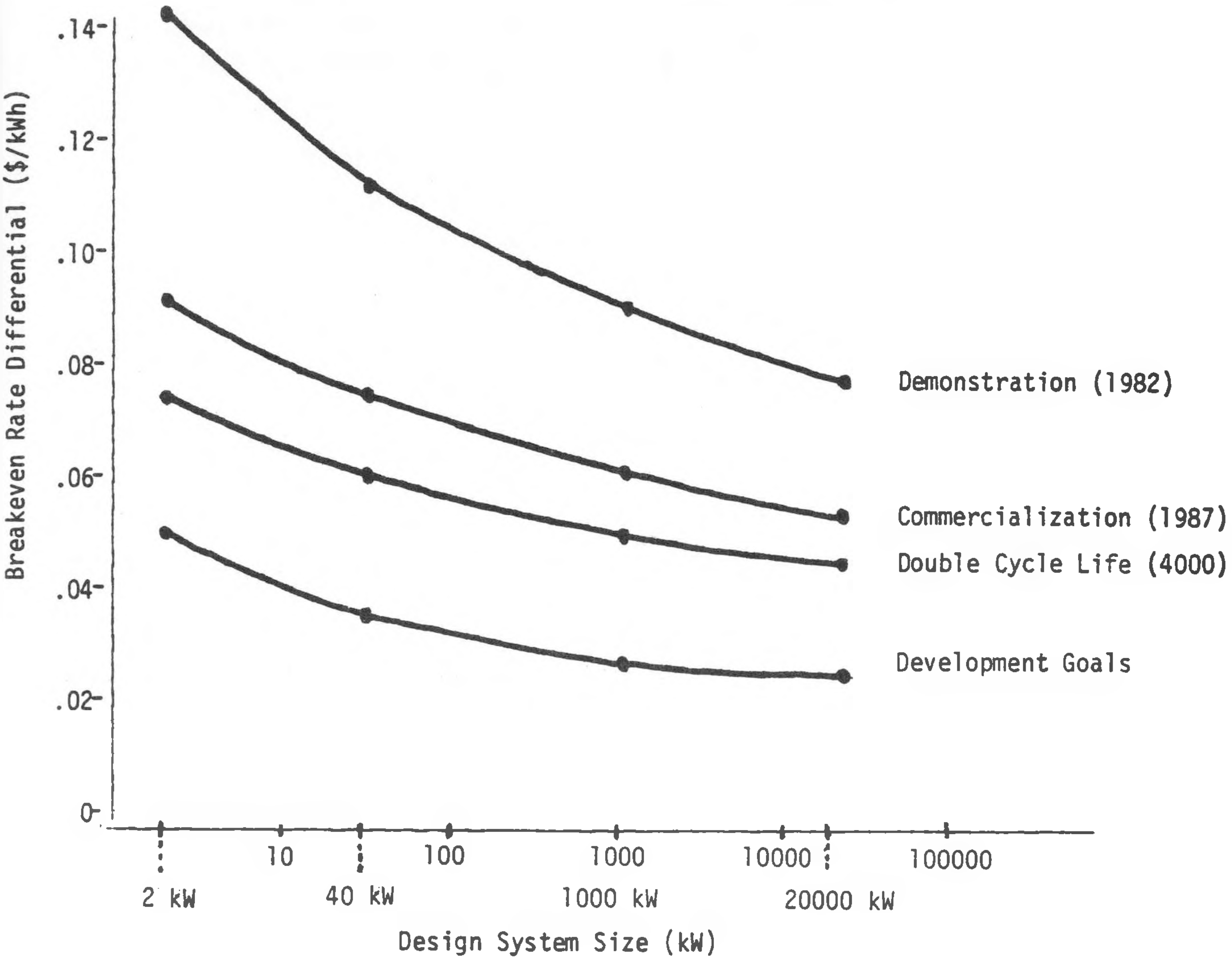


FIGURE VI-4. BATTERY SYSTEM COST EVALUATION
(Semi-log Scale)

$21/kWh. Because many individuals are most familiar with cost estimates for the 20000 kW (Utility size) system, it is somewhat useful to translate the 1000 kW capital costs into 20000 kW capital costs terms. Under the baseline assumptions, a 1000 kW battery system costs roughly 16 percent more on a kWh unit basis than a 20000 kW system. That is to say, achieving a $162/kWh capital cost for a 1000 kW, 5-hour system is the same technological advance as achieving a $140/kW capital cost for a 20000 kW, 5-hour system.

The next step in the analysis is to determine the relative frequency of both traditional and time-of-day rate schedules which could support viable battery storage systems. Figures VI-6 and VI-7 record the number of major utilities which offer rate schedules that result in life-cycle savings equal to or greater than the life-cycle costs of battery storage. The results incorporate two dimensions:

- Breakeven battery system capital costs
- Future electricity rate escalations.

TABLE VI-4. BREAKEVEN BATTERY SYSTEM COSTS FOR A 1000 kW SYSTEM BY DEMAND CHARGE LEVEL AND BY DISCHARGE PERIOD ($/kWh ac)

Demand Charge Level ($/kw)	Discharge Period Duration (Hours) 2	3	5	8	12
12	315	400	275*	86	125
10	393	329	227	150	97
8	336	259	175	113	71
6	247	188	124	77	44
4	159	117	74	39	16
2	68	46	21	3	(10)

* 1987 commercialization costs for a 1000 kW, 5-hour battery system is $162/kWh ac.

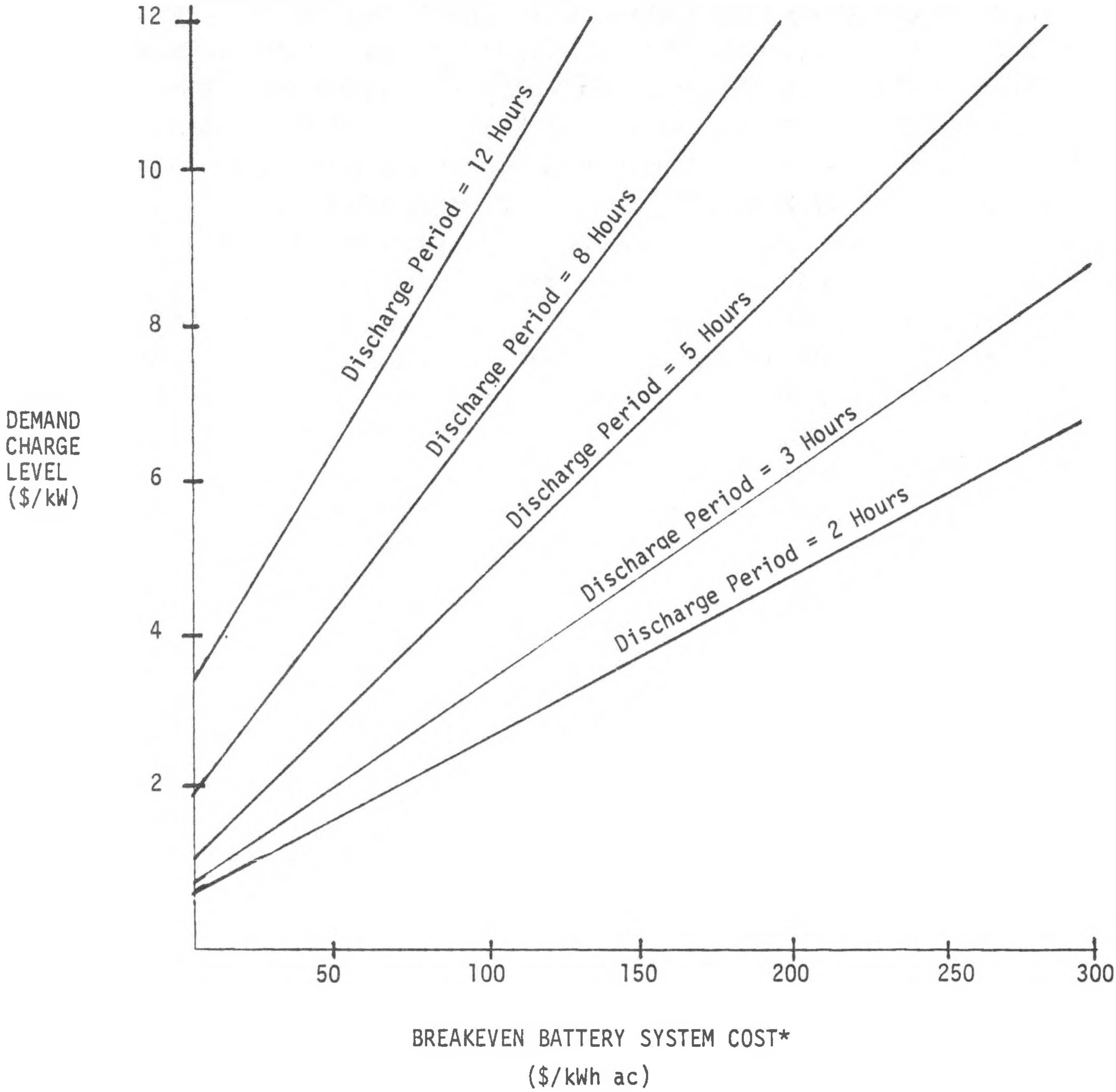


FIGURE VI-5. BREAKEVEN BATTERY SYSTEM COSTS FOR A 1000 kW SYSTEM BY DEMAND CHARGE LEVEL AND BY DISCHARGE PERIOD ($/kWh ac)

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* 1987 Commercialization costs for a 1000 kW, 5-hour battery system are $162/kWh ac.

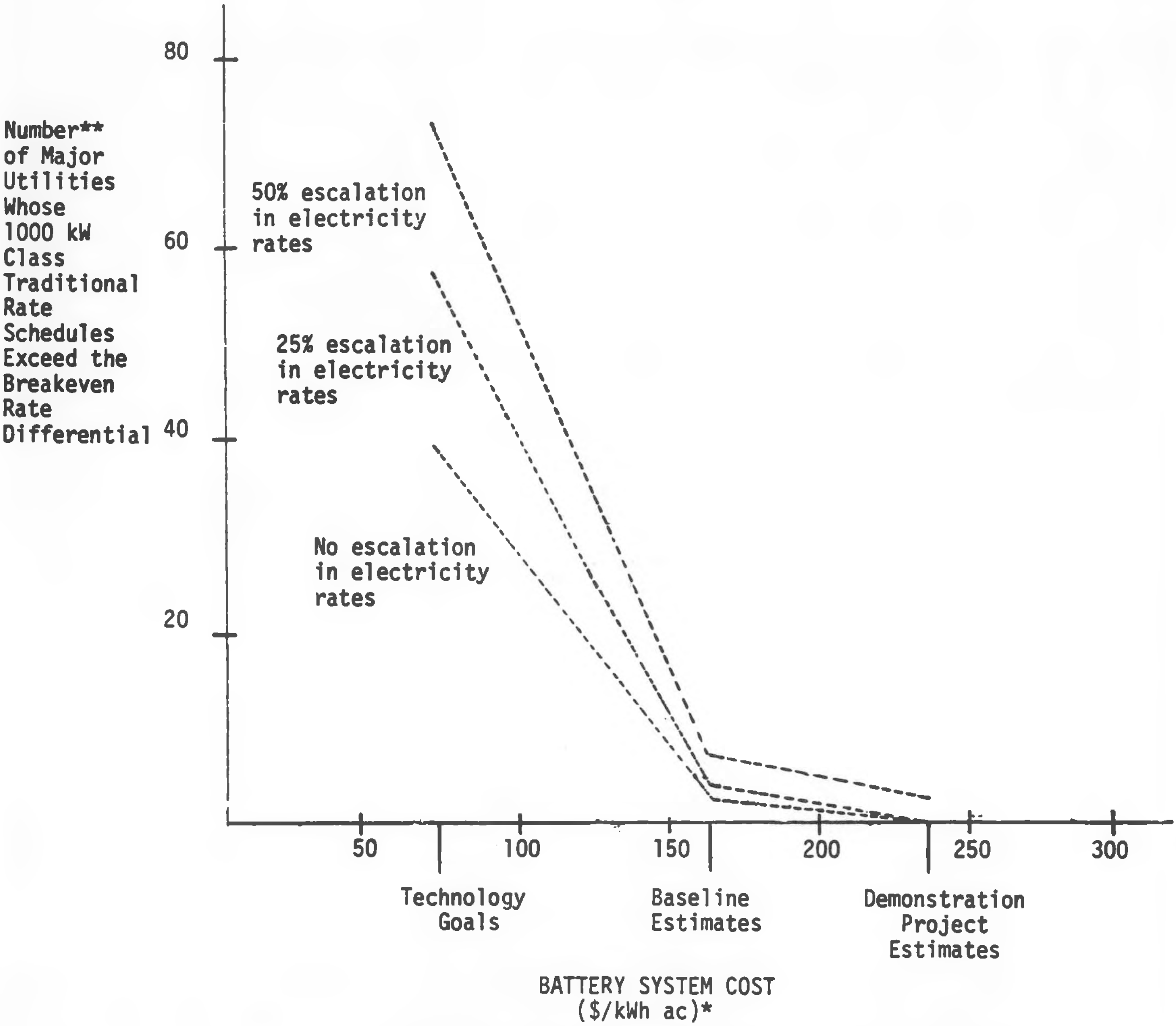

FIGURE VI-6. PENETRATION OF TRADITIONAL RATE SCHEDULES BY 1000 kW, 5-HOUR BATTERY STORAGE SYSTEMS AS A FUNCTION OF BATTERY SYSTEM CAPITAL COSTS AND FUTURE ELECTRICITY RATE ESCALATIONS

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* Assumes customer class of 20000 kW and a discharge period of five hours

** Includes data from 152 major utilities

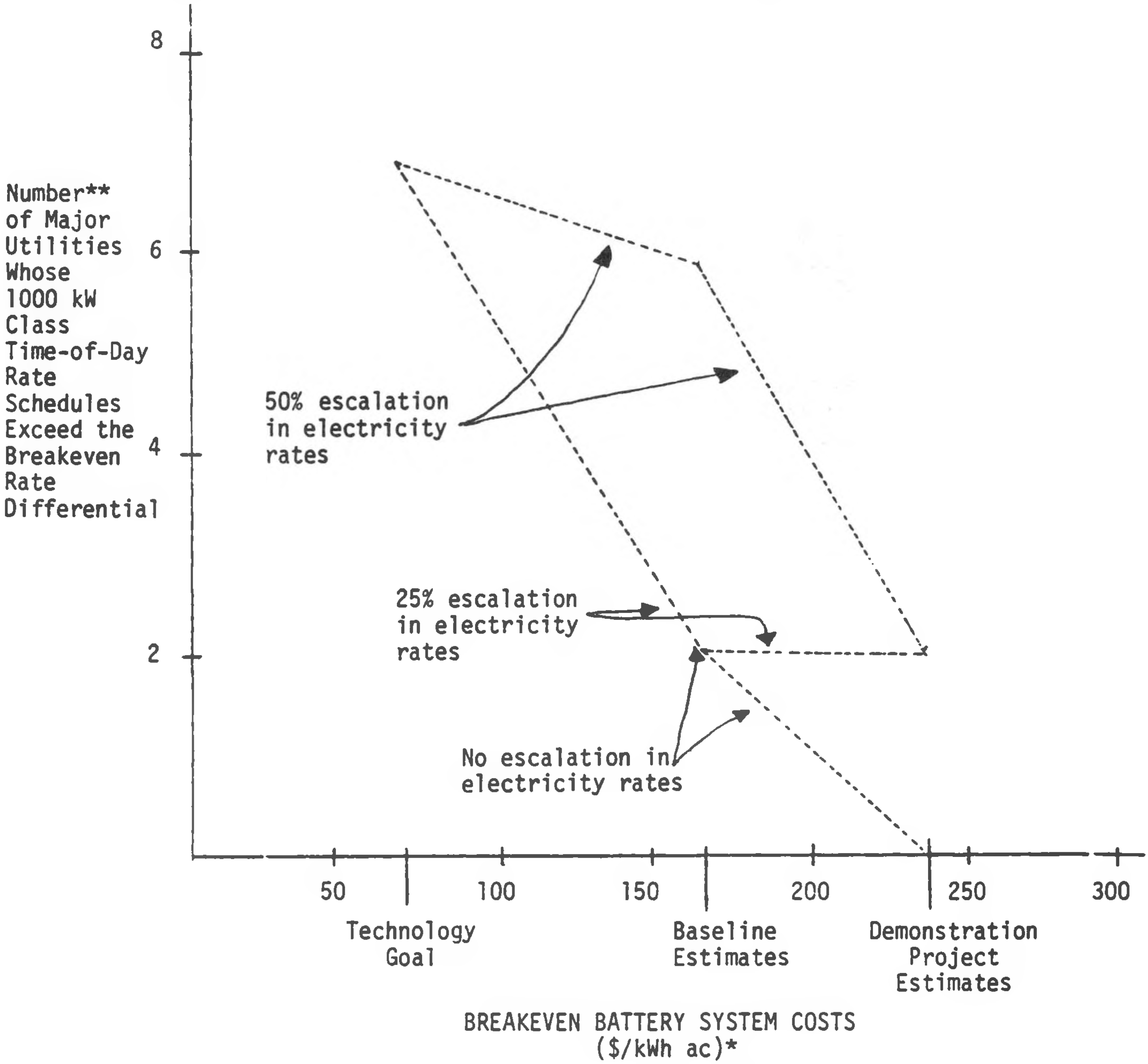

FIGURE VI-7. PENETRATION OF TIME-OF-DAY RATE SCHEDULES BY 1000 kW BATTERY STORAGE SYSTEMS AS A FUNCTION OF BATTERY SYSTEM CAPITAL COSTS AND FUTURE ELECTRICITY RATE ESCALATIONS

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* Assumes customer class of 1000 kW and a discharge period of five hours

** Includes data from 8 major utilities

Under the assumption of $162/kWh$_{ac}$ battery system cost (1987 commercialization estimates for the 1000 kW system) and no increase in real terms for electric rates, there would be eight utilities offering traditional rate differentials exceeding the required breakeven rate differential. The number increases to 46 utilities if the technology development goals are achieved. The number increases to 64 utilities if, in addition, there is a 25 percent increase in real terms in the underlying level of electricity rates. In general, because the majority of existing rate schedules (94 out of 152) have a demand charge of $2/kW or $3/kW, the relative penetration of battery storage rests substantially on whether viable applications can be made at those demand charge levels.

The relative frequency of viable time-of-day rate differentials are presented in Figure VI-7. The results are somewhat limited due to the small number of such rates currently in use at the 1000 kW level. Under the assumption of $162/kWh$_{ac}$ battery systems cost (1987 commercialization estimates) and no increase in real terms for electric rates, there would be two utilities offering time-of-day rate differentials exceeding the required breakeven rate differential. The number increases to seven utilities if the technology development goals are achieved. Although the relative penetration rate is greater under time-of-day rate schedules than under traditional rate schedules, 7/8 vs. 40/152, this study in no way is concluding that time-of-day rates produce, a priori, better rate differentials with regard to battery storage viability. The primary reason that the relative penetration is greater under time-of-day rate schedules is because the utilities which have seen the need to adopt time-of-day rate schedules tend to have the characteristics favorable to battery storage viability (i.e., large rate differentials). Thus, the utilities with the low rate differentials under traditional rate schedules, will not have the need or incentive to adopt time-of-day schedules in the first place.

SENSITIVITY ANALYSES

In the previous section several important parameters were investigated as to their impact on battery storage viability. These included:

- Changes in battery system size
- Changes in the discharge period
- Changes in the baseline capital costs.

This section assesses the impact of six other factors which, while important, are not as closely linked to the battery storage as those listed above. Sensitivity analyses will be conducted in reference to:

- Timing of replacement batteries
- Discount rates
- Lead prices
- Investment tax credits
- Scaling factors
- Peak period durations.

Timing of Replacement Batteries

Under the baseline system assumptions, the battery replacement strategy called for only one battery replacement. Assuming a battery cycle life of 2000 cycles and a cycle frequency of 250 cycles per year, the baseline replacement strategy involved a battery replacement in the eighth year and a salvage of the battery system in the sixteenth year. Thus, under the baseline assumptions, the investment lifetime of the battery system is only sixteen years.

Because the battery system, excluding the battery itself, has a useful life on the order of 30 years, consideration was given to alternative replacement strategies. Table VI-5 records the results for additional replacements. Incorporating the second replacement in the sixteenth year improves battery storage feasibility by seven percent. A third replacement in the twenty-fourth year improves the feasibility by an additional three percent. The favorable impact of the second replacement is more than twice that of the third replacement because the benefits associated with the third replacement occur so far out into the future that they are heavily discounted.

On the whole, these impacts are relatively minor in comparison with the impact of changes by other parameters. For this reason, the baseline replacement strategy is not inappropriate, especially if consideration is given to the risks associated with basing investment evaluations on expected savings accruing 25 or 30 years into the future.

TABLE VI-5. SENSITIVITY ANALYSIS OF REPLACEMENT BATTERY TIMING

	Breakeven Rate Differential	Normalized Breakeven Rate Differential
Base Case (Replacement after 8 years)	.053	1.00
Replacement after 8 and 16 years	.049	0.93
Replacement after 8, 16, and 24 years	.048	0.90

Discount Rate

One of the most subjective parameters that must be incorporated in a feasibility study is the assumed value for the discount rate used to equate cash flows occurring in different time periods. In this study, the discount rate was defined roughly as the difference between the cost of capital (15 percent) and the inflation rate (10 percent). Because inflation has been taken out of all the calculations in the analyses, the discount rate used in this study is a real discount rate. All calculations made in constant 1980$'s. A nominal discount rate, on the other hand, includes the inflation factor and utilizes current year dollars. The use of a five percent real discount rate is based in part upon the recommendation by Bierman and Smidt(1) of employing the default-free interest rate to equate cash flows occurring in different time periods. In real terms this rate would be roughly equal to the Treasury bill rate less the expected rate of inflation or roughly 5 percent (15 percent-10 Percent) at present rates.

VI-(1) Harold Bierman, Jr. and Seymour Smidt, The Capital Budgeting Decision (Fourth Edition) MacMillan Publishing Co., Inc., New York, NY (1975), page 183.

A number of sensitivity analyses can be conducted to determine the relative importance of the discount rate. These included real discount rates of eight percent, three percent, and zero percent. These variations could represent in some measure what Chapter V identified as the differences in the cost of capital between different customer classes. Although it may be difficult to conceptualize a zero percent discount rate, present interest rates could be evaluated as negative real discount rates when inflation and taxes are considered. The eight percent discount rate is in recognition of the high ROI hurdle rates firms require on investments involving new or risky technology.

The results of the discount rate sensitivity analysis are shown in Table VI-6. They are calculated using the assumptions associated with the baseline system with only the discount rate being changed. As shown in the table, the discount rate can have a substantial impact on the overall feasibility of the battery system. Potential battery users will have to be questioned as to the appropriate discount rate to be used in their particular situation.

TABLE VI-6. DISCOUNT RATE SENSITIVITY ANALYSIS

	Breakeven Differential	Normalized Breakeven Differential
Base Case (Real Discount = 5%)	.053	1.00
Real Discount Rate = 8%	.062	1.17
Real Discount Rate = 3%	.046	0.86
Real Discount Rate =0%	.036	0.69

Lead Prices[2]

Any economic evaluation study must give consideration to the critical raw materials that are utilized in the energy system. In lead-acid battery storage the principal raw material of note is lead. For the last two years lead prices have experienced a great deal of investor interest which, in part, is a spillover from speculative demand in the precious metals markets. As such, lead prices have gyrated widely since 1978, after having remained relatively stable over the 25-year time period prior to that. Figures VI-8 and VI-9 depict the price history for lead.

Projecting future prices of raw materials is a risky enterprise and one which lies outside the scope of this study. However, a number of factors can be identified which could significantly impact the relative prices for lead. Listed below are the factors and trends tending to limit lead prices.

- Current domestic measured and indicated reserves containing about 28 million tons are nearly adequate to support the probable cumulative domestic demand during 1976-2000 of 28.5 million tons at an annual growth rate of 1.9 percent. World measured and indicated reserves containing about 136 million tons exceed the estimated cumulative world demand during 1976-2000 of 127 million tons at an annual growth rate of 2.9 percent. Moreover, the resource expansion resulting from technological development and exploration activity in recent years indicates that there is a high probability that commercially minable reserves will be augmented.

- In light of evidence pointing to the potential environmental and safety hazards placed by lead-containing products, demand for lead in a number of end uses has decreased substantially. Environmental Protection Agency (EPA) regulations have restricted the use of lead as an antiknock additive in gasoline, and Consumer Product Safety Commission (CPSC) regulations have restricted the use of lead in paint and other surface coatings.

- There are several alternative combinations of metals and non-metals that can be used as batteries to store electric energy. Advanced design batteries (e.g., zinc-chloride, sodium-sulfur, and lithium-sulfur) all have relatively high energy densities that could significantly penetrate the electric vehicle market.

VI-(2) Adapted from Lead-1977, J. Patrick Ryan and John M. Hasue, Mineral Commodity Profiles, Bureau of Mines, United States Bureau of Mines.

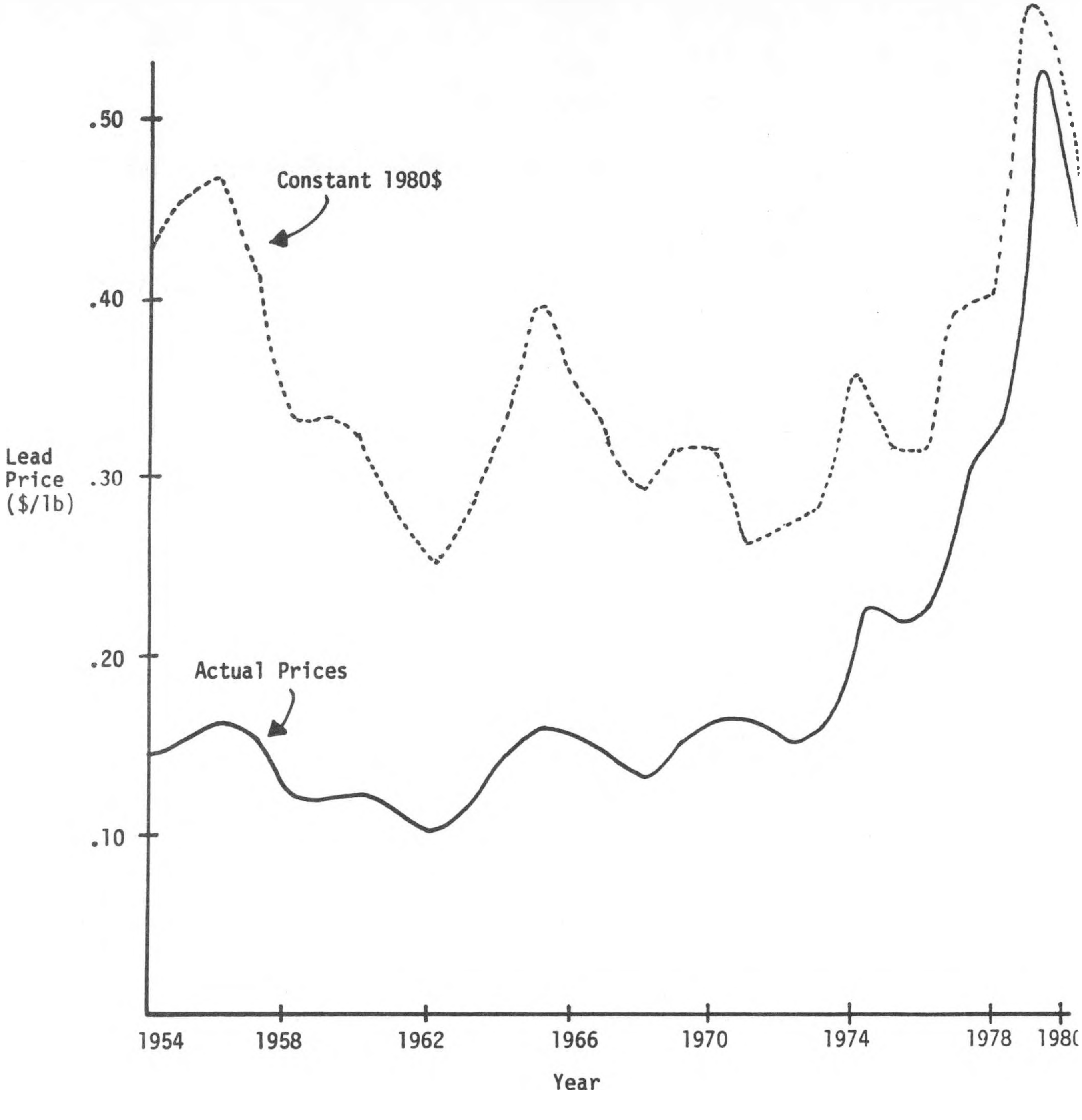

FIGURE VI-8. AVERAGE ANNUAL LEAD PRICES (1954-80)

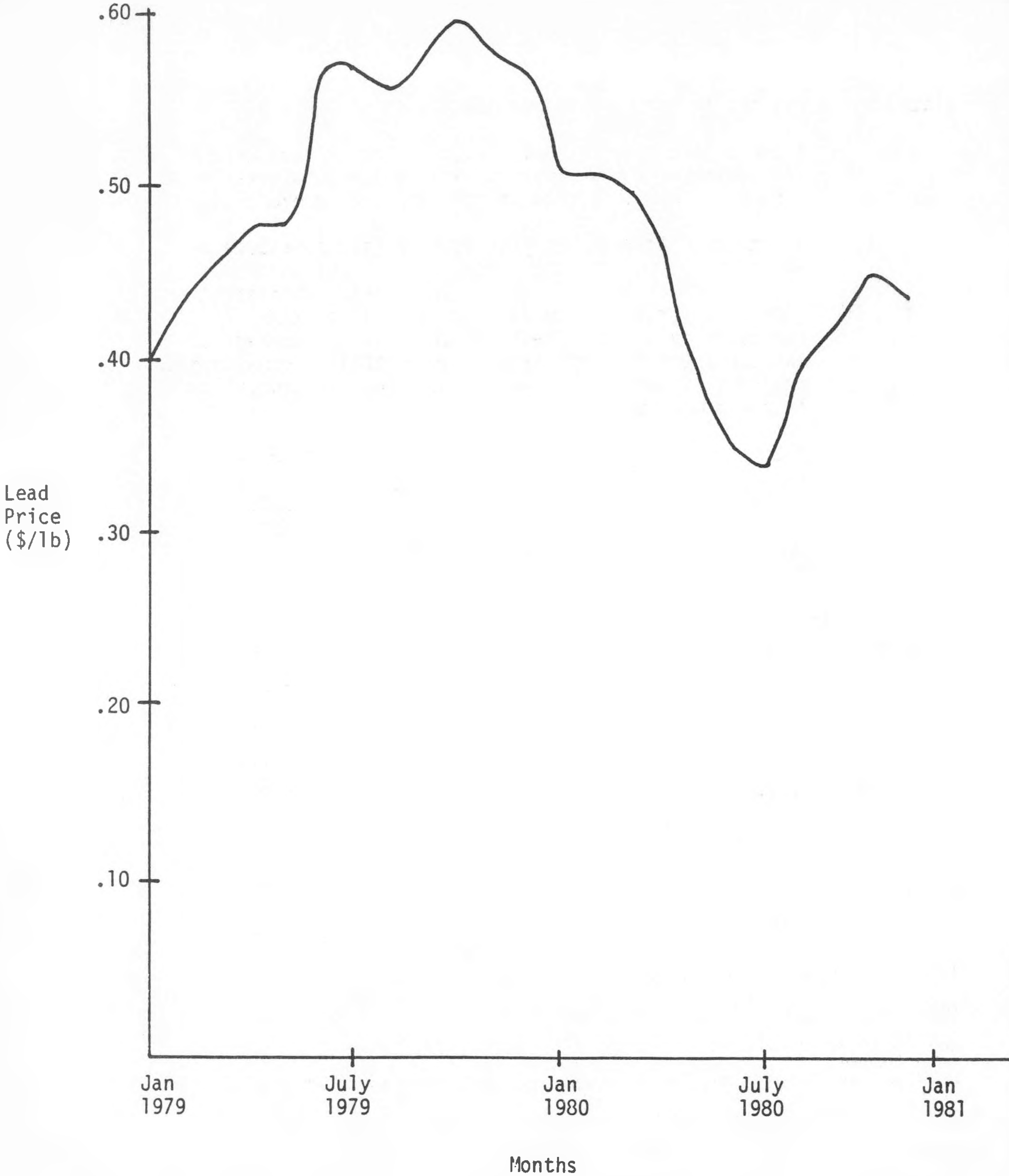

FIGURE VI-9. MONTHLY LEAD PRICES (1979-80)

Listed below are the factors and trends tending to escalate lead prices.

- As described earlier, speculative elements have created uncertainty and upward pressure in all natural resource markets. This influence is not expected to diminish.
- A number of Federal regulations have been considered which could significantly increase the cost to produce lead. The Occupational Safety and Health Administration (OSHA) has proposed regulations to develop lead standards to mitigate health hazards in the work-place. The Environmental Protection Agency (EPA) is considering programs to require states to lower lead concentrations in the atmosphere.
- The growth projections for domestic consumption of lead have incorporated a doubling of the annual consumption in the transportation sector. If lead-acid batteries for electric vehicles were to achieve significant technological breakthroughs, then this projected growth rate may be underestimated.

The above factors seem to indicate that while there appears to be no real problems in lead supplies, it is reasonable to expect that prices will be subject to the fluctuations experienced in the recent past. The important question then is the degree to which lead prices affect the viability of battery storage. Discussion in Chapter III - Equation (3) described the effect of lead prices (in $/lb Pb) on battery cost (FOB) as:

$$C_3 = 50.60 + 80.75 \text{ (\$/lb Pb)} \qquad \text{Equation (2)}$$

where,

C_3 = specific cost of the battery component, $/kWh ac.

This relationship translates into the impact on battery storage viability as depicted in Figure VI-10. The lead price assumed in the baseline analysis was $0.34/lb resulting in an overall battery system cost of $140/kWh. Lead prices for the middle of November, 1980 are approximately $0.43/lb or 27 percent higher. However, the lead price increase raises the battery system cost by only 5 percent - from $140/kWh to $147/kWh. Lead prices at $0.80/lb or nearly double the present price level, increase battery system costs by $37/kWh or 26 percent.

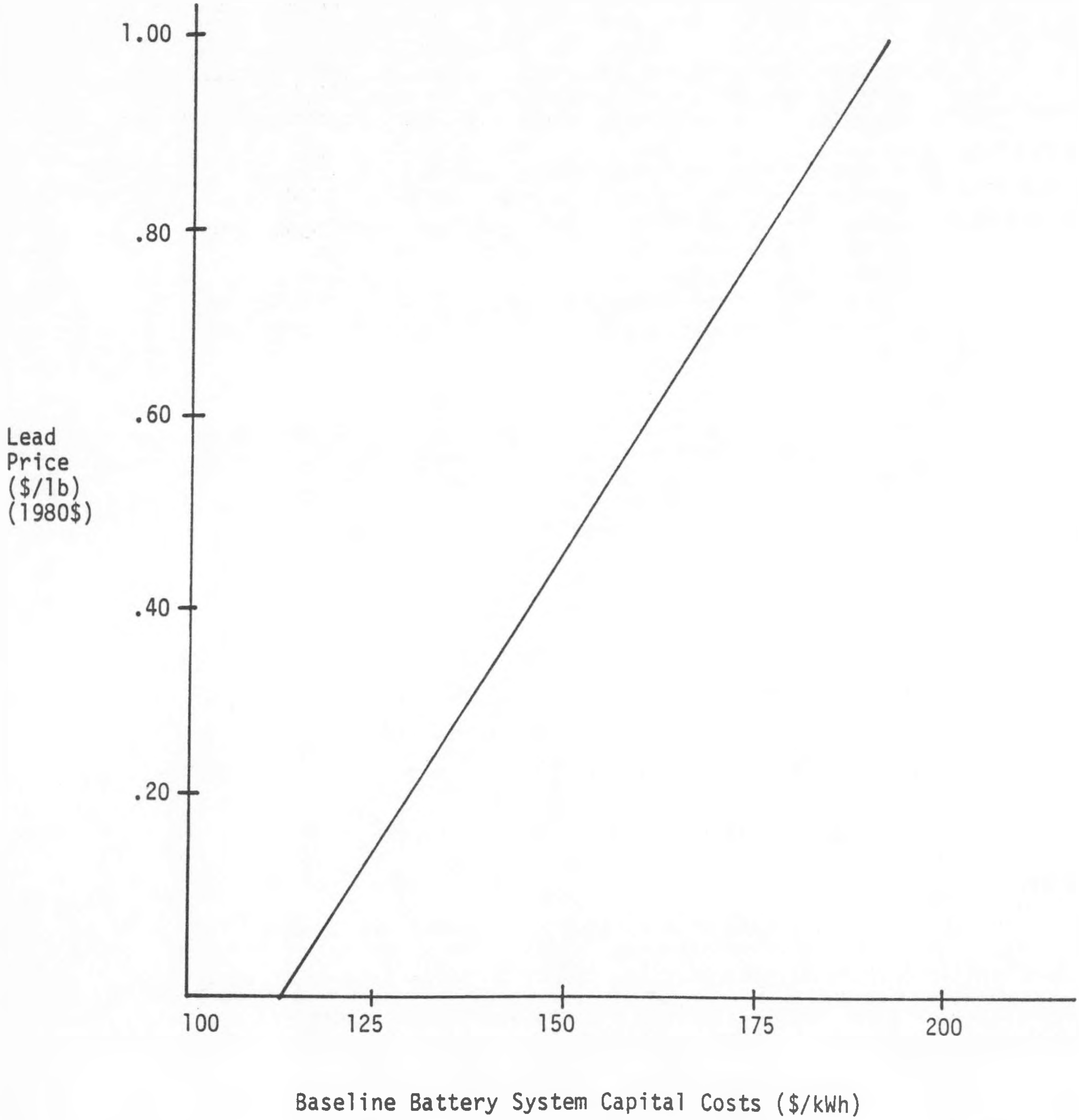

FIGURE VI-10. IMPACT OF LEAD PRICES ON BATTERY SYSTEM CAPITAL COSTS

Note that any lead prices recorded beyond mid-1980 should be reduced to correct for inflation effects beyond the baseline system cost estimates which are in mid-1980$.

The overall conclusion for this sensitively analysis is that while lead prices may continue to vary widely, the net impact on battery storage viability using baseline estimates is less than 10 percent for a price level less than $0.52/lb. The price impact could be reduced even further if battery manufacturers were to secure long-term contracts for their lead supplies.

Investment Tax Credit

The baseline battery system cost analysis assumes that batteries could qualify for a 20 percent tax credit. This assumption is based upon the normal business investment tax credit of 10 percent combined with the energy investment tax credit of 10 percent. Residential applications could only qualify for a 15 percent energy tax credit. Altough not specifically mentioned in the energy tax credit legislation, it appears that promotion of battery storage systems through the tax credit incentives would be consistent with the intent of the regulations. However, depending on the Treasury's interpretation of the regulation and on subsequent action by Congress, there could be the possibility that neither the business nor residential applications would qualify for the energy investment tax credit. If they do not qualify for the energy investment tax credit, then business applications could utilize the normal investment credit of 10 percent, while residential applications would have no investment tax credit inventives.

Shown in Table VI-7 are the impacts of investment tax credits at levels lower than the 20 percent assumed in the baseline system. Because there is a one-to-one correspondence between the total investment tax credit reduction and the level of the breakeven differential, incorporation of the 20 percent tax credit will decrease the breakeven differential by 20 percent, (.066-.053)/.066. In order to enhance the feasibility of battery storage systems, it is important to facilitate qualifying battery systems for the energy investment tax credit.

TABLE VI-7. INVESTMENT TAX CREDIT ANALYSIS

	Breakeven Differential	Normalized Breakeven Differential
Base Case (Total Investment Tax Credit - 20%)	.053	1.00
Total Investment Tax Credit - 15%	.056	1.06
Total Investment Tax Credit - 10%	.059	1.12
Total Investment Tax Credit - 0%	.066	1.25

Scaling Factors

In the battery system cost and performance analysis two scaling factors were used to cost equipment sizes other than those employed in the baseline system. In Chapter III the factors F_2 and F_5 represented the scaling formulas for the power conditioning equipment (Equation 16) and battery equipment (Equation 19), respectively:

$$F_2 = \left(\frac{20,000}{P_d}\right)^{0.028}$$

$$F_5 = \left(\frac{100,000 \cdot V_m}{P_d \cdot t_d \cdot 1505}\right)^{0.075}$$

where, V_m = minimum battery voltage, volts dc

P_d = maximum discharge power output, kW ac

P_c = maximum charge power, kW ac

t_d = rated discharge time, hours

Sensitivity analyses were conducted on both scaling factors at plus/minus 50 percent. The impact of these changes on the initial capital costs of the battery system and on the breakeven rate differential are displayed in Table VI-8.

The results indicate a fairly minor impact of the scaling factors considering they were adjusted by 50 percent. Naturally, there was no impact for the 20000 kW system design because it served as the base size in deriving the scaling factors. The impacts reached approximately 8 percent, 12 percent, and 18 percent on the 1000 kW, 40 kW, and 2 kW system designs, respectively. The only impact at a significant level is the impact on the 2 kW residential system. However, based on the conclusions made in other sections, the residential application could have difficulty in achieving widespread application even with an 18 percent reduction in life-cycle costs due to more favorable scaling factors.

TABLE VI-8. SENSITIVITY ANALYSIS OF SCALING COEFFICIENTS

System Size (kW)	Power Conditioning Scaling Coefficient		Battery Scaling Coefficient	Initial Battery System Capital Costs ($/kWh)	Breakeven Rate Differential ($/kWh)	Normalized Breakeven Differential
20000	.028	(baseline)	.075	140	.053	1.00
20000	.014		.0375	140	.053	1.00
20000	.042		.1125	140	.053	1.00
1000	.028	(baseline)	.075	162	.061	1.00
1000	.014		.0375	150	.056	0.93
1000	.042		.1125	174	.066	1.09
40	.028	(baseline)	.075	194	.074	1.00
40	.014		.0375	173	.065	0.89
40	.042		.1125	221	.084	1.13
2	.028	(baseline)	.075	241	.093	1.00
2	.014		.0375	202	.078	0.84
2	.042		.1125	300	.112	1.21

Peak Period Durations

In Chapter IV on Regulatory Issues and Rate Schedules the following formula was derived to assess the demand charge savings potential under time-of-day rate schedules (Equation 5):

$$\text{Demand charge savings} = \frac{\left[(D_p) - \frac{P_c}{P_d} \cdot (D_f)\right]}{t_d \cdot d \cdot w}$$

where,

P_c = maximum charge power (ac basis)

P_d = maximum discharge power (ac basis)

D_p = on-peak demand charge \$/kW-month

D_f = off-peak demand charge \$/kW-month

d = number of cycles per week = number of days in a week in the peak period

w = average number of weeks per month less holidays = (50 working weeks per year)/(12 months per year) = 4.166

The maximum charge power to discharge power ratio (P_c/P_d) gave recognition to the situation in which maximum peak period duration was so long that the maximum charge power had to exceed the maximum discharge power in order to fully charge the battery system in a short amount of time. For a time-of-day duration of 16 hours, a discharge period of 12 hours, and a charging period of 5 hours, this ratio equals 2.72. In Chapter IV it was noted that even though such extended time-of-day peak period durations are infrequent, they would not exert much effect on the rate differential anyway because the off-peak demand charge (D_f) is typically low or nonexistent. This same charge power/discharge power issue also affects battery system cost estimates. The size of the power conditioning equipment must be increased when the charging power greatly exceeds the discharging power. Naturally, this cost increase only affects the power conditioning equipment and not the other components in the battery system.

Factor F_3 from Chapter III, Equation (28), determines these relative cost increases:

$$F_3 = \frac{1}{0.981\ t_c - \frac{0.216}{t_d}} \qquad \text{for } \frac{P_c}{P_d}\eta_r \cdot \eta_i \geq 1$$

$$= 1.0 \qquad \text{otherwise}$$

where,

t_c = time for initial constant current charge, hours

t_d = time for constant power discharge, hours

η_r = converter efficiency in rectification mode

η_i = converter efficiency in inverter mode

The relative impact of various peak period durations is displayed in Table VI-9. The results show that the peak period duration has less than 4 percent impact on battery system costs in all but the 16-hour peak period duration case. Therefore, for the range of peak periods that are generally applied in practice (14 hours or less) and for the range of discharge periods that seem to have any potential viability (8 hours or less), the time-of-day peak period duration has little impact. The relative impacts of other combinations of discharge periods and peak period durations are substantially higher than those for the above ranges.

TABLE VI-9. IMPACT OF TIME-OF-DAY PEAK PERIOD DURATIONS ON BATTERY STORAGE VIABILITY AS PROPORTION OF BATTERY SYSTEM COSTS WITH NO CHARGING POWER CONSTRAINTS

System Size (kW)	Discharge Period = 16 hours TOD Peak Period=Duration (hours) 16	Discharge Period = 12 hours TOD Peak Period=Duration (hours) 16	 14	 12	Discharge Period = 8 hours TOD Peak Period=Duration (hours) 16	 14	 12	 10
20000	1.16	1.12	1.08	1.04	1.06	1.02	1.00	1.00
1000	1.15	1.11	1.07	1.03	1.06	1.02	1.00	1.00
40	1.19	1.18	1.13	1.09	1.10	1.03	1.00	1.00
2	1.20	1.23	1.16	1.14	1.13	1.04	1.00	1.00

CUSTOMER ATTRIBUTE EVALUATION

The primary attributes that determine battery storage viability such as the level of demand charges and the length of the discharge period were extensively described in Chapter IV, Regulatory Issues and Electric Rates, and evaluated in previous sections of this Chapter.

Additional attributes were identified during the technical, institutional, and market assessment activities of this research. After identification, research was conducted to ascertain: (1) whether the attribute was important in determining battery storage viability, and (2) whether the attribute could be quantified and incorporated into the economic analysis.

In many cases, the customer attributes are simply dichotomous characteristics. For example, some customers could have the attribute of being able to utilize the waste heat generated by the battery system. For others, qualitative assessments have been prepared and are included in the Market Assessment Chapter. In the following sections of this Chapter, appropriate attributes are assessed as to their relative importance. Where the attribute has been described in a previous Chapter, it is simply evaluated in this Chapter. While for others, the attribute has not been addressed previously, and it is therefore described and evaluated in this chapter.

Uninterruptible Power Supply

There are many potential users of customer side battery storage who have the attribute of requiring an uninterruptible power supply (UPS). These customers are predominantly in the commercial and industrial classes. The UPS requirements range from computer and medical life support equipment to lighting and security power needs.

The question of concern regarding UPS systems is: Can customer owned battery systems for load leveling purposes also fulfill the UPS requirements of some customers? Given an affirmative answer, a customer with a battery system designed for load leveling could fill their UPS requirements for a minimal incremental cost. This requirement could then be counted as an added benefit for the customer owned battery storage system.

UPS's are generally classified into two categories, those that are "on line" continuously and those that are only activated when the main power supply is interrupted. Systems for computers and life support purposes are normally of the former type, while those for lighting and security purposes are of the latter type.

Continuously "on line" UPS's generally serve the dual function of power backup and electric power filtering and cleaning. (Filtering and cleaning of electric power eliminates most of the "electrical noise" of grid supplied power before it is fed to the specific power needs.) Due to the very exact power needs of computer and life support equipment, a very short (fraction of a second) interruption of power is unacceptable. Therefore, the UPS system is continuously on and supplying power to the equipment to supply clean, filtered power and uninterrupted service. This continuous nature is required because current technology power transfer switches will not switch power supply from the main power supply to the battery backup quickly enough. Therefore, customer owned batteries for load leveling cannot presently also meet these UPS requirements.

If faster power transfer switches are developed, cost savings could be realized by the load leveling system also serving the UPS requirements. To evaluate the impact of such a development representative costs of UPS systems are required. From conversations with a UPS manufacturer's representative (Exide), the following estimates were obtained:

- A typical small system presently costs about $40,000 (1980 $'s) for a 30 kVA, 24 kW system with 15 minutes of battery backup. This short duration backup allows for the orderly shutdown of affected equipment.
- A typical large system presently costs about $220,000 (1980 $'s) for a 500 kVA, 400 kW system with 15 minutes of battery backup.

To evaluate the potential impact of this dual use of load leveling batteries we have evaluated a 24 kW and a 200 kW system. The first is typical of a small computer facility while the second is the level of power required for a large main frame computer system. This evaluation, of course, assumes faster transfer (from grid to battery backup) mechanisms become available.

Table VI-10 shows that the cost savings of this dual use of the load leveling batteries will have an increasing economic impact as the load leveling battery systems get smaller and/or the replaced UPS gets larger. This is to be expected and merely says that as the cost of the replaced UPS becomes a larger percent of the load leveling battery system cost, it increasingly improves economic viability. However, the potential impact is rather limited as shown in the last line of the Table where the UPS size is fully 20 percent of the load leveling battery system. The rate differential is only reduced by 13 percent and significant operational constraints would be placed on the load leveling function so that power was always available for the UPS system.

UPS systems that are purely backup systems for lighting and security can be supplied from batteries "sitting on the shelf" because short (fractions of a second) power interruptions are acceptable. Therefore, customer owned battery systems could supply this requirement if they were operated in a mode that always allowed for additional discharge during power interruptions. To evaluate the impact on battery system viability of this category of UPS system, cost estimates for this category of UPS system were also acquired from a manufacturer's representative (Exide).

Very small UPS systems are typically used in small business establishments or homes. These systems supply power to a few lights and perhaps a security system for up to one day. The power needs are minimal and the costs of the UPS system are only one to two hundred dollars. Therefore, the impact on system viability is minimal.

Larger UPS systems that may be used in nursing homes, office buildings, schools, large stores, etc., are comprised of a power module and batteries. The power is generally for minimal useful lighting requirements and other uses that are considered essential to continued operation. Costs (1980 $'s) for a 5 kW system range from $13,000 for a one half hour power supply to $18,000 for a four hour power supply. Larger systems are typically supplied as modules of these with correspondingly higher costs. The relatively low cost for these backup systems means there is very little improvement in economic viability when combined with a load leveling battery system.

TABLE VI-10. UNINTERRUPTIBLE POWER SUPPLY EVALUATION

Battery Size (kW)	UPS Size (kW)	Rate Differential without UPS Credit	Rate Differential with UPS Credit
20000	24	.053	.053
	200	.053	.053
1000	24	.061	.058
	200	.061	.053

Waste Heat Utilization

The rising cost of energy, as well as environmental regulations with regard to atmospheric and thermal pollution, have created an incentive for energy conservation in the United States. One method for conserving energy is to use heat which has been discharged from some conversion mechanism or industrial process. The waste heat from batteries must be evaluated from the perspective of energy conservation and for the potential for increased economic viability for the customer owned battery system.

The waste heat discharged from battery systems considered for demonstration (lead-acid), is of a low temperature, 60 to 80°F. Economic use of this low quality energy source is very restricted by limited potential market applications and by the additional costs required to use the energy.

Space heating use is an obvious first choice application. However, limitations preclude this use, except in unique applications. The waste heat would have to be extracted from the battery system via a heat exchange mechanism. The reduction in temperature during the heat exchange process generally reduces the temperature below normal space heating temperatures. This temperature reduction, together with the cost additions of the necessary equipment, preclude the space heating applications.

Other potential applications are similarly restricted. For example, there are some industrial processes that require hot water at <100°F. The potential applications for this quality of process energy is extremely limited. One survey conducted by Battelle indicated process heat requirements in the U.S. at more than 7800 x 10^{12} Btu/year while only 26 x 10^{12} Btu/year were required at less than 100°F. These extremely limited applications, coupled with the impact of a heat exhanger (reduced temperature and increased cost), preclude the utilization of this low temperature waste heat source.

Some advanced battery systems will produce higher temperature/higher quality waste heat. As these technologies are developed, a further evaluation should be made of the benefits that may be derived from utilization of the waste heat.

In either the near-term or advanced battery systems, the benefits associated with the utilization of the waste heat would be limited by the

the relative inefficiency of the battery system. Even with 100 percent heat exchanger efficiency, benefits of possible waste heat utilization would be limited to:

$$\frac{F}{1 - E} - C$$

where, F = Price of the fuel eliminated by the use of waste heat

E = Battery storage system efficiency

C = Levelized capital and operating cost of the waste heat utilization equipment, $/kWh.

Because of the substantial capital investment in heat exchange equipment required to utilize the waste heat, and because of the low-grade quality of the waste heat produced by lead-acid batteries, no waste heat credit can be assigned to lead-acid battery storage under present conditions. Advanced battery system impacts may be larger and should be evaluated as their operating characteristics become clear.

Customer Use of DC Electricity

In the United States most users of electricity are employing the ac power directly for such uses as lighting, space conditioning, industrial machinery, etc. However, in a few industries some of the ac power consumed is rectified to dc by the industry for use in their processes. Industries where significant amounts of dc electricity are used are:

SIC 2812	Alkalines and Chlorines
SIC 2813	Industrial Gases
SIC 3313	Electrometallurgical Products
SIC 333	Primary Nonferrous Metals
SIC 3341	Secondary Nonferrous Metals
SIC 3471	Fabricated Metal Products.

Where this dc requirement exists there could be customer-side battery storage system economies through the direct use of battery discharge current without inverting back to ac power. The economies of such a system could come about through the reduced capital expenditure for the power conditioning component of the system and through increased energy conversion efficiencies through the absence of inverting back to ac.

The level of reduction in power conditioning costs depends upon the mode of operation of existing rectification equipment owned by the user. Dc equipment use mode, in turn, determines the rectification operation mode. In some industries (e.g., "chlor-aklali") the dc equipment is operated 24 hours per day. Therefore, it is assumed the existing rectification equipment is at or near capacity during the normal charge times for batteries. The battery storage equipment would need its own rectification. The capital cost savings under this configuration would be the difference in cost between a power conditioner (rectification and inversion) and rectification alone. Capital cost savings for rectification alone are expected to amount to an approximate 10 percent reduction in power conditioning costs per our estimates prepared from several literature sources.

In other industries (e.g., electroplating) dc equipment typically is operated for one shift per day of eight to ten hours or for shorter periods (e.g., electric commuter systems). For this mode of operation the existing rectification equipment is idle during normal charging times for batteries. Significant battery storage system capital cost savings can be realized here due to the presence of all the necessary power conditioning equipment. Thus, the power conditioning capital cost component becomes zero. (Some small increases in balance of plant costs may result from increases in interface equipment and regulation of battery discharge requirements.)

In addition to these power conditioning capital cost savings, an increase in battery storage system efficiency will be realized because the power is not inverted to ac. A five percent increase in system efficiency is expected to result from the absence of the inverstion requirement based upon a review of pertinent literature.

To assess the most advantageous situation, the mode of operation with excess rectification equipment available for charging load leveling batteries has been evaluated. The evaluation assumes there are no power conditioning capital costs associated with the installation of a load leveling battery system. Table VI-11, Power Conditioning Cost Sensitivity Analysis-DC Application, displays the impact.

In the most likely applications, the impact on rate differentials required is on the order of a ten percent decrease. However, for applications where short discharge periods exist (three hours) there are potential decreases in the breakeven rate differential ranging up to 25 percent.

Consumer Owned Electric Generation

Consumers of electricity generally rely on the power grid for 100 percent of their electricity needs. Within some groups of electricity consumers there are individual firms that self-generate some of their electrical requirements. Examples include:

- SIC 2611 Pulp Mills
- SIC 28 Chemicals
- SIC 29 Petroleum and Coal Products
- SIC 33 Primary Metals
- Misc. Railroads, Pipelines, etc.

TABLE VI-11. POWER CONDITIONING COST EVALUATION DC APPLICATION

Battery Size (kW)	Discharge Period (Hours)	Rate Diff. With PC ($/kWh)	Rate Diff. Without PC ($/kWh)
20000	8	.047	.042
	5	.053	.044
	3	.064	.048
1000	8	.054	.048
	5	.061	.052
	3	.072	.056
40	(Not Applicable)		
2	(Not Applicable)		

Where self-generation supplements the power grid electricity, there are several factors that influence the impact of self-generation on battery storage. These factors are the mode of operation for the self-generation, the electricity load shape of the user, the magnitude of the self-generation relative to the user's electricity requirements, present or potential use of self-generation for cogeneration, and the cost of the self-generated power relative to the off-peak grid supplied power cost. These factors are each complex; each influences the others; and, most importantly, all are facility-specific. An in-depth evaluation of these factors is beyond the scope of this project and is best undertaken on a facility-by-facility basis.

However, keeping in mind the thrust of this evaluation, identifying potential benefits to battery storage viability, a few generalizations can be stated. First, self-generation must be less than total electrical requirements during most week days of the year. This is necessary to spread the capital cost of the battery system over as many kWh's as the capacity of the battery system allows. Second, when self-generation costs are greater than off-peak grid costs, there will be no added benefit to the battery system due to the presence of self-generation. Third, when self-generation costs are less than off-peak grid electric costs, an in-depth analysis of the mode of operation of self-generation and the specific facility is required to determine if added benefits can be derived to increase the viability of battery storage.

On this last point a rough estimate of the potential impact has been made. Self-generation is likely to be significantly less than off-peak grid costs only where there is essentially no fuel cost, (e.g., hydroelectric or wood waste). In these cases the difference in self-generated electricity and off-peak grid costs may approach one cent per kWh. The resulting impact on the rate differential for breakeven is a decrease of from 10 to 20 percent. Thus, the presence of self-generation could, in some rather specific cases, improve battery system viability significantly.

Conservation of Scarce Fuels

Energy conservation together with increased domestic petroleum production are the two general approaches being used to reduce our dependence on foreign petroleum supplies. As such, conservation of scarce fuels is a primary objective of energy policy in the United States. During 1979 about 28 percent, or 620 million kWhrs, of the electricity generated used oil or natural gas as a fuel source.(3) Many routes are being used to reduce this consumption, including fuel switching at the generator and selected load management directed at consumption.

Battery storage can contribute to a reduction in scarce fuel consumption for generation if battery charging is supplied by non-scarce fuel generation, and if it replaces scarce fuel generation during discharging. There are many possible ways this fortuitous combination could occur. However, this combination will generally only occur when coal and nuclear is used for base generation and petroleum products are the primary fuel used for peak and shoulder-hour intermediate generation.

However, scarce fuel savings is not an important attribute from the customer's perspective merely because they are located in a utility service area that has this combination. Very few customers will install battery storage solely because it conserves scarce fuels. An economic incentive must be given to the customer, thereby reflecting the benefits of conservation. This economic incentive would be reflected in the schedule of rates paid by the customer. Where time-of-day rates reflect actual costs on a time differentiated basis (reflecting higher cost of petroleum fired peak vs. the lower cost of coal/nuclear base), the pricing signal to the customer will reflect the national objective of reducing scarce fuel consumption. Thus the scarce fuel savings attribute is reflected in the rate differentials employed in this project. Time-of-day rate structures reflecting geographic locations of electric utilities with the desired generation combination are discussed in Chapter IV.

VI-(3) 1980 Summary of Projected Peak Demand Generating Capacity and Fossil Fuel Requirements, National Electric Reliability Council (July 1980).

CONCLUSIONS

The economic evaluation associated with battery storage systems is fairly complex due to the many possible factors that could impact their viability. Throughout the study, effort was made to identify the most important of these attributes. The factors listed below are organized according to the Chapter VI section in which they appear:

- Base Case Analysis
  - Battery System Size
  - Battery System Cost
  - Electricity Costs
  - Discharge Period Duration
- Sensitivity Analyses
  - Timing of Replacement Batteries
  - Discount Rates
  - Lead Prices
  - Investment Tax Credits
  - Scaling Factors
  - Peak Period Durations
- Customer Attribute Evaluation
  - Uninterruptible Power Supply
  - Waste Heat Utilization
  - Electricity Consumer Owned Generation
  - Conservation of Scarce Fuels.

The overall economic results are presented in Table VI-12. They indicate that assuming a 3¢/kWh energy charge, a demand charge of between $6/kW and $7/kW is required to breakeven with a five-hour, 20,000 MW battery storage system. The breakeven demand charge level increases to between $7/kW and $8/kW for the five-hour, 1000 kW system. The battery system capital cost levels decrease by roughly 10 percent and 20 percent for eight-hour and twelve-hour battery systems, respectively, and increase by roughly 20 percent and 40 percent for three-hour and two-hour battery systems, respectively. This increase in unit capital costs for shorter discharge periods is more than compensated for by the increase in the rate differential associated with demand charge levels in excess of $4/kW. Therefore, at demand charge levels high enough to support battery systems, the shorter the discharge period, the greater viability of battery storage. Naturally, for those time-of-day rates that do not include an off-peak demand charge savings, the longer

TABLE VI-12. SUMMARY ECONOMIC EVALUATION

System Description	Demand Charge Level Required to Breakeven ($/kW)*
20000 kW System (Baseline Assumptions)	$ 6.60
8-Hour Discharge Period	10.60
3-Hour Discharge Period	4.00
Capital Costs Based on Technology Goals	3.50
Increase Lead Prices from $.34/lb to $.80/lb	8.30
1000 kW System (Baseline Assumptions)	7.50
8-Hour Discharge Period	12.00
3-Hour Discharge Period	4.50
Capital Costs Based on Technology Goals	3.80
40 kW System (Baseline Assumptions)	8.80
8-Hour Discharge Period	14.20
3-Hour Discharge Period	5.30
Capital Costs Based on Technology Goals	4.60
2 kW System (Baseline Assumptions)	10.70
8-Hour Discharge Period	17.40
3-Hour Discharge Period	6.50
Capital Costs Based on Technology Goals	6.00

* Assumes an energy charge level of 3¢/kWh.

discharge periods will achieve greater battery storage viability. At present, baseline battery storage systems are viable for selected utilities and for selected discharge periods.

Residential battery systems of 2 kW size are 67 percent more costly on a unit basis than the 20,000 kW systems. For this reason and for the reason that there appears to be no corresponding premium in rate differentials associated with residential rate schedules, battery system viability is greater for the larger size systems. On the other hand, although the viability is greatest for the short discharge period, 20,000 kW battery system, there appears to be few companies with those battery requirements. Therefore, the greatest battery storage attractiveness lies in the middle ranges-medium size batteries in commercial and industrial applications.

Achievement of the DOE development goals will significantly improve battery storage viability by lowering unit costs from baseline levels by more than 50 percent. For battery systems in the 1000 kW category, there are presently eight utilities offering traditional rate schedules that could support five-hour battery storage systems with baseline costs and performance. The number increases to 46 utilities if the technology development goals are achieved. The market penetration would increase even further if electricity prices were to increase in real terms.

The sensitivity analyses indicated that:

- Additional battery replacements beyond the first one did not significantly impact the viability of battery storage (less than 10 percent).
- Large differences between the baseline discount rate and the rate that is used by firms to evaluate battery storage viability could significantly impact the viability of battery storage.
- Increase in lead prices up to $0.52/lb can be absorbed without significantly impacting the viability of battery storage.
- Investment tax credits at the 20 percent level certainly improve battery storage viability and should be evaluated as to their applicability to battery storage systems.
- Changes of 50 percent in the scaling factors used in costing the power conditioning and battery equipment do not significantly impact battery storage viability.

- The duration of the time-of-day peak period does not affect either battery costs or the rate differential calculations for typical ranges of peak period durations and for required discharge period durations.

- None of the additional customer attributes identified appear to exert a significant impact on a widespread scale.

CHAPTER VII. CUSTOMER CLASS MARKET POTENTIAL IDENTIFICATION AND EVALUATION

INTRODUCTION

This Chapter describes the conduct and results of an identification and evaluation of the market potential of customer-owned battery storage systems among various generic customer classes in the industrial, commercial and residential sectors.

The purpose of this examination of market potenital is two-fold. The primary purpose is to determine which general classes of customers have the types of characteristics which would most likely cause them to seriously consider and implement customer-owned battery storage systems. Secondarily, the results of such an examination are intended to contribute to a systematic strategy for the selection of specific customers for participation in a demonstration of the viability of such battery storage systems.

In keeping with these purposes, the methodology employed for market potential identification and evaluation does not specifically measure or predict absolute market penetration. Instead, a comparative assessment is made, resulting in a ranking or grouping of customer classes according to their relative market potential.

Definitions

Customer Classes

The customer classes employed are generic customer types rather than specific customers. Table VII-1 displays how individual customer classes are placed within industrial, commercial, residential, and miscellaneous categories. In nearly all cases, the Standard Industrial Classification (SIC) Codes are used to identify individual customer classes. Customer classes are most frequently displayed at the three-digit SIC Code level; two-digit Codes are used for customer classes which would show a comparatively small amount of electricity

TABLE VII-1. LIST OF CUSTOMER CLASSES

SIC Descriptor	Industrial Customer Classes
201	Meat products
202	Dairy products
203	Preserved fruits & vegetables
204	Grain mill products
205	Bakery products
206	Sugar, confectionary products
207	Fats, oils
208	Beverages
209	Miscellaneous food products
21	Tobacco products
221	Cotton weaving mills
222	Manmade fiber weaving mills
223	Finishing mills
224	Narrow fabric mills
225	Knitting mills
226	Textile finishing (excluding wool)
227	Floor coverings
228	Yarns, threads
229	Miscellaneous textiles
23	Apparel, other textile products
24	Lumber and wood products

TABLE VII-1 (continued)

SIC Descriptor	Industrial Customer Classes (continued)
25	Furniture and fixtures
261	Pulp mills
263	Paperboard mills
264	Miscellaneous converted paper products
265	Paperboard containers and boxes
266	Building paper and board mills
27	Printing and publishing
2812	Alkalines and chlorines
2813	Industrial gases
2816	Inorganic pigments
2819	Other organic chemicals
282	Plastics, materials, synthetics
283	Drugs
284	Soaps, cleaners, toilet goods
285	Paint and allied products
286	Industrial organic chemicals
2873	Nitrogenous fertilizers
2874	Phosphatic fertilizers
2875	Mixing fertilizers
2879	Other agricultural chemicals
289	Miscellaneous chemical products

TABLE VII-1. (Continued)

SIC Descriptor	Industrial Customer Classes (continued)
291	Petroleum refining
295	Paving and roofing materials
299	Miscellaneous petroleum and coal products
30	Rubber, miscellaneous plastic products
31	Leather and leather products
32	Stone, clay and glass products
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire and related products
3316	Cold finishing steel
3317	Steel pipes and tubes
332	Iron and steel foundries
3331	Primary copper
3332	Primary lead
3333	Primary zinc
3334	Primary aluminum
3339	Other primary metals
334	Secondary nonferrous metals
335	Nonferrous drawing and rolling
336	Nonferrous foundries
339	Miscellaneous primary metals production

TABLE VII-1. (Continued)

SIC Descriptor	Industrial Customer Classes (continued)
34	Fabricated metal products
35	Machinery, excluding electrical
36	Electrical, electronic equipment
37	Transportation equipment
38	Instruments and related products
39	Miscellaneous manufacturing
	Commercial Customer Classes
Commercial, office, public buildings (SIC 60-67, 73, 801-804, 808, 81, 83, 86, 89, 91-97)	
Retail (SIC 52-59, 72, 76)	
Wholesale (SIC 50, 51)	
Schools/Colleges (SIC 821, 822, 824, 829)	
Health (SIC 805-807, 809)	
Hotel/Motel (SIC 70)	
Miscellaneous commercial (SIC 75, 78, 79, 823, 84)	

TABLE VII-1. (Continued)

Descriptor	Residential Customer Classes
Single family detached	
Low density attached (2-4 units)	
Multifamily (5-19 units)	
Multifamily (20 or more)	
	Miscellaneous Customer Classes
01	Agricultural crop production
02	Agricultural livestock production
1011	Iron ores
1022	Copper ores
10	Miscellaneous metal ores
11	Anthracite
1211	Bituminous/lignite
1311	Crude oil/gas
13	Miscellaneous oil/gas
14	Nonmetallic minerals, except fuels
15,16,17	Construction
40, 474	Railroads, passenger and freight

TABLE VII-1. (Continued)

Descriptor	Miscellaneous Customer Classes (continued)
41	Local, suburban, intercity transit
42, 473	Motor freight, warehouse operations
44	Water transport
45	Air transport
46	Pipelines
47	Transport services except 473 and 474
	Non-generating rural electric cooperatives
	Eight percent sample of non-generating municipals

consumption at the three-digit level, while four-digit Codes are used in instances when electricity consumption would be very large when displayed and aggregated at the three-digit level.

Market Potential

Market potential refers to the degree to which the individual customer classes show a potential for the commercialization of state-of-the-art lead acid, customer-owned battery storage systems. This potential is determined by market potential characteristics which are used to evaluate each customer class.

MARKET POTENTIAL CHARACTERISTICS

The market potential characteristics (MPC) described in this section were identified by all members of the project team, on the basis of each member's knowledge and expertise, augmented by a review of pertinent reports and other documents from Battelle's Battery Storage Library. Each MPC thus identified was carefully defined and described, and a ranking scheme was developed to allow each customer class to be evaluated for each MPC. Each MPC and its associated ranking scheme is described below.

A total of eighteen MPC's is presented. Of this number, four MPC's are considered to be major characteristics which may spur the commercialization of battery storage systems:

MPC No. 1: Receptivity to battery storage systems
MPC No. 2: Post-demonstration diffusion potential
MPC No. 3: Load shape
MPC No. 4: Location

The remaining MPC's, Numbers 5 through 18, are considered to be characteristics which may further enhance commercialization:

MPC No. 5: Insurability
MPC No. 6: Need for peak shaving
MPC No. 7: Cost of capital

MPC No. 8: Ability to handle dangerous materials

MPC No. 9: Ability to isolate/monitor battery storage systems

MPC No. 10: Applicability of use restrictions

MPC No. 11: Potential for building code restrictions

MPC No. 12: Profitability

MPC No. 13: Importance of standby power

MPC No. 14: Familiarity with battery storage systems

MPC No. 15: Presence of self-generation

MPC No. 16: Direct current use

MPC No. 17: Availability of time-differentiated rates

MPC No. 18: Availability of interruptible rates.

MPC No. 1: Receptivity to Battery Storage Systems

Whenever an innovative product or idea is offered in the marketplace, it is tried by some and rejected by others. This will also be the case with the concept of battery storage on the customer's side of the meter.

In an attempt to predict the likelihood with which certain customer classes will be receptive to the battery storage idea, the following rationale was developed: customer classes will have a potentially high receptivity if two conditions prevail:

(1) Their cost of electricity is a major component of their total expense for operations.

(2) They operate on a slim profit margin.

If such customers could reduce their cost of electricity (e.g., through off-peak battery storage), many could effect a reduction in the cost of their products and services. This would enable such customers to operate on a more comfortable profit margin, and/or be more competitive in the market. Under these conditions, it is more likely that a customer would be interested in the battery storage concept, and in participating in the battery storage demonstration program.

Accordingly, customer class receptivity has been ranked on a scale of "1" to "5". Those customer classes with a rank of "1" exhibit the highest ratios of cost of electricity per measure of economic activity* (CE/EA), and the smallest ratios of net profit on net sales (NP/NS), and are therefore the most likely to try battery storage. Customer classes with progressively higher rankings - from "2" to "5" - have an increasingly lower CE/EA and an increasingly higher NP/NS. This makes such customers less likely to try the battery storage concept. Specifically, these rankings were established as follows:

First, customer classes with a CE/EA of five percent or greater were identified and rank ordered, with those having the highest percentages ranked highest (e.g., first or second.) (Those with a CE/EA of less than five percent were placed last, and not otherwise rank ordered).

Second, those customer classes having a CE/EA of five percent or greater were rank ordered also according to their NP/NS ratio. Those showing the lowest NP/NS were ranked highest, (e.g., first or second).

Subsequently, a "score" was developed for each customer class. This score was the sum of the two rank ordered scales. For example, a customer class with a rank order of six in the CE/EA scale, and with a rank order of 12 in the NP/NS scale would have a combined score of 18. These scores were then placed within a scale of 1-5 as follows:

1 = Combined score of CE/EA and NP/NS of less than 10

2 = Combined score greater than 10 but less than 20

3 = Combined score greater than 20 but less than 30

4 = Combined score greater than 30 but less than 40

5 = Combined score greater than 40.

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* For industrial and miscellaneous customer classes, the measure of economic activity used is value added. For the commercial sector, operating costs were used, and residential economic activity was based on average income of primary wage-earners (See Appendix B: "Customer Class Baseline Data".)

MPC No. 2: Post-Demonstration Diffusion Potential

An important and desirable consequence of the battery storage demonstration program is the rapid and widespread customer acceptance of the off-peak storage concept. It is therefore preferable to include those types of customer classes in the demonstration that can subsequently influence or affect the diffusion of battery storage in the marketplace.

Industrial Diffusion

In the industrial sector, it is generally true that the actions of the largest companies influence the actions taken by the smaller members of that particular industrial customer class. Assuming, therefore, that one or more large "leaders" can be found in each customer class to influence others, those customer classes containing large numbers of other smaller but similar industrial establishments are more preferable for diffusion than industrial classes containing only a few establishments. Large establishments - such as corporations with facilities throughout the United States - have in themselves a great potential for internal diffusion. However, they may also be equally potent barriers to diffusion, since a decision not to use battery storage would be implemented throughout all corporate facilities. In those industrial customer classes where several large companies representing separate but similar establishments are found, the likelihood of diffusion is therefore greater, since one or more of them may decide in favor of battery storage systems.

Commercial Diffusion

In the commercial sector, customer classes which generally contain "chain" establishments (e.g., fast food restaurants, department stores, variety stores) are more preferable than those made up of singular establishments. Chain organizations can readily replicate one successful installation in other locations. It must be recognized that chain organizations may be diffusion barriers in the same manner as large corporations: if an installation is not successful, it won't be tried elsewhere. However, chain organizations in the commercial sector are more frequently regional or statewide - and only a few are nationwide or international. Thus a decision not to implement battery storage has only a limited effect, and the barriers to diffusion within commercial chains are thus outweighed by the incentives to diffusion.

Residential Diffusion

In the residential sector, diffusion may be greater and more rapid among the considerably greater number of single family homeowners than among owners of the relatively fewer multifamily rental establishments. Multifamily units are generally owned by local companies who are conservative and may lack innovative spirit. In the single family home class the "keeping up with the Jones'" mystique still prevails: if one person successfully tries battery storage, the neighbors are likely to follow suit.

Ranking for Diffusion

The ranking for diffusion potential is also based on a scale of "1" to "5", ranging from highest to lowest potential, respectively.

The procedure for ranking industrial and miscellaneous customer classes is based on a score consisting of the actual number of separate companies in each customer class, multiplied by a factor representing the size (in number of employees) of each of the separate companies. The scores for each customer class are rank ordered, and assigned the numbers "1" to "5" as follows:

1 = Industrial and miscellaneous customer classes with a score for diffusion potential in the upper 25 percent of all customer classes

2 = Score in 25 percent-50 percent range

3 = Score in 50 percent-75 percent range

4 = Score in 75 percent-90 percent range

5 = Score in 90 percent-100 percent range.

The procedure for ranking commercial customer classes is based on a score consisting of the number of separate establishments in each customer class, multiplied by a factor representing the presence of local, regional or nationwide chains. The scores for each customer class are rank-ordered, and assigned the numbers "1" to "5" as follows:

1 = Commercial customer classes with a score in the upper 25 percent of all customer classes

2 = Score in 25 percent-50 percent range

3 = Score in 50 percent-75 percent range

4 = Score in 75 percent-90 percent range

5 = Score in 90 percent-100 percent range

The procedure for ranking residential customer classes is based on the actual number of dwelling units in each customer class, and on the previously described propensity among single family home-owners to imitate each other. The following rankings are thus achieved:

1 = All single family residential units are ranked "1" because they represent more than twice the number of residences than all other housing types combined, and because the "keeping up with the Jones'" psychology is at work here.

2 = No residential classes ranked "2"

3 = Low density (2-4 units per building) is ranked "3" because approximately 1/3 of single family units is represented. Many cooperatives or condominiums are of this density, signifying homeownership and thus a presence of the "Jones" effect.

4 = All other residential classes are ranked "4" because they represent slightly more than 10 percent of all dwelling units.

5 = No residential classes ranked "5".

MPC No. 3: Load Shape

Customer classes with different electrical energy consumption patterns (load shapes) have different incentives for employing battery storage systems for load leveling. Based on the economic evaluation in Chapter VI, the MPC for load shape is given the following ranking along the "1" to "5" scale:

1 = All customer classes which characteristically display a single shift load shape (e.g., a pronounced single peak).

3 = All customer classes which characteristically display a double shift load shape.

5 = All customer classes which show a flat, or nearly flat, load shape, characteristic of 24-hour operation.

(Because of the three-way division of the categories, none of the customer classes were given a "2" or "4" ranking for load shape).

MPC No. 4: Location

Customer classes whose members are generally located within utility service areas which have rate structures favorable to battery storage are rated "1". Those customer classes whose members are primarily located in unfavorable rate structure areas are rated "5". Those customer classes showing a generally dispersed location across the United States are ranked "3". The basis for these rankings can be found in the economic evaluation of Chapter VI.

MPC No. 5: Insurability

Many insurers are unfamiliar with the risks and hazards associated with battery storage systems. Because of this lack of experience they may be hesitant, and express some uncertainty when insurance coverage for battery storage systems is requested of them. Insurability is of concern as it may be a prerequisite for acquiring financing. The insurance industry's attitude also affects the outlook of potential users of battery storage systems.

The following ranking is used to evaluate insurability:

1 = Due to current exposure and coverage for risks similar to those to be experienced with battery storage systems, little or no modification to existing coverage will be necessary.

3 = Some modification to existing coverage will probably be necessary to insure against battery storage system risks and hazards. No difficulty is anticipated in securing coverage.

5 = A new rate structure may have to be developed to account for the risks associated with battery use. There may be some hesitancy on the part of insurers to insure.

MPC No. 6: Need for Peak Shaving Reliability of the Battery Storage System

Some customer classes frequently face demand charges if their electricity use exceeds a fixed maximum peak during any given day. A battery storage system may be an important and useful tool for such customer classes in the control of peak loads. As a result, some commercial and industrial customer classes are ranked "1", showing that they have a need for peak shaving. Those customer classes not facing demand charges are ranked "5", while customer classes for which no distinct demand charge rate pattern exists are ranked "3".

MPC No. 7: Cost of Capital

The effect of capital availability on the introduction and commercialization of energy technologies other than battery storage, such as photovoltaics, has been researched and was found not to be an issue. Nevertheless, it is included here in the form of cost of capital, as a market potential characteristic.

The cost of capital to industrial or commercial customers could potentially be at or near the prime lending rate, depending on their credit rating. Generally, the cost of capital to an individual will be higher. Therefore, industrial and commercial customers are ranked "1" and residential "5".

MPC No. 8: Ability to Handle Potentially Dangerous Materials

Potential safety and environmental hazards could become important obstacles to the use of battery storage systems by prospective user groups. For example, dangerous conditions could develop for the release of toxic gases during battery recharging, the accidental spillage of chemical compounds and acids, fires and explosions could result from the ignition of combustible gases. For each customer class, their experience with similar hazardous and explosive materials and the probability of existing facilities on the premises for handling safety and environmental hazards are rated using the following scale:

1 = Routinely handles potentially hazardous or explosive materials.

3 = Limited facilities and some previous experience in handling potentially hazardous or explosive materials.

5 = No facilities for, or previous experience in handling potentially hazardous or explosive materials.

MPC No. 9: Ability to Isolate and Monitor Battery Storage Systems

Given their potentially dangerous characteristics, battery storage systems should be located in areas having limited access in order to lessen the possibility of personal injury or property damage. In some instances, the required installation of safety and fire monitoring systems, controlled access systems, ventilation systems, and other protective measures may be viewed as a major obstacle to the purchase of battery storage systems by prospective customers. These factors relating to possible constraints in placing battery storage systems in controlled access areas and in installing safety monitoring systems are rated for each prospective class using the following scale:

1 = A controlled access area with an existing monitoring/security system is likely to exist.

3 = Opportunity likely to exist to place battery storage system in a limited access area and/or some modification of an existing monitoring/security system would be required.

5 = Limited opportunity to place battery storage system in a limited access area and the installation of a new monitoring/security system would be required.

MPC No. 10: Applicability of Use Restrictions

Various provisions of zoning ordinances, architectural controls, and other regulations enacted by local governments in the interest of public health, safety, and general welfare could potentially be a significant institutional constraint to the utilization of battery storage systems by various customer classes. Specifically, such laws may place limitations on the construction, location, or style of accessory structures, and may regulate permitted uses within identified use zones. For the most part, such local regulations are patterned after standard "model" ordinances and incorporate, to various levels of detail, specific local considerations. Early ordinances developed a hierarchy of use zones in which permitted uses were cumulative in nature with single family residences on large lots being the exclusive, highest use zone. Recent ordinances have addressed compatibility issues by establishing exclusive districts for other uses (e.g., industrial parks). Additionally, architectural and site design modifications are increasingly being used in planned unit developments and other large scale developments to achieve desired public goals. Such local ordinances remain generally less restrictive for industrial use zones and most restrictive for residential use zones. Therefore, the following scale is used to rate the significance of this potential constraint for each of the various user groups:

1 = Ordinances typically control the use of land for industrial purposes and are not likely to impose any restrictions on battery storage systems.

3 = Ordinances typically control the use of land for commercial purposes and may impose some restrictions on battery storage systems.

5 = Ordinances typically control the use of land for residential purposes and are likely to impose restrictions on battery storage systems.

MPC No. 11: Potential for Building Code Restrictions

Local building codes vary considerably between communities. Generally, provisions of electrical and mechanical codes will probably be particularly applicable to battery storage systems be specifying the types of materials and equipment that can be used or by specifying functional requirements (e.g., performance standards) such as the fire resistance capacity of various components. Such codes may also address weight limitations, ventilation requirements, space restrictions, access routes, and fire and safety systems. Alternatively, the lack of specific reference to battery storage systems or specific standards for battery storage components and systems in local building codes may: inhibit widespread commercialization of standard battery storage systems; result in variations in code interpretations by local officials; and require the establishment of a national code for battery storage systems and modification of existing laws before construction permits are issued. Therefore, the potential difficulty in complying with local building codes is rated for each customer class using the following scale:

1 = Compliance with building code standards should be relatively easy to achieve. Standardized commercially - available battery storage components can be installed to meet code specifications.

3 = Compliance with building code standards may be somewhat difficult and/or costly to achieve. Slight modifications of standardized commercially - available battery storage components will be required to meet code specifications.

5 = Compliance with building code standards is likely to be difficult and expensive to achieve. Manufacturing changes in the design and/or materials of standarized commercially-available battery storage components will be required to meet code specifications.

MPC No. 12: Profitability

Customer classes with high profitability are more likely to be able to afford a battery storage system than those with low profitability.

The profitability index is therefore ranked from "1" to "5", with "1" designating sectors with highest profitability, hence the greatest likelihood of being able to afford and invest in a battery storage system. The rank of "5" represents the sectors with lowest profitability, hence those least likely to be able to afford the investment.

This MPC is potentially in conflict with MPC No. 1 (Receptivity to Battery Storage Systems), because receptivity is in part based on the presence of a narrow profit margin. It is important to understand that these potentially opposite forces have a simultaneous influence on market potential: on the one hand, a solid profitability will make a battery storage system more easily affordable; on the other hand, it is clear that a battery storage system is most attractive only when profit margins are slim, and when the cost of electricity is a major part of total operating costs. This indicates that investment incentives may be necessary in some instances to permit some customers to purchase the battery storage systems they feel they need.

MPC No. 13: Importance of Standby Power

The value to a customer of reliable electric power (uninterrupted power source -UPS) is dependent upon their service requirements and perceived interruption losses. The perceived losses are a function of a number of independent factors including equipment design, ambient weather conditions, time of day or year, day of week, geographic location, availability of emergency back-up generation or other electric energy service such as storage batteries, and others. Besides quantifiable losses, there are other external or non-dollar costs such as impact on customer's comfort, convenience, safety-both human and other, environmental impact, and others.

The rankings for this characteristic are based on several electric power supply reliability surveys, as well as on judgement for the non-dollar costs:

1 = Cost of electrical supply interruption is a significant factor.

3 = Cost of electrical supply interruption is a factor to be considered.

5 = Cost of electrical supply interruption is minimal or unimportant.

MPC No. 14: Familiarity With Battery Storage Systems

Familiarity with battery energy storage systems might be a factor in acceptance by customers, depending on the degree of automation of the battery storage system, maintenance requirements, availability of technically trained personnel, familiarity in dealing with toxic or hazardous gases, and other factors. Lead-acid battery storage for emergency power is used in the telephone (communications) industry and also on military submarines on a large scale. Use of a zinc-chlorine hydrate battery would be of less concern in the chlor-alkali industry. Industries that are involved in electrochemical technology (e.g., large dc users) would also have a high degree of familiarity. Some industries (electric utility, chemical) would have average familiarity. Other technically oriented industries would have trained personnel for maintenance and some familiarity with small battery storage systems (e.g., lift trucks). Less familiarity is expected in the commercial and residential sectors. The following rating system is used:

1 = Very familiar with battery energy storage systems (either lead-acid or zinc-chlorine hydrate)

2 = General familiarity with electrochemical technology

3 = General familiarity with electrical technology and/or chemical technology

4 = Technically oriented industry with trained personnel

5 = Limited familiarity with technology.

MPC No. 15: Presence of Self-Generation

Some customers generate part of their electrical requirements and purchase the remainder from an electric utility. It would appear that battery storage systems might be in competition with, or supplemental to, conventional electrical generation (diesels). Whether this is a desirable or undesirable attribute will need to be evaluated in individual cases, especially in those instances where there is presently an excess of self-generated power during the off-peak period that could be used to charge the battery. For preliminary screening only two ratings are used, based on self-generation being a desirable market potential characteristic:

1 = Likely to have self-generation

5 = Unlikely to have self-generation.

MPC No. 16: Direct Current Use

Certain customer classes use direct current (dc) electricity. This may be advantageous for several reasons:

(1) The output (discharge) of the battery is dc and might be used directly

(a) No inverter (ac to dc) is needed, resulting in possible reduction of capital cost of power conditioners in battery storage systems

(b) No losses in inverter (dc to ac) operation is incurred, possibly resulting in a small increase (a few percent) in overall efficiency of the battery system.

(2) Use of dc implies the existence of ac to dc conversion equipment (e.g., rectifiers). The availability of unused rectification equipment during the off-peak battery charging period could reduce capital investment in the power conditioning portion of the battery system.

Several factors must be considered in assessing the importance of this attribute: the largest users of dc are the aluminum industry and the chlor-alkali industry. However, they operate 24 hours/day, seven days/week and do not have unused rectifier capacity if operating at 100 percent plant capacity. Plants may not always operate at 100 percent. In such instances, it may be possible to commit unused rectification equipment to battery storage systems. Other dc users are subways. Peak demands come at rush hours (morning and evening) for a few hours, and installed rectification equipment is little used in other periods. This appears to be an ideal example for minimizing the cost of power conditioners in battery storage systems. Another example of dc use is the electroplating industry where unused rectification equipment is available for one or two shift operation but not for three shift operation or continuous processes (e.g., electrogalvanizing steel).

The following rating system is used:

1 = Unused rectification equipment available during daily utility off-peak hours

2 = Unused rectification equipment available during weekend

3 = Percentage of installed rectification equipment sometimes available

4 = Uses significant amount of dc in operation

5 = Do not use significant dc.

MPC No. 17: Availability of Time-Differentiated Rates

The availability of time-differentiated rates may improve the viability of a battery storage system.

The implementation of time differentiated rates requires the use of metering that records consumption and possibly demand for electricity during specific time periods. Industrial electric consumers generally are served through metering that is adequate or easily modified for time differentiated rates. For the commercial and residential classes, new metering is generally required. The cost and availability of this metering is a potential constraint to the widespread availability of this type rate structure in the near term. As new metering is employed within these classes the commercial should be first due to two factors: the larger potential load shift per meter and a lower level of adverse customer reaction. Therefore the rankings are:

1 = Industrial class; metering is generally in place or easily adapted

3 = Commercial class; metering changes will generally be required but will probably be cost justified

5 = Residential class; metering changes will be required and generally difficult to justify due to high cost of metering relative amount of electricity that can be shifted.

MPC No. 18: Availability of Interruptible Rates

The availability of interruptible rates can enhance the viability of battery storage systems through an increase in the number of electric customers who can consider such rates. Many electric users cannot consider interruption of electric service due to many considerations, including continuous processes employing significant labor force, safety, etc. Battery storage systems may open this option to them.

Interruptible rates are generally only available to large customers for several reasons, including ease of initiating interruption, ease of monitoring interruption, and level of impact on utility load. Interruptible rates could become available to small customers in the future, but with difficulty. Factors like modifying the customer before the interruption, allowing the customer to refuse to be interrupted with severe rate impact resulting, and ability to monitor the customer response will retard the use for small electric users. Therefore the rankings are similar to those for time differentiated rates:

1 = Industrial customer classes

3 = Commercial customer classes

5 = Residential customer classes.

RANKING PROCEDURE FOR CUSTOMER CLASS MARKET POTENTIAL

Each of the customer classes was examined against each market potential characteristic and assigned a rating of 1, 2, 3, 4, or 5, in accordance with the scheme for each market potential characteristic. Appendix C shows the ratings for each customer class. In addition, Appendix D shows the overall market potential ranking of each customer class. This overall ranking consists of a numerical score, followed by a positive (+) or negative (-) sign. This numerical score, and the (+, -) indicators, are determined as follows.

Numerical Scores

The numerical score for each customer class is based on the following procedure:

Step 1. Compute arithmetic mean of rankings for market potential characteristics 5-17

Step 2. Add rankings for market potential characteristics 1-4 to arithmetic mean of Step 1

Step 3. Determine final score for each customer class by dividing result of Step 2 by 5.

The rationale for this procedure is that MPC 1-4 carry greater significance than the remaining MPCs in the definition of market potential. Although no specific quantitative justification can be developed, the above procedure gives greater numerical weight to the first four market potential characteristics of receptivity, diffusion, load shape, and location.

Positive, Neutral or Negative Indicators

For the purpose of providing a quick overview or scan, the numerical scores obtained for each customer class are now translated into two categories, plus or minus:

+ Indicating mostly positive market potential for a customer class

- Indicating mostly negative market potential characteristics.

All customer classes with a score of 3.0 or lower are given a "+"; those with a score of 3.1 or higher are designated with a "-". The results of this scoring are discussed in the subsequent sections of this Chapter.

MARKET POTENTIAL AMONG THE INDUSTRIAL CUSTOMER CLASSES

The overall scores for market potential among industrial customer classes are predominantly low. (See Appendix D). This is primarily due to low ratings of industrial customer classes in MPC's 1, 2, and 3 (receptivity, diffusion, and load shape). Location (MPC 4), and other market potential characteristics (MPC's 5-18) are rated more favorably in most cases.

Top Scorers Among Industrial Customer Classes

The following industrial customer classes represent the five best in their overall scores among all sixty-nine industrial customer classes:

SIC	Descriptor	Overall Score
35	Machinery, excluding electrical	2.5
3313	Electrometallurgical products	2.8
24	Lumber and wood products	2.8
23	Apparel, other textile products	3.0
3339	Other primary metals	3.0

An examination of the individual ratings of each of these customer classes for each of the MPC's reveals that even these positively ranked customer classes show several poor ratings for the MPCs.

Receptivity to Battery Storage Systems (MPC #1)

Only electrometallurgical products (SIC 3313) was rated "1", and other primary metals (SIC 3339) was rated "2". The other three customer classes, although their overall scores are among the best, were rated "5" for receptivity.

Post-Demonstration Diffusion Potential (MPC #2)

Only SIC 35, machinery, was rated "1", while SIC 23, apparel, was rated "3". The other three customer classes were rated "4" or "5".

Load Shape (MPC #3)

Only SIC 24, lumber and wood products, was rated "1" for load shape, while SIC 23 and SIC 35 each received a "3". The remainder were rated "5".

Location (MPC #4)

All five customer classes are rated "1" for location.

Other MPC's (#'s 5-18)

Average ratings for all five customer classes for the remaining MPC's are 3.1 or lower. An average rating of 1.8 for electrometallurgical products, and 1.9 for other primary metals, indicates that these customer classes have the best characteristics for MPC's 5-18 among the top five industrial scores.

This examination of individual ratings for the top five industrial customer classes shows clearly that serious detriments to market potential exist even among these top scorers: some show weak ratings for receptivity; others are weak in diffusion; and others are weak in load shape characteristics. They show, however, nearly consistent strength in location and other market potential characteristics.

Characteristics of Remaining Scores of Industrial Customer Classes

A study of the individual MPC ratings and overall scores for the remaining 64 industrial customer classes reveals that a similar pattern of strengths and weaknesses prevails as that of the top-scorers: ratings for MPC's #1, 2, and 3 are generally low, and those for MPC's #4 through 18 are more favorable.

This condition has important implications for a demonstration program of the battery storage concept, and for an eventual commercialization of battery storage technology.

Implications for a Demonstration and Commercialization Program Among Industrial Customer Classes

All industrial customer classes share a general weakness in their market potential for battery storage systems: few of the industrial customer classes are likely to have widespread receptivity to battery storage; few show significant diffusion potential; and few have favorable load shapes. On the other hand, all industrial customer classes also share some general strengths: many are located in favorable rate structure areas; and many show high scores among MPC's #5-18, signifying a low susceptibility to institutional barriers or constraints.

The implication of this set of circumstances is a dichotomy: if receptivity to battery storage, diffusion potential, and load shape could be improved, a successful demonstration and subsequent widespread commercialization of battery storage systems would be likely among industrial customer classes. Unfortunately, such improvements are not necessarily desirable or possible, for the following reasons.

Improvement of Receptivity to Battery Storage Systems

Receptivity to battery storage systems among industrial customer classes is characterized by narrow profit margins and a high cost of electricity as a percentage of value added. The fact that most industrial customer classes are rated low is due to a desirable condition: most customer classes do not operate on narrow profit margins, and the cost of electricity is - with few exceptions - a small percentage of value added. To improve receptivity among industrial customer classes would therefore require the removal of these desirable circumstances.

Improvement of Diffusion Potential

The generally low rating for diffusion potential is inherent in the nature of many of the industrial customer classes: most of the customer classes contain a small number of large establishments which carry within them the potential for internal diffusion, but also a potential barrier to diffusion, as previously discussed. This is a condition which cannot be readily changed, as the trend continues toward the formation of larger industrial concerns.

Improvement of Load Shape

Due to the imposition of demand charges upon many industrial establishments, most industrial customer classes now show load shapes which indicate double-shift or triple-shift patterns, or flattened peaks achieved by various forms of load management. Many of these load shapes do not favor battery storage systems. However, it is not necessarily desirable to effect a return to single peak load shapes for the sake of battery storage marketability.

As a result of the foregoing discussion, the market potential among industrial customer classes appears to be generally low, due to a general lack of receptivity, a low diffusion potential, and unfavorable load shape characteristics. This unfavorable condition does, however, not preclude the existence of individual industrial customers who could serve as successful participants in a demonstration program by virtue of their individual market potential characteristics which may deviate from the norm of their customer class. It must be recognized that although successful demonstrations will be possible with industrial customers, this will not necessarily result in significant or immediate commercialization among the industrial customer classes which they represent.

MARKET POTENTIAL AMONG THE COMMERCIAL CUSTOMER CLASSES

The scores for market potential among commercial customer classes (see Appendix D) are significantly different from those of the industrial sector: ratings for receptivity, diffusion and load shape are improved over those for industrial customer classes, while the ratings for other MPC's (4-18) are generally lower than those found among industry. This creates essentially the opposite of the problem faced by industrial customer classes: commercial customer classes show a stronger market potential than industrial concerns, but many face institutional or other barriers which could be more easily overcome by industry.

Top Scorers Among the Commercial Customer Classes

The most significant market potential among commercial customer classes is found in the retail category (SIC 52-59, 72, 76). A variety of dealerships and stores have overall market potential ratings of "3" or less:

Stores

- Groceries (score of 2.6)
- Department stores (2.8)
- Variety stores (3.0)
- Dairy products (3.0)
- Bakeries (2.6)
- Appliance stores (3.0)
- Drug stores (3.0)
- Liquor stores (3.0)
- Book stores (3.0)
- Stationery stores (3.0)
- Hobby/toy stores (3.0)
- Camera stores (3.0)

Dealerships

- Building materials (2.6)
- Mobile homes (2.6)
- New cars (2.4)
- Used cars (2.6)
- Boats (2.6)
- Motorcycles (2.6)
- Fuel/ice (3.0)
- Fuel oil (2.6)

Market Potential Strengths and Weaknesses of Stores and Dealerships

The market potential strengths of stores and dealerships comes from their generally high receptivity due to narrow profit margins and high cost of electricity as a percentage of total operating costs. In addition, the "chain" characteristics of many stores and dealerships gives them high diffusion potential ratings. Load shape and location characteristics are generally neutral: many have two-shift load shapes, and most are dispersed in favorable and unfavorable utility rate areas.

The market potential weaknesses of stores and dealerships stem from low ratings in MPCs 5-18 (an average of 3.9), which indicates probable difficulties with institutional barriers during demonstration and commercialization of battery storage systems.

In addition, hospitals obtained an overall score of 3.0, while news syndicates and linen supply services were rated 2.8 and 3.0, respectively.

Implications for a Demonstration and Commercialization Program Among Commercial Customer Classes

A demonstration program involving stores, dealerships and hospital facilities in the commercial sector has not only the potential for demonstrating battery storage viability, but it can also lead to commercialization due to the high receptivity and diffusion potential in this group of customer classes. Several important caveats must, however, be observed: (1) demonstration program participants must be selected for their individual characteristics favoring battery storage; (2) demonstration program participants must be given assistance in overcoming potential barriers (e.g., insurance, codes, financing); (3) efforts must be made to remove potential barriers to allow subsequent commercialization.

MARKET POTENTIAL AMONG RESIDENTIAL CUSTOMER CLASSES

On the whole, the market potential for battery storage among residential customer classes does not appear to be favorable. The greatest weakness in market potential can be found in receptivity (MPC #1) and in the barriers of MPC's #5-18. Receptivity is poor because electricity costs are generally not a major portion of operating costs. Unless a home is all-electric, the cost of electricity does not necessarily represent the most significant component of total operating expenses. Conversely, all-electric homes represent only a small portion of the total number of residential units, which limits diffusion potential. Furthermore, the constraints represented by MPCs #5-18 are rated extremely high (4.7 for all except multifamily high-rise, which is 4.2).

The only possible exception to this generally negative condition may be single family detached homes. Although receptivity is poor, the potential for diffusion is great due to the vast number of single family homes in the United States, and the manner in which homeowners tend to imitate each other's home improvements. Load shape characteristics are also favorable.

As a result, a demonstration program of battery storage could be attempted for single family homes. Such a demonstration program would, however, be best accomplished with two or more "test homes" constructed in different climatic zones of the U.S. (winter peak versus summer peak). Such homes would be especially constructed or retrofitted for the demonstration, and they would be unoccupied. Instead of being occupied, electric loads and consumption would be simulated to average characteristics, and battery system performance would be carefully monitored to obtain data on economic and technical performance.

MARKET POTENTIAL AMONG MISCELLANEOUS CUSTOMER CLASSES

The market potential of the miscellaneous customer classes is characterized by many of the same weaknesses found in the industrial customer classes: MPC's for receptivity, diffusion potential and load shapes are generally poor. In addition, location and all other MPC's are even less favorably rated than for the industrial classes. This results in a poor overall score for most of the miscellaneous customer classes. The only notable excpetions are:

- Non-generating rural electric cooperatives and non-generating municipal utilities
- Pipelines
- Passenger and freight railroads
- Water transport.

While it would be possible to include one or more of these customer classes in a demonstration program of customer-side-of-the-meter battery storage, it would appear that opportunities in the more promising commercial sector should be examined and attempted first. In addition, other programs, such as SBEED presently address the non-generating utilities.

CONCLUSION

The overall picture emerging from this identification and evaluation of market potential can be summarized as follows:

Industrial Customer Classes

(1) There is a potential for a successful demonstration with one or more representatives of the industrial customer classes. Although the industrial customer classes show little market potential, it is probable that individual industrial companies could posses the conditions for viable battery storage.

(2) The outlook for rapid and widespread commercialization of battery storage among industrial customer classes does not appear favorable. The major weaknesses in market potential are low receptivity to battery storage, low diffusion potential, and unfavorable load shapes.

(3) Industrial customer classes are the least susceptible of any of the customer classes to institutional barriers and constraints.

Commercial Customer Classes

(1) Successful demonstrations appear to be possible with representatives of the commercial customer classes. Because dealerships, stores and hospitals show the greatest market potential among commercial classes, demonstration programs should seek to involve individual stores, dealerships and hospitals.

(2) Commercialization among the above-named customer classes appears to be favorable due to good receptivity and diffusion potential.

(3) The major obstacle to successful demonstration and eventual commercialization lies in institutional barriers and constraints faced by the commercial customer classes.

Residential Customer Classes

(1) Single family residences are possible demonstration candidates. Demonstration programs may best be conducted with specially built or retrofitted test homes that are unoccupied.

(2) Demonstration programs may allow a more definite determination of market potential, and of technical/economic feasibility.

Miscellaneous Customer Classes

The opportunities for demonstration and commercialization are limited. Other customer classes offer significantly better opportunities.

RECOMMENDATIONS

The strongest indicators favoring successful demonstration and commercialization exist in the commercial customer classes. It therefore appears that a demonstration program should emphasize applications in the commercial sector. If such a step is taken, it must be carried out with the full awareness that institutional barriers will need to be overcome during demonstration and commercialization.

Opportunities for commercialization in the industrial customer classes are limited and will probably remain restricted. A demonstration program could include a small number of industrial applications, but this should be done with an understanding of the limited post-demonstration diffusion potential and the generally poor receptivity to battery storage among industrial customer classes.

A demonstration program involving single family homes could be undertaken to further examine the technical and economic feasibility of such installations. Such a program should, however, not involve individual homeowners. Instead, carefully monitored test houses could be built or retrofitted for this purpose.

CHAPTER VIII. SELECTION OF DEMONSTRATION CANDIDATES

INTRODUCTION

Based on the findings of the previous Chapter, it is evident that the market potential among customer classes has a variety of weaknesses and potential constraints. It must be pointed out, however, that customer class market potential is simply a broad indicator of overall market potential: there certainly are individual customers with excellent battery storage system viability, even if they belong to a customer class which has a poor overall market potential ranking. Conversely, many individual customers may not have attributes favoring battery storage, even if their customer class has an excellent overall market potential.

As a result, the selection of demonstration candidates must be guided not only by overall market potential, but also by the individual candidates' characteristics favoring battery storage system applications. Ideally, the demonstration candidates should embody both qualities: they should have favorable individual attributes, and they should represent a customer class with good market potential.

This Chapter describes the procedure used for identifying and selecting potential demonstration candidates, and presents a ranked list of demonstration candidates.

FIRST SOLICITATION

During the early stages of the project, a blanket mailing was prepared and sent to approximately one thousand primarily industrial customers. A copy of a sample letter is in Appendix E. This letter explained the battery storage concept, and requested from the recipient an expression of interest in his or her possible participation in a demonstration program.

The companies selected for this mailing consisted of existing Battelle contacts. This established Battelle as an already known entity, and was perhaps helpful in obtaining more direct and candid responses. A positive response rate of sixteen percent indicates that, at least during this exploratory stage, interest in the battery storage concept was substantial. A list of the positive respondents is shown in Appendix F.

SECOND SOLICITATION

A second solicitation letter was subsequently prepared and sent to all who responded favorably to the first solicitation. Because our research had by this time revealed a significant market potential among commercial customer classes, the second solicitation was also sent to a variety of commercial customers who had not been previously contacted. These customers were randomly selected from a variety of directories, such as Dun & Bradstreet and "The Top 50,000 Corporations in the U.S." Appendix G contains a list of the names and addresses of these commercial customers. Appendix H contains copies of the follow-up letter sent to the not previously contacted commercial customers. Each letter was accompanied by three enclosures: (1) a self-evaluation form for return by the recipients; (2) a list of utility companies with favorable rate structures; (3) a technical description of batteries and storage technology. These enclosures are also shown in Appendix H. The self-evaluation forms permitted customers who wished to be considered for the demonstration to document their electrical consumption and other characteristics pertinent to battery storage viability.

The responses on each of the self-evaluation forms received were subsequently examined by the project team, with the aim of identifying those companies with the best attributes for a demonstration of the battery storage concept.

RATIONALE FOR THE EVALUATION OF POTENTIAL DEMONSTRATION CANDIDATES

While all of the factors cited in the self-evaluation forms are of importance to a successful demonstration, those factors defining economic viability are the most crucial ones. This means, for example, that a large consumption of direct current power on the part of a demonstration candidate can only be meaningful to the demonstration, if that candidate has an otherwise economically feasible application. As a result, the evaluation of potential demonstration candidates focuses on economic factors.

Depending on the candidate's load shape characteristics, and on his utility company's rate structure, a candidate is ranked either positive, neutral or negative.

\+ Candidate could utilize a battery system with a discharge period of eight hours or less and his utility company's rate schedule incorporates a demand charge greater than $7/kW.

0 Candidate could utilize a battery system with a discharge period of eight hours or less and his utility company's rate schedule incorporates a demand charge between $5/kW and $7/kW.

\- Candidate cannot utilize a battery system with a discharge period of eight hours or less or his utility company's rate schedule incorporates a demand charge less than $5/kW.

These criteria were specified in a manner which would divide the potential candidates into three groups. The relative economic viability for any one of these groups can be obtained in reviewing Figure VI-3 in Chapter VI.

EVALUATION RESULTS

The following companies have been ranked positive as potential demonstration program participants:

Bandag, Incorporated
Grumman Corporation
Hughes Aircraft Company
Nabisco, Incorporated
Parker Hannifin Corporation - Brass Products Division
Quanex Corporation, Mac Steel Division
United States Shoe Corporation

Those receiving a neutral ranking are:

ADT Company
Amway Corporation
Blaw-Knox Company
Chase and Sons, Incorporated
Coats and Clark, Incorporated
Cooper Tire and Rubber Company
Cummins Diesel
Signode Corporation
Sonoco Products Company
Sperry Vickers
Texas Eastern Transmission Corporation
The Kroger Company
White Castle System, Incorporated

Those negatively ranked are:

Arvin Automotive Division
Atlantic Richfield Company
Bath Iron Works Corporation
Campbell Soup Company
Carrier Corporation
Chattanooga Glass Company
Exide
Hercules, Incorporated
Nestle Enterprises, Incorporated
Standard Oil Company of California
The Greyhound Corporation
The Sherwin Williams Company
Union Oil Company of California

Copies of the self-evaluation forms on which these ratings are based are on file at Battelle.

CHAPTER IX. CONCLUSIONS AND RECOMMENDED FUTURE PROGRAMS

This report presents the results of Battelle's overview assessment of battery storage on the customer side of the meter. The organization of the research and this report follow a typical energy system decision-making process. This process served as a viable structure for accomplishing the primary objectives of the research which were to:

- Determine the feasibility of customer-owned battery storage and the potential extent of utilization by various electricity customers based on an evaluation of technical, economic, and institutional issues
- Identify electricity customers who may subsequently participate in a battery storage demonstration with DOE.

The energy system decision-making process is displayed in Figure IX-1 which also references the Chapters where the respective activities are reported.

RESEARCH CONCLUSIONS

Major conclusions of this research are:

- Of the various battery types considered, the lead-acid battery is the most viable battery available for customer-side-of-the-meter storage in the near term. Therefore lead-acid batteries are recommended for customer-side demonstration(s).
- Potential institutional and environmental barriers to customer-side battery storage will not restrict this technology if they are given appropriate attention. The most important issues that merit attention are determining the applicability of tax incentives; development of appropriate measures for dealing with hazards; identification and resolution of local use restrictions; and widespread dissemination of information to foster customer acceptance and positive attitudes within financial institutions and the insurance industry.
- Present electric utility rate schedules display a high degree of variability with respect to their structure (e.g., traditional and time-of-day), allocation between demand and energy charges, price level, and complexity of specifications. This variability precludes any general conclusion as to whether traditional or time-of-day rates

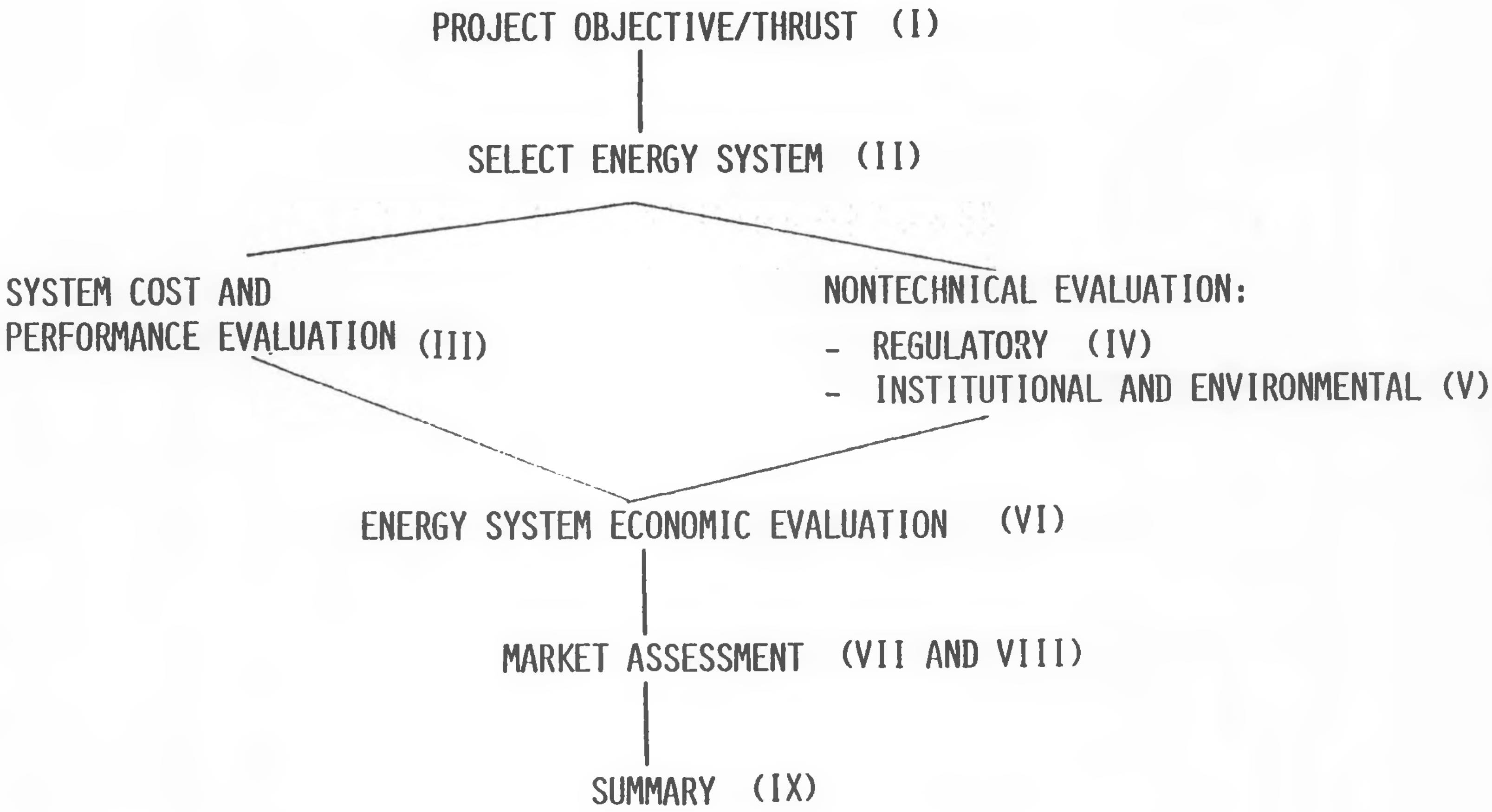

FIGURE IX-1. ENERGY SYSTEM DECISION MAKING PROCESS

NOTE: Roman numerals indicate the Chapters in which relevant material is presented.

are most appropriate for customer-side battery storage. For the most part, the kinds of utility characteristics that would theoretically yield desirable traditional rate schedules would also theoretically yield desirable time-of-day rate schedules.

- Regulatory uncertainty may be a major barrier to customer-side battery storage system adoption. Regulatory uncertainty exists with respect to changing policies, rate structures, and schedules. Elimination of these uncertainties will normally be a prerequisite to a customer investing in storage because a small change in rate structures could have a large impact on economic viability.

- The assessment of economic viability is dominated by two factors. First, the relative level of demand charges within electric utilities' rate schedules and second, the duration of the battery discharge period, as determined by the customer's load shape and the utility rate structure, dominate the benefits associated with the electricity cost reduction potential. Rate differentials were estimated to measure the potential reduction in electricity costs per kWh of battery output. The discharge period also impacts the capital costs of the battery system, but to a lesser extent than its impact on the rate differential. Battery size and voltage levels can also significantly impact viability. Energy charge impacts on viability are small for the range of energy charges currently included in electricity rates.

- Other factors, such as battery replacement timing and moderate changes in lead prices are not expected to be major forces in influencing economic viability.

- Potential battery storage system economic viability was estimated for commercialization in 1987 for some customers in electric utilities with large rate differentials associated with present rate schedules. The achievement of battery system cost and performance goals significantly increases the number of utilities with rate differentials above the breakeven differential, and therefore significantly increases economic viability.

- Perceived trends in demand charge levels and battery system costs could increase customer-side viability. Marginal cost pricing tends to increase demand charges in real terms to account for the significantly higher capital costs of new electric generating plants. At the same time, real battery storage system costs are expected to decrease through present and future RD and D programs.

- The market potential for demonstration customers appears to be greatest for moderate size applications among the commercial and industrial customer classes. The major factors influencing this potential are diffusion potential, receptivity, potential for demand charge or time-of-day savings, and the potential for short discharge periods. Willingness to participate in a demonstration program appears to be greatest among the industrial classes.

- A summary evaluation by major customer class follows:

Customer Class	Potential for Demand Charge Savings or Time-of-Day Savings	Potential for Short Discharge Savings
Large Industrial	Yes	Little
Other Industrial and Large Commercial	Yes	Some
Small Commercial	Little	Yes
Residential	Probably Not	Yes

- Potential demonstration customers have been identified who appear to have the most viable applications and are interested in discussing a battery storage system demonstration with DOE.

RECOMMENDED FUTURE PROGRAMS

The following are recommended programs that will serve to encourage customer-side battery storage:

- Customer-side battery storage demonstration(s) should proceed at carefully selected sites. The initial recommended step is the preparation of preliminary engineering design studies for the specific site(s). These studies should be prepared to define all components of the system; determine cost estimates for the demonstration and a mature (commercial) facility from potential suppliers; evaluate the site-specific institutional, environmental, and regulatory factors; and determine the time schedule for implementation.

- Potential battery storage system users, bankers, insurers, and inspectors presently know very little about battery storage. Dissemination of information to these groups is an important factor in the process of commercializing these systems. Widely publicized conferences in electric utility service areas that offer rates with favorable rate differentials appear to be a viable way to focus a state or region's attention on battery storage. Presentations would be made covering all aspects of battery storage, and attendees should include government, battery system component manufacturers, as well as potential users, bankers, and insurers. Information dissemination through a newsletter to potential users would serve as a means to continue interest in this technology.

- Development of a detailed commercialization strategy for customer-side battery storage completed prior to, or concurrent with, demonstration design studies. This strategy could focus activities and serve as a means for identifying potential problems at an early stage.

- Conduct utility-specific research on rate structures and schedules that are feasible and favor battery storage systems. Using selected utility characteristics, this report identifies utilities that theoretically could offer desirable rate differentials. The proposed research would build on our theoretical study with the intent of identifying those major electric utilities which actually could develop tariffs which offer rate differentials that favor battery storage systems.

- Conduct research aimed at evaluating customer-side battery storage viability versus alternative approaches to reducing the customer's cost of electricity. Other approaches may include self-generation, load management systems, demand limiters, and cogeneration.

- During this research potential demonstration customers have been identified for U.S. DOE follow-up. The findings of our regulatory and economic evaluations could be used by U.S. DOE to identify additional potential demonstration customers.

- Conduct a reevaluation of battery system research and development goals to assure compatibility with customer-side storage requirements. For example, many customer-side users will need load leveling batteries with longer discharge periods than presently proposed for utility-side applications if they are to economically match their load shape changes and the rate structures they are served under.

As shown in the report, market penetration will be improved significantly as battery storage system costs are reduced. Therefore, research on advanced battery storage systems should continue to reduce costs and improve performance, thereby achieving U.S. DOE cost and performance goals.

APPENDIX A

CODE REFERENCES TO BATTERY STORAGE SYSTEMS

APPENDIX A. CODE REFERENCES TO BATTERY STORAGE SYSTEMS

Specific references to battery storage systems in the major codes is limited, hence it can be expected that building code officials will interpret specific portions of the codes to apply to these systems. Following is a review of the more applicable portions of some of the major codes and a brief commentary on their relevance to battery storage systems.

The major codes reviewed were: National Electrical Code; The Building Officials Code; Administrator's (BOCA) Basic Building Code; Uniform Building Code; Standard Building Code; National Building Code; and Uniform Mechanical Code.

Special or Explosion Hazards

All codes contain a section, usually under the general heading of occupancy requirements, that addresses special hazards or explosion hazards. These sections typically refer to rooms or groups of rooms in which flammable liquids, combustible dust or similar hazardous materials are used, stored, developed, or handled. (For example, see Sections 1008, 1009 and 1108 of the Uniform Building Code; Sections 407.4 and 407.5 of the Standard Building Code; and Section 340 of the National Building Code.)

Although no specific language is used relating to battery storage systems, the above references could be considered as surrogates by building code officials and thus become the basis for their interpretation of the code. Design and occupancy criteria and standards are needed relative to battery storage rooms and the containment of hazardous gases emitted from the batteries.

Fire-Resistive Construction

All codes contain a section, usually under the general heading of fire resistive construction, that addresses the type of construction that should be used in hazardous locations such as a battery storage room. Sections from the model codes are referenced that appear to have some implications for the design of battery storage rooms. (For example, see Section 802(d) of the Uniform Building Code; Sections 402 and 408 of the Basic Building Code; Section 407.6 of the Standard Building Code; and Section 340.2 of the National Building Code).

Although fire-resistive requirements for battery storage systems are not directly addressed, the language used in these sections could be the basis for interpretation by various code officials. Design criteria and standards are needed relative to battery storage rooms and the type of construction and materials needed. Otherwise, there will be a great diversity in materials and costs of installing battery storage systems. For example, some code officials may require a 2 hour fire rating on the walls while another code official may require only a 1 hour rating. A 1 hour wall requires a 2-1/2 inch concrete block while a 2 hour wall requires a 4 inch concrete block.

Ventilation

All codes contain a section or sections on ventilation that address the amount of air changes required per hour, the number of fresh air inlets, and the number of exhaust air outlets. These requirements relate to various functional areas ranging from special hazards areas to projection booths. (For example, see Sections 1009(d), 1105, and 4005 of the Uniform Building Code; Sections 401 and 408.3 of the Basic Building Code; and Section 407.6 of the Standard Building Code).

Ventilation criteria or standards are needed relating to the number of air changes, supply vents, and exhaust vents in a battery room to assure personal safety and reduce the potential for explosion.

Fire Protection

All codes state the need for automatic fire-extinguishing systems and standpipes except in certain cases such as single and multi-family dwelling units. It is anticipated that in those buildings in which battery storage systems will be installed automatic fire-extinguishing systems will also be required . (Examples of the specific code language can be found in Section 3802 of the Uniform Building Code; Sections 400.7, 402.1, 408.2, 411.5 and 412.7 of the Basic Building Code; and Section 407.4 of the Stnadard Building Code.)

Fire protection criteria and standards are needed relating to battery rooms. For example, one of the major issues is whether a sufficient hazard exists to require an automatic fire-extinguishing system. Another issue is how the sprinkler heads should be located.

Also, there is a question of whether other types of fire protection systems are needed such as steam blankets or carbon dioxide flooding systems.

Electrical

Within this phase of the work, the National Electrical Code was reviewed. This code is the most widely accepted set of electrical requirements in the United States. It is recognized by all major building codes including the Uniform Building Code, the Basic Building Code, the Standard Building Code, and the National Building Code. The National Electrical Code is sponsored by the National Fire Protection Association and approved by the American National Standards Institute. Specific sections of the code that was reviewed were (1) guarding of live parts, (2) storage batteries, and (3) hazardous locations.

Guarding of Live Parts

Preventing contact with the live parts of a battery storage system is an important aspect of design development. Although there is no direct reference to battery storage systems in the National Electrical Code, Section 110-17 addresses the "Guarding of Live Parts" which might have some relevance in a situation where a building official is making an interpretation on a proposed battery system. (The pertinent sections of the National Electrical Code are 110-17, 110-30, 110-31, 110-32, 110-33, 110-34.)

When the batteries are in a charging or discharging mode guarding the live parts will be an important design consideration. Research has verified that the maximum safe voltage for man is 50 volts for direct current. In 1956, C. F. Dalzeil prepared a paper which stated "From the foregoing (experiment) it is apparent that the reasonably safe 60 cycle let-go voltage for man, for the major current pathways through the body, are between about 10 and 21, and the corresponding voltages for direct current are 51 to 104 volts". (The testing procedure simulated the hand to foot pathway by having the subjects grasp, with wet hands, a pair of 6 inch long-nose pliers in the right hand when standing barefoot in a bucket of salt water to a depth of 4 inches. The hand to hand pathway was simulated by a copper wire connected from the right hand to an armband on the upper arm.) As further confirmation, the author notes: "at a conference sponsored by the Comite Medical of the Electricite de France during the CIGRE meetings of June 1952, French authorities consider the maximum voltages safe for man were approximately 24 volts for 50 cycle AC and 50 volts for DC."* The report further indicates that although no absolutely safe voltage level can be determined, it appears that all PV systems

* Burt, Hill, Kosar, Rittelman, Residential Photovoltaic Module and Array Requirements Study, Iet Propulsion Laboratory (July 1979).

operating at voltages over 50 must be protected from accidental contact. Final design and installation standards must be developed.

Storage Batteries

One of the parts of the National Electrical Code that applies specifically to storage batteries is Article 480. While this article relates directly to storage battery systems, there are some information gaps that need to be filled. For example, Section 480.8 Battery Locations, (a) Ventilation, does not provide any criteria or reference any standards relative to the provision "for sufficient diffusion and ventilation of the gases from the battery to prevent the accumulation of an explosive mixture". Specific information is needed on questions such as:

(1) What is an explosive mixture and how can it be measured?

(2) What amount of diffusion will inhibit the system from reaching a critical point?

(3) What amount of ventilation is needed to make a battery room safe for human occupancy, as well as to prevent the accumulation of an explosive mixture?

Hazardous Locations

The National Electrical Code includes a section on hazardous locations. Although a battery room has not been defined as a hazardous area, some building code officials may consider them to be such. If so, Article 500 - Hazardous Locations would have to be considered.

The key issue is whether a battery room or a building in which a battery room is incorporated is considered to be a hazardous location. For example, even though the code lists various air mixtures, oxygen and hydrogen are not listed. One interpretation could be that battery rooms are not a hazardous area. On the other hand, the potential for fire or explosion exists in a battery room unless certain standards are met in the design and occupancy of the building.

APPENDIX B

CUSTOMER CLASS BASELINE DATA

APPENDIX B

CUSTOMER CLASS BASELINE DATA

The following tables display baseline data on electricity consumption, electricity costs, size, economic activity and self-generation for each of the customer classes of industrial, commercial, residential and miscellaneous.

Customer Classes

Customer classes have been identified in four sections. First, industrial classes are basically two digit SIC's with expansion to three or four digit where merited by level of electricity consumption, intensity of electric cost relative to other costs, or where electricity use offers unique opportunities for battery storage implementation.

Second, commercial classes have been identified on the basis of roughly homogeneous uses for, and use patterns of, electricity. This basis has been stretched to some extent to eliminate the inclusion of a large number of classes that use a small amount of electricity, and consequently, have very little post-demonstration diffusion potential.

Third, residential consumers of electricity are classified by the four main types of housing in the U.S.: single family detached, low density attached (2-4 units), multifamily low rise (5-19 units), and multifamily high rise (20 or more units).

Fourth, miscellaneous classes of electricity users that do not fit into the above sections are listed here. These include classes such as mining, construction, farming, non-generating electric utilities, and electric railway systems.

Baseline Information

Baseline data are presented under the following headings.

Customer Classification and SIC Code

Industrial, commercial, residential and miscellaneous categories are shown under these headings, followed by their respective SIC codes, wherever applicable.

Electrical Consumption

Total electrical consumption by SIC Code categories is expressed in millions if kilowatt hours. This is an important factor in identifying the appropriate level of detail for customer classes. Data used are for the calendar year 1976, the most recent available for many customer classes. Data sources include Annual Survey of Manufactures 1976: Fuels and Electric Energy Consumed for Industrial and Residential Energy: Final Report for both Single-Family and Multi-family Housing.

Electricity Costs

For all SIC Code categories, electricity costs, adjusted for calendar year 1976, are expressed in millions of dollars. This is a financial measure of the importance of electricity. The data sources used are:

Industrial - Annual Survey of Manufactures 1976

Commercial - Edison Electric Institute: Statistical Yearbook of the Electric Utility Industry for 1977

Residential - Estimates calculated from typical electrical bills for average electricity consumption per dwelling unit per billing period.

Measure of Size

Three different quantities were employed as measures of size for the customer classifications. For SIC Code categories 20-39, total employment (in thousands of employees) for the calendar year 1976 was selected as the most representative measure (Source: Annual Survey of Manufactures 1976).

For SIC Code categories 50-97, area occupied building floor space (in millions of square feet) for the calendar year 1975 was selected. Source: Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use.

The measure of size selected as most appropriate for the residential customer classifications is total number of dwelling units (in thousands), adjusted for the calendar year 1976. (Source: Annual Survey of Housing: 1977. Financial Characteristics of the Housing Inventory.)

Measure of Economic Activity

For SIC Code categories 20-39, value added (in millions of dollars) for the calendar year 1976 was used as the representative measure of economic activity. (Source: Annual Survey of Manufacturers, 1976.) For SIC Code categories 50-97, annual operating costs (in millions of dollars) for the calendar year 1976 were used to measure economic activity. (Source: 1976 Statistics of Income Business Income Tax Returns and Corporation Income Tax Returns.) The residential customer classifications' measure of economic activity was represented by the average annual income of families and primary individuals in 1977 dollars. (Source: Annual Survey of Housing: 1977.)

The above three measures of size and economic activity were selected primarily in order to permit the computation of ratios of electricity use per unit size, and cost of electricity per unit of economic activity. These ratios are explained immediately below.

Ratio of Electrical Consumption per Measure of Size

For SIC Code categories 20-39, this ratio is expressed as the number of kilowatt hours consumed per employee. For SIC Code categories 50-97, the ratio is expressed in kilowatt hours per square foot. The ratio for the residential sector consists of kilowatt hours per dwelling unit. These are measures of the intensity of electric consumption among the classes.

Ratio of Cost of Electricity per Measure of Economic Activity

For SIC Code categories 20-39, this ratio is expressed as the ratio (in percentage terms) of the cost of electricity per value added. For SIC Code categories 50-97, the ratio is of the cost of electricity per annual operating cost. In the residential category, the ratio of electricity cost per dwelling unit and the average annual income per household is used. These are measures of the importance of the cost of electricity relative to economic activity in the respective customer classes.

Additional Data Shown for SIC Code Categories 20-39

Self-generated consumption (in millions of kilowatt hours) is shown for many of the SIC Code categories. In certain instances, data were unavailable. "D" denotes..."Withheld to avoid disclosing figures for individual companies." "S" denotes ..."Withheld because the estimate did not meet publication standards, either on the basis of the associated standard error of the estimate or on the basis of a consistent review."

The amounts of self-generated consumption are not included in the respective amounts shown for electrical consumption.

CUSTOMER CLASS BASELINE DATA

Industrial Customer Class / Customer Classification	SIC Code	Electricity Consumption (millions of kWh's)	Electricity Costs (millions of 1976 $'s)	Measure of Size: Total Employment (thousands)	Measure of Economic Activity Value Added	Self-generated Electricity Consumed (millions of kWh's)	kWh/ Employee (thousands)	Electricity Cost/ Value Added (Percent)
Industrial								
Food and Kindred Products	20	39,061.7	902.6	1,535.8	52,760.0	2,584.1	25.434	1.71
Meat Products	201	6,763.6	148.8	311.3	7,530.6	192.9	21.727	1.98
Dairy Products	202	5,310.1	128.8	164.1	5,261.3	(S)	32.358	2.45
Preserved Fruits & Vegetables	203	5,199.3	112.9	222.3	6,798.9	60.9	23.389	1.66
Grain Mill Products	204	6,084.5	135.7	114.4	6,083.0	810.1	53.186	2.23
Bakery Products	205	2,709.0	66.3	241.8	6,908.9	(S)	11.203	.96
Sugar, Confectionary Products	206	2,082.2	51.6	105.8	3,658.2	1,249.2	19.681	1.41
Fats and Oils	207	3,194.4	70.8	40.9	2,033.6	69.3	78.103	3.48
Beverages	208	4,488.3	107.0	204.3	8,832.8	183.6	21.969	1.21
Miscellaneous Food Products	209	3,230.3	80.8	130.9	5,652.7	(S)	24.678	1.43
Tobacco Products	21	1,124.1	26.8	64.8	4,127.9	(D)	17.347	.64
Textile Mill Products	22	28,025.6	586.5	875.9	14,494.9	483.7	31.996	4.04
Weaving Mills, Cotton	2211	4,188.6	83.4	109.8	1,686.5	184.0	38.147	4.95
Weaving Mills, Manmade Fibers	2221	7,004.4	136.6	161.1	2,600.0	77.6	43.479	5.25
Weaving, Finishing Mills	2231	341.7	8.9	15.5	264.6	(D)	22.045	3.36
Narrow Fabric Mills	2241	456.4	10.3	20.1	322.3	(S)	22.706	3.19
Knitting Mills	225	3,926.6	84.2	231.8	3,452.2	(S)	16.939	2.44
Textile Finishing, ex. Wool	226	1,926.2	45.5	71.9	1,315.3	173.3	26.789	3.45
Floor Covering	227	1,002.0	24.1	49.2	1,210.5	(D)	20.366	1.99
Yarn & Thread	228	7,098.0	144.0	145.3	2,117.7	(D)	48.851	6.79
Miscellaneous Textiles	229	2,081.8	49.5	71.2	1,525.8	(D)	29.239	3.24
Apparel, Other Textile Products	23	7,656.3	165.9	1,270.5	16,859.6	(S)	5.317	.98
Lumber & Wood Products	24	15,547.1	304.0	628.5	13,453.5	314.9	24.737	2.26
Furniture & Fixtures	25	3,968.8	101.5	425.7	7,370.0	49.9	9.323	1.38
Paper & Allied Products	26	43,458.8	777.8	614.9	20,603.7	25,487.4	70.676	3.78
Pulp Mills	2611	2,885.8	41.7	15.7	974.6	2,533.0	183.808	4.28
Paperboard Mills	2631	10,152.6	166.3	64.7	3,128.0	10,123.1	156.918	5.32
Misc. Converted Paper Products	264	4,776.4	108.9	200.3	6,448.2	62.0	23.846	1.69

CUSTOMER CLASS BASELINE DATA

Industrial Customer Class Customer Classification	SIC Code	Electricity Consumption (millions of kWh's)	Electricity Costs (millions of 1976 $'s)	Measure of Size: Total Employment (thousands)	Measure of Economic Activity Value Added	Self-generated Electricity Consumed (millions of kWh's)	kWh/ Employee (thousands)	Electricity Cost/ Value Added (Percent)
Paperboard Containers & Boxes	265	3,309.3	88.0	197.3	4,935.1	(D)	16.773	1.78
Building Paper & Board Mills	2661	1,434.4	27.9	9.4	240.0	63.0	152.596	11.64
Printing & Publishing	27	10,122.7	260.5	1,085.8	27,647.2	(S)	9.323	.94
Chemicals & Allied Products	28	145,423.4	2,276.0	850.9	51,407.4	14,954.3	170.905	4.43
Industrial Inorganic Chemicals	281	82,630.3	1,142.0	108.8	6,164.7	4,918.5	759.469	18.52
Alkalines & Chlorines	2812	12,683.4	175.6	13.3	960.4	2,616.9	953.639	18.28
Industrial Gases	2813	11,117.1	194.0	8.0	644.7	(D)	1,389.638	30.09
Inorganic Pigments	2816	1,422.2	31.5	12.9	684.9	(D)	110.248	5.39
Other Inorganic Chemicals	2819	57,407.6	740.9	74.6	3,974.7	2,188.1	769.539	18.64
Plastics Materials, Synthetics	282	16,780.8	300.5	152.8	6,647.8	(D)	109.822	4.52
Drugs	283	3,499.8	88.5	151.1	9,333.1	156.8	23.162	.95
Soaps, Cleaners, Toilet Goods	284	2,080.8	55.6	109.9	8,469.3	(D)	18.934	.66
Paint and Allied Products	2851	984.5	26.7	60.4	2,562.2	(D)	16,300	1,04
Industrial Organic Chemicals	286	27,374.4	433.6	141.8	11,348.5	7,330.1	193.049	3.82
Agricultural Chemicals	287	9,453.9	171.3	52.0	3,762.8	645.4	181.806	4.55
Nitrogenous Fertilizers	2873	4,966.8	81.8	11.3	1,238.6	441.1	439.539	6.60
Phosphatic Fertilizers	2875	3,279.5	65.4	14.9	726.9	(D)	220.101	8.99
Fertilizers, Mixing	2875	189.2	5.5	10.4	410.7	-***	18.192	1.34
Other Agricultural Chemicals	2879	1,018.4	18.6	15.4	1,386.6	(D)	66.129	1.34
Miscellaneous Chemical Products	289	2,619.0	57.7	74.1	3,119.0	192.8	35.344	1.85
Petroleum and Coal Products	29	27,713.1	478.5	144.4	13,168.9	4,499.1	191.919	3.63
Petroleum Refining	2911	26,277.4	440.4	101.7	11,168.9	(D)*	258.381	3.86

CUSTOMER CLASS BASELINE DATA

Industrial Customer Class Customer Classification	SIC Code	Electricity Consumption (millions of kWh's)	Electricity Costs (millions of 1976 $'s)	Measure of Size: Total Employment (thousands)	Measure of Economic Activity-Value Added	Self-generated Electricity Consumed (millions of kWh's)	kWh/ Employee (thousands)	Electricity Cost/ Value Added (Percent)
Paving & Roofing Material	295	1,184.1	31.2	31.8	1,184.2	(D)	37.236	2.63
Paving Mixtures & Blocks	2951	592.2	17.1	12.9	450.8	3.0	45.907	3.79
Asphalt Felts & Coatings	2952	592.2	14.0	18.9	733.4	(D)	31.323	1.91
Miscellaneous Petroleum & Coal Products	299	251.5	7.0	10.9	575.1	(S)	23.073	1.22
Lubricating Oils & Greases	2992	175.0	5.3	9.9	469.2	(D)	17.677	1.13
Other Products	2999	76.5	1.8	1.0	105.9	(S)	76.5	1.69
Rubber, Miscellaneous Plastic Products	30	19,750.4	463.9	627.4	15,950.3	482.3	31.480	2.91
Leather & Leather Products	31	1,509.9	39.4	247.1	3,558.6	12.8	6.110	1.11
Stone, Clay, & Glass Products	32	29,236.3	639.4	598.9	16,772.9	514.8	48.817	3.81
Primary Metal Industries	33	147,641.9	2,217.3	1,106.0	34,182.1	13,698.1	133.492	6.49
Blast Furnace, Basic Steel	331	54,644.2	1,035.9	532.1	17,273.9	7,756.3	102.695	5.99
Blast Furnaces & Steel Mills	3312	44,264.4	863.3	451.9	14,755.5	(D)	97.952	5.85
Electrometallurgical Products	3313	7,889.7	108.9	8.3	289.9	(D)	950.566	37.56
Steel Wire & Related Products	3315	996.1	24.6	39.9	886.2	(S)	24.965	2.78
Cold Finishing Steel	3316	820.5	21.5	17.3	627.0	(D)	47.428	3.43
Steel Pipes & Tubes	3317	673.5	17.6	21.7	715.3	(D)	31.037	2.46
Iron & Steel Foundries	332	11,440.1	269.4	216.3	5,496.5	15.3	52.889	4.90
Gray Iron Foundries	3321	6,993.6	165.6	136.0	3,522.7	(D)	51.423	4.70
Malleable Iron	3322	1,662.3	34.0	17.6	435.5	-	81.949	7.81
Steel Investments	3324	306.2	7.7	9.9	251.3	-	30.929	3.06
Other Steel Foundaries	3325	2,698.0	62.1	52.8	1,287.0	(D)	51.098	4.82
Primary Nonferrous Metals	333	66,809.0	594.2	59.2	2,979.2	5,871.1	1,128.530	19.94
Primary Copper	3331	1,728.0	29.4	14.3	746.0	(D)	120.839	3.94
Primary Lead	3332	232.3	3.7	3.2	152.9	(D)	72.594	2.43

CUSTOMER CLASS BASELINE DATA

Industrial Customer Class Customer Classification	SIC Code	Electricity Consumption (millions of kWh's)	Electricity Costs (millions of 1976 $'s)	Measure of Size: Total Employment (thousands)	Measure of Economic Activity-Value Added	Self-generated Electricity Consumed (millions of kWh's)	kWh/Employee (thousands)	Electricity Cost/Value Added (Percent)
•Primary Zinc	3333	1,132.2	19.4	(S)**	152.9	(D)	NA	12.69
Primary Aluminum	3334	58,776.7	470.9	26.3	1,465.9	4,785.2	2,234.856	32.12
Other Primary Metals	3339	4,939.8	70.8	10.6	462.4	(D)	43.989	2.88
Secondary Nonferrous Metals	3341	783.0	18.2	17.8	632.5	(D)	61.009	3.99
Nonferrous Drawing & Rolling	335	10,451.0	214.1	171.3	5,360.0	69.1	57.836	4.81
Copper Rolling	3351	1,972.2	47.1	34.1	979.0	(D)	120.033	4.76
Aluminum Sheet, Plate, Foil	3353	3,637.0	56.0	30.3	1,176.2	-	42.481	4.61
Aluminum Extruded Products	3354	1,023.8	26.1	24.1	566.3	-	87.690	3.26
Other Aluminum Drawing	3355	368.3	5.3	4.2	162.7	-	-	-
Other Nonferrous Rolling	3356	1,007.4	18.5	17.1	613.4	(D)	58.912	3.02
Other Nonferrous Wire Drawing	3357	2,442.4	61.1	65.1	1,862.4	(D)	37.518	3.28
Nonferrous Foundries	336	2,110.3	50.2	84.7	1,738.2	(D)	24.914	2.89
Aluminum Foundires	3361	1,341.8	31.8	51.3	1,077.8	(D)	26.156	2.95
Brass, Bronze, Copper Foundries	3362	320.6	8.0	13.2	286.2	(S)	24.288	2.79
Other Nonferrous Foundries	3369	448.0	10.3	20.2	374.2	(D)	22.178	2.75
Miscellaneous Primary Metal Prod.	339	1,404.3	35.5	24.6	701.5	(D)	57.085	5.06
Metal Heat Treating	3398	840.4	20.7	14.8	399.9	(S)	56.784	5.17
Other Primary Metal Products	3399	564.0	14.8	9.8	301.6	(D)	57.551	4.19
Fabricated Metal Products	34	25,605.1	650.2	1,471.3	39,145.4	(S)	17.403	1.66
Machinery, ex. Electrical	35	27,600.7	680.7	1,959.7	57,356.9	356.3	14.269	1.19
Electrical/Electronic Equipment	36	23,600.9	552.1	1,578.4	47,746.2	48.3	14.952	1.15
•Transportation Equipment	37	29,536.1	716.8	1,667.7	55,657.1	(S)	17.711	1.29
Instruments & Related Products	38	5,166.8	137.5	518.1	16,386.3	(D)	9.972	.83
Miscellaneous Manufacturing	39	3,722.1	104.7	410.1	8,821.7	(S)	9.076	1.19

CUSTOMER CLASS BASELINE DATA

Commercial Customer Class Customer Classification	SIC Codes	Electricity Consumption (millions of kWh's)	Electricity Costs (millions of 1976 $'s)	Measure of Size Sq. Ft. of Floor Space in Million Sq. ft.	Measure of Economic Activity Operating Costs (millions of 1976 $'s)	kWh/Sq. Ft.	Electricity Costs/ Operating Costs (%)
Commercial Office/Public Buildings	60-67,73, 801-804, 808,81,83, 86,89,91-97	106,504	3,930	6,750	161,000	15.78	2.5
Wholesale/ Retail	52-59, 72,76	108,956	4,020	5,856		18.61	
					} 868,000		.5
Warehouses	50,51	14,826	547	2,290		6.47	
Schools/ Colleges	821,822, 824,829	82,661	3,051	6,561	120,400	12.60	2.6
Health	805-807, 809	50,374	1,859	1,993	NA	25.28	NA
Hotel/Motel	70	19,400	716	1,444	25,500	13.43	2.8
Miscellaneous	75,78, 79,823, 84	55,817	2,060	3,382	NA	16.50	NA

CUSTOMER CLASS BASELINE DATA

Residential Customer Class Customer Classification	Electricity Consumption (millions of kWh's	Electricity Costs (millions of 1976 $'s)	Electricity Cost Per Year Per Dwelling Unit (in 1976 $'s)	Measure of Size: Total Number of Dwelling Units (thousands)	Measure of Economic Activity Average Income of Primary Individual	kWh's Consumed Per Year Per Dwelling Unit	Electricity Cost/Income (percent)
Residential							
Single Family (Detached)	755,727.58	25,876.02	537.84	48,111	15,133	15,708 Yr.	3.55
Low Density (2-4 Units)	109,048.90	4,060.31	264.36	15,359	8,228	7,100 Yr.	3.21
Multifamily Low Rise (5-19 Units)	36,000.00	1,374.80	238.68	5,760	8,418	6,250 Yr.	2.84
Multifamily High Rise (20 or More)	28,365.86	1,071.40	244.80	4,391	8,796	6,460 Yr.	2.78

CUSTOMER CLASS BASELINE DATA

Miscellaneous Customer Classes[a]

Customer Classification	SIC Code(s)	Electricity Consumption (Millions of kWh's	Electricity Costs (Millions of dollars)	Measure of Size: Total Employment	Measure of Economic Activity (see below for details)	kWh/ Measure of Size	Electricity Cost/Measure of Economic Activity (%)
Agricultural Crop Production	01	22,060	551.5	4,400,000	62,055,185[b]	7.293	.88[e]
Agricultural Livestock Production	02	10,028	250.7		38,015,438[b]		.65[e]
Iron Ores	1011	4,130	43.7	19,700	701.5[c]	210	6.22[e]
Copper Ores	1022	4,900	44.2	36,400	1,025.3[c]	135	4.31[f]
Miscellaneous Metals	10 (exc. 1011/1022)	2,564	20.2	24,700	654.8[c]	104	3.08[f]
Anthracite	11	262	4.3	4,500	68.4[c]	58	6.28[f]
Bituminous/Lignite	1211	8,000	101.8	152,200	3,625.7[c]	52	2.81[f]
Crude Oil/Gas	1311	12,483	142.8	116,600	14,421.0[c]	107	.99[f]
Miscellaneous Oil/ Gas	13 (exc. 1311)	1,577	19.4	124,000	3,191.1[c]	13	.61[f]
Nonmetallic Minerals, Except Fuels	14	8,100	108.1	114,200	2,723.0[c]	71	3.97[f]
Construction	15,16,17	3,536	81.3	4,083,465	67.809[c]	.866	.11[f]
Railroads (pass. & freight)	40,474	1,550	69.1	528,000	11,200[d]	2.9	.62[g]
Local/Suburban/ Intercity	41	3,000	132.6	109,000	3,100[d]	27.5	4.28[g]
Motor Freight/ Warehouse Op.	42,473	2,800	83.7	1,009,000	20,000[d]	2.8	.42[g]
Water Transport	44	50	1.4	197,000	3,500[d]	.25	.04[g]
Air Transport	45	950	28.3	370,000	8,200[d]	2.6	.35[g]
Pipelines	46	21,350	619.2	17,000	1,000[d]	1,255.9	61.92[g]
Transport Services	47 (excl. 473 & 474)	225	6.5	----	2,200[d]	NA	.30[g]

(a) Data for SIC Codes 01,02 is 1974; for Codes 1011 thru 17 is 1972; for Codes 40 thru 47 is 1976. All data reflects that which is most recently available.

(b) Dollar Value of Production (millions).

(c) Value Added (millions).

(d) National Income without Capital Consumption Allowance (millions).

(e) Electricity Cost Per Value of Production.

(f) Electricity Cost Per Value Added.

(g) Electricity Cost Per Income.

CUSTOMER CLASS BASELINE DATA

Miscellaneous Customer Classes	kWh Purchased	Cost of Purchased kWh ($)	Measure of Size: Number of Utilities	Measure of Economic Activity: Total Operating Expenses	kWh Purchased per Number of Utilities	(%) Cost of Purchased Electricity per Total Operating Cost
Non-Generating Rural Electric Cooperatives	144,720,442 $\times 10^3$	3,130,815,000	926	4,424,243,000	156×10^6	70.8%
Non-Generating Municipals (8%) Sample*	84,604,459 $\times 10^2$	1,545,361,000	57	1,795,189,000	1484×10^6*	86.0%

* These are the larger municipals who must file annual statements with the FERC.

APPENDIX C

RANKING OF CUSTOMER CLASSES AGAINST MARKET POTENTIAL CHARACTERISTICS

The Tables in this Appendix display the rankings given to each customer class for each of the market potential characteristics.

Industrial Customer Classes (Continued) Customer Classification	SIC Code	Receptivity to BSS	Post Demonstration Diffusion Potential	Load Shape	Location	Insurability	Need for Battery System Reliability	Capital Availability and Cost	Ability to Handle Hazardous & Explosive Materials	Ability to Isolate & Monitor Battery Systems	Applicability of Use Restrictions	Potential for Building Code Restrictions	Profitability Index	Importance of Standby Power	Familiarity With Battery Storage Systems	Presence of Self-Generation	Direct Current (dc) Energy Use	Availability of Time Differentiated Rates	Availability of Interruptible Rates
Industrial							5	1			1							1	1
Food and Kindred Products	20	5	5-	3		3			3	3		3		3	4	5	5		
Meat Products	201				3								2						
Dairy Products	202				1								2						
Preserved Fruits & Vegetables	203				1								4						
Grain Mill Products	204				1								1						
Bakery Products	205				3								2						
Sugar, Confectionary Products	206				3								1						
Fats and Oils	207				1								2						
Beverages	208				3								2						
Miscellaneous Food Products	209				3								2						
Tobacco Products	21	5	5	3	3	3			3	3		3	2	5	4	5	5		
Textile Mill Products	22		5	5		3			3	3		1		3	4	5	5		
Weaving Mills, Cotton	2211	5			1								5						
Weaving Mills, Man-made Fibers	2221	4			1								5						
Weaving, Finishing Mills	2231	5			3								5						
Narrow Fabric Mills	2241	5			3								5						
Knitting Mills	225	5			1								4						
Textile Finishing, ex. Wool	226	5			1								5						
Floor Covering	227	5			1								5						
Yarn & Thread	228	3			1								5						
Miscellaneous Textiles	229				3								5						
Apparel, Other Textile Products	23	5	3	3	1	3			3	3		3	3	5	4	5	5		
Lumber & Wood Products	24	5	4	1	1	3			3	3		3	4	3	4	5	5		
Furniture & Fixtures	25	5	5	3	1	3			3	3		3	4	3	4	5	5		
Paper & Allied Products	26		5	5		1			1	1		1		3	3	1	5		
Pulp Mills	2611	5			5								3						
Paperboard Mills	2631	4			1								3						
Misc. Converted Paper Products	264	5			3								2						
Paperboard Containers & Boxes	265	5			3								2						
Building Paper & Board Mills	2661	3			3								2						
Printing & Publishing	27	5		5	3	3			3	3		3	2	3	4	5	5		
Chemical & Allied Products	28		5	5	1	1			1	1		1		1	3[1]	1	5[1]		
Industrial Inorganic Chemicals	281	5		5	1									3	2				
Alkalines & Chlorines	2812	3		5	1									3	1		3		
Industrial Gases	2813	3		5	1									3	2		3		
Inorganic Pigments	2816	3		5	1									3					
Other Inorganic Chemicals	2819	3		5	1									3	2				
Plastic Materials, Synthetics	282	5		5	1									3					
Drugs	283	5		5	1									2					
Soaps, Cleaners, Toilet Goods	284	5		5	3									1					
Paint and Allied Products	2851	5		5	3									2					
Industrial Organic Chemicals	286	5		5	1									3					
Agricultural Chemicals	287	5		5										3					
Nitrogenous Fertilizers	2873	3		5	1									3					
Phosphatic Fertilizers	2874	3		5	1									3					

Industrial Customer Classes (Continued) Customer Classification	SIC Code	Receptivity to BSS	Post Demonstration Diffusion Potential	Load Shape	Location	Insurability	Need for Battery System Reliability	Capital Availability and Cost	Ability to Handle Hazardous & Explosive Materials	Ability to Isolate & Monitor Battery Systems	Applicability of Use Restrictions	Potential for Building Code Restrictions	Profitability Index	Importance of Standby Power	Familiarity With Battery Storage Systems	Presence of Self-Generation	Direct Current (dc) Energy Use	Availability of Time Differentiated Rates	Availability of Interruptible Rates
Fertilizers, Mixing	2875	5		5	1									3					
Other Agricultural Chemicals	2879	5		5	1									3					
Miscellaneous Chemical Products	289	5		5	3									3					
Petroleum and Coal Products	29	5	5	5	1	1			1	1		1	2	3	3	1	5		
Petroleum Refining	2911			5	1														
Paving & Roofing Material	295			5	3														
Paving Mixtures & Blocks	2951			5	3														
Asphalt Felts & Coatings	2952			5	3														
Miscellaneous Petroleum & Coal Products	299			5	3														
Lubricating Oils & Greases	2992			5	3														
Other Products	2999			5	3														
Rubber, Miscellaneous Plastic Products	30	5	5	3	1	1			1	1		1	3	3	4	5	5		
Leather & Leather Products	31	5	5	1	3	3			3	3		3	3	3	4	5	5		
Stone, Clay, & Glass Products	32	5	5	1	1	3			3	3		3	4	3	4	5	5		
Primary Metal Industries	33		5	5	1	1			1	1		1	4	1	3(1)	1	5(1)		
Steel Furnaces, Basic Steel	331	5																	
Blast Furnaces & Steel Mills	3312	3																	
Electrometallurgical Products	3313	1															3		
Steel Wire & Related Products	3315	5																	
Cold Finishing Steel	3316	5																	
Steel Pipes & Tubes	3317	5																	
Iron & Steel Foundries	332	5																	
Gray Iron Foundries	3321	5																	
Malleable Iron	3322	5																	
Steel Investments	3324	4																	
Other Steel Foundries	3325	5																	
Primary Nonferrous Metals	333	5													3		3		
Primary Copper	3331	4																	
Primary Lead	3332	5																	
Primary Zinc	3333	5			1														
Primary Aluminum	3334	4			1														
Other Primary Metals	3339	3			1														
Secondary Nonferrous Metals	3341	5			3										3		3		
Nonferrous Drawing & Rolling	335	5			1														
Copper Rolling	3351	5																	
Aluminum Sheet, Plate, Foil	3353	5																	
Aluminum Extruded Products	3354	5																	
Other Aluminum Drawing	3355	5																	
Other Nonferrous Rolling	3356	5																	
Other Nonferrous Wire Drawing	3357	5																	
Nonferrous Foundries	336	5			3														
Aluminum Foundries	3361	5																	
Brass, Bronze, Copper Foundries	3362	5																	
Other Nonferrous Foundries	3369	5																	
Miscellaneous Primary Metal Products	339	5			3														

Industrial Customer Classes (Continued) Customer Classification	SIC Code	Receptivity to BSS	Post Demonstration Diffusion Potential	Load Shape	Location	Insurability	Need for Battery System Reliability	Capital Availability and Cost	Ability to Handle Hazardous & Explosive Materials	Ability to Isolate & Monitor Battery Systems	Applicability of Use Restrictions	Potential for Building Code Restrictions	Profitability Index	Importance of Standby Power	Familiarity With Battery Storage Systems	Presence of Self-Generation	Direct Current (dc) Energy Use	Availability of Time Differentiated Rates	Availability of Interruptible Rates
Metal Heat Treating	3398	5																	
Other Primary Metal Products	3399	4																	
Fabricated Metal Products	34	5	2	5	1	3			3	3		3	3	3	3	5	5		
Machinery, ex. Electrical	35	5	1	3	1	1			3	1		1	3	1	3	5	5		
Electrical/Electronic Equipment	36	5	5	5	1	3			3	3		1	4	3	3	5	5		
Transportation Equipment	37	5	5	3	1	1			1	1		1	4	1	3	5	5		
Instruments & Related Products	38	5	5	3	1	3			3	3		3	3	5	3	5	5		
Miscellaneous Manufacturing	39	5	5	3	3	3			3	3		3	3	3	3	5	5		
Commercial Customer Classes							5	1			3					5	5	3	3
Office/Public Buildings	60-67,73, 801-804,808, 81,83,86,89, 91-97	5[2]	5[3]	3[4]	3	3			5	3		5	5	1	5				
Retail	52-59,72,76		2	3	3	3			5	5		5	5	1	5				
Wholesale	50,51		3	3	3	3			3	3		3	5	3	4				
Schools/Colleges	821,822,824, 829		5[3]	3	3	3			3	3		5	1	3	4				
Health	805-807,809		5[3]	3	3	3			3	3		5	1	1	5				
Hotel/Motel	70		5[3]	1	3	3			5	3		3	5	3	5				
Miscellaneous	75,78,79, 823,84		5[3]	3	3	3			5	3		3	3	3	5				
Residential Customer Classes		5[5]					1	5	5			5	NA	5	5	5	5	5	5
Single Family (Detached)		3	1	1	3	5				5	5								
Low Density (2-4 Units)			3	1	3	5				5	5								
Multifamily Low Rise (5-19 Units)			5	1	3	5				5	5								
Multifamily High Rise (20 or More)			5	1	3	3				3	3								
Miscellaneous Customer Classes																			
Agricultural Crop Production	01	5	5	NA	3	3	3	3	3	5	1	3	5	1	5	1	5	3	3
Agricultural Livestock Production	02	5	5	NA	3	3	5	3	5	5	1	3	5	1	5	1	5	3	3
Iron Ores	1011	5	5	5	3	3	3	1	3	3	1	NA	5	3	4	5	5	1	1
Copper Ores	1022	5	5	5	3	3	3	1	3	3	1	NA	3	3	4	5	5	1	1
Miscellaneous Metals	10 (exc. 1011/ 1022)	5	5	5	3	3	3	1	3	3	1	NA	5	3	4	5	5	1	1
Anthracite	11	5	5	5	3	3	3	3	3	3	1	NA	1	3	4	5	5	1	1
Bituminous/Lignite	1211	5	5	5	3	3	3	3	3	3	1	NA	1	3	4	5	5	1	1
Crude Oil/Gas	1311	4	4	5	3	1	3	1	1	1	1	NA	5	3	4	5	5	1	1
Miscellaneous Oil/Gas	13 (exc. 1311)	5	5	5	3	1	3	1	1	1	1	NA	1	3	4	5	5	1	1
Nonmetallic Minerals, Except Fuels	14	5	5	1	3	3	3	1	3	3	1	NA	1	3	4	5	5	1	1
Construction	15,16,17	5	5	1	3	3	3	1	3	3	3	3	4	3	4	1	5	3	3
Railroads (pass. & freight)	40,474	5	5	1	3	1	3	3	1	3	1	NA	5	1	4	1	5	3	3
Local/Suburban/Intercity	41	5	5	3	3	1	3	3	3	3	3	NA	4	1	4	1	5	3[6]	3
Motor Freight/Warehouse Op.	42,473	5	5	1	3	3	3	1	3	3	3	3	5	3	4	1	5	3	3
Water Transport	44	5	5	1	3	1	3	1	1	3	1	NA	2	1	4	1	5	3	3
Air Transport	45	5	5	5	3	1	3	1	1	3	1	NA	4	1	4	1	5	3	3

Miscellaneous Customer Classes (Continued) Customer Classification	SIC Code	Receptivity to BSS	Post Demonstration Diffusion Potential	Load Shape	Location	Insurability	Need for Battery System Reliability	Capital Availability and Cost	Ability to Handle Hazardous & Explosive Materials	Ability to Isolate & Monitor Battery Systems	Applicability of Use Restrictions	Potential for Building Code Restrictions	Profitability Index	Importance of Standby Power	Familiarity With Battery Storage Systems	Presence of Self-Generation	Direct Current (dc) Energy Use	Availability of Time Differentiated Rates	Availability of Interruptible Rates
Pipelines	46	1	5	5	3	1	3	1	1	1	1	NA	1	1	4	1	5	3	3
Transport Services	47 (excl. 473 and 474)	5	5	NA	3	3	3	1	3	3	3	NA	5	1	4	1	5	3	3
Nongenerating Rural Electric Cooperatives		1	3	1	3	1	5	3	3	1	1	1	NA	1	3	5	5	1	1
Nongenerating Municipals 8% Sample*		1	3	1	3	1	5	3	3	1	1	1	NA	1	3	5	5	1	1

*These are the larger municipals who must file annual statment with the FERC.

(1) Except as noted in Chapter VII.

(2) Overall rank for all Commercial categories is "5" Significant exceptions and their rankings are:

SIC Code	*Descriptor*	*Rank*	*SIC Code*	*Descriptor*	*Rank*
5411	Grocery Stores	1	5451	Dairy Product Stores	3
5463	Retail Bakeries	1	5521	Used Car Dealers	3
5983	Fuel Oil Dealers	1	5551	*Boat Dealers*	3
8062	Hospitals	1	5571	Motorcycle Dealers	3
8421	Zoos and Botanical Gardens	1	5599	Auto Dealers	3
8631	*Labor Organizations*	1	5722	Appliance Stores	3
5311	Department Stores	2	5912	Drug/Proprietary	3
5599	Auto Dealers	2	5921	Liquor Stores	3
7351	News Syndicates	2	5942	Book Stores	3
8051	Skilled Care Fac.	2	5943	Stationery Stores	3
5211	Bldg. Matls. Dealers	3	5945	Hobbies/Toys	3
5271	Mobile Home Dealers	3	5946	Cameras/Photo	3
5331	Variety Stores	3	5982	*Fuel/Ice Dealers*	3
			7213	Linen Supply	3

(3) Professional Membership Organizations, such as those representing users in SIC 80-84, are possible vehicles for post demonstration diffusion among the individual members they represent. The members themselves are ranked low.

(4) Overall rank is "3", but several 4 digit SIC codes are "1": 5211, 5271, 5521, 5551, 5571, 5599.

(5) All-electric units are ranked "3".

(6) Subways are ranked "1".

APPENDIX D

OVERALL MARKET POTENTIAL RANKING OF CUSTOMER CLASSES

D-1

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1	2	3	4	5-18		
	INDUSTRIAL CUSTOMER CLASSES	Receptivity	Diffusion	Load Shape	Location	Other MPCs	Overall Score	Overall Indicator
201	MEAT PRODUCTS	5	5	3	3	2.9	3.8	-
202	DAIRY PRODUCTS	5	5	3	1	2.9	3.4	-
203	PRESERVED FRUITS & VEGETABLES	5	5	3	1	3	3.4	-
204	GRAIN MILL PRODUCTS	5	5	3	1	2.8	3.4	-
205	BAKERY PRODUCTS	5	5	3	3	2.9	3.8	-
206	SUGAR, CONFECTIONARY PRODUCTS	5	5	3	3	2.8	3.8	-
207	FATS, OILS	5	5	3	1	2.9	3.4	-
208	BEVERAGES	5	5	3	3	2.9	3.8	-
209	MISCELLANEOUS FOOD PRODUCTS	5	5	3	3	2.9	3.8	-
21	TOBACCO PRODUCTS	5	5	3	3	3	3.8	-
221	COTTON WEAVING MILLS	5	5	5	1	2.9	3.8	-
222	MANMADE FIBER WEAVING MILLS	4	5	5	1	2.9	3.6	-
223	FINISHING MILLS	5	5	5	3	2.9	4.2	-
224	NARROW FABRIC MILLS	5	5	5	3	2.9	4.2	-
225	KNITTING MILLS	5	5	5	1	2.9	3.8	-
226	TEXTILE FINISHING (EXCLUDING WOOL)	5	5	5	1	2.9	3.8	-
227	FLOOR COVERINGS	5	5	5	1	2.9	3.8	-
228	YARNS, THREADS	3	5	5	1	2.9	3.4	-
229	MISCELLANEOUS TEXTILES	3	5	5	3	2.9	3.8	-

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	INDUSTRIAL CONTINUED							
23	APPAREL, OTHER TEXTILE PRODUCTS	5	3	3	1	3.1	3	+
24	LUMBER & WOOD PRODUCTS	5	4	1	1	3	2.8	+
25	FURNITURE AND FIXTURES	5	5	3	1	3	3.4	-
261	PULP MILLS	5	5	5	5	2	4.4	-
263	PAPERBOARD MILLS	4	5	5	1	2	3.4	-
264	MISCELLANEOUS CONVERTED PAPER PRODUCTS	5	5	5	3	2	4.0	-
265	PAPERBOARD CONTAINERS AND BOXES	5	5	5	3	2.	4.0	-
266	BUILDING PAPER & BOARD MILLS	3	5	5	3	2	3.6	-
27	PRINTING AND PUBLISHING	5	5	5	3	2.7	4.2	-
2812	ALKALINES & CHLORINES	3	5	5	1	1.5	3.1	-
2813	INDUSTRIAL GASES	3	5	5	1	1.5	3.1	-
2816	INORGANIC PIGMENTS	3	5	5	1	1.5	3.1	-
2819	OTHER ORGANIC CHEMICALS	3	5	5	1	1.5	3.1	-
282	PLASTICS MATERIALS, SYNTHETICS	5	5	5	1	1.5	3.5	-
283	DRUGS	5	5	5	1	1.5	3.5	-
284	SOAPS, CLEANERS, TOILET GOODS	5	5	5	3	1.5	3.9	-
285	PAINT AND ALLIED PRODUCTS	5	5	5	3	1.5	3.9	-
286	INDUSTRIAL ORGANIC CHEMICALS	5	5	5	1	1.5	3.5	-
2873	NITROGENOUS FERTILIZERS	3	5	5	1	1.5	3.1	-

D-3

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	INDUSTRIAL CONTINUED							
2874	PHOSPHATIC FERTILIZERS	3	5	5	1	1.5	3.1	-
2875	MIXING FERTILIZERS	5	5	5	1	1.5	3.5	-
2879	OTHER AGRICULTURAL CHEMICALS	5	5	5	1	1.5	3.5	-
289	MISCELLANEOUS CHEMICAL PRODUCTS	5	5	5	3	1.5	3.9	-
291	PETROLEUM REFINING	5	5	5	1	2.0	3.6	-
295	PAVING AND ROOFING MATERIALS	5	5	5	3	2.0	4.0	-
299	MISCELLANEOUS PETROLEUM & COAL PRODUCTS	5	5	5	3	2.0	4.0	-
30	RUBBER, MISCELLANEOUS PLASTIC PRODUCTS	5	5	3	1	2.4	3.3	-
31	LEATHER & LEATHER PRODUCTS	5	5	1	3	2.9	3.4	-
32	STONE, CLAY & GLASS PRODUCTS	5	5	1	1	3.3	3.1	-
3312	BLAST FURNACES & STEEL MILLS	3	5	5	1	1.9	3.2	-
3313	ELECTROMETALLURGICAL PRODUCTS	1	5	5	1	1.8	2.8	+
3315	STEEL WIRE & RELATED PRODUCTS	5	5	5	1	1.9	3.6	-
3316	COLD FINISHING STEEL	5	5	5	1	1.9	3.6	-
3317	STEEL PIPES & TUBES	5	5	5	1	1.9	3.6	-
332	IRON AND STEEL FOUNDRIES	5	5	5	1	1.9	3.6	-
3331	PRIMARY COPPER	4	5	5	1	1.9	3.4	-
3332	PRIMARY LEAD	5	5	5	1	1.9	3.6	-
3333	PRIMARY ZINC	5	5	5	1	1.7	3.5	-
3334	PRIMARY ALUMINUM	4	5	5	1	1.9	3.4	-

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	INDUSTRIAL CONTINUED							
3339	OTHER PRIMARY METALS	2	5	5	1	1.9	3.0	+
334	SECONDARY NONFERROUS METALS	5	5	5	3	2.4	4.1	-
335	NONFERROUS DRAWING & ROLLING	5	5	5	1	2.4	3.7	-
336	NONFERROUS FOUNDRIES	5	5	5	3	2.4	4.1	-
339	MISCELLANEOUS PRIMARY METALS PRODUCTION	4	5	5	3	2.4	3.9	-
34	FABRICATED METAL PRODUCTS	5	2	5	1	2.8	3.2	-
35	MACHINERY, EXCLUDING ELECTRICAL	5	1	3	1	2.3	2.5	+
36	ELECTRICAL, ELECTRONIC EQUIPMENT	5	5	5	1	2.8	3.8	-
37	TRANSPORTATION EQUIPMENT	5	5	3	1	2.1	3.2	-
38	INSTRUMENTS & RELATED PRODUCTS	5	5	3	1	2.9	3.4	-
39	MISCELLANEOUS MANUFACTURING	5	5	3	3	2.8	3.8	-

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	COMMERCIAL CUSTOMER CLASSES							
	The following 4-digit customer classes are exceptions to the ratings shown for retail and other commercial on the next page.							
5211	BUILDING MATERIALS DEALERS	3	2	1	3	3.9	2.6	+
5271	MOBILE HOME DEALERS	3	2	1	3	3.9	2.6	+
5311	DEPARTMENT STORES	2	2	3	3	3.9	2.8	+
5331	VARIETY STORES	3	2	3	3	3.9	3.0	+
5411	GROCERY STORES	1	2	3	3	3.9	2.6	+
5451	DAIRY PRODUCTS STORES	3	2	3	3	3.9	3.0	+
5463	RETAIL BAKERIES	1	2	3	3	3.9	2.6	+
5521	USED CAR DEALERS	3	2	1	3	3.9	2.6	+
5551	BOAT DEALERS	3	2	1	3	3.9	2.6	+
5571	MOTORCYCLE DEALERS	3	2	1	3	3.9	2.6	+
5599	AUTO DEALERS	2	2	1	3	3.9	2.4	+
5722	APPLIANCE STORES	3	2	3	3	3.9	3.0	+
5912	DRUGS/PROPRIETARY	3	2	3	3	3.9	3.0	+
5921	LIQUOR STORES	3	2	3	3	3.9	3.0	+
5942	BOOK STORES	3	2	3	3	3.9	3.0	+
5943	STATIONERY STORES	3	2	3	3	3.9	3.0	+
5945	HOBBIES/TOYS	3	2	3	3	3.9	3.0	+
5946	CAMERAS/PHOTO	3	2	3	3	3.9	3.0	+
5982	FUEL/ICE DEALERS	3	2	3	3	3.9	3.0	+
5983	FUEL OIL DEALERS	1	2	3	3	3.9	2.6	+

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	COMMERCIAL CONTINUED							
7213	LINEN SUPPLY	3	2	3	3	3.9	3.0	+
7351	NEWS SYNDICATES	2	2	3	3	3.7	2.8	+
OTHER RETAIL (SIC 52-59, 72, 76)		5	2	3	3	3.9	3.4	-
NOTE:	DIFFUSION UNDER WHOLESALE/RETAIL WILL BE MOST LIKELY AMONG "CHAINS" AND HIGHLY COMPETITIVE ESTABLISHMENTS (→ Diffusion)							
	COMMERCIAL OFFICES/PUBLIC BUILDINGS (SIC 60-67, 73, 801-804, 808, 81, 83, 86, 89, 91-97)	5	5	3	3	3.7	3.9	-
	WHOLESALE (SIC 50-51)	5	3	3	3	3.2	3.4	-
	SCHOOLS, COLLEGES (SIC 821, 822, 824, 829)	5	5	3	3	3.1	3.8	-
8051	SKILLED CARE FACILITIES	2	5	3	3	3	3.2	-
8062	HOSPITALS	1	5	3	3	3	3.0	+
	OTHER HEALTH FACILITIES (SIC 805-807, 809)	5	5	3	3	3	3.8	-
	HOTELS/MOTELS (SIC 70)	5	5	1	3	3.4	3.5	-
8421	ZOOS AND BOTANICAL GARDENS	1	5	3	3	3.3	3.1	-
	OTHER MISCELLANEOUS COMMERCIAL (SIC 75, 78, 79, 823, 84)	5	5	3	3	3.3	3.9	-

NOTE: (→ Diffusion)

DIFFUSION UNDER ALL OTHER COMMERCIAL CUSTOMER CLASSES MAY BE AIDED BY PROFESSIONAL ASSOCIATIONS OR OTHER MEMBERSHIP ORGANIZATIONS, SUCH AS THOSE REPRESENTED IN SIC 80-84.

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	RESIDENTIAL CUSTOMER CLASSES							
	SINGLE FAMILY DETACHED	5	1	1	3	4.7	2.9	+
	LOW DENSITY ATTACHED (2-4 UNITS)	5	3	1	3	4.7	3.3	-
	MULTIFAMILY (5-19 UNITS)	5	5	1	3	4.7	3.7	-
	MULTIFAMILY (20 OR MORE)	5	5	1	3	4.2	3.6	-

NOTE: (Receptivity)

RECEPTIVITY MAY BE GREATER IN ALL-ELECTRIC RESIDENTIAL BUILDINGS. THEY ARE RATED "3".

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1 Receptivity	2 Diffusion	3 Load Shape	4 Location	5-18 Other MPCs	Overall Score	Overall Indicator
	MISCELLANEOUS CUSTOMER CLASSES							
01	AGRICULTURAL CROP PRODUCTION	5	5	NA	3	3.2	4.1	-
02	AGRICULTURAL LIVESTOCK PRODUCTION	5	5	NA	3	3.2	4.1	-
1011	IRON ORES	5	5	5	3	2.9	4.2	-
1022	COPPER ORES	5	5	5	3	2.8	4.1	-
10	MISCELLANEOUS METAL ORES	5	5	5	3	2.9	4.2	-
11	ANTHRACITE	5	5	5	3	2.8	4.1	-
1211	BITUMINOUS/LIGNITE	5	5	5	3	2.8	4.1	-
1311	CRUDE OIL/GAS	4	4	5	3	2.5	3.7	-
13	MISCELLANEOUS OIL/GAS	5	5	5	3	2.1	4.0	-
14	NONMETALLIC MINERALS, EXCEPT FUELS	5	5	1	3	2.6	3.3	-
15,16,17	CONSTRUCTION	5	5	1	3	3.1	3.4	-
40,474	RAILROADS, PASSENGER & FREIGHT	5	5	1	3	2.6	3.2	-
41	LOCAL, SUBURBAN, INTERCITY TRANSIT	5	5	3	3	2.9	3.8	-
42,473	MOTOR FREIGHT, WAREHOUSE OPERATIONS	5	5	1	3	3.1	3.4	-
44	WATER TRANSPORT	5	5	1	3	2.2	3.2	-
45	AIR TRANSPORT	5	5	5	3	2.4	4.1	-

CUSTOMER CLASS MARKET POTENTIAL EVALUATION

SIC	DESCRIPTOR	MPCs 1	2	3	4	5-18		
	MISCELLANEOUS CONTINUED	Receptivity	Diffusion	Load Shape	Location	Other MPCs	Overall Score	Overall Indicator
46	PIPELINES	1	5	5	3	2	3.2	-
47	TRANSPORT SERVICES EXCEPT 473 and 474	5	5	NA	3	3.1	4.0	-
	NON-GENERATING RURAL ELECTRIC COOPERATIVES	1	3	1	3	2.4	2.1	+
	8% SAMPLE OF NON-GENERATING MUNICIPALS	1	3	1	3	2.4	2.1	+

APPENDIX E

SAMPLE COPY OF FIRST SOLICITATION

Battelle's Energy Economics Group is currently conducting a research program for the U.S. Department of Energy on the concept of storing electricity in customer-owned batteries. One of the goals of this program is to identify for U.S. DOE any organizations that may benefit from, and have interest in, customer-owned battery storage. U.S. DOE may later invite some of these organizations to participate in a demonstration program of the battery storage concept. Battelle's preliminary research indicates that an economically viable battery storage application may exist within your company. As a research organization, Battelle holds no proprietary interest in the manufacture or sale of batteries and related system components. The sole intent of this letter is therefore to alert your organization to the possible benefits of customer-owned battery storage, and to solicit your response in the event that battery storage is of interest to you.

With a battery storage system a customer can purchase and store power during periods when electricity rates are their lowest and discharge and consume power from the batteries when rates are high. The viability of battery storage may be enhanced by the recent trend toward alternative rate structure forms such as those addressed in the Public Utility Regulatory Policies Act of 1978 (PURPA). For example, one of these rate structure forms is time-of-day pricing, under which charges for daytime use of electricity are significantly greater than charges for nighttime consumption. The rationale behind time-of-day rates is as follows:

- During the daytime, or when the demand for electricity is greatest, the utility is forced to use its least efficient production units. These units frequently utilize scarce and expensive fuels such as petroleum and natural gas.

- Emphasis on daytime consumption will necessitate continued expansion in new electric generation and transmission facilities to meet higher peak loads. The utility companies must pass the costs of such added facilities on to you, the consumer.

Time-of-day pricing holds that since nighttime production costs are less than daytime production costs, nighttime prices should be less than daytime prices.

The concept behind the use of batteries is based on this time differentiated price variance. Batteries will be economically feasible in applications where nighttime power is sufficiently less expensive than daytime power to compensate for the capital and operating costs of the battery storage system. Studies have shown that ratios of daytime to nighttime electricity costs exceeding 8:1 are possible. With ratios of this magnitude, the payback period of a battery system can be short.

The viability of customer-owned battery storage is not solely dependent on PURPA-type rate structures. For example, current industrial electric rates typically include a demand charge under which the electricity customer's billing is based in part on the maximum demand placed on the electric grid. Batteries can reduce this maximum demand by smoothing the customer's load shape - i.e., storing energy during the customer's low demand periods for use during the maximum demand period. Moreover, since stored electricity can be used as emergency or standby power in the event of an electrical service interruption, battery systems can offer improved service reliability and operational flexibility. In this mode of operation, batteries are serving as an uninterruptible power source. An added benefit of off-peak storage for on-peak consumption is the reduction of our Nation's dependence on scarce fuels.

Not every company should consider battery storage. The economic feasibility of such technology is highly dependent upon the composition and shape of the customer's load and upon the system characteristics of the utility serving the customer. Because our preliminary research found that your company appears to have the potential for at least one economically viable application of battery storage, we ask that you indicate to us your interest in learning more about the benefits of customer-owned battery storage. Once we have completed our in-depth battery storage viability analysis, we will contact you with more specific information which will permit you to better assess battery storage viability for your company.

Please send your expression of interest to me at the above address, or call me (614) 424-6499 or Mr. Tom Martineau (614) 424-6477. We look forward to future contact with you.

With best regards,

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FJB:djb

APPENDIX F

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Findlay, Ohio 45840

Mr. John M. Ruland
Vice President, Operations
Bay State Milling Company
1776 Heritage Drive
N. Quincy, Massachusetts 02171

Mr. John A. Jacobi
Plant Manager, Corporate Planning & Development
Tenneco Inc.
Tenneco Building, P.O. Box 2511
Houston, Texas 77001

Mr. K. H. Thompson
Vice President, Manufacturing & Facilities
Rexnord
3500 First Wisconsin Center
Milwaukee, Wisconsin 53202

Mr. William D. Johnston, PE
Vice President, Engineering & Construction
White Castle System Inc.
P.O. Box 1498
Columbus, Ohio 43216

Mr. R. Rambacher
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Parker Hannifin Corporation
17325 Euclid Avenue
Cleveland, Ohio 44112

Mr. Ken W. Hamby
Manager of Engineering
Cosden Oil & Chemical Company
P.O. Box 1311
Big Spring, Texas 79720

Mr. R. E. Boers
Vice President, Real Estate
Administration
Finance Division
Household Finance
2700 Sanders Road
Prospect Heights, Illinois 60070

Mr. James V. Flanigan
Senior Energy Engineer
Nestle Enterprises Inc.
100 Bloomingdale Road
White Plains, New York 10605

Mr. W. H. Presley, Jr.
Vice President, Manufacturing
Sperry Vickers
World Headquarters
1401 Crooks Road
Troy, Michigan 48084

Mr. D. T. Axon
Manager, Energy Engineering Dept.
Ford Motor Company
The American Road
Dearborn, Michigan 48121

Mr. Paul Shapiro
Ford Motor Company
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Industrial Relations
Aerojet-General Corporation
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Mr. O. Paul Doyle
Vice President, Engineering
Murphy Oil Corporation
200 Jefferson Avenue
El Dorado, Arkansas 71730

Mr. Jim Pouncy
Murphy Oil Corporation
200 Jefferson Avenue
El Dorado, Arkansas 71730

Mr. J. H. Wyatt
Executive Vice President
Reeves Brothers Inc.
115 Summit Avenue
Summit, New Jersey 07901

Mr. David L. Williams
Director, Energy Utilization
McGraw-Edison Company/Corporate Hdqtrs.
One Continental Towers
1701 Golf Road
Rolling Meadows, Illinois 60008

Mr. John M. Able
Manager, Corporate Planning & Evaluation
Union Oil Company of California
Union Oil Center, Box 7600
Los Angelese, California 90051

Mr. T. P. McNulty
Vice Presidnet, Technical Operations
Kerr-McGee Chemical Corporation
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Dr. Douglas W. Carlson
Senior Vice Presidnet, Technology
Bandag Inc.
Bandag Center
Muscatine, Iowa 52761

Mr. Frank J. Fumia
Energy Manager
E. R. Squibb & Sons Inc.
World Headquarters
P.O. Box 4000
Princeton, New Jersey 08540

Mr. Henri Korb
Manager, Energy Management Section
Safeway Stores Inc.
425 Madison Street
Oakland, California 94660

Mr. W. F. Brusher
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Engineering Department
Standard Oil Company of California
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San Francisco, California 94105

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Research Supervisor
Alternative Energy Research
The Standard Oil Company
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Mr. T. R. Shaw
Engineering & Services
Manager, Design Engineering Division
Phillips Petroleum Company
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Bartlesville, Oklahoma 74004

Mr. Bion D. Barger
Senior Consultant
Technical Evaluation & Forecasting
Standard Oil Company (Indiana)
Amoco Research Center
P.O. Box D400
Naperville, Illinois 60540

Mr. Manos Fourakis
Honeywell Inc.
Honeywell Plaza
Minneapolis, Minnesota 55408

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Vice President, Manufacturing
Dundee Cement Company
Dundee, Michigan 48131

Mr. R. S. Proctor, Vice President
Manufacturing Department
Chevron USA Inc.
575 Market Street
San Francisco, California 94105

Mr. R. C. Lach
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Interlake Inc.
150 W. 137th Street
Chicago, Illinois 60627

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Real Estate & Construction Division
IBM Corporation
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Tarrytown, New York 10591

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Director of Engineering
Beverage Management Inc.
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P.O. Box 16514
Columbus, Ohio 43216

Mr. C. J. Strader
Director, Manufacturing Engineering
Prestolite Battery Division
511 Hamilton Street
Toledo, Ohio 43694

Mr. Robert C. Dancy
Director, Manufacturing Services
Allis-Chalmers
P.O. Box 512
Milwaukee, Wisconsin 53201

Mr. George H. Keller
Becton Dickinson & Company
Mack Centre Drive
Paramus, New Jersey 07652

Mr. E. F. Parry
Power Systems & Corporate Electric Group
Engineering Division
Proctor & Gamble Company
Sharon Woods Technical Center
11510 Reed Hartman Highway
Cincinnati, Ohio 45241

Mr. Virgil L. Sewell
Senior Vice President
Texas Industries Inc.
8100 Carpenter Freeway
Dallas, Texas 75247

Mr. Ralph DeForest
Vice President, Economics & Planning
Coastal States Management Corporation
The Coastal Tower
Nine Greenway Plaza East
Houston, Texas 77046

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Manager, Plant Services
Hughes Aircraft Company
Electron Dynamics Division
3100 W. Lomita Boulevard
Torrance, California 90509

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Mail Stop B-104
Hughes Aircraft Company
P.O. Box 3310
Fullerton, California 92634

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Corporate Energy Coordinator
Potlach Corporation
Two Embarcadero Center, Floor 20
P.O. Box 7864
San Francisco, California 94120

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Senior Project Engineer IMD
Richardson-Merrell Inc.
Ten Westport Road
Wilton, Connecticut 06897

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Director of Energy Management
Johnson & Johnson
New Brunswick, New Jersey 08903

Mr. B. J. Thompson, Vice President
Engineering & Development
Oscar Mayer & Company
P.O. Box 7188
Madison, Wisconsin 53707

Mr. Robert C. Bohley
Hydrocarbons & Energy Research
Dow Chemical USA
A-2303 Building
Texas Division
Freeport, Texas 77541

Mr. Edward M. Nussbaum
Manager of Energy Programs
Dow Chemical USA
220 Building
Midland, Michigan 48640

Mr. Wil Williams
Manager, Communications & Training
EXIDE
101 Gibraltar Road
Horsham, Pennsylvania 19044

Mr. R. R. Cooke
Manager, Energy Affairs
The Coca Cola Company
P.O. Drawer 1734
Atlanta, Georgia 30301

Mr. David L. Hintermeister
Vice President & General Manager
Research & Engineering
Cities Service Company
Cities Service Building
Box 300
Tulsa, Oklahoma 74102

Mr. Bob Frick
Director of Engineering
SYSCO Corporation
1177 W. Loop South
Houston, Texas 77027

APPENDIX G

COMMERCIAL CUSTOMERS INCLUDED IN SECOND SOLICITATION

Unishops Inc.
21 Caven Point Avenue
Jersey City, New York 07305

Mr. K. L. Margolis
Lerner Stores Corporation
460 W. 33rd Street
New York, New York 10001

Mr. L. H. Wexner
Limited Stores Inc.
P.O. Box 16528

Pic-N-Pay Stores
P.O. Box 745
Matthews, North Carolina 28105

Mr. L. A. Henderson
Pier 1 Imports
2520 West Freeway
Fort Worth, Texas 76102

Mr. L. Turner
McDonalds Corporation
2111 Euco Drive
Oak Brook, Illinois 60521

Mr. J. M. Biggar
Stouffer Corporation
5750 Hooper Road
Cleveland, Ohio 44139

Mr. C. R. Walgreen
Walgreen Company
200 Wilrout Road
Deerfield, Illinois 60015

Mr. S. Drowkin
Revco Drug Stores Inc.
1925 Enterprise
Twinsburg, Ohio 44087

Mr. D. R. Baty
Hillhaven Corporation
1015 Center Street
Tacoma, Washington 98411

Mr. J. J. Zilber
Unicare Services
105 W. Michigan
Milwaukee, Wisconsin 53203

Mr. D. A. Jones
Humana Inc
P.O. Box 1438
Louisville, Kentucky 40201

Mr. H. W. Sichter
Dayton Osteopathic Hospital
405 W. Grand Avenue
Dayton, Ohio 45405

Santa Rosa Medical Center
519 W. Houston
San Antonio, Texas 78207

Mr. L. O. Barnes
Ryder Systems Inc.
Box 520816
Miami, Florida 33152

Mr. F. A. Olson
Hertz Corporation
660 Madison Avenue
New York, New York 10021

Mr. R. E. Winegarden
Holiday Inns Inc.
3742 Lamar Avenue
Memphis, Tennessee 38118

Mr. J. W. Marriott
Marriott Corporation
5161 River Road
Washington, D.C. 20016

Mr. J. W. McCarthy
Quality Inns International
10750 Columbia Pike
Silver Springs, Maryland 20901

A. H. Krausman
Ace Hardware Corporation
2200 Kensington
Hinsdale, Illinois 60521

E. Blank
Sammons Enterprises
403 S. Akard
Dallas, Texas 75202

Mr. H. G. Jarecki
Mocatta Metals Co.
25 Broad Street
New York, N.Y. 10004

Mr. W. L. Moore
Unijax Inc.
1301 Gulf LF Drive
Jacksonville, Fla. 32203

Mr. A. J. Erey
Sandoz-Wander
Route 10
Hanover, N.J. 07936

Mr. R. Milliken
Milliken and Company
1045 Avenue of the Americas
New York, NY 10018

Mr. E. L. McNeley
Wickes Corp
110 West A. Street
San Diego, Calif. 92101

Mr. O. E. Wastson
Payless Cashways
Highway 65 South
Englewood, Co 80110

Mr. J. W. Hechinger
Hechinger Company
3500 Pennsey Drive
Landover, Md 20785

Mr. T. C. Henderson
Puregro Company
1111 W. 6th Street
Los Angeles, Calif 90017

Mr. M. Weinberg
Franks Nursery Sales
6399 E. Nevada
Detroit, MI. 48234

Mr. E. R. Telling
Sears Roebuck & Co.
Sears Tower
Chicago, ILL 60684

Mr. R. E. Dewar
K Mart Corporation
3100 W. Big Beaver
Troy, MI 48084

Mr. H. Krewsky
Federated Department Stores
7 West 7th Street
Cincinnati, Ohio 45202

Mr. E. J. Gibbons
F. W. Woolworth Co.
233 Broadway
New York, NY 10007

Mr. C. Gass
McCrory Corporation
888 Seventh Street
New York, NY 10019

Mr. W. S. Mitchell
Safeway Stores Inc.
4th & Jackson
Oakland, Calif. 94660

Mr. L. Everingham
Kroger Company
1014 Vine Street
Cincinnati, Ohio 45201

Mr. C. P. McCalill
Kayo Oil Company
1221 E. Main Street
Chattanooga, Tenn 37408

Mr. H. I. Wexler
Hudson Oil Company
4720 Rainbow Blvd
Kansas City, KS 66103

Mr. David L. Hintermeister
VP 7 General Manager
Research & Eng.
Cities Service Co.
Cities Service Bldg
Box 300
Tulsa, OK 74102

Mr. Bob Frick
Dir of Eng
Sysco Corp
1177 W. Loop S
Houston, Texas 77027

Volkswagen of American
818 Sylvan Avenue
Englewood, NY 07632

Mr. J. Maritz
Maritz Inc.
1353 N. Highway
Fenton, MO 63026

Mr. D. E. Pardue
Exec. VP
Towers Companies Inc.
Box 111
North Wilesborough, NC 28656

M. T. A. Riley
Nash Finch
3381 Gorham Avenue
St. Louis Park, MN 55426

Mr. F. D. Laraga
General Coal Company
123 S. Broad Street
Philadelphia, PA 19109

Mr. W. B. Whaley
Graybar Electrical Co. Inc.
420 Lexington Avenue
New York, NY 10017

APPENDIX H

SAMPLE LETTERS AND ENCLOSURES OF SECOND SOLICITATION

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

October 15, 1980

Several months ago, we contacted your company to ascertain your potential interest in participating in a U.S. Department of Energy-sponsored demonstration program of electricity battery storage on the customer's side of the meter.

Since you had indicated your willingness to further explore your potential participation, we now request your assistance in determining the potential viability of battery storage systems for your company.

The enclosed "Self-Evaluation for Battery Storage Viability" (Enclosure 1) has been designed to let you assess your own circumstances against various economic, institutional, and environmental factors influencing battery stoage viability. If possible, please complete and return this document on or before October 31, 1980 so that we may complete our analysis of all responses.

We will use the answers you give to rank you and others on a list of potential demonstration program participants. The rank which you will occupy on this list will depend on: (1) the degree to which your own circumstances favor battery storage; and (2) the relative viability of battery storage for other demonstration program candidates.

What Makes Battery Storage Potentially Viable?

It is important to note that the Department of Energy's battery system cost goal is $65 per installed kilowatt-hour in 1980 dollars. Given the achievement of this goal, Battelle's cost/benefit analysis indicates that the differential in on-peak versus off-peak rates will have to be in the 3¢ to 4¢ per kilowatt-hour range for economic viability. Some utility companies presently offer this differential, while other utilities and regulatory bodies are considering similar on-peak/off-peak rates.

These cost parameters are the basic viability measure, but several other favorable indicators for battery storage viability should also be considered. Conditions are favorable, if:

- Your utility offers time-differentiated rates and/or interruptible rates at a level equal to, or greater than, the 3¢ to 4¢ differential noted above;
- You need a reliable way to shave peak loads in order to avoid the imposition of high utility demand charges;
- You need/use a considerable amount of direct current electricity;
- Standby power in the event of utility service interruption is extremely useful or important to you;
- Your electrical load is generally greater during daytime operations than during the night;
- You face few, if any, institutional constraints to the installation of energy systems;
- You are familiar with the operation of battery storage systems or similar installations.

Please note that the degree to which your own circumstances match, or differ from, the above indicators does not automatically cause you to be selected or rejected as a potential demonstration program participant. Your responses will instead be ranked relative to all responses we receive.

What Happens After the Ranking?

We will send to the U.S. Department of Energy (DOE) a list of all respondents, rank-ordered on the basis of battery storage viability. DOE is expected to select potential demonstration candidates from this list for preliminary discussions. Subsequently, DOE will send to each candidate a formal Request for Proposal (RFP). Candidates responding to the RFP will then have their formal proposal evaluated for selection as demonstration program participants.

How to Complete the Self-Evaluation

The enclosed self-evaluation form contains instructions for its completion. In addition, the following suggestions are offered:

(1) If you have more than one facility or building in different areas of the U.S., use the viability indicators listed above to select not more than three of your facility locations where battery storage may be especially viable. Then complete one self-evaluation for each of the up to three facilities selected.

(2) If you have facilities other than industrial plants, such as offices, commercial/retail/wholesale stores or warehouses, you are invited to furnish data on these as well. Battery storage feasibility is not limited to industrial facilities alone.

(3) Check the list of utility companies (Enclosure 2): facilities located in the service areas of these utilities face rate structures which may favor battery storage systems.

(4) If you need to become more familiar with the technical and cost aspects of batteries, please read the enclosed "Battery Energy Storage System Description" (Enclosure 3).

A Note About Confidentiality

The information you furnish will be used by Battelle researchers to establish your ranking on the list. The information will not be published or disseminated. It will be shared confidentially with the DOE officials in charge of the battery storage program.

We look forward to receiving your response. If you have any questions please call us at any time.

Very truly yours,

F. Jere Bates
Economics, Planning and
Policy Analysis Section
(614) 424-6499

Thomas Martineau, R.A.
Principal Research Architect
Economics, Planning and
Policy Analysis Section
(614) 424-6477

FJB/TM:amm

Enclosures:

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

October 16, 1980

Battelle's Energy Economics Group is currently conducting a research program for the U.S. Department of Energy on the concept of storing electricity in customer-owned batteries. One of the goals of this program is to identify for U.S. DOE any organizations that may benefit from, and have interest in, customer-owned battery storage. U.S. DOE may later invite some of these organizations to participate in a demonstration program of the battery storage concept. Battelle's preliminary research indicates that your type of business operation may be economically suitable for such a battery storage application. As a research organization, Battelle holds no proprietary interest in the manufacture or sale of batteries and related system components. The sole intent of this letter is therefore to alert your organization to the possible benefits of customer-owned battery storage, and to solicit your response in the event that battery storage is of interest to you.

What Makes Battery Storage Potentially Viable?

With a battery storage system a customer can purchase and store power during periods when electricity rates are their lowest and discharge and consume power from the batteries when rates are high. The viability of battery storage may be enhanced by the recent trend toward alternative rate structure forms such as those addressed in the Public Utility Regulatory Policies Act of 1978 (PURPA). For example, one of these rate structure forms is time-of-day pricing, under which charges for daytime use of electricity are significantly greater than charges for nighttime consumption. The rationale behind time-of-day rates is as follows:

- During the daytime, or when the demand for electricity is greatest, the utility is forced to use its least efficient production units. These units frequently utilize scarce and expensive fuels such as petroleum and natural gas.

- Emphasis on daytime consumption will necessitate continued expansion in new electric generation and transmission facilities to meet higher peak loads. The utility companies must pass the costs of such added facilities on to you, the consumer.

Time-of-day pricing holds that since nighttime production costs are less than daytime production costs, nighttime prices should be less than daytime prices.

The concept behind the use of batteries is based on this time differentiated price variance. Batteries will be economically feasible in applications where nighttime power is sufficiently less expensive than daytime power to compensate for the capital and operating costs of the battery storage system.

It is important to note that the Department of Energy's battery system cost goal is $65 per installed kilowatt-hour in 1980 dollars. Given the achievement of this goal, Battelle's cost/benefit analysis indicates that the differential in on-peak versus off-peak rates will have to be in the 3¢ to 4¢ per kilowatt-hour range for economic viability. Some utility companies presently offer this differential, while other utilities and regulatory bodies are considering similar on-peak/off-peak rates.

The viability of customer-owned battery storage is not solely dependent on PURPA-type rate structures. For example, some current electric rates include a demand charge under which the electricity customer's billing is based in part on the maximum demand placed on the electric grid. Batteries can reduce this maximum demand by smoothing the customer's load shape - i.e., storing energy during the customer's low demand periods for use during the maximum demand period. Moreover, since stored electricity can be used as emergency or standby power in the event of an electrical service interruption, battery systems can offer improved service reliability and operational flexibility. In this mode of operation, batteries are serving as an uninterruptible power source.

In summary, the following are therefore favorable indicators of battery storage viability for your operations:

- Your utility offers time-differentiated and/or interruptible rates;

- You need a reliable way to shave peak loads in order to avoid the imposition of high utility demand charges by your utility;

- Standby power in case of utility service interruption is extremely useful or important to you;

- Your electrical load characteristics are higher during your daytime operations than during the night.

How to Find Out If Battery Storage May Benefit You

If the foregoing discussion indicates that you might potentially benefit from customer-owned battery storage, we invite you to complete Enclosure 1, "Self-Evaluation for Battery Storage Viability." This enclosure has been designed to let you assess your own circumstances against various economic, institutional, and environmental factors influencing battery storage viability. If possible, please complete and return this document on or before October 31, 1980 so that we may complete our examination of your response.

We will use the answers you give to rank you and others on a list of potential demonstration program participants. The rank which you will occupy on this list will depend on: (1) the degree to which your own circumstances favor battery storage; and (2) the relative viability of battery storage for other demonstration program candidates.

Please note that the degree to which your own circumstances favor battery storage viability does not automatically cause you to be selected or rejected as a potential demonstration program participant. Your responses will instead be ranked relative to all responses we receive.

What Happens After the Ranking?

We will send to the U.S. Department of Energy (DOE) a list of all respondents, rank-ordered on the basis of battery storage viability. DOE is expected to select potential demonstration candidates from this list for preliminary discussions. Subsequently, DOE will send to each candidate a formal Request for Proposal (RFP). Candidates responding to the RFP will then have their formal proposal evaluated for selection as demonstration program participants.

How to Complete the Self-Evaluation

The enclosed self-evaluation form contains instructions for its completion. In addition, the following suggestions are offered:

(1) If you have more than one facility or building in different areas of the U.S., use the viability indicators listed above to select not more than three of your facility locations where battery storage may be especially viable. Then complete one self-evaluation for each of the up to three facilities selected.

(2) All types of facilities - offices, commercial/retail/wholesale stores, warehouses, industrial plants, hotels, hospitals, etc. - are eligible for consideration. You should send data on those facilities which appear to be your best candidates.

(3) Check the list of utility companies (Enclosure 2): facilities located in the service areas of these utilities face rate structures which may favor battery storage systems.

(4) If you need to become more familiar with the technical and cost aspects of batteries, please read the enclosed "Battery Energy Storage System Description" (Enclosure 3).

A Note About Confidentiality

The information you furnish will be used by Battelle researchers to establish your ranking on the list. The information will not be published or disseminated. It will be shared confidentially with the DOE officials in charge of the battery storage program.

We look forward to receiving your response. If you have any questions please call us at any time.

Very truly yours,

F. Jere Bates
Economics, Planning and
Policy Analysis Section
(614) 424-6499

Thomas Martineau, R.A.
Principal Research Architect
Economics, Planning and
Policy Analysis Section

FJB/TM:amm

Enc:

ENCLOSURE 1

SELF-EVALUATION

for

BATTERY STORAGE VIABILITY

Please complete your responses to the attached questions and return them if possible by October 31 to:

F. Jere Bates
Project Manager
Battelle Columbus Division
505 King Avenue
Columbus, Ohio 43201

NAME OF CANDIDATE FIRM OR COMPANY:

____

Corporate Address: ____

Facility Address, if different: _______________________________

Name of Contact Person: _______________________________________

Telephone: ____

Availability of Time Differentiated and/or Interruptible Rates

Time-differentiated or time of day rates will permit users of battery storage systems to store lower cost, off-peak power and to use such stored power during on-peak hours, when higher utility charges would prevail.

Lower cost interruptible rates can frequently not be considered by electricity users because involuntary service interruptions without standby power may cause severe problems in operations. A battery storage system may, however, permit customers to take advantage of interruptible service, since it provides a source of standby electrical power.

Please answer the following questions about your rate structures.

- ________________________________(insert name of utility company) offers time differentiated rates. Off-peak hours are ______ to ______, and the rate differential between on-peak and off-peak is ______ cents per kwh.
- ______________________________(name of utility) offers interruptible rates which are ______ cents per kwh lower than regular rates available to us.

Comments: ____

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Need for Battery Storage
System Reliability

You can rely on a battery storage system to reduce your peak demand for electricity from a utility. If your electricity rate is determined based on a peak usage, the need for reliability of the battery storage system is high. If the system should fail and you are forced to compensate by using power from the grid, your cost of electricity would be adjusted upward for a period of time (typically one year) to reflect the higher peak usage. Rate determination based on peak usage (demand charge) is not applied nationwide, but is based on your particular utility's rate structure.

Please indicate below if your utility imposes demand charges, and briefly describe their magnitude and duration.

______ Our utility presently imposes demand charges on our company. Demand charges are imposed for a period of ______ months after allowable peak usage has been exceeded, and are at a level of $ ______ per kilowatt.

______ We expect to face demand charges starting ______ (insert date). Demand charges will be imposed for a period of ______ months after allowable peak usage has been exceeded, and are expected to be at a level of $ ______ per kilowatt.

______ We do not face demand charges at this time.

Comments: ____

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Importance of Standby Power

Depending on your specific circumstances as an industrial or commercial user of electricity, an interruption in electrical service may range from being a minor inconvenience to being a major, dramatic and costly occurrence. Because a battery storage system can provide a limited amount of standby power in the event of an interruption in utility service, please indicate below the degree of importance you place on such a feature.

______ We already have emergency standby power facilities. (Briefly describe under comments).

______ Cost of electrical supply interruption is a significant factor.

______ Cost of electrical supply interruption is a factor to be considered.

______ Cost of electrical supply interruption is minimal or unimportant.

Comments: ____

Direct Current (dc)
Electricity Use

If you regularly require direct current power as part of your operations, you may have certain cost advantages with respect to the installation and use of a battery storage system:

(1) The output (discharge) of the battery is dc and might be used directly

(a) No inverter (ac to dc) is needed, resulting in possible reduction of capital cost of power conditioners in battery storage systems

(b) No losses in inverter (dc to ac) operation are incurred, possibly resulting in a small increase (a few percent) in overall efficiency of the battery system.

(2) Use of dc implies the existence of ac to dc conversion equipment (e.g., rectifiers). The availability of unused rectification equipment during the off-peak battery charging period could reduce capital investment in the power conditioning portion of the battery system.

With reference to the above, please respond to the following questions, and use the comment section for further elaboration:

- We use ______kwh of dc power on an average business day, which is ______ percent of our total consumption on an average business day.
- We have ______ percent of already installed rectification equipment available for other purposes. (Describe when equipment is available, e.g. on weekends, each night for 12 hours, in the comment section).

Comments: ____

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Comments (cont'd): ____

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<u>Familiarity with Battery Storage Systems</u>

Please check below the statement which most closely describes your company's or firm's familiarity with the proper and safe maintenance and operation of battery storage systems.

_____ Very familiar with battery energy storage systems

_____ General familiarity with electrochemical technology

_____ General familiarity with electrical technology and/or chemical technology

_____ Technically oriented industry with trained personnel, but not directly in related technology.

_____ Limited or no familiarity with technological systems of any kind.

Comments: ____

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Ability to Deal
with Safety Issues

The presence of a battery storage system on your premises will require you to safely handle and prevent potentially dangerous conditions such as the release of toxic gases during recharging and the accidental spillage of chemicals/acids. Please check below the extent to which you are currently able to handle similar safety matters:

______ We routinely handle potentially dangerous materials.

______ We have limited facilities and some previous experience in handling potentially dangerous materials.

______ We have no facilities for, or previous experience in, handling potentially dangerous materials.

Comments: ____

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Potential Building
Code Restrictions

Local building codes vary considerably between communities. Generally, provisions of electrical and mechanical codes will probably be particularly applicable to battery storage systems by specifying the types of materials and equipment that can be used or by specifying functional requirements (e.g., performance standards) such as the fire resistance capacity of various components. Such codes may also address weight limitations, ventilation requirements, space restrictions, access routes, and fire and safety systems. However, most local codes lack specific reference to battery storage systems or specific standards for battery storage components and systems.

Please indicate below the degree to which you may be facing building code restrictions.

______ We cannot assess building code imapct at this time.

______ Compliance with building code standards should be relatively easy to achieve. Standardized commercially - available battery storage components can probably be installed to meet code specifications.

______ Compliance with building code standards may be somewhat difficult and/or costly to achieve. Slight modifications of standardized commercially - avaiable battery storage components will probably be required to meet code specifications. (Specify modifications under comments).

______ Compliance with building code standards is likely to be difficult and expensive to achieve. Manufacturing changes in the design and/or materials of standardized commercially - available battery storage components will probably be required to meet code specifications. (Specify modifications under comments).

Comments: ____

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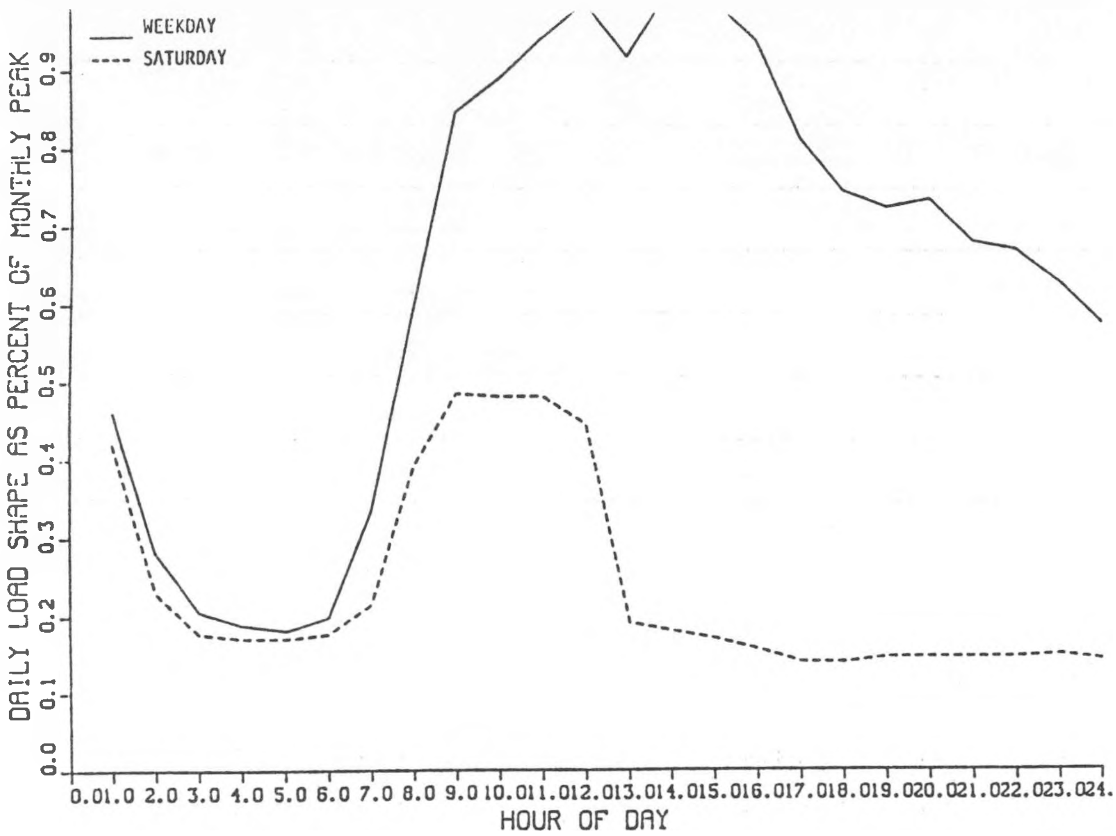
Load Characteristics

Your pattern of electricity use - the "load shape" - will impact the viability of battery storage for your particular application. Unless your operations are the same on weekdays as well as on weekends, your load shapes for these periods will differ significantly from each other. If your operations vary seasonally, or if you require more electrical power for either heating or cooling during certain periods, your load shapes will vary accordingly.

If possible, we ask that you attach load shape graphs, similar to the example below, to this document. The load shape graph should display, at a minimum, the load characteristics for an average weekday. The graph should be detailed enough to show any short-duration load "spikes" (2-5 hours) which may commonly occur during on-peak periods. If appropriate, a separate curve showing weekend consumption may be added; if seasonal variations are significant, typical average daily curves should be supplied for each major season (e.g. cooling or heating season).



In the even that loadshapes cannot be furnished, please answer the following questions:

- Our hours of operation on weekdays are ______ to ______.
- Our hours of operation on weekends (Saturday, Sunday) are ______ to ______ (place "N.A." in blanks if not operating).
- Our average electrical consumption during business hours on a weekday is ______ kwh.
- We experience an average daily load increase of ______ kwh between the months of ______ and ______ because of extra loads due to cooling/heating or ______ (circle heating or cooling, or fill in blank).

Comments: ____

____

____

____

(Comments cont'd) ____

____

____

____

____

____

____

Expression of Continued Interest

My Company is actively interested in continued discussions concerning participation in a demonstration of battery storage. I understand that the enclosed response will serve as an evaluation mechanism to determine the relative viability of battery storage at the facility for which the information is supplied.

The information we are supplying is to be considered proprietary. Battelle will share it confidentially with DOE, but it will not be published or disseminated in any way.

Signed: ____________________________

Print Name: ____________________________

Title: ____________________________

Address: ____________________________

Date: ____________________________

Phone: ____________________________

ENCLOSURE 2

LISTING OF UTILITY COMPANIES

- with rates that encourage customer-owned storage
- with characteristics that indicate future rates may encourage customer-owned storage

NOTE: THESE ARE PRELIMINARY LISTS. BATTELLE DOES NOT GUARANTEE THEIR EXHAUSTIVENESS OR COMPLETENESS. IF YOU HAVE INFORMATION ABOUT FAVORABLE RATES FROM UTILITIES NOT LISTED HERE, WE WOULD SINCERELY APPRECIATE YOUR SHARING IT WITH US.

THANK YOU.

Utility Companies with Rates That Encourage Customer-Owned Storage

(1) San Diego Gas and Electric

(2) Connecticut Light and Power Company

(3) Hartford Electric Light Company

(4) Indianapolis Power and Light

(5) Iowa Electric Light and Power Company

(6) Boston Edison Company

(7) Massachusetts Electric Company

(8) Detroit Edison

(9) Public Service of New Jersey

(10) Central Hudson Gas and Electric

(11) Consolidated Edison Company of New York

(12) Central Vermont Public Service Company

(13) Dayton Power and Light Company

(14) Western Massachusetts Electric Company

(15) Consumer's Power Company

(16) Central Illinois Public Service Company

(17) Minnesota Power and Light Company

(18) Missouri Edison Company

(19) Carolina Power and Light Company

(20) Appalachian Power Company (VA and WVA)

Utility Companies Whose Future Rates May Encourage Customer-Owned Storage

CALIFORNIA

Burbank Public Service Department

COLORADO

Colorado Springs Department of Public Service

Public Service Company of Colorado

CONNECTICUT

The Hartford Electric Company

The United Illuminating Company

FLORIDA

Florida Power and Light Company

Florida Power Corporation

Gulf Power

Jacksonville Electric

Lakeland Department of Electricity

Orlando Utilities Commission

City of Tallahassee

ILLINOIS

Central Illinois Light Company

INDIANA

Public Service of Indiana

IOWA

Iowa Public Service Company

Iowa Southern Utilities Company

KANSAS

Empire District Electric Company

KENTUCKY

Kentucky Utilities Company

MASSACHUSETTS

Cambridge Electric Light Company

Fitchburg Gas and Electric Light Company

Holyoke Power Company

New Bedford Gas and Edison Light Company

MICHIGAN

Alpena Power Company

MINNESOTA

Auston Utilities

MISSOURI

Independence Power

St. Joseph Light and Power Company

Springfield City Utility

NEW HAMPSHIRE

Public Service Company of New Hampshire

NEW JERSEY

Jersey Central Power and Light Company

NEW YORK

Rochester Gas and Electric Corporation

NORTH CAROLINA

Duke Power Company

NORTH DAKOTA

Montana-Dakota Utilities Company

OHIO

Dayton Power and Light Company

RHODE ISLAND

Narragansett Electric Company

SOUTH CAROLINA

South Carolina Public

SOUTH DAKOTA

Northwestern Public Service Company

TEXAS

City of Bryan

Garland Power and Light

VIRGINIA

Virginia Electric and Power Company

ENCLOSURE 3

BATTERY ENERGY STORAGE SYSTEM DESCRIPTION

BATTERY ENERGY STORAGE TECHNOLOGY

Introduction

An electric energy storage system can be considered a "black box" that is connected to the electric utility lines as shown in Figure 1. During off-peak hours, electricity from the utility lines is stored in the energy storage system (charging mode of operation). During on-peak hours, electricity from the energy storage system is returned to the utility lines and/or directly to the electrical load of the consumer (discharging mode of operation). Of the many possible energy storage systems, battery energy storage is distinctive in that electrical energy is stored by conversion of electrical energy to chemical energy and later released by reconversion of chemical energy to electrical energy. Since the electrochemical conversion requires direct current (dc), an essential component of the battery energy storage system is a power conditioning subsystem to convert electric utility supplied alternating current to direct current (i.e., operation as a rectifier). For the special case of direct current loads, the output of the battery during discharge could be directly connected to the load. For the more general case, the direct current output of the battery is returned to the power conditioning subsystem and converted back to alternating current (i.e., operation as an inverter).

Battery Energy Storage System

The three principal elements of a battery energy storage system are the:

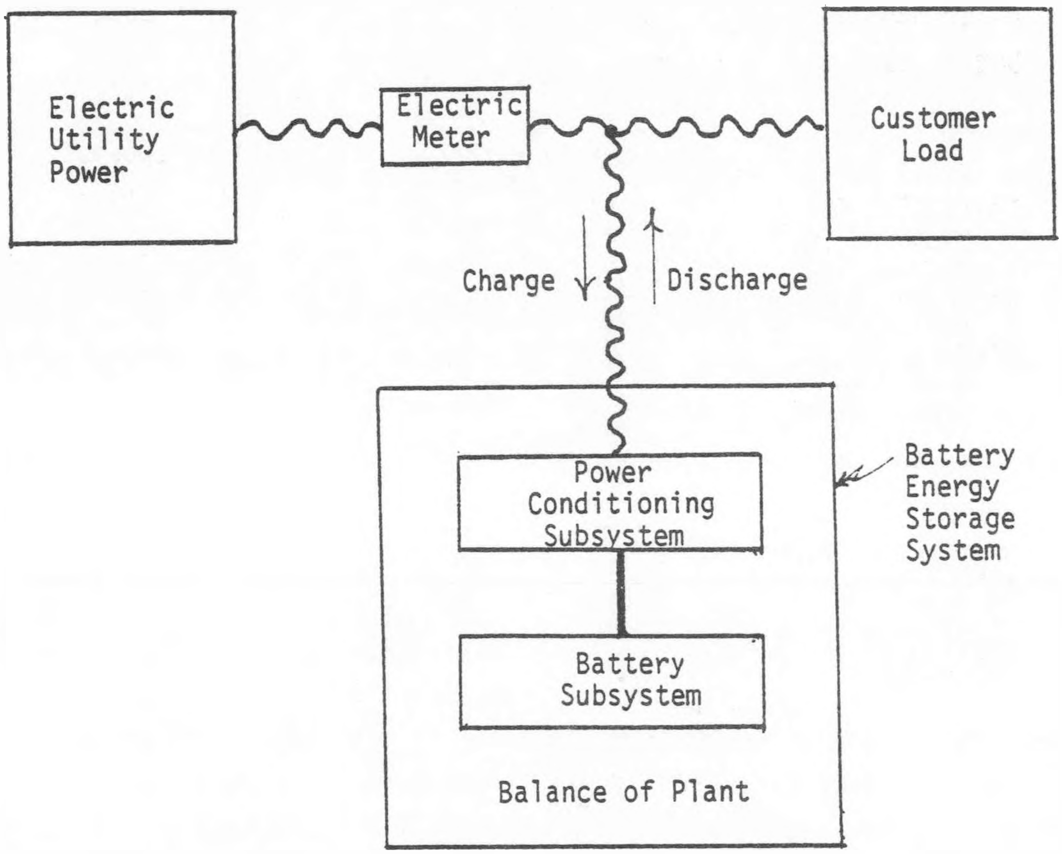


FIGURE 1. SCHEMATIC OF BATTERY ENERGY STORAGE SYSTEM

- Battery subsystem (B)
- Power conditioning subsystem (PC)
- Balance of plant (BOP).

The relative importance of the three principal elements to the total cost of the battery energy storage system depends on many factors such as energy storage capacity. For preliminary discussion, a 100 MWhr, 5-hour discharge battery plant might have a cost distribution as shown in Table 1.

Generally, the purchase price of the battery subsystem (F.O.B.) represents the major cost element. Depending on battery type, the battery is also the major contributor to balance of plant costs. The power conditioning subsystem is practically independent of the battery type.

Power Conditioning Subsystem

The term "power conditioning subsystem" includes everything associated with electrical ac-dc-ac conversion. A typical breakdown of components is shown in Table 2 for one type of power conditioning subsystem.*

Balance of Plant

"Balance of plant" (BOP) is a term used to cover all components of the total system not included in either the power conditioning subsystem or the battery subsystem. As a minimum, BOP includes the site. Depending on the particular battery system, BOP may include foundation, weatherproof enclosure, electrical connections, and any ancillary equipment (e.g., for cooling, ventilation, battery-handling, electrical control, instrumentation, safety).

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* Conceptual Design of Electrical Balance of Plant For Advanced Battery Energy Storage Facility, United Technologies Corporation, ANL-80-16 (January, 1980).

TABLE 1. TYPICAL DISTRIBUTION OF BATTERY ENERGY STORAGE SYSTEM COSTS*

Total Energy Storage System (100%)
Battery Subsystem (56%)
Power Conditioning Subsystem (14%)
Balance of Plant (30%)

*Baseline 20Mw, 100 Mwhr System

TABLE 2. TYPICAL DISTRIBUTION OF POWER CONDITIONING SUBSYSTEM COSTS*

Power Conditioning Subsystem			(100%)
Power Conditioner		(95.4%)	
Converter	(71.3%)		
Three-phase Bridges			
Low Voltage Magnetics			
Output Transformer			
AC Isolator			
Miscellaneous Components			
AC Interconnect Equipment	(3.3%)		
DC Interconnect Equipment	(20.8%)		
Auxiliary Power System		(4.6%)	
Uninterruptible Power Source	(0.6%)		
Auxiliary Diesel Generator	(0.3%)		
Other	(3.7%)		

*Percentage distribution of costs in parentheses based on costs in Reference II-1.

For the purpose of this discussion, the battery (cells or modules) subsystem and power conditioning subsystem are considered to be truck transportable items purchased from the factory (i.e., costs are F.O.B. the factory). Thus, the cost of transportation and installation is included in the balance of plant costs.

Battery Terminology

The terms cell, submodule, module, battery, and battery plant (or system) are used in the description of large energy storage systems and the terminology depends on the type of battery. Other terms used are "rated capacity," "depth of discharge," and "cycle life." It is also important to appreciate that any battery-type can be optimized for a particular application. A simplified example based on a lead-acid battery will help to clarify the terminology.

The most familiar example of a storage battery is the lead-acid battery used in automobiles and referred to as the SLI-type (for Starting, Lighting, and Ignition). The typical 12-volt battery contains six cells connected in series internally (nominal 2 volts/cell open circuit). A cell is defined by the smallest integral of voltage for the electrochemical couple. Each cell contains a number of positive and negative electrodes in a electrolyte of aqueous sulfuric acid that are connected electrically in parallel. The electrodes (lead alloy grid plus the active material, predominatly lead dioxide at the positive and lead at the negative in the charged state) are referred to as plates (e.g., a 5-plate cell contains two positive plates interspersed between three negative plates with separators between plates). Capacity in ampere-hours increases in the proportion to the number of plates (e.g., positives) connected in parallel electrically. The important factor in cell design is the total plate area per cell (e.g., number of positive plates times the geometric area per plate). Ideally, as in the lead-acid case, the electrolyte of one cell does not interconnect with the electrolyte of other cells, so there are no shunt current losses from cell to cell. Any number of cells can be connected electrically in various series and parallel combinations to achieve a desired system voltage and current capacity (ampere-hours) or energy capacity (kilowatt-hours). For example, if two 12-volt SLI "batteries" were connected in series electrically to produce 24-volts, or in parallel to double the capacity at 12-volts, each "battery" of six cells could be referred to as a module. A module is the smallest building block of a battery plant and the module may be a single large cell in the case of large lead-acid battery plants.

Cells are rated by the manufacturer in terms of the specified time of discharge with discharge voltage above a particular discharge "cut-off" voltage (or recommended discharge termination voltage) when discharged at a constant current. For example, a cell rated at C = 100 ampere-hours at the 5-hour rate has a rated discharge current of $\frac{C}{5}$ or 20 amperes.

With reference to the lead-acid cell, the actual capacity for a new cell may be higher (e.g., 125 ampere-hours) but the manufacturer "derates" the cell in order to assure that the rated capacity can be achieved after a specified number of cycles. In effect, the initial (e.g., first 10 cycles) depth of discharge in the above example would be 80 percent (i.e., $\frac{\text{100 ampere-hours}}{\text{125 ampere-hours}}$). If data and experience indicated that such a derating will allow long cycle life (e.g., 2000 cycles or 8-10 year life), the increased initial cost of the cell (25 percent more because of derating) is ususally considered to be an economical tradeoff for load leveling batteries.

The above discussion relative to rating and derating is typical of a lead-acid battery (and other battery types in which the active materials are contained within the cell during charge and discharge) which can be classified as conventional. However, some types of batteries can be classified as unconventional and cycle life does not depend on depth of discharge.

For any particular battery type, the specific design depends on the intended application. For example, the lead-acid type includes the familiar SLI-type which is designed primarily for short (high current) discharges in automobile starting and shallow depth-of-discharge (percentage of available capacity in ampere-hours removed.) Motive-power batteries (as used in fork lifts) are designed for repetitive daily deep discharges with long cycle life (a cycle is one complete discharge followed by recharge). Stationary batteries (as used by telephone companies for back-up power) are designed to "float" on the electric line at full charge with occasional deep discharge. Stationary batteries as the name implies are not subjected to vibration and are usually constructed with light plastic cases. In contrast, motive-power batteries are usually designed with a more rugged case and special separators to favor retention of the active material on the grids. Shedding of active material from the positive electrode is a cycle life-limiting factor for deep discharge lead-acid batteries and is a function of the depth of discharge and cell operating temperature.

The two principal applications of advanced battery research and development are directed toward electric vehicle use and large size electric utility load leveling use. For the commercially available lead-acid battery technology, there are distinctions made in terms of state-of-the-art (SOA) battery which could be designed and built with today's technology and an improved state-of-the-art (ISOA) battery which will result from current R&D (1-2 years) and future R&D over the next 5-8 years. The principal thrust of research on lead-acid batteries for electric vehicles is to reduce weight whereas the principal thrust of research for load-leveling applications is to increase cycle life. The load-leveling application requires compromise with features borrowed from several types of lead-acid battery: low-cost plastic case from stationary battery design, separator design from motive power battery for deep discharge cycle life, and possibly pasted plates (for positive as well as negative) from SLI Design for low manufacturing cost.

It is important to note that the advanced batteries that are the subject of intensive R&D support by government and industry are being developed with both the electric vehicle application and the electric utility load leveling application as potential markets. In fact, the potential for application in both markets was one factor in selection of the battery types to be developed.

Type of Batteries

From a functional viewpoint, there are many potential battery systems that fit the "black-box" definition of an energy storage system shown previously in Figure 1. Table 3 shows some typical examples of electrochemical energy storage systems organized in the two broad categories of chemical batteries and hydrogen systems consistent with the usual U.S. terminology.* The somewhat arbitrary categorization of batteries and hydrogen systems appears to have originated in early assessment studies in 1974,** and the term "battery" usually implies the types listed under "chemical batteries." However, all of the examples in Table 3 are "battery" systems in the sense that electrical energy is converted to chemical energy which is stored and later reconverted to electric energy.

The first four examples in Table 3 are batteries that have received significant funding for R&D as load-leveling batteries (and as electric vehicle batteries, too). The lead-acid, lithium-metal sulfide, and sodium-sulfur types can be considered coventional in cell design. The zinc-chloride battery is classified as unconventional since

*Clifford, J.E. and Brooman, E.W., "Development of the Water Battery for Energy Storage," First National Seminar on Electrochemical Systems: Batteries and Fuel Cells," Federal University of Ceara, Brazil (March, 1980).

**An Assessment of Energy Storage Systems Suitable for Use by Electric Utilities, Public Service Electric & Gas Co., EPRI EM-264 (July, 1976).

TABLE 3. TYPICAL EXAMPLES OF ELECTROCHEMICAL ENERGY STORAGE SYSTEMS CONSIDERED FOR ELECTRIC UTILITY USE

CHEMICAL BATTERIES

Conventional Design

- Lead-acid
- Lithium-metal sulfide
- Sodium-sulfur

Unconventional Design

- Zinc-chloride (zinc chlorine hydrate)
- Redox
- Nickel-hydrogen

HYDROGEN SYSTEMS

Irreversible (multiple devices)

- Commercial alkaline electrolyzer/gas turbine
- Advanced alkaline electrolyzer/alkaline fuel cell
- Advanced SPE electrolyzer/phosphoric acid fuel cell

Reversible (single devices)

- Hydrogen-chlorine
- Hydrogen-bromine
- Hydrogen-oxygen
    - Regenerative fuel cell
    - Water battery (reversible electrolyzer)

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the active materials are stored outside the cell as an aqueous solution in the discharged state and as a solid inside the cell (zinc) and as a solid (chlorine hydrate) outside the cell in the charged state. The redox battery (being developed for photovoltaic battery storage) stores the active materials as an aqueous solution outside the cell in both the charged and discharged state.

The nickel-hydrogen battery is a recent consideration for load leveling and has been added to Table 3 to illustrate the problem of categorization as either chemical batteries or hydrogen systems.

Typical Customer Applications

For electric utility applications, the economic size range is usually considered to be 10 MW-20 MW for use at utility substations. For this study of customer-side-of-the-meter battery storage, it was necessary to investigate a wide range of battery sizes for various types of customers. Four examples were selected as shown in Table 4 to span a range of sizes (power or energy) and voltages at which the electricity would be delivered from the battery system. Example 1 is the baseline system selected.

BASELINE SYSTEM SELECTION

The lead-acid battery was selected for the baseline system because the technology is well-established. There is consensus among battery manufacturers that a lead-acid battery with a useful life of 2000 deep discharge cycles can be produced at reasonable cost using state-of-the-art technology. A large battery system (100MWhr, 20 MW) was selected for the baseline to utilize the extensive data available on cost and performance of lead-acid batteries that were developed from 1974 to 1976 in prior studies of electric utility load-leveling batteries.* A 100-MWhr battery (5-hour rate) has become a standard size

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* Lead-Acid Batteries for Utility Application; Workshop II, EPRI EM-399-SR (March, 1977).

TABLE 4. EXAMPLES OF REPRESENTATIVE BATTERY SYSTEM SIZE AND VOLTAGE FOR A RANGE OF CUSTOMER APPLICATIONS

Example	Power, kw	Energy, kwhr	Line Voltage (volts ac)	Possible Customer Application
1	20,000	100,000	∿15,000	large industrial
2	1,000	5,000	∿15,000	small industrial
3	40	200	∿440	small commercial
4	2	10	∿220	small residential

for costing studies* that also assume a standard battery manufacturing facility producing 25 batteries per year (annual output of 2500 MWhr). While 3-, 4-, 5-, and 10-hr batteries have been used in various studies, the 5-hr battery (e.g., 20 MW of constant power output for five hours) appears to be typical. A charging period of 7-10 hours is also typically used.

Another reason for selecting the lead-acid battery for the baseline system is consistent data on cell design and performance** and plant layout for determining balance of plant costs.***

The baseline system is not necessarily the preferred battery type or size. However, it is a frame of reference for making comparisons.

Baseline Battery Plant Layout

In a plant layout for the baseline (100 MWhr, 20 MW) system, 5,472 lead-acid cells are arranged in five parallel strings. Each string contains 912 series-connected cells. The cells in each string are arranged in twelve rows (76 cells/row). Such a single-layer configuration requires a large plant area. As an alternative, a 3-tiered layout can reduce plant area to about one third, whereas the total plant costs remain about the same.

Table 5 shows the building area and site area for the various assumed plant sizes in Table 4. A single-layer configuration is assumed, and a 3-tiered configuration would use less area.

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*Lead-Acid Batteries for Utility Application; Workshop II, EPRI EM-399-SR (March, 1977)

** Engineering Study of a 20 MW Lead-Acid Battery Energy Storage Demonstration Plan, Bechtel Corporation, ERDA Contract E (04-3)-1205, CONS/1205-1 (October, 1976).

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TABLE 5. SUMMARY OF TYPICAL BATTERY PLANT LAYOUTS FOR SINGLE LAYER CONFIGURATION

Power kw	Energy kw hr	Voltage DC	Voltage AC	Area Ft.^{2} Bldg	Area Ft.^{2} Site	Floor Loading Lb./Ft.^{2} Cell	Floor Loading Lb./Ft.^{2} String	Floor Loading Lb./Ft.^{2} Bldg
20,000	100,000	1,505	15,000	33,235	45,410	982	673	364
1,000	5,000	1,505	15,000	6,394	11,071	402	255	95
40	200	297	440	1,283	3,463	38	26	4
2	10	165	220	(within residential area and load feasibility)				

APPENDIX I

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