LONG-TERM ENERGY DEMAND FORECASTING: DETERMINATION OF AN ENERGY BASELINE AND ENERGY CONSERVATION SUPPLY CURVES FOR THE MANITOBA HEALTH CARE SUBSECTOR

BY

© JERRY R. MACPHERSON

A Practicum Submitted
in Partial fulfillment of the
Requirements for the Degree,
Master of Natural Resources Management

Natural Resources Institute
The University of Manitoba
Winnipeg, Manitoba, Canada
April, 1989

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Service
Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

ISBN 0-315-51654-2

LONG-TERM ENERGY DEMAND FORECASTING: DETERMINATION OF AN ENERGY BASELINE AND ENERGY CONSERVATION SUPPLY CURVES FOR THE MANITOBA HEALTH CARE SUBSECTOR

by

Jerry R. MacPherson

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of Master of Natural Resources Management.

Abstract

The Manitoba Department of Energy and Mines, and the public electrical utility, Manitoba Hydro, have an ongoing interest in long-term energy demand forecasting and energy conservation. They are currently investigating using an end-use model - the Commercial End-use Planning System, also known as COMMEND - for long-term energy demand forecasting in the commercial sector.

End-use models require large amounts of detailed data regarding energy consumption practices, the stock of energy consuming equipment, and the physical characteristics of buildings. The data is used to estimate parameters to satisfy the input requirements of the end-use computer model.

This study collected requisite data from a variety of sources, including existing provincial energy audit data, electric and natural gas utility monthly sales data, and the provincial Health Services Commission's physical data. This data was analyzed and the large majority of COMMEND's parameter input requirements were estimated. Conducting an actual forecast was beyond the scope of this study. Data concerning the stock of energy consuming equipment was obtained from the provincial energy audits and was used to assess the potential for energy conservation in the Manitoba

Health Care subsector. This potential is presented in the form of Supply Curves of Conserved Energy (interactive effects were not taken into account for this study).

This study estimated input parameters for an end-use model, but it concludes that there are a number of limitations placed on these estimates by the small number of observations used in making the estimates. In particular not enough energy audits of health care facilities have been performed. The study also concludes that there is a large potential for electrical energy conservation in the Manitoba Health Care subsector at a cost per unit of energy below that of supply.

Acknowledgements

I would like to thank my practicum advisory committee for their guidance and comments: Prof. T. Henley, Faculty Advisor, Natural Resources Institute; Mr. Grant McVicar, Senior Planning Analyst, Manitoba Department of Energy and Mines; Prof. George Chuchman, Economics Department, University of Manitoba; Mr. R. McDowall, Energy Manager, University of Manitoba; and Prof. D. Young, Oral Examination Chairperson, Natural Resources Institute.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Chapter One: Introduction

Preamble

Long-term planning -having a 20 to 25 year time horizon- is important to energy policy makers and utilities because of the large capital expenditures and long lead times required to place energy supply facilities on line. In the past, long-term planning was carried out mostly by governments and producers (eg,. utilities), by matching expected customer growth in energy demand with the appropriate "supply-side" generating capacity or energy purchases.

Certain energy events since the early 1970s have, however, caused utilities to change their approach to managing energy resources. The fluctuations in energy prices which have occurred since the early 1970s have had a three fold impact on supply side management. First, the cost of building, financing and operating power plants increased dramatically. Second, utilities did not expect, and were thus not prepared for, their customers change in energy use behavior; and thirdly, the uncertainty associated with long range projections increased, and the risk of making incorrect projections became very large. The reaction by utilities was to look for alternatives to the way they planned, developed and managed energy resources.

As mentioned above, the vastly increased costs of constructing energy plants, transmission and distribution systems, and the increased risk involved with tying up large quantities of capital, has in many areas of North America, motivated governments and producers to look for alternatives to the need for large supply facilities. Two approaches to reducing this need, are Least-Cost Planning (LCP) and Demand Side Management (DSM). The term Least-Cost Planning refers to efforts by utilities and regulators to ensure that both supply side and demand side options are fully considered in constructing resource plans for the provision of energy sources to meet societies energy needs at the least cost (Public Utilities Fortnightly 1987). Demand Side Management refers to efforts by utilities to control or change the quantity and timing of their customers consumption to avoid costly capacity or supply acquisition. This balancing of the mix of supply and demand side alternatives is called Integrated Resource Planning (IRP) (EPRI 1987b).

The rising energy prices mentioned earlier caused customers to change the way they used energy. Customers responded to higher energy prices by reducing their energy consumption. The higher energy prices initiated a search for new and more energy efficient technologies, which in turn enabled energy users to get more energy services for an equivalent amount of money. Meanwhile, some industries have made technological breakthroughs, enabling them to compete with electrical utilities by producing energy as a secondary product of their primary production (eg., cogeneration). Another result was to increase competition for customers by energy producers within the energy marketplace.

Some long-term energy demand forecasters believed the impact of more energy efficient technologies and changes in energy consuming behavior would have a large influence on the demand for energy in the future. As a result a new type of energy demand forecasting computer model was developed which attempted to take into account changes in energy efficiencies and stocks of energy end-use equipment. These models were aptly called end-use models.

The focus of this study is on a particular end-use model called COMMEND, and the development of parameters (which, when taken together, are called the "energy baseline") to be used as inputs to COMMEND for the purpose of making a long-term energy demand forecast for a portion of the Manitoba Commercial Sector - the Manitoba Health Care Subsector. The scope of this study includes development of the above mentioned parameters and an assessment of the potential for energy conservation in the Manitoba Health Care subsector. The scope does not include making an actual forecast.

Problem Statement

The Manitoba Department of Energy and Mines and the public utility, Manitoba Hydro, have an ongoing interest in energy conservation and energy forecasting. They are currently investigating using an end-use model for long-term forecasting of energy demand in different commercial sub-sectors and require the collection and analysis of end-use energy data from these subsectors. The Health Care sub-sector (including both public and private facilities), is a large consumer of electricity and natural gas and is of particular interest at this time.

Research Objectives

The study has four main objectives:

1. To construct an energy baseline for the Manitoba Health Care sub-sector using existing and collected end-use data.

2. To examine the potential for energy conservation in this sector.

3. To recommend energy conservation measures in the form of energy conservation supply curves.

4. To contribute to the energy planning and end-use modelling efforts conducted towards integrated resource planning, and particularly least-cost planning, in Manitoba.

Study Approach

The report can be considered to consist of two parts. The first part, the development of an energy baseline, is contained in Chapters Two and Three. The second part, the development of supply curves of conserved energy, is found in Chapter Four. The approach taken for the first part of this study is as follows:

1. A brief discussion of energy forecasting models and the main requirements of COMMEND, the end-use model selected by Energy and Mines.

2. Sources of data for the Manitoba Health Care subsector were identified and data was collected.

3. The data was analyzed and the model input parameters were estimated.

The approach taken for the second part of the study is as follows:

1. The method of calculating and constructing supply curves of conserved energy was determined.

2. Sources of information on conservation methods and costs were identified.

3. Priority fuels, end-uses, and conservation measures were identified.

4. Data was analyzed to determine an end-use breakdown of the Manitoba Health Care subsector's energy use.

5. Estimates were made of energy savings for each building type under a penetration rate which assumed that total technical potential would be achieved, eg., a penetration rate equal to one..

6. A technology data base was prepared for the Manitoba Health Care subsector containing profiles of the conservation measure, its cost, applicability and penetration rate.

7. The energy saving impacts of the individual conservation measures were summarized in supply curves of conserved energy.

Chapter Two: Energy Demand Forecasting for Manitoba's Commercial Sector: The Development of an Energy Baseline.

Energy is a requirement of both individuals and society. It is needed to sustain satisfactory economic growth and to enhance individual and social well being. The prospect of energy scarcity demands that we manage it in a manner which will ensure both a present and a future supply. An integral part of such an energy management plan is the use of energy demand projections, or forecasts. Accurate energy demand forecasts are necessary to ensure a reasonably reliable availability of energy supplies, to help plan the expansion of energy supply systems, and to efficiently plan the capital intensive investments needed for building energy systems. The cost of undertaking detailed and reliable demand studies is small in comparison to the costs which might be incurred if energy shortages develop, or if large amounts of capital with high opportunity costs are needlessly tied up for long periods of time. Presently, major uncertainties in the energy market, such as the course of technological advances, political instabilities and economic policies, makes any forecasting attempt a daring one. For this reason, long-term forecasting is perceived by some as an academic exercise. However, a failure to make long-term forecasts would mean decisions being made about immediate problems with little or no knowledge of future consequences, so that future energy policy becomes a collection of randomly selected remedies. The requirement for efficient policy making dictates that we must try to understand what the future will be like, and this is achieved through long-term forecasting. Therefore, the definition and the implementation of energy policies must take place in a long-term context (20-25 years). An energy baseline, the total energy consumption for a specified component of the economy for a specified time period, is required as a base from which to forecast energy demand. This energy baseline concept and the methodology used in deriving it will be discussed later in this chapter.

This chapter will provide a brief overview of the various models available for energy demand forecasting, and will highlight the model which has been selected by the Manitoba Department of Energy and Mines.

Decision Making in the Energy Field: Forecasting Methods and Models.

Reliable decision making in the energy field requires a knowledge of energy demand, of it's determinants, and of it's dynamic aspects. Determinants of energy demand are factors which explain the generation of energy demand at a given time, as well as its evolution. These determinants influence the evolution of energy demand both quantitatively and qualitatively (Chateau 1982). Energy demand is dynamic because demand is influenced, both positively and negatively, by economic and social fluctuations such as price increases and concern over the environment. The acquiring of knowledge concerning the determinants of energy demand is, however, not sufficient for making clear and expeditious decisions regarding the future. Another step is required - forecasting. Forecasting is the step "which consists of the transcription of this analysis into a methodological tool allowing one to draw from the past and from the present one or more quantified images of the future in terms of which the decisions may be made" (Chateau 1982:181). The forecasting methods and tools may differ greatly, according to the needs and questions for which the forecast is needed.

There have been three types of energy demand forecasting models used for long-term forecasting over the years. They are trend analysis, econometric models, and the most recent and the focus of this study, end-use models. Trend analysis is the simplest method of forecasting. It consists of the extrapolation of past growth pattern determinants of demand, such as income, prices, consumer tastes, etc (Munasinghe 1983). The main advantages of trend analyses are their simplicity and the fact that they can be based on available data. However, forecasting on the basis of past trends can give unreliable indications of the requirements for additional supplies when conditions affecting energy demand change rapidly (Commission of Inquiry into Manitoba Hydro 1979). Rapid changes in energy demand cause trend analysis forecasts to produce a wide range of growth rates of demand for energy. This has resulted in a trend towards the use of other methods for energy forecasting. Trend analysis models are no longer widely used, and were used in only 10 per cent of energy forecasts in 1986 (Energy Resources Conservation Board 1987).

Econometric modelling is a more sophisticated approach to energy forecasting. The econometric model works on the rationale that, given a number of conventional economic indicators which give a representation of the economy, the level of energy demand, globally, per sector, or per energy form, can be calculated (Chateau 1982). Some examples of the economic indicators are GDP, income, and value added per sector. Econometric model relationships are of a statistical nature, their shape and parameters being based on the correlation between the energy demand and the economic indicators (Chateau 1982). The quality of the statistical correlations determines the caliber of the model relationships. Statistical tests, such as R^2 and Durbin-Watson, are used to evaluate the validity of the statistical correlations.

Technico-Economic or End-Use Models

Technico-economic, or end-use models, were developed to describe the impact of technological and socio-economic determinants on energy demand. The premise of the end-use model is that energy demand is not for energy, but for the energy services it provides (for example - light and heat). End-use models are characterized by:

(1) being very disaggregated and considering energy demand at the level of end-uses - thus the name "end-use model".

(2) energy demand being secured both in terms of useful energy - energy in the form that is wanted by the consumer (eg., heat for heating, light for lighting, mechanical power for movement) - and final energy - any form of primary or secondary energy available to the final consumer (eg., petrol, electricity). This results in energy demand being classified in terms of fuel type and end-use - for example natural gas - heating, and electrical - heating.

(3) useful energy needs being connected to physical indicators of activity or of needs (eg., number of refrigerators in an average home, or the number of beds in a hospital), or else to economic indicators (eg., incomes, value added) (Chateau 1982).

End-use models consider energy demand by sector and sub-sectoral components, and then by end-use and fuel-type components. Total energy projections, for end-use classifications, are generally broken down into several sectors. They are residential, commercial, industrial, and transport.

The above characteristics stem from the importance given to technology in the creation and development of energy demand. The impact of prices on the development of energy consumption is accounted for by technical choices (industrial processing, etc), and substitution of energy forms (natural gas heating for electric heating).

End-use model limitations are a result of the high level of disaggregation, and are linked to:

(1) the accessibility of large quantities of varied information, in both the technical and economic fields. The models require detailed information on energy using equipment, including age structure, efficiency and equipment costs. Information concerning the behavior of decision makers when purchasing end-use equipment is also required (Jaccard 1987);

(2) the difficulty of parameter determination. Some parameters may be determined by statistical regression, and others are technical or behavioral estimations (Jaccard 1987). Since these estimates are not determined by statistical regression, they do not have empirical backing and it is therefore difficult to prove their validity; and

(3) 'End-use models tend to be "over determined"' (Jaccard 1987:7), which means that they have a large number of estimated parameters. The result of this is that when the results of a forecast are backcast over a previous 5 to 10 year period to see if any of the behavioral parameters

should be adjusted, it is found that more than one set of parameter values could give the same set of results.

Energy Forecasting in Manitoba

Manitoba's long-term energy demand forecasting has traditionally been based upon trend extrapolation and econometric modelling. Both Energy and Mines, and Manitoba Hydro have produced long-term forecasts in the past, with Winnipeg Hydro's long-term forecasts being incorporated into those of Manitoba Hydro. Inter-City Gas' annual forecasts are based upon trend extrapolation.

Energy and Mines produced its most recent long-term energy demand forecast in 1983 for the years 1981-2005. The forecast was based upon "The Manitoba Energy Demand Model", a disaggregated econometric model, which forecasts energy demand for all economic sectors (residential, commercial, industrial, and road transport) based on key explanatory variables including economic output, heating degree days, demographic variables, employment, and energy prices (Manitoba 1983 as cited in Esler 1987). For a discussion of limitations of the Manitoba Energy Demand Model, see Esler 1987.

Energy and Mines models energy demand for all energy forms while Manitoba Hydro forecasts energy demand for electricity only. Manitoba Hydro's forecasting methodology varies for the various economic sectors, which include residential and farm, commercial and industrial and miscellaneous, and other major electricity consumption categories (uncertain loads, system energy use, and Winnipeg Hydro) (Esler 1987). Manitoba Hydro's energy demand forecasts for all sectors and consumption categories were based solely on trend extrapolation up to 1980. After this time the residential and farm sector were modelled using econometric equations, with price changes, changes in provincial income, and changes in demographic indicators as the main explanatory variables (Esler 1987).

Energy use in the Commercial and Industrial sector forecasts are considered by industry type as defined by 1980 Standard Industrial Classification Codes (SIC Codes), developed by Statistics Canada. Forecasting of energy consumption for commercial and industrial business types is done using trend extrapolation. Periodically, expected changes in general equipment efficiency and patterns of use are subjectively incorporated into these trend extrapolations (Kellas 1987 as cited in Esler 1987). Trend extrapolation is also used by Manitoba Hydro to forecast energy demand for Winnipeg Hydro, uncertain loads, and for system energy use.

Manitoba Hydro and Energy and Mines are members of a Least-Cost Study Team. They have recently begun to examine the potential of end-use modelling for the residential and commercial sectors. The end-use model which has been selected by Energy and Mines for the Commercial sector is called the Commercial End-Use Planning System, or COMMEND. Manitoba Hydro will continue to use trend extrapolation to forecast energy demand for industrial and "other" users, since these sectors represent only a small number of users. Due to their few numbers, it is also possible to estimate future energy consumption of these sectors on a client by client basis (Manitoba 1987 as cited in Esler 1987).

Commercial End-Use Planning System Model and Data Requirements

COMMEND, the selected end-use model, was developed by the Electric Power Research Institute in the United States and is one of the most widely applied commercial sector end-use models. COMMEND was initially developed in 1981 and has since been used by more than fifty utilities in the United States, Canada, and Australia (EPRI 1987a as cited in Esler 1987). The model is able to provide an integrated framework for examining the end-use and load shape programs of Demand Side Management by means of its combination of energy sales model and peak load sub-model.

COMMEND's modelling approach views energy demand as a function of three factors:

(1) the physical stock of energy using capital (ie., end-use equipment);

(2) the base year energy use; and

(3) a utilization factor that represents actual utilization of equipment relative to the base year (EPRI 1985).

In the short run - the time period in which the stock of capital is fixed - only the utilization factor is able to respond when exogenous factors, such as fuel prices, change. In the long run, the fuel and efficiency characteristics, and the utilization factor, of capital stock can change (EPRI 1985).

The modelling of changes in utilization is accomplished by using short run econometric fuel price elasticities. "Fuel choice is forecast with a life-cycle-cost behavioral micro-simulation sub-model, and changes in equipment efficiency are determined using engineering and cost information for space heating, cooling and ventilation equipment and econometric elasticity estimates for the other end-uses (lighting, water heating, ventilation, cooking, refrigeration, and others) (EPRI 1985).

COMMEND is distinguished from traditional modelling approaches by three characteristics. They are:

(1) a reliance on engineering relationships to determine future heating and cooling efficiency. This provides a sounder basis for forecasting long-run changes in cooling and space-heating energy use requirements than econometric studies by themselves can supply;

(2) a variety of engineering data on the energy using characteristics of commercial buildings is provided for the simulation model; and

(3) estimates of energy consumption by end-uses, fuel-types, and building-types are provided by COMMEND (EPRI 1985). The specific building-types, end-use and fuel-types used by COMMEND are shown below.

Building-Types	End-Uses	Fuel-Types
1. offices	1. space heating	1. electricity
2. restaurants	2. air conditioning	2. natural gas
3. retail	3. ventilation	3. fuel oil
4. grocery stores	4. water heating	
5. warehouses	5. cooking	
6. elem/sec school	6. refrigeration	
7. colleges	7. lighting	
8. health	8. miscellaneous	
9. hotel/motel		
10.miscellaneous		

Peak demand and peak day hourly load profiles forecasts are provided by COMMEND using the same end-use and building type detail (EPRI 1985).

An advantage to using COMMEND is that existing data deficiencies can usually be compensated for and that complex relationships reflecting commercial end-use systems can be endogenously represented in an end-use modeling structure. Only a general knowledge of the commercial sector is required to utilize COMMEND in addressing policy issues (EPRI 1985).

The following section was taken directly from An Implementation Guide for the EPRI Commercial Sector End-Use Energy Demand Forecasting Model: COMMEND, EPRI 1985:2-2 to 2-7.

Overview of the Model Structure

'Figure 2-1 is a schematic representation of the energy portion of the model structure. The stock of energy-using capital (i.e., end-use equipment) is measured in the model by the stock of commercial floor space. Floor space is a fairly accurate measure of energy-using capital since most commercial end-use systems are installed to provide illumination levels per square foot of floor space. Heating and cooling systems are also designed according to the area served.

Future floor space stock is forecast as a function of employment forecasts by commercial subsectors (eg., employment in retail/wholesale buildings) and estimates of floor space per employee, or directly as a function of population, income, interest rates, and other relevant variables. Forecasts of future floor space along with estimates of the age distribution of existing floor space stock and estimated depreciation rates yield estimates of additions to floor space by building type. All of this new floor space requires new end-use systems. Estimates of the age distribution and depreciation rates of end-use systems allow us to estimate the replacement of end-use systems for existing commercial buildings.

Those end-use systems which are not installed in new buildings and are not new replacements for existing systems retain efficiency and fuel use characteristics of the previous period. The efficiency of new systems is determined endogenously in the model in one of two ways. For space heating and cooling systems, engineering relationships between operating cost and initial cost for alternative heating and cooling system designs are used along with estimated discount rates (which reflect commercial establishments' preference concerning trading of future savings for an increase in equipment costs) and expected future fuel prices to determine choice of equipment efficiency. This efficiency determination is equivalent to choice of efficiency using a minimum life-cycle-cost criterion.

The average efficiency of new systems is determined as the energy-weighted average efficiency choices of a small sample of firms whose characteristics (discount rate and price expectations) are described by population distributions, with specific values determined through sampling from the population. This microsimulation approach to modeling permits representation of a cost-based relationship where behaviorally determined variables play an important role. This representation is a necessary condition that must be fulfilled if one hopes to explain recent space heating fuel choices actually observed in the commercial sector.

Fuel price and efficiency elasticities are used to estimate the efficiency of the other end-use systems (water heating, lighting, ventilation, cooking, refrigeration, and other end-uses). These efficiency elasticities are econometrically determined from a pooled cross-section time series analysis of commercial energy demand. Short-run elasticities are netted out of long-run price elasticities to implicitly determine the price induced increase in efficiency.

Equipment utilization, reflecting intensity of equipment use, is dependent both on equipment efficiency and fuel price. Changes in utilization are modeled using fuel-specific short-run price elasticities. For equipment that has not been added or replaced in the previous year, utilization will change relative to utilization of the previous year only as a result of changes in fuel prices.

Since utilization of equipment actually depends on the price of producing the end-use service, fuel price changes must be weighted by efficiency changes in those cases where new or replacement equipment has been installed in the current year. For instance, if the price of oil increases by 10 per cent, but the new space heating equipment is 10 per cent more efficient, one would not expect to observe a change in the space heating thermostat settings (ie a change in utilization), since the cost of providing space heating services has not changed.

Current and expected fuel prices and efficiencies of new systems determine fuel choice characteristics of new space heating systems. Again, since the price of delivering the end-use service is the relevant price variable, fuel price must be weighted by efficiencies.

Annual electricity use by end-use and building type is an input to the peak demand model which forecasts sector peak demand as well as defines the load curve for all end-use building type detail. This is represented schematically in Figure 2-2. End-uses are categorized as weather-sensitive or nonweather-sensitive. For nonweather-sensitive loads, a so-called standard day fraction is used to allocate a portion of annual energy to daily use. This fraction can vary by season and consequently reflects the slight weather-sensitivity and seasonal operational variations of these end-uses. Daily energy is then distributed across hour of the day by normalized load curves.

For weather-sensitive loads (space heating and air conditioning), the daily energy allocation is a function of heating degree days for the winter peak day and cooling degree days for the summer peak day and two preceding days. The use of several preceding days' cooling degree days permits representation of heat build-up prior to summer peak.

Daily energy is then allocated across hours of the day with normalized hourly load curves. These normalized load curves are developed from hourly temperature characteristics of the peak days supplied as exogenous inputs. Thus, specification of dry bulb temperature for each hour in the day is needed to develop a normalized load curve from a response function estimated from hourly load data obtained from a heat load simulation model such as DOE 2.1. Both dry bulb and wet bulb temperature are used in a temperature humidity index to account for the impact of humidity in determining air conditioning hourly loads.

Hourly loads are then summed across all end-uses to develop a building load curve; a summation across building types yields the commercial sector load curve and peak demand'.

Figure 1: Schematic Diagram of Causal Linkages in the Commercial End Use Model.

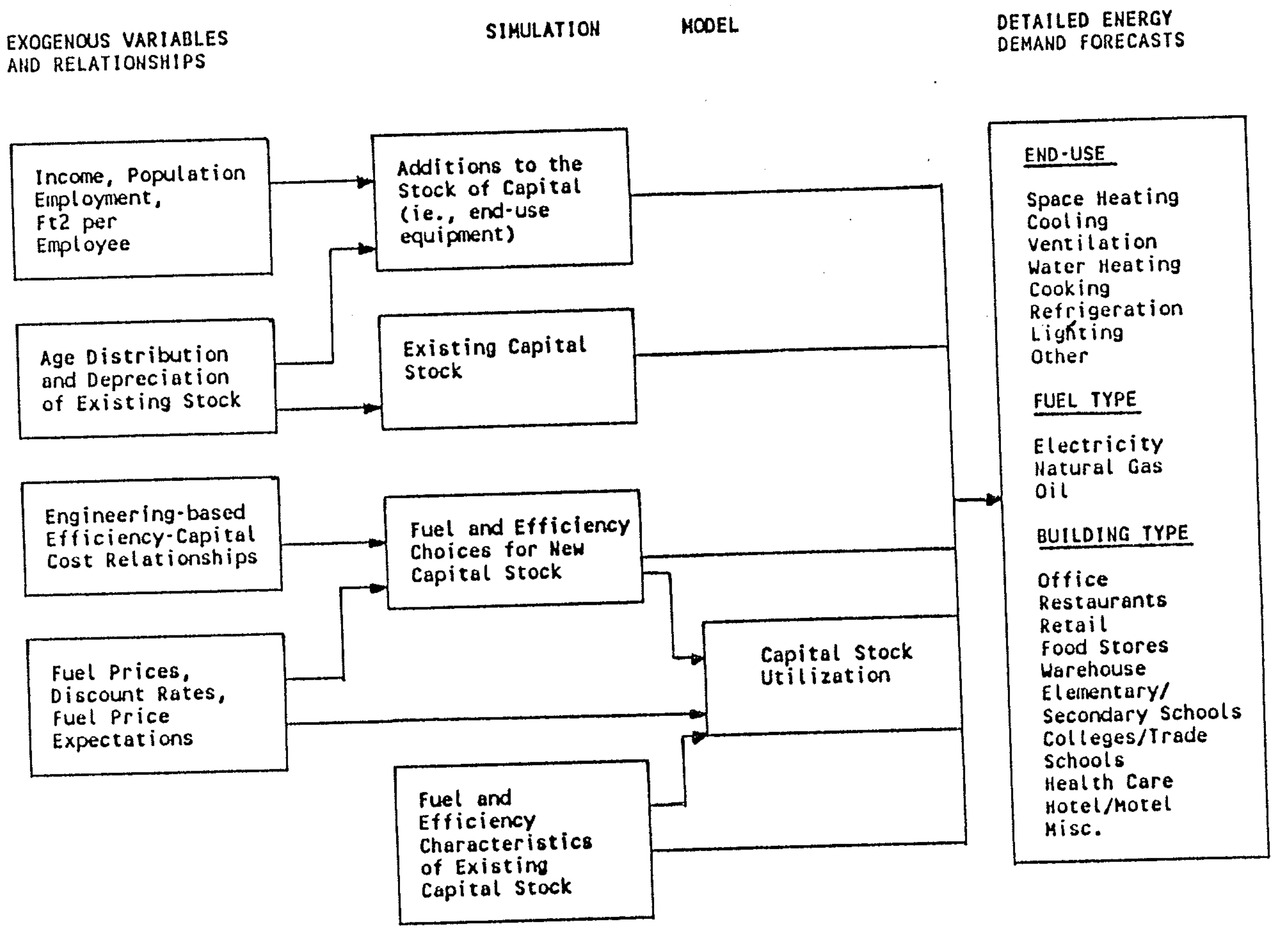
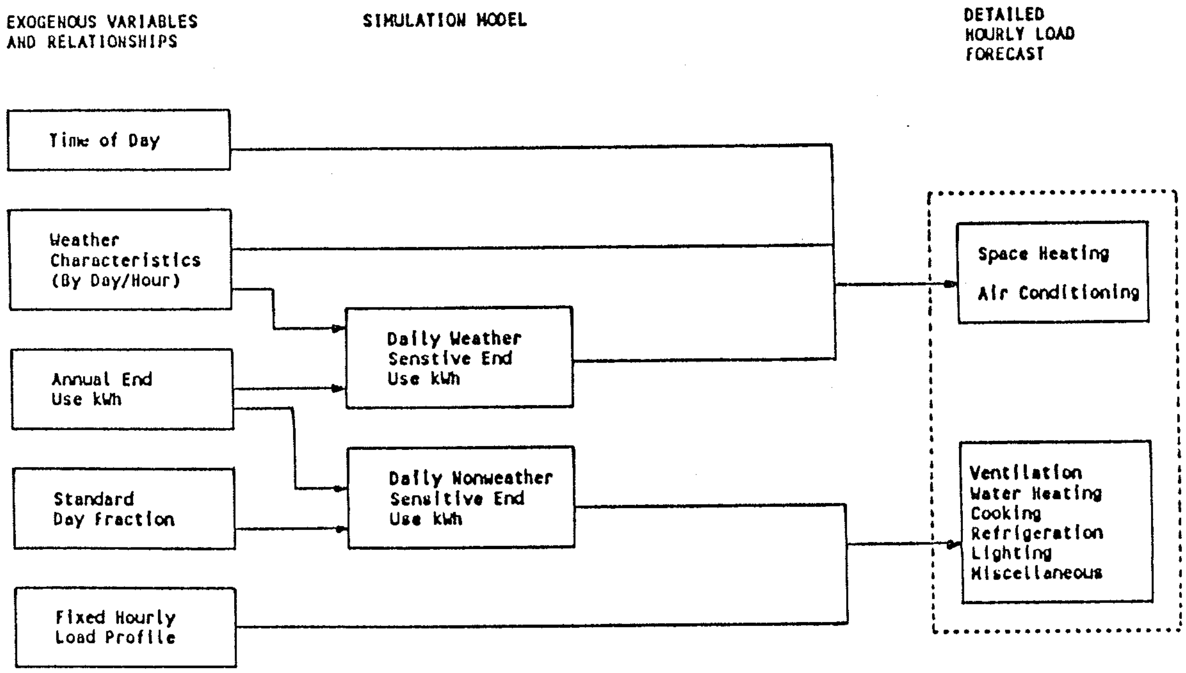


Figure 2: Schematic Diagram of the Commercial End-use Peak Load Sub-module.



Details of the Energy Model Structure

The causal relationships described above operate through the following central equation:

$$Q^T_{i,k,l} = sum^T_{t=to}\ U^t_{i,k,l} * e^t_{i,k,l} * a^t_{i,k,l} * A^t_l *d(T-t)$$

where:

T = simulation or forecast year.

$Q_{i,k,l}$ = energy demand for fuel i, end-use k, and building type l.

t_o = age of oldest building stock additions.

$U^t_{i,k,l}$ = utilization, relative to some base year (for each fuel, end-use, building type, and vintage).

$e^t_{i,k,l}$ = $EUI_{i,k,l}$ = annual energy use requirement (for each fuel, end-use, building type, and vintage).

$a^t_{i,k,l}$ = S_e = fraction of floor space served (for each fuel, end-use, building type, and vintage) (eg., fuel share).

A^t_l = floor space additions of vintage (t) for building type (l).

d(T-t) = fraction of floor space of vintage t still standing in forecast year T (EPRI 1985:2-6).

For a detailed discussion of the model components, see EPRI 1985 or Esler 1987. The scope of this study does not include a critique of COMMEND in terms of its constraints and its weaknesses. COMMEND has been assessed by the Manitoba Department of Energy and Mines and it has been determined that the computer model will be used in its energy forecasting program. The author does recognize that there are limitations to the model and the reader is referred to EPRI 1985 or Esler 1987 for a relevant discussion. The next chapter will estimate the parameters to be used as inputs to COMMEND.

Chapter Three: The Development of an Energy Baseline in Manitoba's Commercial Sector: The Health Care Subsector.

The purpose of this chapter is to develop parameters to be used as inputs to an energy demand forecasting end-use computer model. The computer model, known as COMMEND (Commercial End-use Planning System Model), is used to forecast energy demand for the commercial sector of an economy, or for components of the commercial sector. The actual forecasting of energy demand is beyond the scope of this study and will be done by the Manitoba Department of Energy and Mines at a later time.

The focus of the development of inputs in this study is on the Manitoba Health Care sector, a subsector of the Manitoba Commercial sector. The chapter begins by identifying and characterizing the Manitoba Health Care subsector and by classifying it into three building types - Hospitals, Personal Care Homes (PCH), and Combination Hospital/PCH. It then proceeds to discuss the major data sources for this subsector and to evaluate the existing data in terms of the computer model's requirements so that parameters may be estimated for use as inputs.

Taken together, the estimated parameters are commonly referred to as the "energy baseline", and represent energy consumption and physical characteristics (for example, amount of floorspace in a building category) of the subsector under study. The energy baseline is developed for a particular time period, in this case 05/87 tp 04/88..

Table 21 in Chapter 5 presents the input requirements for COMMEND, and notes which of these have been estimated in this study.

<u>Energy Baseline Study Methodology</u>

The methodology for the energy baseline portion of the study is as follows:

1. Identification and Characterization of the Manitoba Health Care subsector.

2. Identification of potential data sources.

3. Evaluation of existing data in terms of estimating COMMEND's equation components.

<u>Identification and Characterization of the Manitoba Health Care Subsector</u>

Energy users within the economy are broken down into several sectors, based upon their economic activities. The sectors are the residential, commercial, industrial and transport. These sectors are very broad in scope and are therefore further broken down into smaller subsectors, based in part upon their energy use characteristics, and upon their activities.

The commercial, or service sector, is the focus of this study. The commercial sector is disaggregated into discrete subsectors based upon unique energy characteristics and a separately definable rationale for forecasting growth of the subsector itself. These subsectors include retail, wholesale, finance and insurance, education, health care, food stores, government, other service buildings. The commercial sector includes all energy users who purchase energy at commercial rates. In the United States the commercial sector is the fastest growing of the energy consuming sectors. This is also true in Manitoba, where it represented about 22 per cent of energy consumption in 1986 (Canada 1986 as cited in Esler 1987:7) Growth in commercial sector electricity sales has historically come from new uses. For example, air conditioning when introduced in the 1940's was a small load but grew significantly through the 1950's to date, and now consumes 36 per cent of all commercial sector electricity in the United States (Squitieri 1986:31). This dynamism in end-uses of energy allows for significant opportunities to conserve energy by legislating efficiency standards, and providing more energy efficient technologies and building designs.

The Manitoba Health Care subsector is an important component of the commercial sector. In 1987 the Manitoba provincial expenditures on Health Care was 31.5 per cent of total expenditures (in comparison education was 17.7 per cent) (Manitoba 1986:122). It is thought that energy costs accounted for 2 to 4 per cent of the total operating budget in Canadian hospitals in 1982. The 1982 operating budget of 1037 public hospitals in Canada was approximately $10.4 billion. This means the energy costs for Canadian public hospital was between $208 million and $416 million in 1982 (Canada 1983:27).

The Manitoba Health Care subsector has been classified for the purpose of this study, in the following way:

HEALTH CARE SUBSECTOR

- HOSPITALS
- PERSONAL CARE HOMES
- RESIDENTIAL CARE HOMES

<u>Hospitals</u>

> For this study, a hospital is defined 'as a health care institution where patients are accommodated on the basis of medical need and are provided with continuing medical care and supporting diagnostic and therapeutic services and which is licensed or approved as a hospital by a provincial government, or is operated by the government of Canada' (Canada 1988:59).

As of April 1, 1987, there were 105 hospitals in operation in Manitoba, which included 85 public and 20 federally operated (Canada 1988:59). Hospitals are the most costly component of the Health Care subsector using up about 50 per cent of total Health expenditures (Canada 1977:3). In 1985-86, Manitoba's total hospital operating expenses were $647,941,000 (65.8 per cent for gross salaries and wages, 21.96 per cent for supplies and other expenses, 5.6

per cent for employee benefits, 3.86 per cent for medical and surgical supplies and 2.78 per cent for drugs) (Canada 1987a).

Personal Care Homes (PCH)

Personal care homes, of which there are 123 in Manitoba with 8467 beds, are defined as being those facilities which maintain four or more beds for residents who require care principally because of the aging process. These facilities are maintained for people who reside there more or less permanently (Canada 1987b).

Residential Care Homes (RCH)

Residential care homes, of which there are 193 in Manitoba with 4408 beds, are defined as those facilities which maintain four or more beds for residents other than members of the staff, and which provide care to at least one resident. These facilities are maintained for people, chronically ill or disabled, who reside there more or less permanently. These include the following groups:

1. Physically handicapped and/or disabled, including blind and deaf.
2. Mentally retarded.
3. Mentally handicapped.
4. Emotionally disturbed children.
5. Alcohol/drug problems.
6. Delinquents.
7. Transients.

8. Others (including unwed mothers and shelters for families in crisis) (Canada 1987b).

Rationale for the Manitoba Health Care Subsector Classification

There are other economic activities related to health care in Manitoba which have not been included in the above classification. These include "offices of health care professionals", such as physicians, surgeons, dentists and diagnostic and therapeutic services. Miscellaneous health services, such as voluntary health organizations, as well as welfare organization, such as the Canadian National Institute for the Blind are also health related. All of these have, for the purposes of this study, been placed in the "office building" component of the commercial sector because, while these health care offices have an economic activity which links them to the health care subsector, they have other characteristics which suggest they should be placed with office buildings. These characteristics are explained below.

The level of economic activity in a subsector is difficult to determine. This is an important limitation to energy forecasting because economic activities are used to forecast floor space, which is then used to forecast energy demand. We therefore use floor space as a proxy to drive energy demand in forecasts. The driving parameter for floor space in health care offices and in office buildings in general, is the number of employees, while in the other health care components (eg., hospitals, PCH and RCH), the driving parameter for floor space is the number of beds (Manitoba 1988b). This difference in this driving parameter of floor space is a reflection of the difference in economic activities between the subsectors.

Health care offices and Hosp/PCH/RCH differ in their energy consumption characteristics. The energy consumption characteristics of health care offices compare more favorably to office buildings than to other health care program buildings, such as hospitals. Also, many health care offices are located in office buildings and shopping malls. The utility bills are often paid by landlords, making it difficult, to collect data on energy use within individual health care offices. Since utilities forecast for aggregate energy demand, placing the health care offices in the office building component will not impact the utilities ability to forecast energy demand for the commercial sector. At the same time, data collection for the office building's will be simplified since there will be no need to distinguish between different types of offices in the office buildings.

There are some drawbacks to classifying health care offices within the office building subsector. If demand side management impacts differently on health care offices than on other office types (for example, medical offices might not adopt low level light bulbs because of the activity in the office), then the assumptions that utilities make about the effectiveness of conservation programs in the office buildings subsector may be overstated.

We might assume, however, that since the number of health care offices are very small relative to the number of other offices in the office building subsectors, that any anomalous demand side management impact in the health care offices would be insignificant.

Other utilities in Canada, including Ontario Hydro and TransAlta Utilities of Alberta, have classified health care offices with office buildings.

An Overview of the Major Data Sources

The main approaches to data collection for COMMEND are engineering simulations, survey research, end-use metering and literature reviews (EPRI 1985). Generally, data collection efforts in Manitoba have been limited to survey research and some engineering simulations and estimates (Esler 1987).

The main data sources for the Health Care subsector in Manitoba include: (1) Statistics Canada; (2) the provincial energy utilities (Manitoba Hydro, Inter-City Gas and Winnipeg Hydro); (3) the Manitoba Health Services Commission; (4) the National Health and Welfare Medical Services Branch; (5) ENERHOSP (Hospital Energy Retrofit Program); and (6) Energy and Mines' Energy Bus Program.

Statistics Canada publishes an annual list of Canadian Hospitals and Special Care Facilities (including personal care homes) operating in each province by category (public, private or federal), type, ownership and capacity, as well as annual hospital statistics and an analysis of hospital expenditures. Statistics Canada also publishes quarterly statistics on provincial energy consumption by different fuels and sectors in its Quarterly Report on Energy Supply and Demand in Canada.

Manitoba's three major energy utilities: Manitoba Hydro, Inter-City Gas and Winnipeg Hydro, are able to provide energy consumption by customer class. These data are not readily retrievable however, due to differences in the utilities' respective customer coding systems and in their definition of commercial customers (Esler 1987). Provincial oil and propane suppliers were not contacted for this study for two reasons: (1) an analysis of the energy audits indicated that these fuels do not appear to have large penetrations in the Manitoba Health Care subsector, and (2) there is no central source of oil or propane consumption data - the supply industry consists of many small suppliers - and consumption data for specific classes of customers could only be obtained by approaching each supplier on an individual basis, which is beyond the abilities of this study. Esler (1987) indicates that for future modelling of energy demand, aggregated sales statistics for these fuels available from Statistics Canada may be adequate.

Manitoba Hydro's major attempt at analyzing commercial sector energy consumption was a survey undertaken in 1984. However, the survey design was problematic and it has not contributed much to the understanding of commercial sector end-use energy consumption. For a discussion of the problems of the survey, see Esler 1987.

The Manitoba Health Services Commission administers the Manitoba Health Services Insurance Plan. The plan finances an integrated system of hospital care, medical treatment, personal care, pharmacare, and other health services (Manitoba 1988a). The Commission publishes an Annual Report and Annual Statistics which include information on health programs, population, hospital care, medicare, and personal care. The Commission also makes available annually updated lists and addresses of urban and rural health facilities (hospitals, personal care homes and juxtaposed facilities) which includes the number of beds. The Commission is also in charge of construction of health care facilities in the province. However, it does not maintain an historical record of floor space additions per year, or a list of when each facility was originally built.

The National Health and Welfare Medical Services Branch oversees and administers the federally operated health care facilities in the province. These include nursing stations and hospitals in the north. Information is available upon request.

ENERHOSP (Faraci 1984), the Hospital Energy Retrofit Program, was a study conducted by the consulting company of Faraci and Associates for the Manitoba Health Services Commission and the Manitoba Dept. of Energy and Mines. Its purpose was to examine the MHSC records and determine the energy costs based on KW.h/gross sq. ft., or some other suitable parameter. Building retrofitting was to be based upon the results from this study. The report itself gives a condensed and abridged summary of the data from the study and is of limited use for this study. Faraci and Associates was in possesion of the original study data containing facility construction dates and floor space per health care facility. However, they have indicated that they cannot find the files containing the data and it appears that the data may be lost.

The year 1980 saw the beginning of a federally/provincially sponsored Energy Bus Program, which has produced a significant quantity of engineering and energy consumption data for various business types, including hospitals and personal care homes. The programs objective is to identify areas of potential energy cost savings in commercial industrial buildings in Manitoba (Esler 1987). Of the more than 1300 energy audits which have been performed by Energy and Mines, 500 of them were done within commercial and institutional buildings (Webb 1987 as cited in Esler 1987:73). Forty-seven of these commercial/institutional audits were performed on health care facilities, which is 11.2 per cent of the 419 health care facilities in Manitoba. Of these 47 audits, 17 were hospitals (22.7 per cent of the 75 hospitals not combined with PCH in Manitoba), 19 were personal care homes (20.2 per cent of the 94 personal care homes not combined with hospitals), 10 were combination hospital/personal care homes (33.3 per cent of the 30 combination hosp/PCH), and 1 was a residential care home (less than 1 per cent of the 220 residential care homes in Manitoba).

Bias in the sample distribution may occur because the audits are performed on demand. Facilities tend to be active in energy conservation or not, which means that interested groups (those wishing to have energy audits performed) would tend to be more energy conservative and disinterested groups less energy conservative. Bias in the sample distribution would therefore be that those facilities which are already more energy conservative than the norm would be over-represented in the distribution. The audits do not represent a large sample of the population and it is difficult to assess the sample bias. In the case of residential care homes (where there is only one audit), the lack of data will not permit an analysis. The other groupings (hospitals, personal care homes and combination hosp/PCH) will be assumed to be representative of their respective populations.

Evaluation of Existing Data in Terms of COMMEND's Equation Components

The following section will evaluate data sources to estimate the main equation components of COMMEND. Table 21 in Chapter Five provides a summary of this evaluation. It summarizes the main data requirements for each COMMEND equation component, and indicates if these components were estimated in this study.

Note that deficiencies in existing data can usually be compensated for, since the complex relationships reflecting choices of commercial end-use systems are represented endogenously in the model. COMMEND has endogenous default values which are used when data input requirements are not met.

It should also be noted that for the purpose of this study a parameter is defined as a number describing some aspect of a population. The value of the parameter is unknown but a statistic is developed and used to make inferences about the parameter. In short, the statistic, known as the estimator, is used to estimate the unknown parameter. The actual numerical value obtained by evaluating the estimator is called the estimate. It is desirable that the sampling distribution of an estimator have a small standard deviation, so that large estimation errors are not likely to occur. However, as will be noted in the following discussions, the sample used to develop estimators in much of this study was quite small, and the subsequent standard deviations were sometimes quite large.

Developing Floor Stock Data

This section will develop floorstock data parameters required by COMMEND.

Definition of Building Segments

COMMEND's definitions of building types form the primary market segments. We classify by building type because specific types of structures have unique and characteristic energy-using patterns. These patterns are reflected in energy intensity values and differences in load profiles.

> COMMEND defines the Health building category in the following way: 'Major differences exist between hospitals, nursing homes, clinics, and medical offices. Some analysts define health to include hospitals only, allocating other buildings elsewhere. In particular, medical offices and clinics are sometimes included in the office category. Nursing homes are sometimes treated as a separate category or included in miscellaneous' (EPRI 1988:2-4).

The writer has decided to include personal care homes in the health care building type category because in many rural communities in Manitoba, personal care homes are attached to hospitals, making their energy consumption patterns interdependent.

Estimating the Current Floor Stock

COMMEND requires three types of floor stock data entries as input values. They are:

(1) Estimates of total floor stock in some distant base year (eg., 1945);

(2) A series of gross additions to the stock (eg., 1950 to 1980);

(3) A set of building survival functions (EPRI 1988).

The general method of developing these inputs, is to develop estimates for a recent base year (eg., 1986) and then to estimate the distant base year (method to be described later). This section will estimate floor stock in the recent base year. This is referred to as the "current floor stock".

The recent base year for this study is 05/87 to 04/88. This period was chosen for three reasons: (1) to avoid breaking the energy consumption data in the middle of a high energy consumption period, such as January; (2) consumption data from the various utilities could all be obtained for this period; and (3) it was the most recent set of consumption data when the study began. Note that floor stock is measured in square feet.

Floor stock or area is defined as conditioned (eg., space heated or air conditioned) floor space within a building and includes all the areas enclosed by the exterior walls of the building including basements, hallways, lobbies, stairways, elevator shafts, and excluding parking areas. It is important to understand the definition of floor space which has been used since different definitions can lead to as much as a 20 per cent difference in the floor area of a specific structure (EPRI 1988).

There are several approaches to estimating current floor stock. They are:

(1) physical measurement,

(2) survey expansion using response weights,

(3) survey expansion using ratio estimates,

(4) parametric methods using multipliers, and

(5) direct data sources (EPRI 1988)

The approach used in this study is the parametric method using a multiplier. For a discussion of the other approaches see EPRI 1988.

Parametric techniques use parameters called secondary estimates, as opposed to primary or direct approaches. Parametric techniques have two elements:

(1) "the parameter is usually a ratio, with square feet in the numerator, and

(2) the scale variable is in the same units as the denominator of the ratio" (EPRI 1988:2-11).

Common approaches include:

(1) per capita multipliers (ex. 200 sq. ft./person)

(2) per employee multiplier (ex. 600 sq. ft./employee)

(3) intensity multiplier (ex. 90 kW.h/sq.ft.)

(4) others - area/bed for health care facilities.
area/room for lodging establishments.
area/seat for eating establishments.

This study uses the area/bed multiplier. The scale estimator is the number of beds. The data on the number of beds for hospitals and personal care homes was provided by the Health Services Commission (Manitoba 1988c, 1988d, 1988e) and by Statistics Canada (Canada 1987a, 1987b, 1988), and by the Energy Bus audits. The current floor stock (F) was estimated using the following equation:

F = area/bed * bed

The floor area data for the various facilities was obtained from the Energy Bus Audits, the ENERHOSP report, government agencies (eg., Dept. of National Defence for military hospitals), and from data which Energy and Mine's summer students collected.

The ratio of sq.ft./bed was calculated for each facility which had values of area and beds available. The facilities were then grouped according to the number of beds and placed into size ranges. These ranges were 1-24, 25-49, 50-99, 100-199, 200-299, and >300. The average sq.ft./bed for each size range was calculated and these figures were then used as multipliers to estimate the areas of facilities in which area data was not available (number of beds data was available for all facilities). Table 1 presents a summary of the average sq.ft./bed ratios along with their associated standard deviations and number of observations.

Table 1: Average sq.ft./bed ratios for Manitoba hospitals and personal care homes.

Bed Range	Average $ft.^2$/bed	Standard Deviation	Number of Observations
Building Type = Hospital			
1-24	994.4	579.7	19
25-49	895.2	539.2	9
50-99	971.8	400.3	7
100-199	972.3	278.8	3
200-299	960	0	1
>300	943	128.7	
Building Type = Personal Care Home			
1-24	704	0	1
25-49	767.5	480.7	13
50-99	538.9	169.2	21
100-199	557.2	330.6	9
200-299	491	65.4	3
>300	627	217.8	2
Building Type = Combination Hosp/PCH			
1-24	---	---	---
25-49	883	278.4	19
50-99	819.6	321.4	7
100-199	1035	132.9	2
200-299	---	---	---
>300	---	---	---

Notes: --- indicates data was not available.

Note that the large standard deviations indicate that estimation errors are possible. However, the average area/bed calculated for use as multipliers compared favorably with those from the Building Energy Technology Transfer (Canada 1983). The following table presents average ft.^{2}/bed for Canadian hospitals and personal care homes, from BETT. The average ft.^{2}/bed ratios in Table One are used for this study because they were calcualated for Manitoba, and also because there are no others available for Manitoba at this time.

Table 2: Average sq.ft./bed ratios for Canadian hospitals and personal care homes (BETT 1983:D-11).

Bed Range	Average ft.2/bed
1-24	841.7
25-49	736.3
50-99	910.5
100-199	901.9
200-299	1011.6
300-499	972.8
500-799	1063.2
800-1999	1071.8
>2000	813.8

A report by Ontario Hydro indicates that not all hospitals have equal floor space per bed allocations. It states "that as the size of hospitals increases, up to around 300 beds, there is a tendency towards more efficient floor space utilization. Hospitals with more than 300 beds tend to have larger average floor space per bed allocations, possibly because of increased use of sophisticated diagnostic and therapeutic equipment" (Ontario Hydro 1985:2). The average area/bed ratio in Ontario is approximately 900 sq. ft./bed (Ontario Hydro 1984). This too compares favorably with the calculated figures for Manitoba.

Below is a summary of the facility types, the total number of facilities, and the number of facilities for which the area was estimated.

Facility Type	Total No.	No. for Which Actual Measured Floor Space was Obtained	No. for Which Floor space was Estimated
Hospital	75	46	29
PCH	94	49	45
Combination	29	47	2

The current floor stock for the recent base year is presented in Table 3.

Table 3: Current floorstock values for Manitoba hospitals and personal care homes.

Facility Type	Current Floor Stock
Hospitals	5,646,859 sq. ft.
Personal Care Home	5,328,163 sq. ft.
Combination H/PCH	1,290,564 sq. ft.

Estimating Floor Space Additions (Historical Stocks) A^t_l * d(T-t)

Floor area is the key driving variable for forecasting energy demand in a commercial subsector. The floor space additions component of the COMMEND equation is comprised of two terms: "A^t_l", representing new floor space additions of vintage "t" for building type "l"; and "d(T-t)", representing the fraction of floor space of vintage "t" still standing in forecast year "T".

Thus, the COMMEND model requires vintage profiles for floor stock and for the annual additions to this stock. The use of vintage profiles serves two purposes, aside from the one stated above. They are:

"(1) the appliance decay and replacement algorithms rely on building age. In essence the building vintage profile is used as a way to smooth appliance replacement decisions over time; and

(2) energy use patterns differ across vintages, due to differences in structure characteristics, fuel choice patterns, and end-use equipment efficiencies" (EPRI 1988:2-21).

The COMMEND model requires input data on the floor stock in a distant base year, annual additions to the current base year, and a set of building survival functions that provide the link between new construction and changes in the building stock.

COMMEND uses two sets of survival functions (referring to that stock which has survived). They are distant base survival and additions survival.

<u>Distant Base Survival</u>

The distant base stock is the entire stock standing in the distant base year. In the years following this distant base year, less and less of this floor stock survives as an active component of the commercial floor stock.

In the COMMEND model, the oldest part of the floor stock is assumed to have an exponential survival function of the form:

$$F_{T,t} = F_T \, r^{(t-T)} \qquad \text{where}$$

F_T is the floor stock in the distant base year T,

FT,t is the amount of stock remaining in year t, and

r is the annual survival rate (EPRI 1988:2-21).

COMMEND has default data sets for instances where required inputs are not available. The default data for r, the annual survival rate is 0.985, which means that 1.5 % of the remaining stock decays in each year after the distant base year. Figure 3 presents exponential survival functions with several annual survival rates. For very old vintage categories, EPRI (1988:2-22) suggests an overall building demolition rate of 0.8% annually with rates of about 1.2%. This study shall use the default value for r of 0.985 since there are few buildings in the very old vintage categories. The r value of 0.985 corresponds to a decay specification with a 45-year mean life. According to EPRI (1988:2-24) 'the 45-year mean life assumption has a long history in commercial sector analysis. Alternatives to this value have been suggested. For example, as reported in the Bureau of Economic Analysis, estimated mean service lives for nonresidential structures is 36 years for commercial categories (offices and retail), and 48 years for institutional categories (education, health, and religious)'. Using the 45-year mean life as recommended by EPRI would therefore seem to be valid.

Data is not available for floorstock for any distant base year for the Health Care subsector in Manitoba. Distant base year floorstock in the Health Care subsector is estimated in the next section using a demographics approach.

Figure 3: Examples of Geometric survival functions (EPRI 1988:2-23).

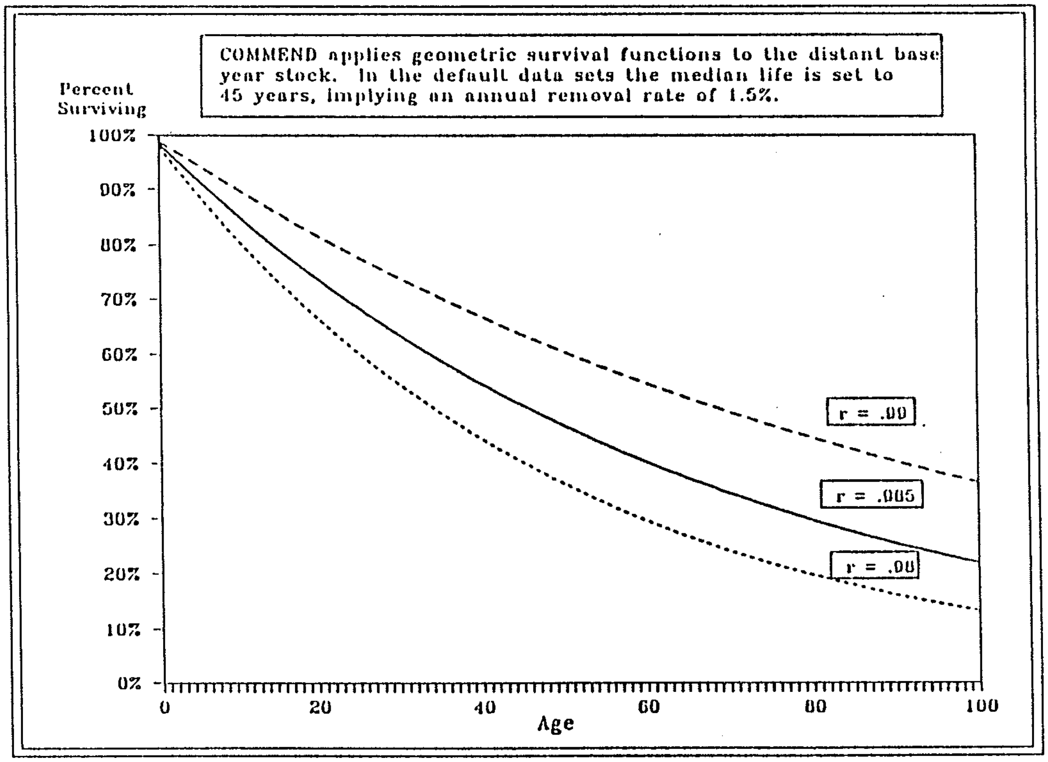
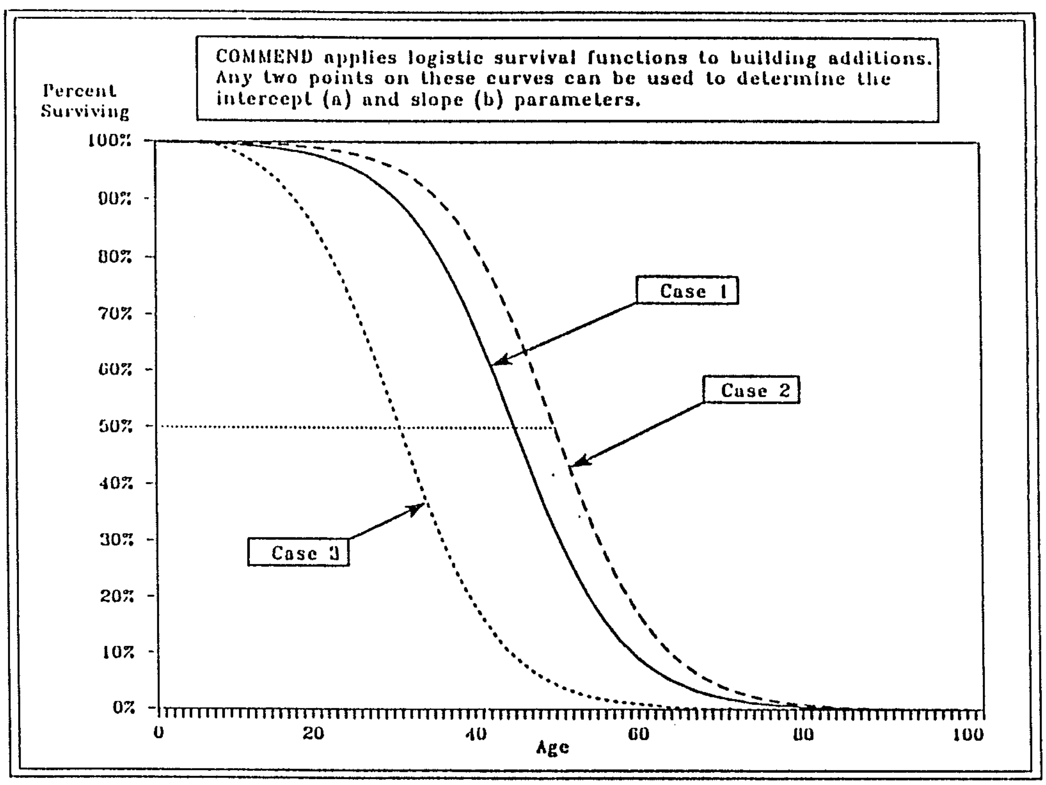


Figure 4: Examples of Logistic Survival Functions (EPRI 1988:2-23).



Additions Survival

Historical additions are entered year by year since the distant base year. COMMEND uses a common logistic survival function for each vintage. Figure 4 presents examples of logistic survival function. The logistic function can be written as:

$D_t = 1/\{1+\exp[a+b(t)]\}$

$R_t = 1 - 1/\{1+\exp[a+b(t)\}]$ where

Dt is the percentage of additions decayed after t years,

R_t is the percentage of additions remaining after t years, and

a and b are the logistic function parameters which are taken from the S shaped decay or survival curves (EPRI 1988:2-22).

The R_t and D_t values can be read directly from Figure-4. Note that in Figure 4; Case 1 is the standard COMMEND shape, with a 45 year mean life (a=6.9, b=-0.153), Case 2 has a 50 year mean life, with 98% survival after 25 years (a=7.8, b=-0.156), and Case 3 has a 30 year mean life, with 98% survival after 15 years (a=3.9, b=-0.260) (EPRI 1988:2-24). This study uses Case 1 (eg., it assumes a 45 year mean life for buildings) as recommended by EPRI (1988:2-24).

An example of the use of the logistic curve is: $R_{15} = 1 - 1/\{1+\{\exp\{a+b15\}\] = 0.99$ which can be read from the logistic curve (although not as accurately). Thus the percentage of additions remaining after 15 years is 99.

COMMEND's decay specification has the following properties:

(1) a 45 year mean and median life,

(2) symmetric survival profiles around the mean life,

(3) strong survival through the first 25 years (96% survives),

(4) rapid decay from the 25th to the 65th years (90% decays), and

(5) extremely low remaining stock after 70 years (only 3% remains) (EPRI 1988:2-24). These values are installed in COMMEND (version 2) and are applied to all building types.

The building survival functions are used to develop historical vintage profiles and to develop construction forecasts. Total new construction is translated into net additions to the floor stock using the decay assumptions. The decay functions can be altered, if need be, to tailor COMMEND to Manitoba. "In reverse, any change in floor stock will imply the required amount of new construction only after decay of the existing stock has been considered" (EPRI 1988:2-24).

The three approaches that are typically used to construct historical vintage profiles are:

(1) Demographics approach. In this approach data on a scale variable are used to infer the vintage profile.

(2) Additions approach. In this case data on annual building additions are used to develop the vintage profile.

(3) Mixed approach. Here, additions data are used for the near past, and the demographic approach is used for the more distant past (EPRI 1988).

As stated earlier, the Manitoba Health Services Commission does not keep a record of annual additions to health care facilities. Therefore, since the data on annual building additions is not available for health care facilities , the demographics approach shall be applied in developing historical vintage profiles. For a detailed discussion of the other two approaches, see EPRI 1988.

The demographic approach is the simplest and requires the least data. It uses a single demographic scale variable for each building type, such as total employment, population, or school age population. The scale variable is not usually used on an annual basis, but is used for a series of years, for example 1920-30-40-50-60-70-80.

The exact vintage profile of the building stock is not a key input to the COMMEND model, but a general spread of the stock over time is required to run the appliance decay and replacement algorithms. EPRI (1988) recommends the demographic approach for initial implementation. If additions data is available, the mixed approach is recommended.

Population (the most easily obtained data) is not an accurate scale variable. This is because the rate of growth of population in Manitoba is decreasing, resulting in a rising median age and a changing age structure in the population. The premise when backcasting or forecasting using a scale variable is that the estimated values will change in proportion to changes in the scale variable. This is likely not the case with fore- or backcasting floorstock using population as the scale variable however, since the demand for healthcare (and intuitively floorstock) may indeed increase as the median age of the population increases. This is important because the scale variable is used in forecasting and backcasting floorstock, which in turn is used by COMMEND as a proxy for forecasting energy demand. This is done on the premise that greater amounts of floorstock will require more energy consuming equipment. For this reason more than one scale variable was assessed.

The scale variables assessed in this study are total provincial population and employment in the health care subsector.

Step One: Backcast Stock

Backcast stock from the recent base year (1987) to the distant base year assuming proportionality to the scale variable. A distant base year of 1940 is used. Floorstock was backcast to 1920 since this was the most distant year for which population could be obtained.

$F_t = F_{87} (P_t/P_{87})$ for t equal to a series of years (eg., 1920,30,40,50,60,70,80,87).

Where F_t is the stock in year t, and
P_t is the scale variable value in year t.

Backcasting stock using population as the scale variable. Population data came from Canadian Economic Observer (1988:91).

Year (t)	Manitoba Pop(x1000) (P_t)	P_t/P_{87}
1920	606	0.566
1930	689	0.643
1940	728	0.680
1950	768	0.718
1960	906	0.847
1970	983	0.919
1980	1025	0.958
1987	1070	1.000

Table 4 presents the backcast floorstock for each year and building type for population as the scale variable.

Table 4: Backcast floorstock using population as the scale variable.

Year (t)	Floorstock (ft.^{2}) in year t (F_t) Hospital	PCH	Comb Hos/PCH
1920	3198127	3017632	730918
1930	3636155	3430938	831027
1940	3841975	3625142	878066
1950	4053072	3824326	926311
1960	4781359	4511509	1092757
1970	5187721	4894938	1185630
1980	5408846	5103583	1236167
1987	5646859	5328163	1290564

Backcasting floorstock using employment as the scale variable. Data on employment in the Health Care subsector came from Dimensions (1988:2-87).

The floor stock was backcast using the following formula: $F_t = F_{86} * (E_t/E_{86})$ for t = a series of years.

Hospitals:

Year (t)	No. Employed (E_t)	E_t/E_{86}
1971	17950	0.813
1981	21015	0.952
1986	22075	1.000

Personal Care Homes:

Year (t)	No. Employed (E_t)	E_t/E_{86}
1971	4705	0.270
1981	13635	0.782
1986	17440	1.000

Table 5 presents the backcast floorstock for the two building types with employment in the Health Care subsector as the scale variable.

Table 5: Backcast floorstock using employment as the scale variable.

Year (t)	Floorstock (ft.^{2}) in year t (F_t) Hospitals	PCH
1971	4590896	1438604
1981	5375809	4166623
1986	5646859	5328163

Figures 5, 6, 7, and 8 present backcasted floorstock for the various building-types using the two different scale variables. A comparison of the floorstock using the two scale variables indicates that more data on employment in the Health Care subsector (eg., prior to 1971) is required before employment can be assessed for use as a scale variable. Note that there are no past actual floorstocks available to which one can scale to check the accuracy of the backcasted floorstocks.

FIGURE 5:

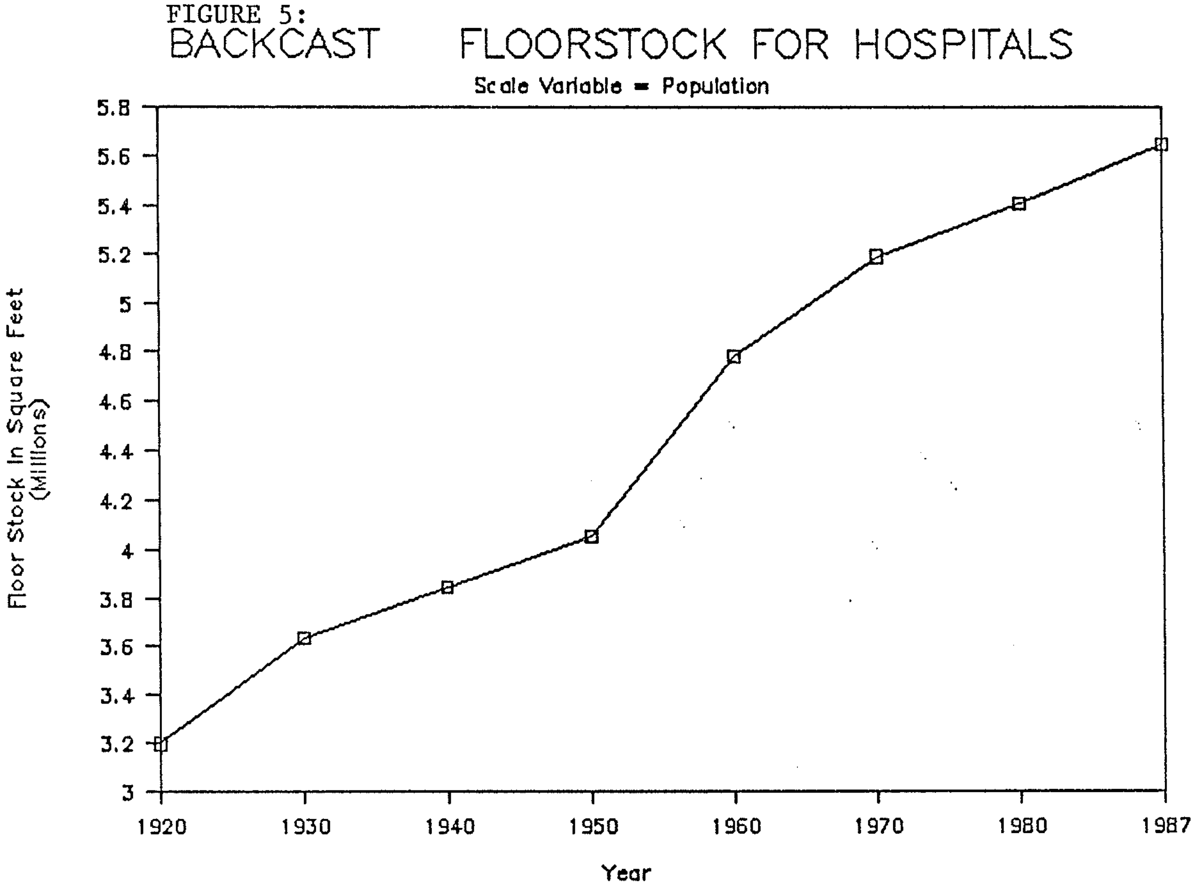


FIGURE 6:

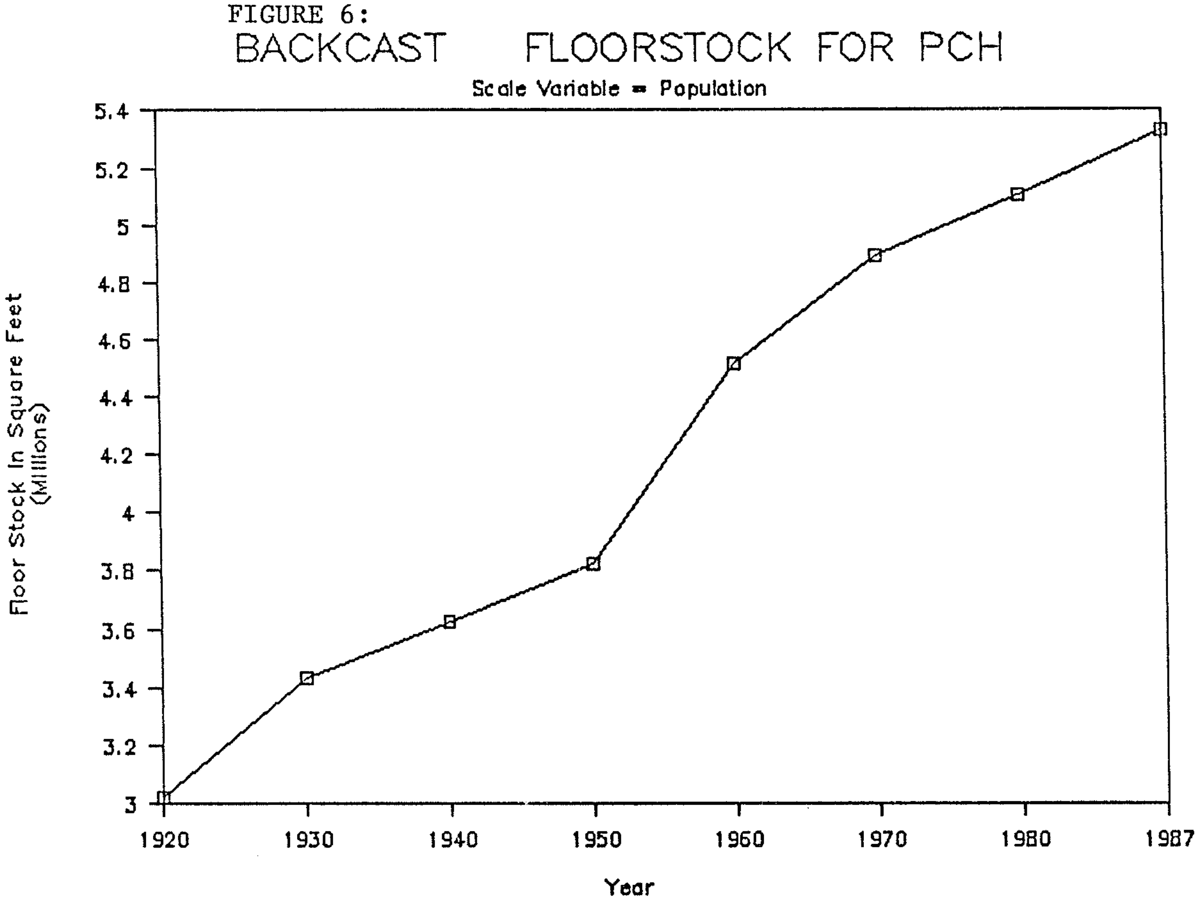


FIGURE 7:
BACKCAST FLOORSTOCK FOR HOSPITALS

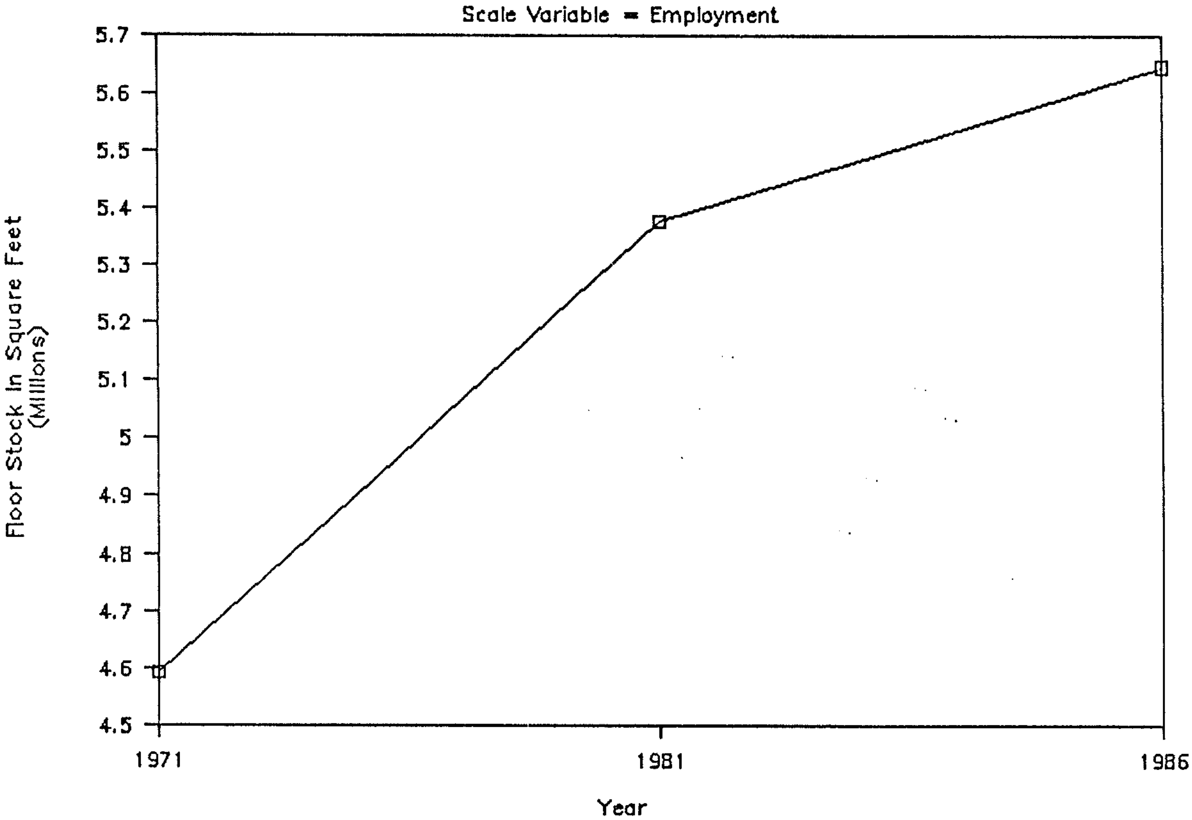
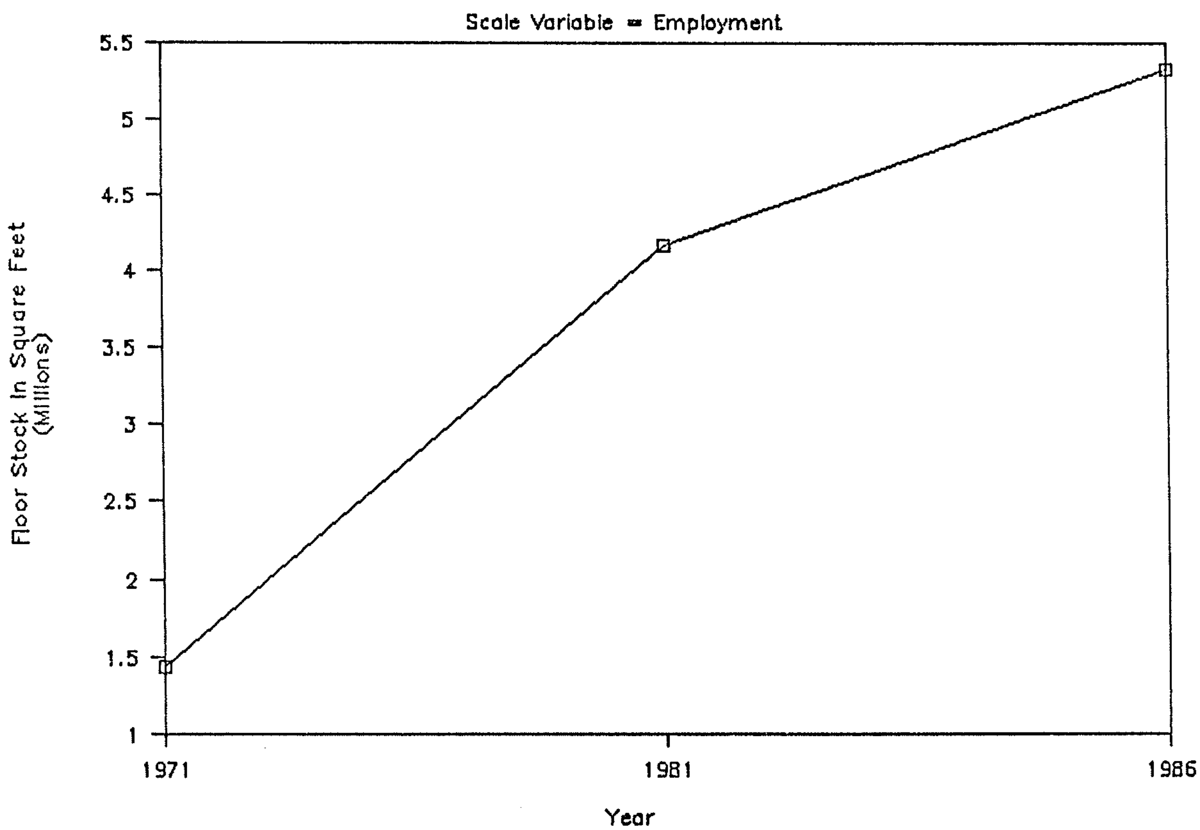


FIGURE 8:
BACKCAST FLOORSTOCK FOR PCH



Step 2: Determine Average Additions

This step determines the average floorstock addition for the time intervals between each of the scale variable values. This relies on the decay functions determined earlier (D_t and R_t) and the relationship between stock and additions.

Assuming a distant base year of 1940

$$F_T = F_{40} * r^{(T-40)} + sum^T{}_{t=41} A_t R_{T-t}$$

where
F_T is the building stock in year T,
r is the geometric decay rate for the distant base stock,
A_t is building additions in year t, and
R_{T-t} is the fraction of additions remaining after i years (EPRI 1988:2-26).

If we apply this equation to the first interval, 1940 to 1950, and assuming constant additions over that interval, the equation becomes:

$$F_{50} = F_{40} r_{10} + Abar_{41-50} * [R9+R8+....+R1+1]$$

where
$Abar_{41-50}$ is the average additions over the 1941 to 1950 interval (EPRI 1988:2-26). Rewriting the equation and solving for average additions (A_t):

$A_t = Abar_{41-50} = [F_{50} - F_{40} r^{10}]/[R_9+R_8+...+R_1+1]$
for t = 41,....,50 (EPRI 1988:2-26).

Repeating this procedure for the next interval, using the basic equation results in the following:

$F_{60} = F_{40} * r^{20} + Abar_{41-50} [R_{19}+....+R_{10}] + Abar_{51-60}$
$[R_9+..+R_1+1]$ (EPRI 1988:2-26).

The above equation can be rewritten in terms of average additions, At:

$A_t = Abar_{51-60} = \{F_{60} - F_{40} r^{20} - Abar_{41-50}$
$[R_{19}+...+R_{10}]\}/[R_9+...+R_1+1]$

In general, the formula for additions in an interval from years Ti=1 to Tj is:

$$A_t=(F_{Tj}-F_D r^{(Tj-D)} - sum^{Ti}_{t=D+1} A_t R_{Tj-t})/sum^{Tj}_{t=Ti+1} R_{Tj-t}$$

where

F_T is the building stock in year T,

r is the geometric decay rate for the distant base stock,

A_t is building additions in year t, and

R is the fraction of additions remaining after i years (EPRI 1988:2-26)

These two steps, backcasting and determination of average additions, result in a distant base year stock value (F_{40}) and a set of annual additions that are constant in each interval. Employing the decay functions, the additions will reproduce the current base year stock value (F_{87}) and will produce intermediate stock values proportional to the demographic scale variable (EPRI 1988). The annual additions values ($A_{41}, \ldots A_{87}$) and the distant base year stock (F_{40}) are placed directly into the COMMEND input file (Epri 1988).

The value for F_{40}, the building stock in 1940, was determined in the previous section by backcasting stock using population as a scale variable.

Example of calculations:

$$A_t = Abar_{41-50} = (F_{50} - F_{40}\, r^{10})/(R_9+R_8+...+R_1+1)$$

For Hospitals:
F_{40} = 3841975 ft.^{2}
F_{50} = 4053072 ft.^{2}
r = 0.985 (EPRI 1988:2-23)

R values were calculated using the following formula:
Rt = 1 - 1/{1+exp[a+bt]}
where a = 6.9 and b = -0.153

A_{41-50} = (4053072-3841975*.985^{10})/9.979
A_{41-50} = 75159 ft.^{2} is the average addition for the interval 1941 to 1950 for hospitals.

Continuing the example for the next interval, 51-60:

$$A_{51-60} = [(F_{60} - F_{40}\, r^{20}) - (Abar_{41-50}\, [R_{19}+...+R_{10}])] / \{R_9+...+R_1+1\}$$

where
F_{60} = 4781359 ft.^{2}
F_{40} = 3841975 ft.^{2}
r = 0.985
A_{41-50} = 75159 ft.^{2}
$R_{19}+...+R_{10}$ = 9.899
$R_9+...+R_1+1$ = 9.979

A_{51-60} = 120014 ft.^{2} is the average addition for the interval 1951 to 1961 for hospitals.

Similar calculations were carried out for the noted intervals for all building types and are presented in table 6. Figures 9, 10, and 11 are a graphical presentation of the gross floorstock additions.

Table 6: Gross floorstock additions for Hospitals, Personal Care Homes, and Combination Hosp/PCH.

	Average Additions ($ft.^2$)		
Interval	Hospital	PCH	Comb.
1941-50	75159	70917	17177
1951-60	120014	113240	27428
1961-70	203250	191780	46452
1971-80	269450	254244	61581
1981-87	576824	544270	131830

FIGURE 9:

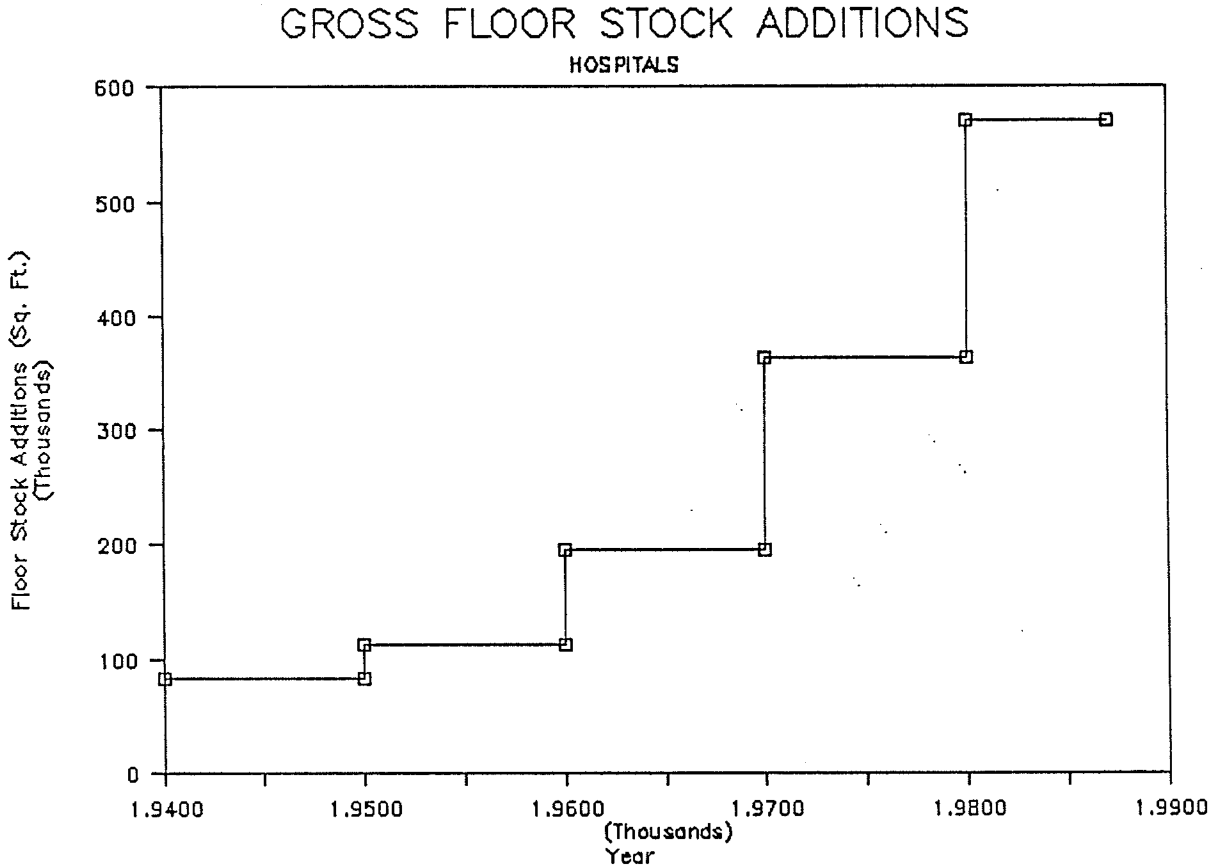


FIGURE 10:

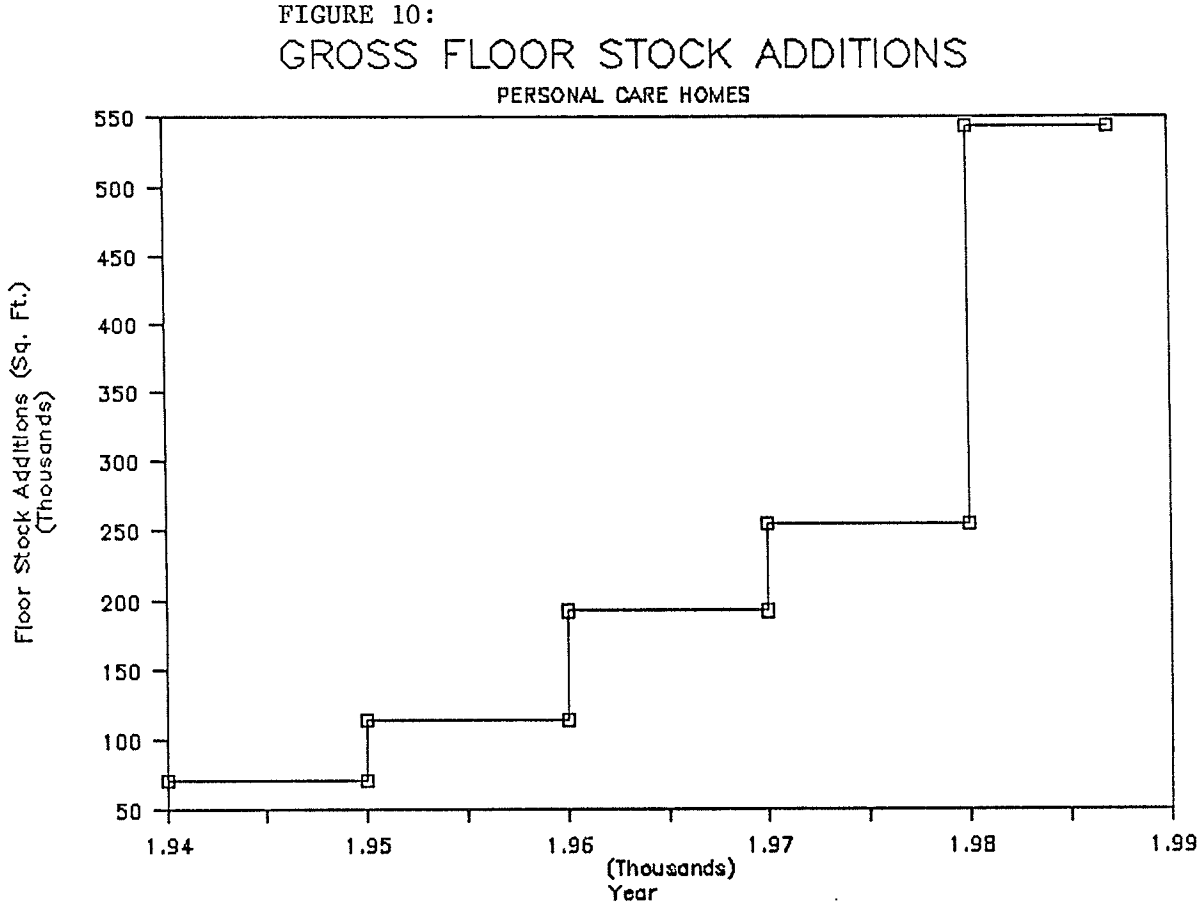
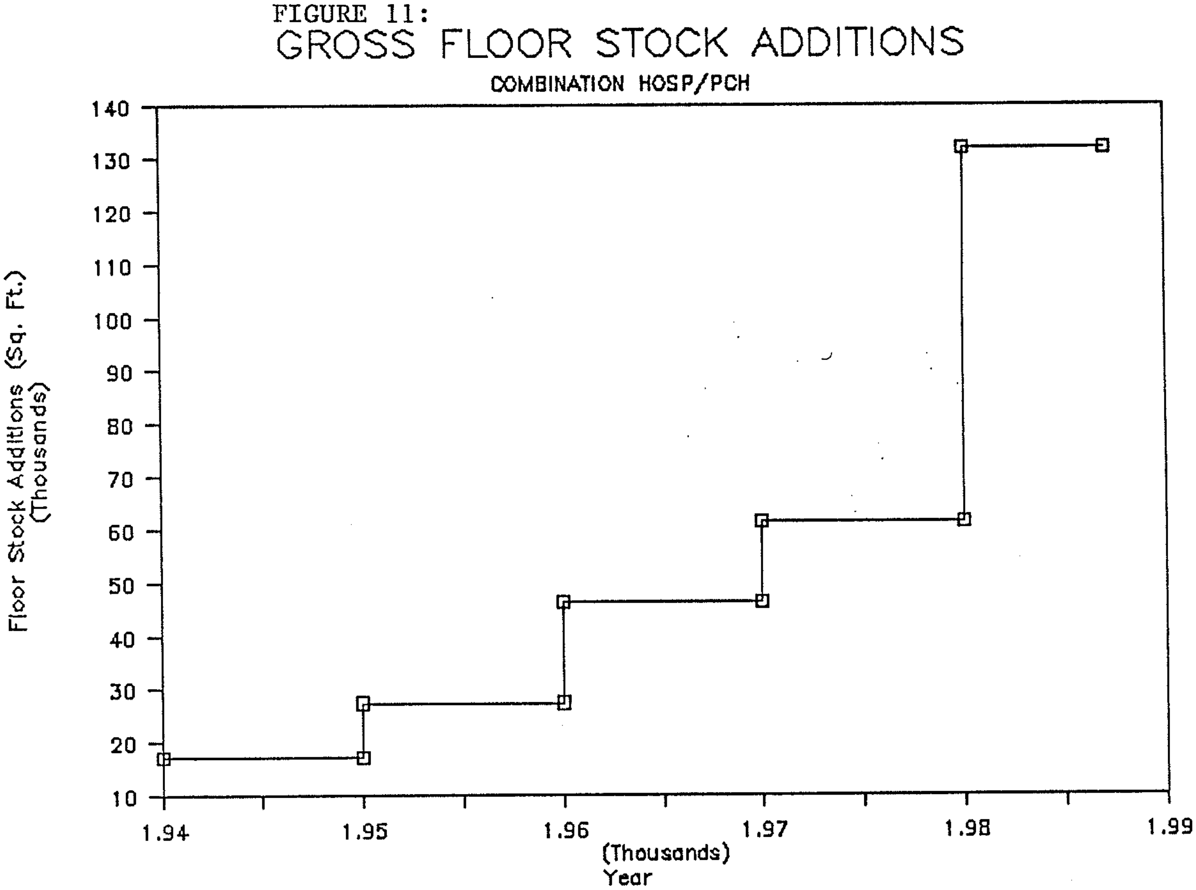


FIGURE 11:


GROSS FLOOR STOCK ADDITIONS
COMBINATION HOSP/PCH
Floor Stock Additions (Sq. Ft.)
(Thousands)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1.94
1.95
1.96
1.97
1.98
1.99
(Thousands)
Year

Annual floor stock growth rates were estimated using the additions values in Table 6. These estimated growth rates are presented below.

Estimated annual floor stock growth rates in square feet per year.

	Building Types		
Period	Hospital	PCH	Combination
1941-50	7516	7092	1718
1951-60	12001	11324	2743
1961-70	20325	19178	4645
1971-80	26945	25424	6158
1981-87	82403	77753	18833

Health care Building Vintage Categorization

The proportion of Manitoba health care buildings within specific vintage classes was estimated in the study. These proportions give a rough estimate of the proportion of floor space within each vintage category. Vintage classes were derived by analyzing the frequency distribution of year of construction for a sample of each building type. The date of construction was not available for all buildings. Figures 12, 13, and 14 illustrate these frequency distributions.

FIGURE 12:

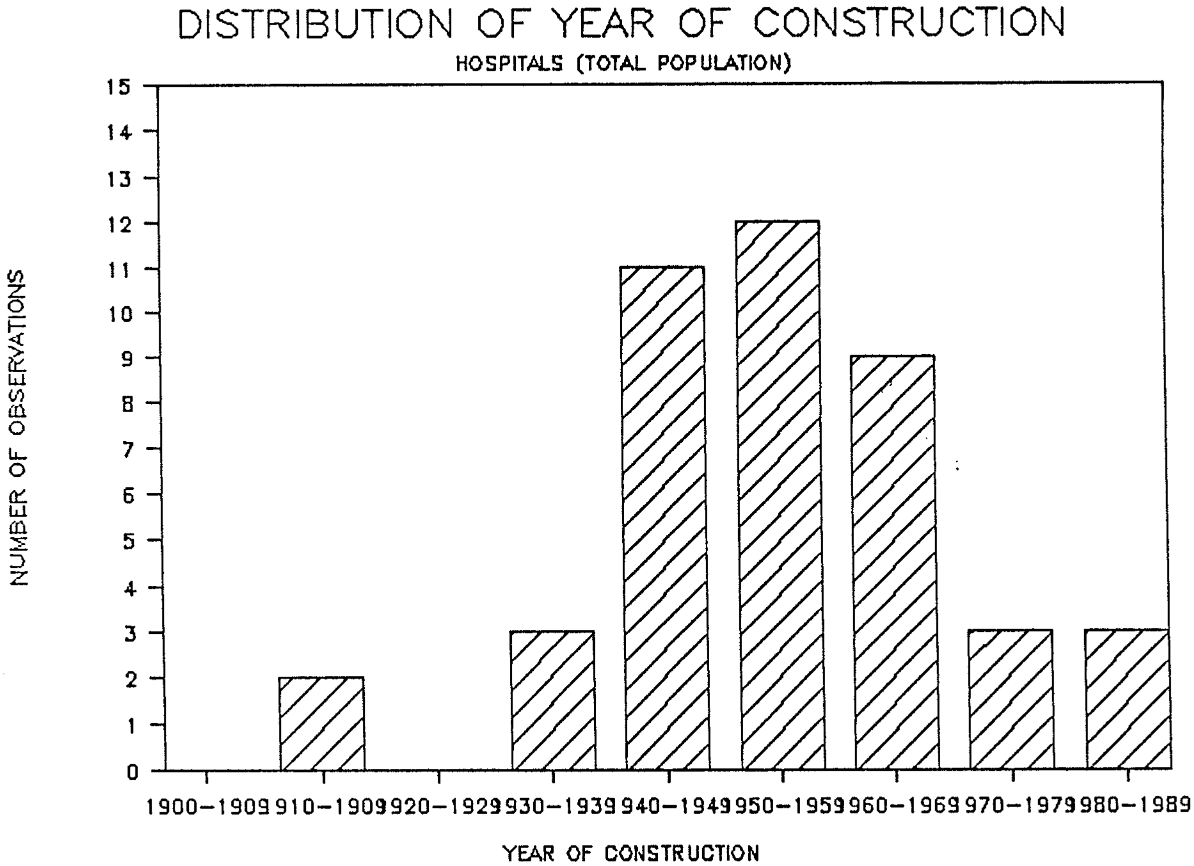


FIGURE 13:

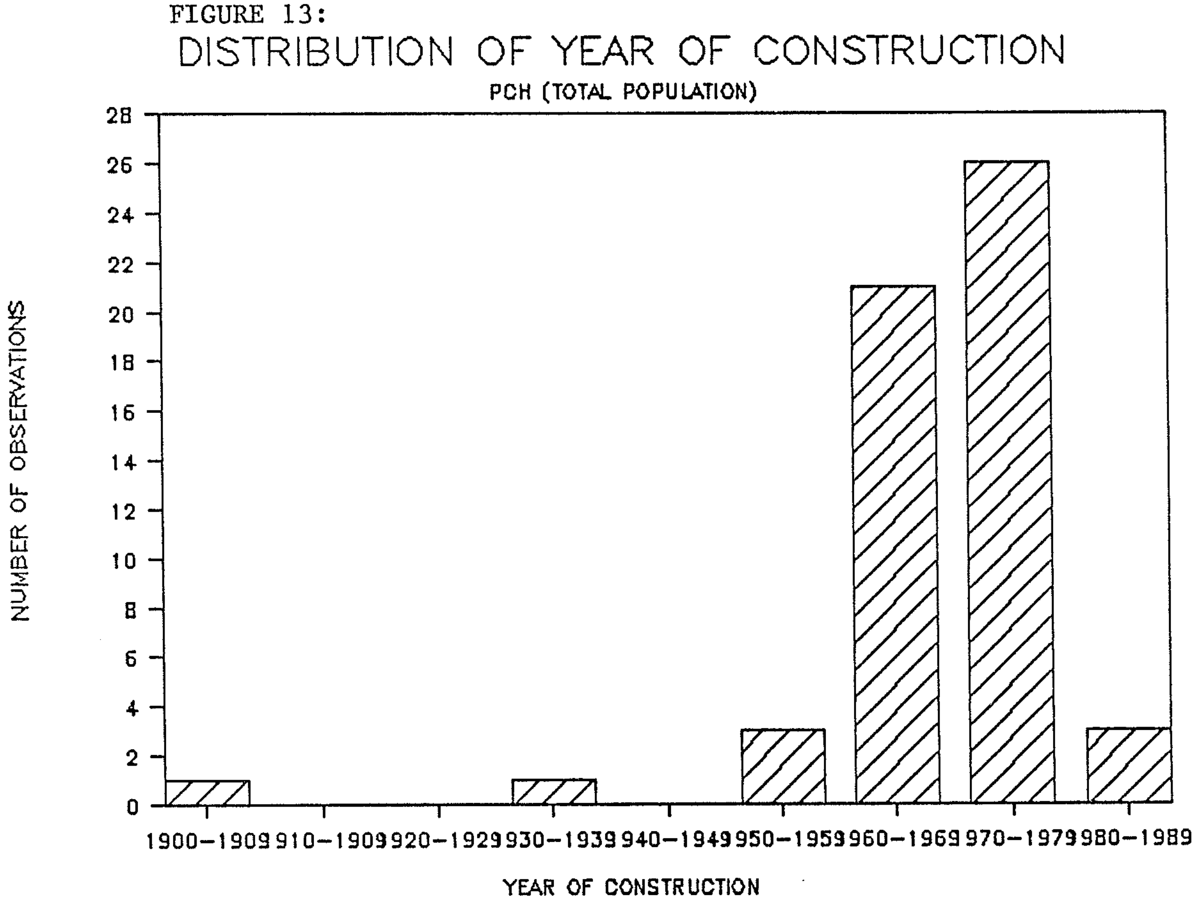
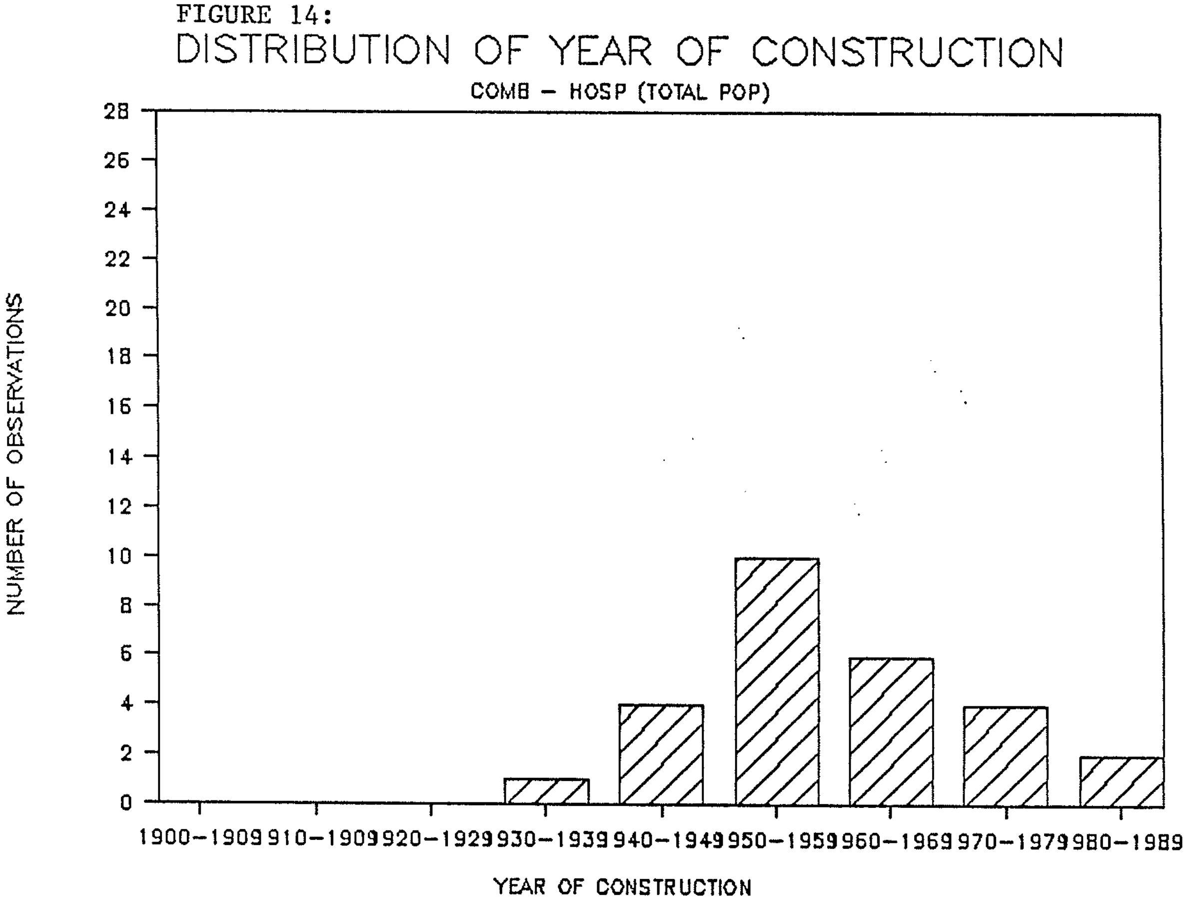


FIGURE 14:


DISTRIBUTION OF YEAR OF CONSTRUCTION
COMB – HOSP (TOTAL POP)
NUMBER OF OBSERVATIONS
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1900–1909
1910–1909
1920–1929
1930–1939
1940–1949
1950–1959
1960–1969
1970–1979
1980–1989
YEAR OF CONSTRUCTION

The Hospital building category was grouped into three vintage categories which correlated to major energy events and to demographic periods. These categories are <1940, 1940 to 1970, and >1970.

The relative proportion of buildings (and therefore floor area) within vintage classes was calculated for both the large population sample and the energy audit sample. The results are shown in Table 7.

Table 7: Comparison of a population sample and energy audit sample for frequency distribution of Manitoba Hospitals within vintage classes.

Vintage Class	Population Sample	Energy-Audit
<1940	12%	28%
1940-1970	74%	61%
>1970	14%	11%
Total ft.^{2}	100%	100%

Similar vintage category analysis was carried out on the two other building types in this study. The PCH building category was grouped into three vintage categories. These categories corresponded to major demographic trends and major energy events. The vintage classes selected and the proportion of buildings falling into that class are presented in Table 8.

Table 8: A comparison of the population sample and energy audit sample for frequency distribution of Manitoba Personal Care Homes within vintage classes.

Vintage Class	Population Sample	Energy-Audit
<1960	9%	15%
1960-1979	85%	80%
>1980	6%	5%
Total ft.^{2}	100%	100%

The Comb. Hosp/PCH building category posed special problems when it came to placing it into vintage categories. In many instances the Hospital portion of the building was built much earlier than the PCH section. This disparity in construction dates made it impossible to come up with a meaningful set of vintage categories for this building type. It was decided to use the vintage category for hospitals since the hospitals generally made up the larger floor area of the combined building type.

The differences in the distribution between the sample of the population and the energy audits does not lend conclusive support to the hypothesis that the energy audits are a representative sample of health care buildings in Manitoba. However, these differences may be due to the relatively small sample of energy audits performed for these building types. It should be noted that Esler (1987), with a much larger number of energy audits performed on schools, found that the energy audits are a representative sample of schools in Manitoba. The differences may also be due to the fact that the population figures were themselves only a sample of the population and may therefore be imprecise.

Floor Stock Forecasting

The COMMEND model provides a framework for forecasting growth in floor stock and building additions. There are two approaches:

> (1) 'Additions approach. Building additions are forecasted directly. Floor stock forecasts are given by decaying the existing stock and adding in the additions.
>
> (2) Stock approach. The building stock is forecasted directly. Additions are inferred as the amount of new construction required to produce the stock forecasts' (EPRI 1988:2-39).

In both approaches, COMMEND allows the input of forecast parameters and forecast exogenous variable values. COMMEND allows the user to employ a wide variety of data and estimation approaches. The options available are:

'-linear or double log

-with or without lagged dependent variables, and

-up to four exogenous variables for each building type' (EPRI 1988:2-39)

EPRI indicates that the stock approach is most often used and it was employed in this study. The goal of this method is to create a sensible link between floor stock and planning assumptions about the economy.

For simplification, a single variable proportional model of the following form shall be used.

$$F_T = b\ X_T$$

Where F is stock

T is the forecast year

X is an exogenous variable, and

b is a coefficient

The exogenous variable, X, should be a measure of activity within the sector, such as "output", or the price of floor space. Since this type of data is usually unavailable, an alternative measure of activity must be used, some examples of which are regional income, population and employment.

Population is a natural proxy variable for activity in the health care subsector, since demand is driven by the number of people (among other factors, such as median age, income, stress, etc). Employment is a very common explanatory variable in floor stock equations (eg., people and space go together), and will be discussed in more detail at a later point.

In this study population is used as the proxy variable for activity in the health care subsector. As indicated earlier, population is not an accurate proxy variable, but is the only one available at this time. Another limitation to be noted is that presently in Manitoba floor space is planned on a per health care program basis. For example, if a region of the province requires better service in cardiovascular analysis, a central hospital would be allocated funds to develop the program, including adding floor space if required. Also, as noted earlier, the median age of the population in Manitoba is rising and this may have a positive impact on the number of individuals seeking care in both hospitals and personal care homes. There is no data available on future employment in the health care sector (likely the best proxy variable), and therefore population will have to serve.

The coefficient b is a ratio of floor stock (F) to the exogenous variable (X), in the near base year.

$$b = F_{88} / X_{88}$$

$$\text{so } F_T = b\ X_T$$

$$\text{and } F_T = (F_{88} / X_{88}) * X_T$$

With this approach, the forecast ensures that the ratio of floorstock to population will remain fixed in all forecast years. By forecasting the exogenous variable, in this case population, a forecast of future floorstock can be derived.

The following is a projection of Manitoba's population to the year 2006. The figures are taken from the Statistics Canada publication <u>Population Projections for Canada, Provinces and Territories 1984-2006</u>, Projection 1 (1985:69). While the publication offers five different projections, the projection figures used in this study represent "the most plausible course of events in the short term" (Canada 1985:41) and are, in effect, the most conservative.

Year	Population (x1000)
1988	1088.4
1989	1099.1
1990	1108.3
1991	1116.3
1992	1122.9
1993	1128.3
1994	1132.4
1995	1135.2
1996	1136.9
1997	1137.5
1998	1137.6
1999	1137.4
2000	1136.9
2001	1136.1
2002	1135.1
2003	1133.8
2004	1132.4
2005	1130.7
2006	1129.0

Forecast of Floorstock.

$$F_T = (F_{87}/P_{87}) * P_T$$

where F_T is the floorstock in forecast year T
F_{87} is the estimated floorstock in 1987
P_{87} is the population of Mb. in 1987
P_T is the population of Mb. in forecast year T.

(a) Hospitals
$F_T = (5646859/1070000) * P_T$
$F_T = 5.277 * P_T$

(b) Personal Care Homes
$F_T = (5328163/1070000) * P_T$
$F_T = 4.979 * P_T$

(c) Comb. Hosp/PCH
$F_T = (1290564/1070000) * P_T$
$F_T = 1.206 * P_T$

The following table presents forecast floorstock for the three building types using population as the scale variable.

Table 9. Forecast floorstock in square feet (1988-2006) for Hosp., PCH, and Comb. using population as the scale variable.

Year	Forecast Floorstock F_T Hosp.	PCH	Comb.
1988	5743963	5419787	1312756
1989	5800432	5473069	1325662
1990	5848984	5518881	1336758
1991	5891204	5558718	1346408
1992	5926035	5591583	1354368
1993	5954533	5618473	1360881
1994	5976171	5638889	1365826
1995	5990947	5652832	1369203
1996	5999919	5661297	1371254
1997	6003086	5664285	1371978
1998	6003613	5664783	1372098
1999	<u>6002558</u>	<u>5663787</u>	<u>1371857</u>
2000	<u>5999919</u>	<u>5661297</u>	<u>1371254</u>
2001	<u>5995697</u>	<u>5657314</u>	<u>1370289</u>
2002	<u>5990420</u>	<u>5652334</u>	<u>1369083</u>
2003	<u>5983559</u>	<u>5645860</u>	<u>1367515</u>
2004	<u>5976171</u>	<u>5638889</u>	<u>1365826</u>
2005	<u>5967199</u>	<u>5630424</u>	<u>1363776</u>
2006	<u>5958227</u>	<u>5621958</u>	<u>1361725</u>

Notes: Underlined figures should not be used as floorstock forecasts (see the discussion below).

Figures 15, 16 and 17 present a graphical representation of Table 9. The forecast shows an increase in floorstock up to the year 1998, after which the floorstock decreases. This aberration is a result of the use of population as a scale variable because population projections for Manitoba indicate a decrease in population after the year 1998. However, once floorstock is added to existing floorstock, it will likely not be removed (except by natural decay) once population starts to decrease. For this reason floorstock forecast values for 1998 should be use for subsequent years.

Note that for personal care homes the forecast floorstock figures may be larger than in reality since Manitoba has been increasing its Home Care Program in recent years. The Home Care Program gives care to elderly residents in their own homes in an attempt to delay their entrance into a personal care home. The rationale for this program is that it is cheaper to care for people in their own homes than to provide space and care in a personal care home.

FIGURE 15:

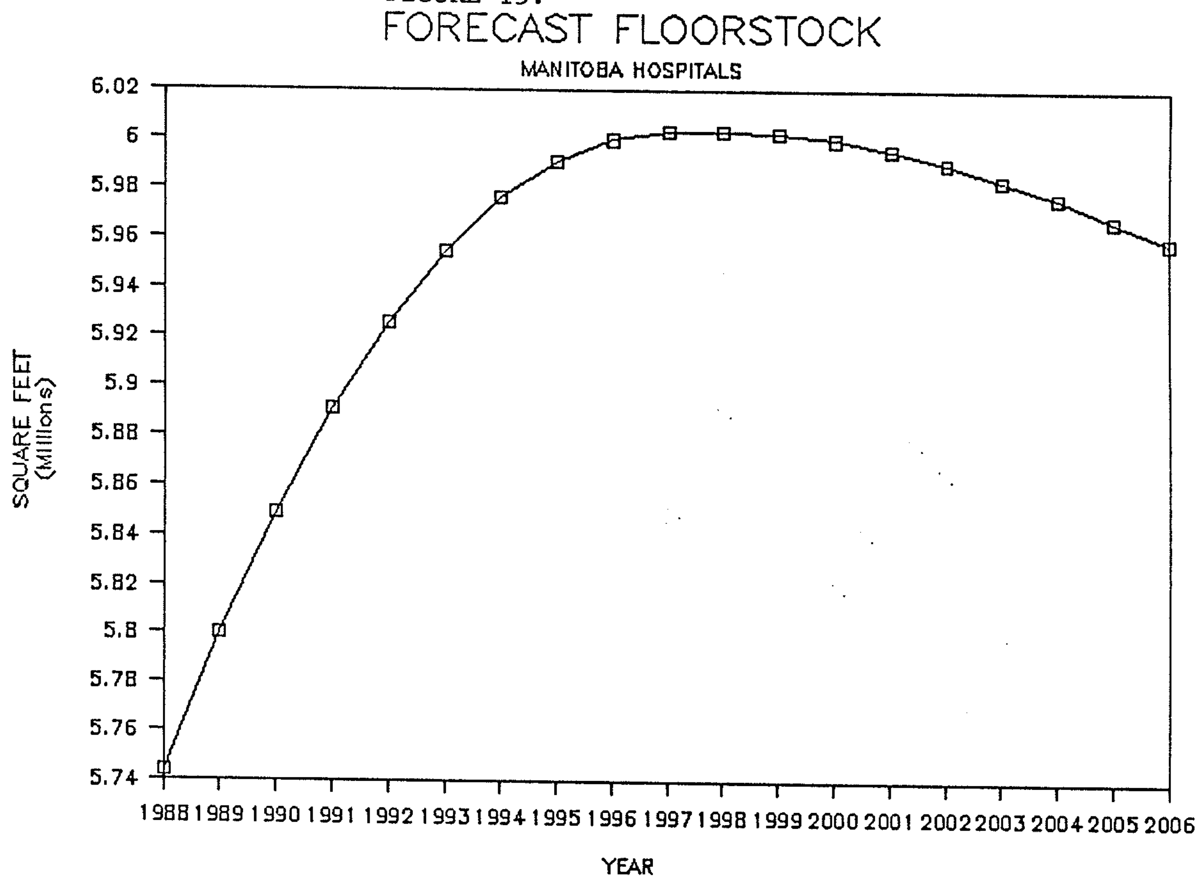


FIGURE 16:

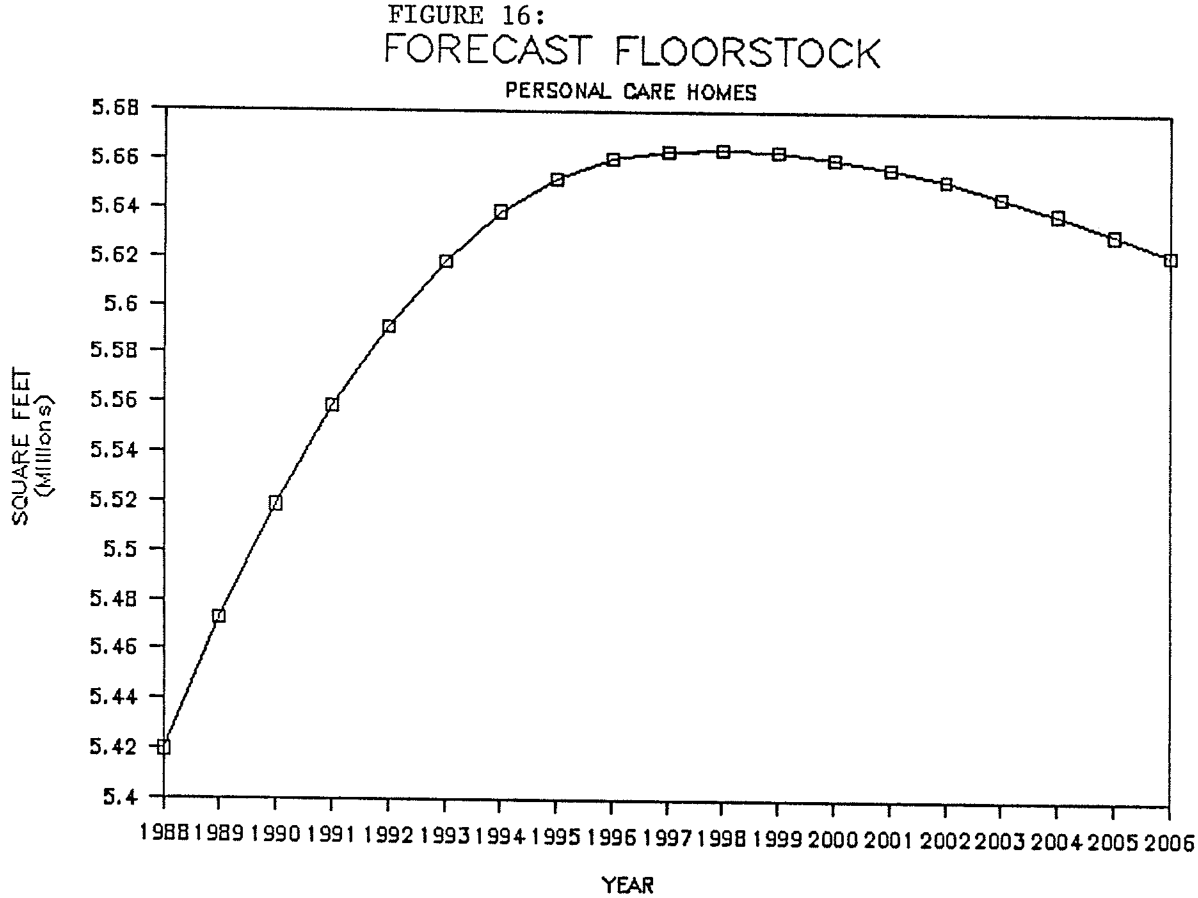
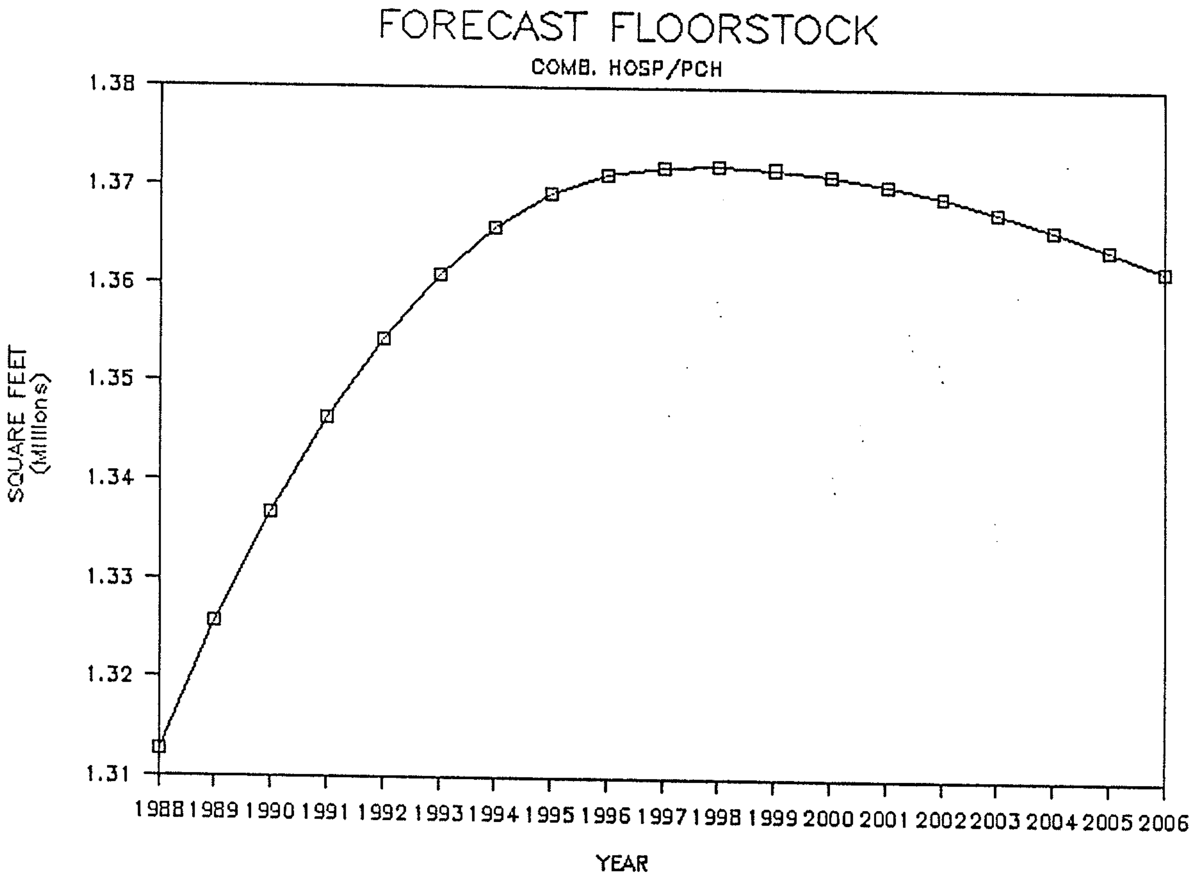


FIGURE 17:


FORECAST FLOORSTOCK
COMB. HOSP/PCH
1.38
1.37
1.36
1.35
1.34
1.33
1.32
1.31
SQUARE FEET (Millions)
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
YEAR

Developing Energy Intensity Estimates (EI=EUI*S)

This section discusses energy intensity values (EI), energy use indices values (EUI), and fuel shares (S). Annual EI values are a measure of annual energy use per square foot of floor area. There are two ways of presenting EI values:

(1) EI values for individual buildings (energy use per square foot for a single site), and

(2) EI values for specific building types. These aggregate values refer to average energy use per square foot for a group of sites.

Individual Building Intensities

For an individual building, the annual energy intensity for a specific fuel can be calculated as follows:

$$EI_b = E_b / F_b$$

where E_b is the annual consumption of the fuel in building b, and

F_b is the size of building b in square feet (EPRI 1988:3-1).

Aggregate Intensities

For a specific building group (eg., hospitals), the annual EI for a specific fuel can be calculated as follows:

$$EI = \frac{\text{sum}_{b->B} Eb}{\text{sum}_{b->B} Fb} = \frac{E}{F}$$

where E is total annual consumption of the fuel,

F is total floor stock for the building type,and b -> B indicates all individual cases for the building type (EPRI 1988:3-2).

The most common units of measurement for EI values is KWh/ft.^{2} for electricity, and Kbtu/ft.^{2} for fossil fuels.

Annual energy use index values (EUI values) measure annual energy use per square foot of floor space in buildings for a specific end-use and specific fuel type. For example, 10 KWh/ft.^{2} for electricity-spaceheating-hospitals.

COMMEND requires as inputs, average annual energy use indices by end-use/fuel-type/building-type. COMMEND uses these values to calculate average annual EI values in the following way:

$$EI = S_e * EUI_e$$

where EI is the EI ratio for a building type,

S_e is the average fuel share for end-use e, and

EUI_e is the average EUI for end-use e.

<u>Energy Use Indices Estimates (EUI)</u>

Various methods exist for estimating disaggregated average annual EUI's. These include: (1) using estimates derived from other studies; (2) conducting end-use metering studies; (3) using building simulation models; (4) performing conditional demand analysis (Esler 1987). For a discussion of the advantages and disadvantages of these methods see Esler 1987.

The Energy Bus Audits are the source of the data used in calculating the average annual EUI estimates used in this study. The audits contain a summary of energy consumption called the Energy Out Summary (See Appendix A for a sample). Esler describes this summary:

'The Energy Out Summary contained in the audits, a table of final energy consumption, is determined by a computer analysis program which uses inputs on building characteristics, weather data, operational parameters and monthly energy consumption. Annual energy consumption attributable to each end-use in the Summary is expressed in terms of KW.h and energy cost. The efficiency of heating and ventilation equipment is taken into account in this table through the "stack losses" term' (Esler 1987).

End-uses examined within the energy audits include heating, ventilation, lighting, fans and motors, water heating, air cooling, car plugs, laundry and miscellaneous consumption.

The Energy Bus auditing program has been carried out over many years, and as a result the audits may not be representative of average consumption. To adjust for these variances the annual fuel consumption estimates were weather adjusted to a long term average (eg., 30 years). The methodology for doing this is described in Appendix B. Note that only weather sensitive end-uses - heating, ventilation and air conditioning - were weather normalized.

There are limitations inherent in generalizing on the energy characteristics of health care buildings by placing them into vintage categories. Hospitals in many instances have been built in stages over many years. The latter additions may have different energy consumption characteristics than the original building. This makes classifying a hospital within one vintage category problematic in terms of calculating average annual EUI's.

The majority of PCH's on the other hand, have been mainly built in the 1960's and 1970's with few latter additions. Classifying PCH's within vintage categories is therefore not problematic in terms of calculating EUI's. The Comb. Hosp/PCH's building category gives rise to a special problem. PCH's in many rural communities were built as additions to existing hospitals. The energy audits do not, in general, treat this combination as two different buildings, and often annual energy consumption is given for the combination instead of for the Hospital and PCH separately. Future energy audits should attempt to break out the separate energy consumptions. Also, when there was multiple fuel usage in a building, there was no consistency in the number of electricity meters for the buildings, making it difficult to differentiate with any certainty the electricity consumption in the separate building types. However, there was usually only one gas meter for the two buildings. These inconsistencies make it impossible to separate the Hospital EUI's from those of the attached PCH.

In most instances the hospitals make up the larger floor area of the Comb., and therefore it has been decided to use the year of construction of the hospital as the vintage category for both. Therefore, classifying a Comb. building within one vintage category is problematic.

EUI estimation is also complicated by multiple fuel heating use within a building. The energy audits showed that a large proportion of hospitals are heated with more than one fuel, which may or may not service different portions of the total building floor area.

The energy audits also showed that the majority of PCH's are heated by multiple fuels. Comb. buildings, by nature of the definition of the building type, and according to the energy audits are heated by multiple fuels also. The analysis intended to address these problems in the following manner. It was assumed that an entire building type (eg., Hospital, PCH, or Comb.) belonged to the vintage under which it was first constructed. EUI's were to be calculated for each building type for : (a) buildings heated by a single fuel, and then (b) for buildings heated by multiple fuels. It should be noted that hospitals should perhaps be categorized by the number of beds since, as mentioned earlier, not all hospitals have similar floor space per bed allocations. However, the small number of energy audits performed on health care buildings makes classification according to single and multiple fuel heating impossible, as statistically valid EUI estimates could not be calculated for such a small number of observations. The same is true for categorizing according to vintage classes. Therefore, due to the limitations of the existing data, the analysis calculates EUI's for each building type, assuming one vintage category and without classifying according to single or multiple fuel heating. Average annual EUI's were determined by calculating annual end-use consumption for each separate fuel and apportioning it evenly across total floor space for the individual building. The EUI estimates for each end-use and building type, along with their standard deviations and number of observations, are given in Tables 10, 11, and 12.

Limitations to this analysis are:

(1) The small amount of detailed information available on the percentages of total floor area for each building type within a particular vintage category;

(2) The lack of information on the proportion of total floor area space conditioned by a particular fuel type; and

(3) The small number of energy audits performed on health care buildings.

The large standard deviations associated with the energy use indices estimates indicates that there may be large estimation errors. Marbek (1987:28) presents electrical energy use indices values for some end-uses for Ontario Hospitals. They are as follows (in KW.h/ft.^{2}):

Lighting	8.5
Motors	5.0
Cooling	2.0
Space Heat	18.1

A comparison of Marbek's EUI values with those in Table 10 indicates the following. The Lighting EUI value (hospitals) calculated for this study may be to low, although the lighting energy consumption values are the most consistently detailed in the energy out summaries, and should therefore have the most confidence placed in them. The motors EUI values from the two studies in question, as well as the cooling values, are very similar, and there is therefore, little reason to doubt the Motors and cooling EUI values from this study. The space heating EUI value from Marbek's report is much higher than that for Manitoba as indicated in this study (18.08 as compared to 6.65 $KW.h/ft.^2$). This may in fact be a result of the inability of this study to determine the proportion of the floorstock in individual buildings which were heated by electricity and by natural gas. Calculations for EUI values assumed energy consumption for electric space heating was spread over the entire floorstock, but in cases where there is multiple fuel usage for space heating (for example electric and natural gas space heating) this would result in underestimated EUI values. The data could not be assessed on a sinle fuel - multiple fuel basis as the small number of observations for each group would not produce statistically valid EUI values. The writer concedes that the value may indeed be to low, but until more data is available, the calculated EUI value will have to suffice.

Table 10: Energy use indices for Manitoba Hospitals, all vintages.

Fuel Type	Lighting	Space Heating	Ventil.	Water Heating	Air Cooling	Motors	Car Plugs	Laundry	Misc.
					End-uses				
Electricity	6.45	6.65	23.22	4.86	2.78	4.59	1.28	5.06	6.32
(KW.h/ft2)									
n.o.	13.00	6.00	1.00	2.00	10.00	9.00	13.00	1.00	13.00
s.d.	2.78	5.38	----	6.08	1.81	2.70	2.52	----	1.30
Natural Gas	n/a	21.57	29.70	16.38	n/a	n/a	n/a	7.96	8.49
(KW.h/ft2)									
n.o.	n/a	13.00	10.00	9.00	n/a	n/a	n/a	6.00	5.00
s.d.	n/a	9.86	12.27	8.97	n/a	n/a	n/a	4.38	8.98
Oil	n/a	30.67	46.15	7.29	n/a	n/a	n/a	----	----
(KW.h/ft2)									
n.o.	n/a	3.00	1.00	1.00	n/a	n/a	n/a	----	----
s.d.	n/a	15.08	----	----	n/a	n/a	n/a	----	----

Table 11: Energy use indices for Manitoba Personal Care Homes, all vintages.

Fuel Type	Lighting	Space Heating	Ventil.	Water Heating	Air Cooling	Motors	Car Plugs	Laundry	Misc.
					End-uses				
Electricity	3.58	14.09	11.61	7.97	1.44	3.46	0.58	10.41	4.65
(KW.h/ft2)									
n.o.	16.00	9.00	7.00	5.00	13.00	11.00	14.00	3.00	15.00
s.d.	1.54	9.13	4.64	4.45	0.96	1.24	0.52	12.66	2.52
Natural Gas	n/a	14.46	15.22	9.24	n/a	n/a	n/a	8.63	6.86
(KW.h/ft2)									
n.o.	n/a	12.00	11.00	8.00	n/a	n/a	n/a	6.00	6.00
s.d.	n/a	5.88	8.35	4.82	n/a	n/a	n/a	6.18	7.50
Oil	n/a	----	----	----	n/a	n/a	n/a	----	----
(KW.h/ft2)									
n.o.	n/a	----	----	----	n/a	n/a	n/a	----	----
s.d.	n/a	----	----	----	n/a	n/a	n/a	----	----

Table 12: Energy use indices for Manitoba Combination Hosp/PCH, all vintages.

Fuel Type	Lighting	Space Heating	Ventil.	Water Heating	Air Cooling	Motors	Car Plugs	Laundry	Misc.
					End-uses				
Electricity	5.32	11.79	12.43	5.21	1.51	5.36	0.56	3.02	6.96
(KW.h/ft2)									
n.o.	9.00	9.00	7.00	5.00	8.00	7.00	6.00	3.00	7.00
s.d.	2.80	4.67	7.39	3.99	1.09	2.28	0.29	1.27	3.87
Natural Gas	n/a	3.40	11.92	7.94	n/a	n/a	n/a	----	----
(KW.h/ft2)								----	----
n.o.	n/a	2.00	2.00	2.00	n/a	n/a	n/a	----	----
s.d.	n/a	4.81	5.68	1.76	n/a	n/a	n/a	----	----
Oil	n/a	21.14	23.76	18.63	n/a	n/a	n/a	----	----
(KW.h/ft2)								----	----
n.o.	n/a	5.00	3.00	2.00	n/a	n/a	n/a	----	----
s.d.	n/a	12.57	11.65	18.33	n/a	n/a	n/a	----	----

Notes: n.o. refers to the number of observations
s.d. refers to the standard deviation
n/a means that this combination of end-use and fuel type is not used by COMMEND
---- means that data was not available to determine this value

Utility Sales Data

COMMEND also requires monthly utility sales data - preferably disaggregated into commercial subsectors - for calibrating EUI estimates. To this end, a request was submitted to Manitoba Hydro for the monthly electricity consumption of the 419 health care buildings considered in this study, including hospitals, personal care homes, and residential care homes. Data was not retrieved for approximately 24% of these buildings. This was due to problems with name changes, closures, and incorrect addresses.

Monthly utility electrical sales data was collected for 50 of the 75 hospitals in Manitoba (67%), 80 of the 94 personal care homes (85%), and 26 of the 27 combination Hosp/PCHs (96%). Residential care homes are not assessed in this study.

Permission was given by InterCity Gas to collect data on monthly natural gas consumption, but only for those customers from which a formal written permission was obtained. For this reason a written request for permission to search natural gas utility sales data was mailed to all health care facilities for which addresses were available and which were in the service areas of InterCity Gas. Monthly utility natural gas sales data was collected for 20 of the 75 hospitals (27%), 44 of the 94 PCHs (47%), and 7 of the 27 combination Hosp/PCHs (26%). While it can be assumed that all health care facilities consume electricity, the same cannot be assumed for natural gas.

To obtain the total utility sales figures, part of the consumption data had to be estimated. For electrical consumption, this was achieved by calculating energy intensity values ($KW.h/ft^2$) using existing data on area and electricity consumption. These EI values were then placed into groups corresponding to the number of beds in a facility. These groups were 1-24, 25-49, 50-99, 100-199, 200-299, and >300. An average EI was determined for each of these groups. These averages and their associated standard deviations and number of observations are presented below in Table 13.

Table 13: Estimates of energy intensity values from electrical utility sales data and floorstock.

Size (beds)	Average ($KW.h/ft^2$)	Standard Deviation	Number of Observations
HOSPITALS			
1-24	23.98	17.39	18
25-49	19.82	11.45	7
50-99	12.11(used 20)	6.51	7
100-199	29.75	6.21	4
200-299	19.86	0	1
>300	23.35	8.14	5
PERSONAL CARE HOMES			
1-24	10.39	8.39	5
25-49	16.09	9.04	15
50-99	17.79	9.59	27
100-199	14.57	5.92	10
00-299	11.96	4.07	9
>300	15.91	0.52	2
COMBINATION HOSP/PCH			
1-24	----	----	----
25-49	31.25	16.46	15
50-99	26.53	14.74	8
100-199	3.48	0	2
200-299	----	----	----
>300	----	----	----

Note: ---- indicates data was not available for this group.

The average EI values had, for the most part, large standard deviations which indicates there may be large estimation errors. This is possibly due to the small sample size in each group, and to the varying behavior in consumption practices within the building-type groups. BETT (1983:i) estimated average energy consumption in all Canadian hospitals (all fuel types) for 1981 as 72.6 $KW.h/ft.^2$. The report unfortunately did not break down the

EI value into different fuel types. EPRI (1988:3-12) estimated the average energy intensity value for Health buildings at 18.6 KW.h/ft.^{2} which is reasonably close to the average EI for Manitoba hospitals (21 KW.h/ft.^{2}).

The calculated average annual EI values for Hospitals, PCHs, and Comb.s within the different size groups were used (except where noted) in estimating electricity consumption. This was done by determining the product of the estimated EI value (corresponding to the number of beds in a facility) and the floor area of that facility for all building types. The collected data on electrical consumption was then summed and added to the estimated consumption figures. Table 14 presents the electrical sales data for all three building types.

Table 14: Electrical utility sales data for the Manitoba Health Care subsector (time period 05/87 to 05/88)

Building Type	Energy Sales
Hospitals	119.988 GW.h
Personal Care Homes	82.555 GW.h
Combination Hosp/PCH	26.541 GW.h
Total	229.084 GW.h

The same process was used in assessing natural gas utility sales figures. Table 15 presents the average annual EI values for natural gas in Manitoba Health Care facilities.

Table 15: Estimates of energy intensity values from natural gas utility sales data and floorstock.

Size (beds)	Average (ft3/ft2)	Standard Deviation	Number of Observations
HOSPITALS			
1-24	197.74	190.88	2
25-49	78.37	89.49	6
50-99	51.98	75.02	3
100-199	89.16	153.34	3
200-299	1.78	0	1
>300	3.8	6.52	5
PERSONAL CARE HOMES			
1-24	----	----	----
25-49	45.99	68.86	9
50-99	35.33	63.22	17
100-199	33.90	67.91	9
200-299	33.43	78.66	6
>300	1.86	0	1
COMBINATION HOSP/PCH			
1-24	----	----	----
25-49	50.32	26.64	4
50-99	121.2	63.1	3
100-199	----	----	----
200-299	----	----	----
>300	----	----	----

Note: ---- indicates data was not available for this group.

Natural gas utility sales data were not estimated due to the large inequities in the calculated average EI values. These inequities are likely due to instances where multiple fuel consumption took place. In these instances, assuming the fuel can be apportioned to the entire floorstock for a building where only a fraction of the floorstock is serviced by that fuel, would result in underestimating the fuel consumption per square foot.

End-use Equipment Penetrations

COMMEND also requires as an input, end-use equipment penetrations. Currently there is no available data on end-use equipment penetrations in the Manitoba commercial sector. However, a recent study by Engineering Interface Ltd., entitled Commercial/Institutional Buildings Electrical Energy Technology Study (1988), provides current (1988) and future (2000) end-use equipment penetrations for Ontario. The future penetrations are given, both for a scenario where there are no government supplied incentives to buy the assessed end-use, and also where incentives are supplied.

Current end-use penetrations from the above mentioned report have been used in this study to assist in the development of energy conservation supply curves, which will be discussed in the next chapter. Appendix C contains a summary of these penetrations.

HVAC System Fuel Efficiency

Average annual HVAC system fuel efficiency is required as an input to COMMEND for calibrating base year EUI's. Average efficiencies for each fuel type broken down into Hospital and PCH building-types were obtained from the energy audits. These efficiency estimates, along with their standard deviation and number of observations are presented in Table 16. Average efficiencies for the Comb. building-type were not calculated as it was felt that the hospital and PCH building types would provide suitable information. Table 16 illustrates that the efficiency of electric heating systems is constant for all building types, as it is a convention to consider electric furnace efficiency to be 100%. Natural gas efficiencies appear to be slightly better in hospitals than PCHs, although this is possibly due to inaccuracies caused by the small size of the sample.

Table 16: Furnace efficiencies for buildings in the Manitoba Health Care subsector (all vintages).

Fuel Type	Average Efficiency	Standard Deviation	Number of Observations
Hospitals			
Electricity	100%	0	2
Natural Gas	80%	3.40	14
Personal Care Homes			
Electricity	100%	0	5
Natural Gas	77%	3.34	12

Fuel Shares (Se)

Fuel shares refer to that fraction of floor space conditioned by a particular fuel/end-use combination. Fuel shares can be defined in two ways:

Whole-Building Approach. The whole building approach is based on total building space. Fuel shares are defined as follows:

$$S_e = \frac{\text{sum}_{b @ e} F_b}{\text{sum}_b F_b}$$

where S_e is the share for equipment type e,

F_b is square footage for building b, and b @ e indicates a sum over buildings that have equipment type e (EPRI 1988:4-1).

With this definition a building is included in the numerator if it has the specific end-use being analyzed. If it is included, all square footage for that building is included. The whole-building approach, therefore, measures that fraction of space that is in all buildings of the type being analyzed (eg., hospitals) that have the specified end-use equipment.

Conditioned Space Approach. This approach is based upon the conditioned portion of the total space. Fuel shares are defined as follows:

$$S_e = \frac{\text{sum}_{b@e}\ F_b\ C_{be}}{\text{sum}_b\ F_b} = \frac{\text{sum}_{b@e}\ F_{be}}{\text{sum}_b\ F_b}$$

where C_{be} is the fraction of building b conditioned by end-use e, and
F_{be} is the area in building b conditioned by end-use e (EPRI 1988:4-2).

This approach is used for two reasons. The first is for dealing with cases where only a fraction of floor space is conditioned. This is usually applied to heating and cooling end-uses, but is not used for water heating, refrigeration, or miscellaneous.

The second reason for using this approach is to deal with cases where there are multiple fuels. In the above formula, C_{be} is the fraction of total space that is served by a specific fuel type. This may be a fraction of the conditioned space or of total space.

EPRI (1988) indicates that either approach (whole-building or conditioned-space) may be used, as long as the EUI values are estimated accordingly. The section of this report dealing with the estimation of EUI values, used a whole building approach (eg., end-use/fuel consumption was divided by the total conditioned floor area for a specific building to estimate the EUI value). For this reason, and also because the Energy Bus audits do not contain information on fractions of total space conditioned by specific end-uses, the whole-building approach to estimating fuel shares was used. Also, the energy audits do not contain information concerning fractions of the conditioned space serviced by a fuel type when there are multiple fuel types present.

Fuel shares were estimated for the Manitoba Health Care subsector using data from the Energy Bus audits and are presented in Table 17. Note that COMMEND assumes that water heating fuel shares are predetermined by space heating fuel shares, and that light, air conditioning and fans/motors end-uses are fueled entirely by electricity. COMMEND also assumes that ventilation is fueled entirely by electricity. This is not a valid assumption as evidenced by analysis of the ventilation fuel shares. It is important to note that the Energy Bus audit data does not make the same assumptions as COMMEND concerning ventilation energy. The ventilation in the Energy Bus audits is due to reconditioning of air brought into the building and could be powered by a number of fuels including oil, natural gas, electricity, and propane. Users of COMMEND must take this into account, perhaps by modifying the program.

Table 17: End-use fuel shares (%) for Manitoba Health Care facilities.

End-uses	Electricity	Natural Gas	Oil
	Fuel Types		
Building type = Hospital			
Sample size = 18			
Total floor area of sample = 2,236,832 ft.^{2}			
Lighting	100	n/a	n/a
Space Heating	15	88	9
Ventilation	0.3	59	1
Water Heating	2.5	55	1
Air Condition	100	n/a	n/a
Fans/Motors	100	n/a	n/a
Car Plugs	62	n/a	n/a
Laundry	5	46	n/a
Miscellaneous	62	46	---
Building type = Personal Care Home			
Sample size = 20			
Total floor area of sample = 952,546 Ft.^{2}			
Lighting	100	n/a	n/a
Space Heating	24	69	---
Ventilation	18	69	---
Water Heating	14	47	---
Air Condition	100	n/a	n/a
Fans/Motors	100	n/a	n/a
Car Plugs	78	n/a	n/a
Laundry	10	34	---
Miscellaneous	79	41	---
Building type = Combination Hosp/PCH			
Sample size = 11			
Total floor area of sample = 524,560 Ft.^{2}			
Lighting	100	n/a	n/a
Space Heating	69	6	65
Ventilation	41	6	37
Water Heating	28	6	31
Air Condition	100	n/a	n/a
Fans/Motors	100	n/a	n/a
Car Plugs	54	n/a	n/a
Laundry	20	---	---
Miscellaneous	59	---	---

Notes:
n/a = not applicable; these end-use/fuel combinations are assumed to be technically infeasible.
--- No data were recorded for this category.

Utilization

COMMEND requires data on the change in implementation of end-use equipment from one year to the next for two circumstances. Esler (1987) points out 'COMMEND models utilization for two scenarios: (a) for existing buildings where there is no change in equipment, thus, utilization is responsive only to price changes; and (b) for new and existing buildings where equipment is added, thus, utilization is responsive to both price responses and the efficiency of new equipment. Data on end-use equipment penetrations and changes in existing commercial buildings, and equipment penetrations in new building stock are not available for Manitoba' (Esler 1987:105).

Chapter Four: The Cost of Conserved Energy in the Manitoba Health Care Subsector: Supply Curves of Conserved Energy.

This chapter calculates the costs of saving a KW.h of electricity associated with the application of several different conservation methods to electrical end-uses (for example, the replacement of standard electric motors with energy efficient electric motors). It also determines the potential quantity of electricity which could be saved in the Manitoba Health Care subsector assuming a 100 percent market penetration rate for the electrical energy conservation end-uses (for example, assuming that all existing standard electric motors are replaced with energy efficient motors).

The costs per KW.h of saved electricity and the potential quantities of saved electricity are presented graphically in the form of "Electricity Conservation Supply Curves" (Appendix F) for the various conservation methods and three building types in the Manitoba Health Care subsector (hospitals, personal care homes, and combination hospital/PCH), and in the form of "Composite Electricity

Conservation Supply Curves" (Figures 19, 20 and 21) for the afore mentioned three building types.

The chapter begins with a brief introduction to supply curves of conserved energy. It then presents a detailed discussion of the development of theses curves, including data requirements, interactive effects (eg., the effect that the implementation of one conservation method has on another), and the various types of conservation supply curves. The chapter proceeds to develop the costs/unit of electricity for the selected conservation measures and calculates the potential quantity of saved electricity. These values are presented in the supply curves discussed above and their meaning is discussed in the section titled "Interpreting the Supply Curves of Conserved Energy".

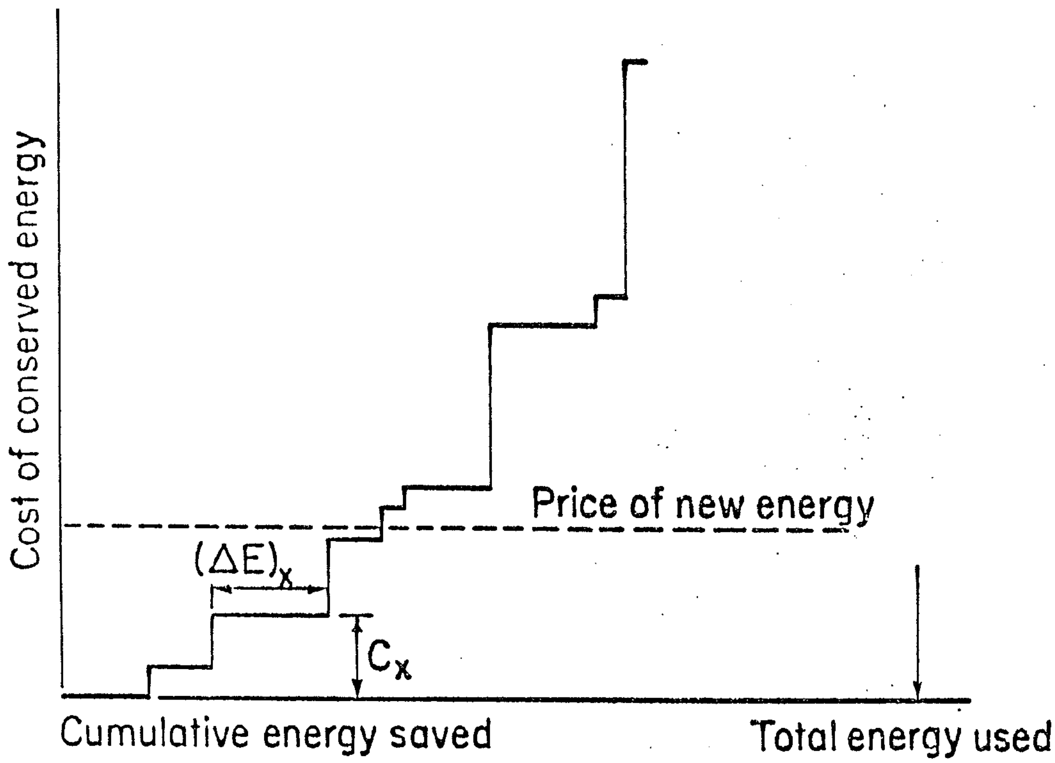
Introduction

Since the mid 1970's, utilities have become interested in planning methods that concentrate on alternatives to supply-side options. Least-cost planning (LCP) and demand-side management (DSM), as discussed in Chapter Two, are two of these alternatives. They reduce the need for new energy sources by changing the way energy is used. Least-cost planning is an attempt to balance the mix of supply-side and demand-side options to meet societies energy needs at the least-cost (EPRI 1987b).

One important aspect of LCP is the development of "conservation supply curves". The notion of these curves came from the end-use perspective on the analysis of fuel supply and demand. This approach begins by recognizing that demands for energy are derived from more fundamental demands for energy services (such as lighting and heating). LCP seeks the most cost effective way of providing the energy end-use services in an economy. To accomplish this, techniques (such as scheduling of motors) and technologies (such as energy efficient motors), which can reduce the energy requirements for a particular end-use service must be compared on a symmetrical basis with energy supply options. The "conservation supply curve" is a conceptual tool for addressing such symmetrical comparisons. It is partially analogous to the conventional economic supply curve (Marbek 1987).

Within economic theory, the concept of a supply curve is one that expresses the instantaneous relationship between the price of a commodity and the quantity which will be delivered at that price. In a conservation supply curve, "price" is replaced by "cost" (the cost of conserving a unit of energy), and the "quantity" refers to quantity of energy which can be conserved (or supplied through conservation) given a specific conservation measure. The cost of supplying a unit of energy through conservation can then be compared to the cost of supplying a unit of energy through constructing new supply structures. Figure 18 presents an illustrative example of a supply curve of conserved energy.

Figure 18: Example of a supply curve of conserved energy.
(from Meier 1983:19)



A schematic supply curve of conserved energy. Implementation of "measure x" will save energy, $(\Delta E)_x$, at a cost per unit of conserved energy, C_x.

Developing Conservation Supply Curves

A supply curve of conserved energy is similar to a supply curve for reserves of any energy source. It ranks the reserves of energy in order of increasing cost and shows how large each reserve is. The curve slopes upward since increasing quantities of conserved energy becomes available at higher costs.

Three types of information are required to construct a conservation supply curve. They are:

(1) the baseline energy use (against which the energy savings are measured),

(2) the quantity of energy that can be saved by a particular conservation measure, and

(3) the cost of the conservation measure.

Baseline Energy Use

The conservation "supply" is essentially the difference between the energy use if the conservation measure were not implemented and the energy use after the conservation measure is implemented. It is, therefore, important to have accurate baseline energy end-use data.

Quantity of Saved Energy

The horizontal co-ordinate (x-value) on the supply curve is the cumulative energy saved annually by that measure and all measures preceding it in the supply curve. Determining this value requires research into the characteristics of the energy-using stock. Research looks into experience with end-use technologies and techniques, and into mathematical models (for example, building energy models). Models are used to assess conditions when several measures are being considered on one curve, because the baseline energy use will change after each measure, and this in turn will affect the savings that can be achieved with subsequent measures (Marbek 1987). This will be further discussed in the section titled Interactive Effects.

The Cost of Conserved Energy

Determining the cost of conserved energy (y-value) requires engineering and economic data. The unit cost of conserved energy, CCE (in cents per kW.h), is calculated by dividing the annual investment in conservation (for materials and labour) by the annual energy savings:

$$\text{CCE} = \frac{\text{annual investment (\$ per year)}}{\text{annual energy saved (kWh per year)}}$$

Investment occurs only once and must be annualized by multiplying it by the capital recovery factor,

$$\frac{d}{1 - (1 + d)^{-n}}$$

where n is the life time of the measure (in years), and
d is the discount rate.

The unit cost of conserved energy is therefore determined by the formula:

$$\text{CCE} = \frac{\text{(capital recovery factor) x (investment)}}{\text{annual energy saved}}$$

or $$\text{CCE} = (I/E) \left(\frac{d}{1 - (1 + d)^{-n}}\right)$$

where I is the initial investment
E is the annual saving in energy (compared to the baseline)

It can be seen therefore, that the cost of conserved energy is dependant upon four variables:

(1) 'Investment (or initial cost) of the conservation measure,

(2) Annual energy savings expected from the measure,

(3) Amortization period of the investment, and

(4) Discount rate of the investor' (Meier 1983:21).

There are obvious analogies to the criteria for investment in the supply sector:

(1) 'Cost of extraction facility,

(2) Rate of extraction,

(3) Depreciation of facility (and possibly depletion of the reserves), and

(4) Discount rate of the firm' (Meier 1983:21).

<u>Interactive Effects</u>

'The baseline against which energy savings are measured is affected by all other measures previously implemented, and this is the root of the interactive effects which constitute the most difficult methodological problem in the construction of conservation supply curves. Measures typically save some percentage of the baseline energy use, and so the absolute savings they achieve change (usually downward) in proportion to the amount of energy saved by all the previous measures. This in turn affects the unit cost of the measure (which is inversely proportional to the absolute value of E).

An example is provided by Meier (1982), who developed an algorithm for calculating the CCE for a sequence of space heating conservation measures for a house. First, the CCE of each of the eight measures is calculated as if it were the first to be implemented. Then the lowest cost measure (duct insulation in this case) is implemented, the baseline energy is recalculated and the unit costs of the remaining measures are recalculated and re-ordered. The iteration continues until the optimum order is identified. However, if the initial cost of duct insulation is increased until it is slightly more expensive than the next cheapest measure (wall insulation), its ultimate position in the order falls not to second but to fourth because of the interactive effects on other measures of insulating the walls first.

Commercial lighting conservation measures provide another example of these interactive effects. Reductions in the energy output of lights reduce the cooling requirements in commercial buildings in the summer and increase the heating requirements in the winter. Thus, lighting efficiency improvements also save air conditioning energy but, if implemented first, increase the unit costs of air conditioning efficiency improvements, and conversely for heating energy.

These interactive effects illustrate an important limitation of conservation supply curves that are based on the cost of the conserved energy. The implementation of one measure can send the unit cost of a similar measure sky-rocketing. For example, measured against a common baseline, insulating an attic to level A may save electricity at 2 cents/kWh, and insulating it to level B may save more electricity at a slightly higher unit cost. But because of the high labour component of this measure, if the attic is insulated to level A, the unit cost of insulating to level B, given the new baseline, will increase greatly. Thus to avoid double counting, a unit cost value must be selected to provide a basis for choosing between similar and mutually exclusive (for practical purposes) options' (Marbek 1987:5).

Micro Conservation Supply Curves

The micro conservation supply curve is one for a single unit end-use device or process (Marbek 1987). For example, a conservation supply curve designed to show collections of technical changes that could save electricity in a standard electric motor, and show their costs compared with the resulting savings. At this level it is possible to get precise data on the end-use device and hence prepare a precise curve.

Macro Conservation Supply Curves

This type of supply curve is used to describes the total conservation potential for many units of an end-use device. For example, a curve showing the conservation potential of technical changes in lighting for the Health Care subsector. Macro supply curves can be used to describe the aggregate of multiple end-use conservation potential in an entire sector of the economy and thus, can be quite complex. The analysis uses average baseline energy use, average costs for measures, average effects of the measures, and, most difficult, average interactive effects (Marbek 1987). As Marbek points out 'Until much larger statistical energy end-use and conservation data bases are available, the development of macro conservation supply curves will require the heroic assumption that distributions are normal about the averages, and that the data allow one to make a reasonable approximation of the average' (Marbek 1987:6).

Conservation Supply Curves Study Methodology

The methodology for the development of the supply curves of conserved energy for the Manitoba Health Care subsector is as follows:

1. Identification of potential data sources.

2. Identification of conservation measures to be assessed.

3. Calculation of the baseline energy.

4. Calculation of the energy savings.

5. Calculation of the cost of the conservation measures.

6. Construction of the conservation supply curves.

7. Interpreting the conservation supply curves.

The Potential for Energy Conservation in the Manitoba Health Care Subsector

An Overview of the Major Data Sources

The major approaches to data collection for developing supply curves of conserved energy are engineering simulations, survey research, end-use metering, and literature reviews - including technical reports, manufacturers publications, consultants reports, and end-use studies. Since supply curves of this nature have never been constructed before in Manitoba, there is no organized data base from which to draw.

The main data sources for determining the baseline energy use for specific end-use/fuel-type/building-type combinations were the Energy Bus Audits, ENERHOSP, and data collected by Energy and Mines summer students. These data sources are described in Chapter Three.

The main data sources for calculating the energy savings which can be achieved by a particular conservation measure, and the cost of that measure, include: (1)

technical reports; (2) manufacturers publications; (3) consultants reports; (4) discussion with experts; (5) energy bus audits; and (6) retail and installation cost data from retailers.

Ontario Hydro and the Ontario Ministry of Energy are currently pursuing studies in energy conservation potential within its economic sectors. They have commissioned a number of studies by various consulting companies, in particular Marbek Resource Consultants Ltd. and Engineering Interface Ltd. (EIL). These studies include technical reports such as the <u>Commercial/Institutional Buildings: Electrical Energy Technology Study</u> by EIL, and the development of conservation supply curves such as <u>Electricity Conservation Supply Curves for Ontario</u> by Marbek. TransAlta Utilities in Alberta is currently pursuing end-use forecast studies and therefore has the potential to develop conservation supply curves.

<u>Identification of Conservation Measures to be Assessed</u>

Conservation measures to be used in the supply curves were assessed based on the following criteria: availability of data regarding end-use energy efficiencies, end-use market penetrations, and fuel consumption by end-use and building type.

Table 18 presents the nine conservation measures which were selected and applied to the three building types in the study.

Table 18: Conservation measures assessed in the study. These nine measures are applied to all building types.		
MEASURE	END-USE	FUELTYPE
E.E. FLUOR. L-1	LIGHTING	ELECTRIC
E.E. FLUOR. L-3	LIGHTING	ELECTRIC
COMPACT FLUOR.	LIGHTING	ELECTRIC
H.E.CENTRAL COOLING	SPACECOOL	ELECTRIC
H.E.UNITARY COOLING	SPACECOOL	ELECTRIC
E.E. MOTORS	MOTORS	ELECTRIC
E.MAN.CONTROL SYS	MOTORS	ELECTRIC
MOTOR BALANCE-AIR	MOTORS	ELECTRIC
MOTOR BALANCE-WATER	MOTORS	ELECTRIC

Appendix D contains a description of the conservation measures. Note that one measure included in Appendix D is not assessed in this study due to lack of data. That measure is called Energy Efficient Lighting - Level Two. The above measures are applied only to the fuel type electricity for the following reasons.

The commercial sector's use of natural gas is mainly for space heating. Hospitals and PCHs commonly use natural gas boilers, which have for the most part, already been upgraded to a high energy efficiency. Other conservation measures which could be employed to conserve natural gas (or other energy forms for that matter) in the space heating end-use include such things as caulking/weatherstripping, and temperature setback. These types of measures are considered to be "no-cost/low-cost" measures and represent a large energy conservation potential. They have not been assessed in this study because it is impossible to know how much has already been implemented (eg., what are the penetration rates of the measures?), and also because the costs of the measures are very site specific (eg. the cost varies significantly from building to building) and any calculation of costs would have therefore been very imprecise. Low-cost/no-cost measures exist for other fuel types also - for example turning off lights when not in use. The conservation supply curves which will be produced in this study are therefore not complete in terms of the energy conservation potential of the Health Care subsector, and may well under-represent it.

As mentioned in Chapter Three, there is not enough data available to determine baseline energy use for oil and propane. For this reason conservation measures for these fuel types were not assessed.

The above discussion makes it clear that these supply curves of conserved energy for the Manitoba Health Care subsector are not complete and should therefore be considered preliminary.

Calculation of the Baseline Energy Use

The baseline energy use is calculated for end-use/fuel-type combinations for each building type in the following manner:

$$\begin{aligned}\text{Baseline energy use} &= \text{EUI} * \text{Floorstock} \\ &= \text{KW.h/ft.}^2 * \text{ft.}^2 \\ &= \text{KW.h}\end{aligned}$$

The EUI's were estimated in Chapter Three and can be found in Tables 10, 11, and 12. The floorstock for each building type was also estimated in Chapter Three and can be found in Table 3.

Table 19 is a summary of the baseline energy use for the time period 05/87 to 04/88.

Table 19: Summary of baseline energy use for end-use/fuel-type combinations in the Manitoba Health Care subsector for the time period 05/87 to 04/88.

HOSPITALS — TOTAL AREA = 5646859 SQ. FT.

FUEL	END-USE	TOT ENERGY CONSUMED BY END-USE(KWh)
ELEC	LIGHTING	36422240
ELEC	SP.HTNG	37551612
ELEC	VENTIL	131120065
ELEC	WAT HTNG	27443734
ELEC	AIR COOL	15681327
ELEC	MOTORS	25919082
ELEC	CARPLUGS	7227979
ELEC	MISC	35744617
	Total=	317110656 KW.h

PERSONAL CARE HOMES — TOTAL AREA = 5328163 SQ. FT.

FUEL	END-USE	TOT ENERGY CONSUMED BY END-USE(KWh)
ELEC	LIGHTING	19074824
ELEC	SP.HTNG	75073817
ELEC	VENTIL	61859972
ELEC	WAT HTNG	42465459
ELEC	AIR COOL	7672555
ELEC	MOTORS	18488725
ELEC	CARPLUGS	3090334
ELEC	MISC	24775957
	Total=	252501643 KW.h

COMBINATION	HOSPITAL/PCH	TOTAL AREA= 1290564 SQ.FT.
FUEL	END-USE	TOT ENERGY CONSUMED BY END-USE(KWh)
ELEC	LIGHTING	6865800
ELEC	SP.HTNG	15215749
ELEC	VENTIL	16041710
ELEC	WAT.HTNG	6723838
ELEC	AIR COOL	1935846
ELEC	MOTORS	6917423
ELEC	CARPLUGS	735621
ELEC	LAUNDRY	4491162
ELEC	MISC	8982325
	Total=	67909474 KW.h

Total electrical energy consumption for the Manitoba Health Care Subsector = 637521773 KW.h

Calculation of the Energy Savings (ES)

Energy savings refers to the amount of energy which can be saved from the baseline of energy use by applying a specific conservation measure, such as replacing a standard efficiency motor with an energy efficient motor. Energy savings for the selected conservation measures were calculated using the following formula:

$$ES = BE \times A \times S \times (P - Pc)$$ where

ES = energy saved (KWh)

BE = total Baseline energy used (KWh) for a specific end-use/fuel-type/building-type combination (for example, total electric lighting consumption in hospitals)

A = Applicability (that fraction of the end-use energy consumption to which the measure is applicable)

S = Per cent energy savings compared to standard technology

P = Total potential market penetration of the end-use.
P = 1.0 for all end-uses.

Pc = Current market penetration (1988) (these values were obtained from Engineering Interface Ltd. 1988:42).

The following is an example of these calculations:

end-use:	lighting
fuel type:	electricity
building type:	hospital

standard technology: fluorescent lamp fixture
2 - 40 watt lamps
1 - 16 watt ballast
system energy = 96 watts

conservation measure: replace with the following:
2 - 34 watt EE lamps
1 - 10 watt EE ballast

so system energy is
lamp energy = 2 x 34 watts +
ballast energy = 10 watts - 2 watts (due to 1 watt reduced draw for energy efficient tubes)
system energy = 76 watts

Difference in system energies = 96 - 76 = 20 watts

S = per cent savings from baseline energy use
= 20 watts/96 watts = 21 %

A, the fraction of energy use to which the measure is applicable was obtained from Engineering Interface Ltd.'s Commercial/Institutional Buildings: Electrical Energy Technology Study (1988:Appendix B). EIL derived the applicability factors from various sources and where no information was available, an estimate of the application factor was made based on EIL experience (Engineering Interface Ltd. 1988).

Pc, the current market penetration was also obtained from Engineering Interface Ltd.'s <u>Commercial/Institutional Buildings Electrical Energy Technology Study (1988:Appendix B)</u>.

Continuing with the example:

BE = 36,422,240 KW.h
S = 0.21
A = 0.82
Pc = .15
P = 1.00

ES = BE x S x A x (P - Pc)
ES = 5,331,123 KW.h

Thus, 5,331,855 KWh of electrical energy can be saved in Hospitals by installing Level One Energy Efficient Fluorescent Lighting.

A complete summary of energy savings (ES), baseline energy use (BE), savings from baseline energy use (S), applicability (A), current market penetration (Pc) and market penetration in the year 2000 (P) for the various end-uses/fuel type/building type can be found in Appendix E, Data Base Summary. It should be noted that the database presents only the potential savings that might be achieved in the current building stock without any interaction with other measures. To estimate future savings, it is necessary to take into account differences between new and existing stock and to allow for interaction between conservation measures. This requires the use of sophisticated energy demand models such as those used by the Ontario Ministry of Energy and Ontario Hydro.

The three types of data used in the data base - the baseline energy use, the quantity of energy that can be saved by a particular conservation measure, and the cost of the conservation measure - are used to generate inputs to these models.

Calculation of the Cost of Conserved Energy (CCE)

As discussed previously the cost/unit of energy for a conservation measure was calculated using the formula

$$CCE = (I/E) \left(\frac{d}{1 - (1 + d)^{-n}} \right)$$

where I is the initial investment
E is the annual saving in energy (compared to the baseline)
d is the discount rate
n is the lifetime of the measure

The following, a continuation of the previous example, is an example of calculating the cost/unit of energy.

end-use:	lighting
fuel type:	electricity
building type:	hospital
conservation m.:	level one lighting

BASELINE TECHNOLOGY	COST EACH	LIFE YRS	REPLACEMENT TECHNOLOGY	COST EACH	LIFE YRS
2-40W F LAMPS	$1.45	5	2-34W F LAMPS	1.82	5
1-16W BALLAST	$11.44	20	1-10W EE BALL	$14.50	20

(Costs are in 1988 figures)

Annualizing the investment:

$$\left(\frac{d}{1 - (1 + d)^{-n}} \right) \qquad \text{where } d = 0.04$$

[Note: A 4 percent discount rate was used because several of the costs per unit energy used in this study were obtained from Marbek (1987), who used a 4 percent discount rate in their cost calculations. The Treasury Board (1976:26) recommends the use of a social discount rate of 10%, and of 5% and 15% for sensitivity analyses. However, Sumner (1980) argues that the 10% discount rate recommended as a mean by the Treasury Board, is to high and should be treated as an upper boundary. Burgess (1981) also argues that the 10% figure is to high and indicates that a social discount rate of 7.0% to 7.5% should be used as the mean. Future studies should do sensitivity analyses using different discount rates. This study was unable to do so do to the lack of detailed information for many of the equipment costs.]

lamps: premium = \$1.82 - \$1.45 = \$0.37 x 2 tubes/fixture
= \$0.74/fixture

$$\text{annualized investment} = \$0.74 \times \frac{.04}{1-(1.04)^{-5}} = \$0.1662/\text{year}$$

ballasts: premium = \$14.50 - \$11.44 = \$3.06/fixture

$$\text{annualized investment} = \$3.06 \times \frac{.04}{1-(1.04)^{-20}} = \$0.225/\text{year}$$

Total annualized cost = \$0.1662 + \$0.225 = \$0.3912/year

Assuming a 50 per cent load factor (Marbek 1987:51), lights were on for 4383 hours/year.

Total energy saved per fixture = 0.02 KW/yr x 4383 hrs/yr
= 87.66 KWh

Cost per KWh = 39.12 cents / 87.66 KWh
= 0.446 cents / KWh

Similar calculations were carried out for the other conservation measures. The costs of the conservation measures are presented in Appendix D.

Cost of Supply

The cost of supplying a KW.h of electricity by building a hydro-electric dam in Manitoba was calculated in the following way:

The cost of the next hydro electric plant + distribution system + transmission system = $5 billion in 1999 dollars (McVicar 1989).

Discounting this value to 1989 dollars using a 5% discount rate:

Vo = present value (1989)
Vn = future value (1999)
n = number of years to future = 10

$Vo = Vn/(1=i)^n$
Vo = $3,069,566,267

Assuming a plant capacity of 1300 MW (McVicar 1989).

X = the theoretical amount of energy which can be obtained from the plant
X = 1300 MW * 1000 KW/MW * 8766 hrs/year
$X = 1.13958 * 10^{10}$ KW.h

Factoring out line and distribution lossess accounts for a reduction of 12% (McVicar 1989).

Y = the quantity of electricity that can be delivered to the user.
Y = X * 0.88
$Y = 1.00283 *10^{10}$ KW.h

Taking into account the Manitoba load factor which for planning purposes is 60% (McVicar 1989).

Z = total energy available to Manitoba from plant.
Z = Y * 0.6
Z = 6,016,982,400 KW.h

Note: If there is energy available at nonpeak times (eg., overcapacity of supply), it can be sold at interruptible rates.

Assuming a dam life of 67 years (McVicar 1989), and annualizing the initial investment:

$$A = \frac{[\$3,069,566,267 * 100 \text{ cents}/\$]}{6,016,982,400 \text{ KW.h}} * [0.05/1-(1.05^{-67})]$$

$$A = 2.65 \text{ cents/KW.h}$$

Thus, the cost per unit of energy of supply is 2.65 cents/KW.h (the marginal cost of the next unit of supply).

Interpreting the Supply Curves of Conserved Energy

Appendix F contains supply curves of conserved energy for each conservation measure and building type for the fuel type electricity. The curves show cost per KW.h of electricity on the y-axis, and quantity of electricity (which could be saved if the specific conservation measure was implemented to the point where the penetration rate of the measure was equal to 100 percent) on the x-axis. These curves do not take into account the interactive effects discussed earlier in this chapter, and are therefore preliminary in nature. Future studies could acquire an energy model capable of taking these effects into account.

As they are, the supply curves give a useful measure of the potential for electricity conservation in the Manitoba Health Care subsector. The following table summarizes the energy conservation potential for the assessed conservation measures in the Health Care subsector. The table also lists the conservation block numbers which correspond to the energy conservation supply curves in Appendix F.

Table 20: Summary of the energy conservation potential for the assessed conservation measures in the Health Care subsector.

Bl. No.	Building Type	Energy Saved (MW.h)	Cost/Unit of Energy (cents/KW.h)
	Energy Efficient Fluorescent Lighting - Level One.		
1	Hospital	5331.1 MW.h	0.45 cents/KW.h
10	PCH	2018.8	0.45
19	Comb.	870.5	0.45
	Total Pot. =	8220.4 MW.h at 0.45 cents/MW.h	
	Energy Efficient Fluorescent Lighting - Level Three		
2	Hospital	4326.9 MW.h	3.96 cents/KW.h
11	PCH	2266.1	3.96
20	Comb.	815.7	3.96
	Total Pot. =	7408.7 MW.h at 3.96 cents/MW.h	
	Compact Fluorescent		
3	Hospital	653.9 MW.h	6.90 cents/KW.h
12	PCH	570.8	6.90
21	Comb.	164.4	6.90
	Total Pot. =	1389.1 MW.h at 6.90 cents/KW.h	
	High Efficiency Central cooling		
4	Hospital	2108.5 MW.h	2.00 cents/KW.h
13	PCH	273.4	2.00
22	Comb.	164.6	2.00
	Total Pot. =	2546.5 MW.h at 2.00 cents/KW.h	
	High Efficiency Unitary Cooling		
5	Hospital	372.6 MW.h	2.00 cents/KW.h
14	PCH	555.2	2.00
23	Comb.	93.0	2.00
	Total Pot. =	1020.8 MW.h at 2.00 cents/KW.h	
	Energy Efficient Motors		
6	Hospitals	1443.1 MW.h	0.71 cents/KW.h
15	PCH	776.5	0.71
24	Comb.	338.6	0.71
	Total Pot. =	2558.2 MW.h at 0.71 cents/KW.h	

	Motors Scheduling		
7	Hospitals	787.9 MW.h	1.63 cents/KW.h
16	PCH	931.8	1.63
25	Comb.	276.3	1.63
	Total Pot. =	1996.0 MW.h at 1.63 cents/KW.h	
	Motor Balancing - Air		
8	Hospital	1924.4 MW.h	1.34 cents/KW.h
17	PCH	915.2	1.34
26	Comb.	433.1	1.34
	Total Pot. =	1540.7 MW.h at 1.34 cents/KW.h	
	Motor Balancing - Water		
9	Hospital	244.9 MW.h	1.34 cents/KW.h
18	PCH	54.9	1.34
27	Comb.	44.1	1.34
	Total Pot. =	343.9 MW.h at 1.34 cents/KW.h	

The weighted average cost of conserved energy for the different building types are:
Hospitals: 1.99 cents/KW.h
PCH: 2.25 cents/KW.h
Combination: 2.06 cents/KW.h

The weighted average cost of conserved energy for an aggregate of all building types is:
2.08 cents/KW.h

The weighted average cost of conserved energy was determined for each building type and for an aggregate of all building types. These values are presented at the bottom of Table 20.

The summary in Table 20 indicates that the Energy Efficient Lighting - Level One and Level Three conservation measures hold the greatest potential for electricity conservation in the Health Care subsector. It is interesting to note that the Level One measure also has the lowest cost per unit of saved energy.

Conservation measures with a medium potential for conserving electricity include Compact Fluorescent, H. E. Central Cooling, H. E. Unitary Cooling, E. E. Motors, Motor Scheduling, and Motor Balancing - Air. Of these, E. E. Motors has the lowest cost/unit of saved energy.

Only one conservation measure had a relatively low potential for conserving electricity - Motor Balancing - Water.

Figures 19, 20, and 21 represent composite energy conservation supply curves for the three different building types assessed in this study. The figures show energy conservation blocks in order of increasing cost per unit of energy saved for each building type. The x-axis shows cumulative quantities of electricity which could be saved if the measures were implemented. The numbers above each block correspond to the different conservation measures as noted in Table 20 and in Appendix F. Table 20 presents the cost/KW.h of each measure and the quantity of electricity which can potentially be saved using that measure. Note that these curves do not take into account the interactive effects as discussed earlier.

Figures 19, 20, and 21 also show the curve for supplying a KW.h of electricity by building a hydro-electric dam. This cost was calculated earlier and is 2.65 cents per KW.h (the marginal cost of the next unit of supply). It is included to enable a comparison to be made between the cost of supplyiny a unit of energy through conservation and through building a dam.

Figure 19. Electricity Conservation Supply Curve for Manitoba Hospitals (interactive effects not included).

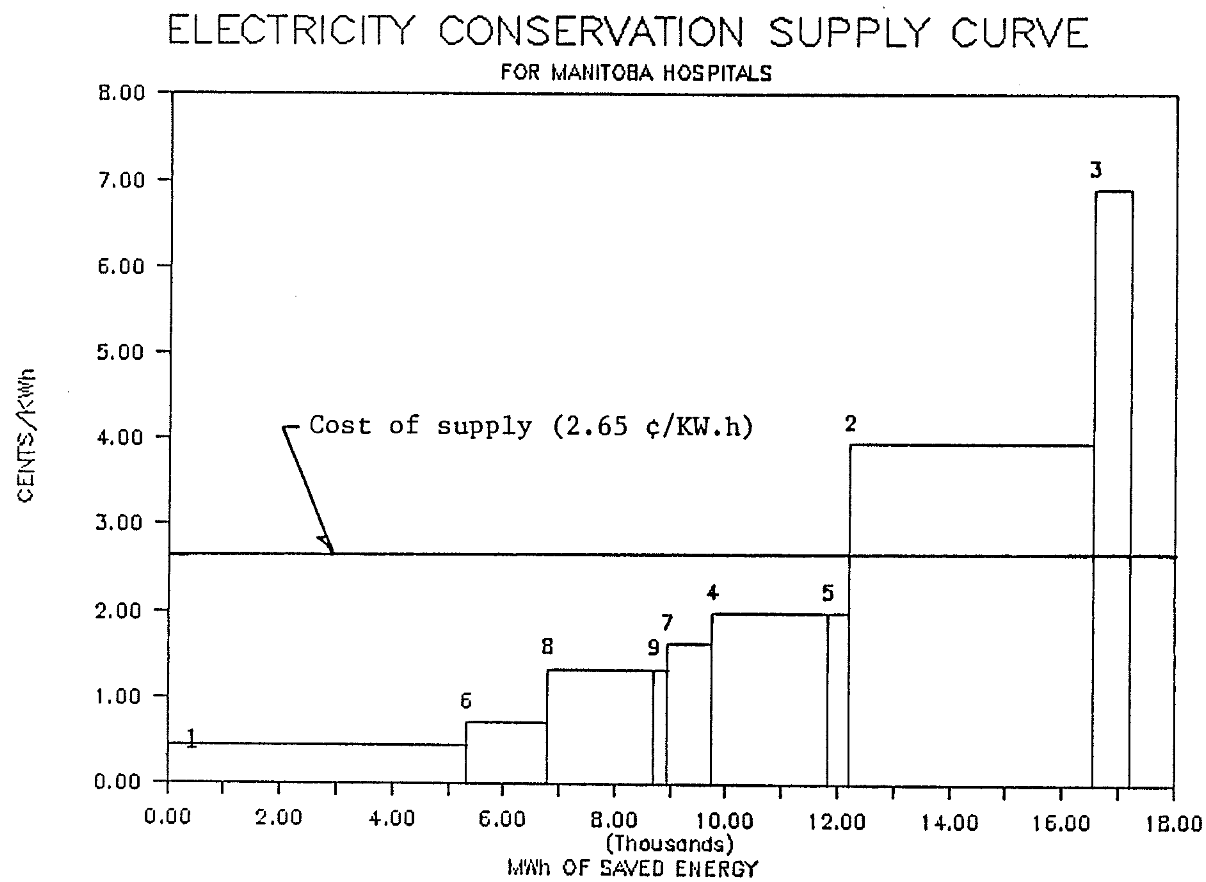


Figure 20. Electricity Conservation Supply Curve for Manitoba Personal Care Homes (interactive effects not included).

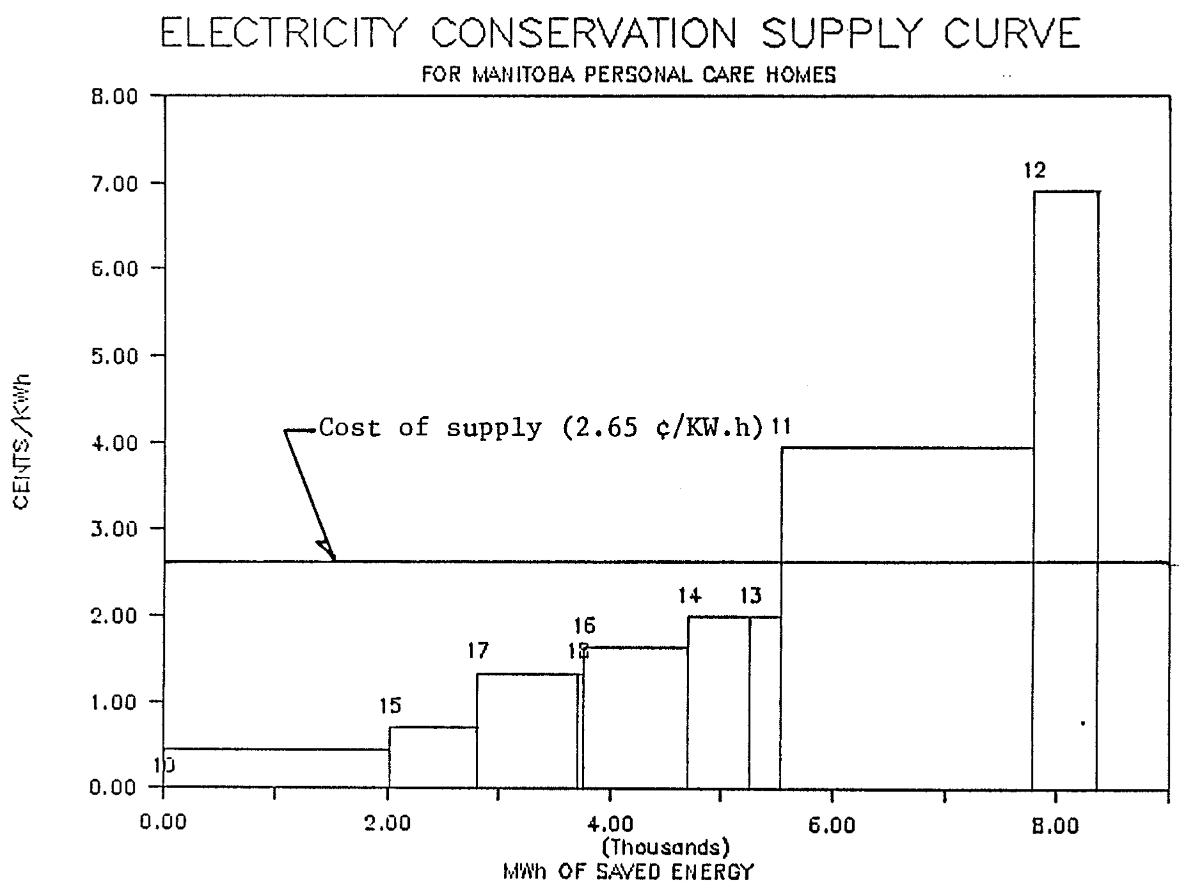
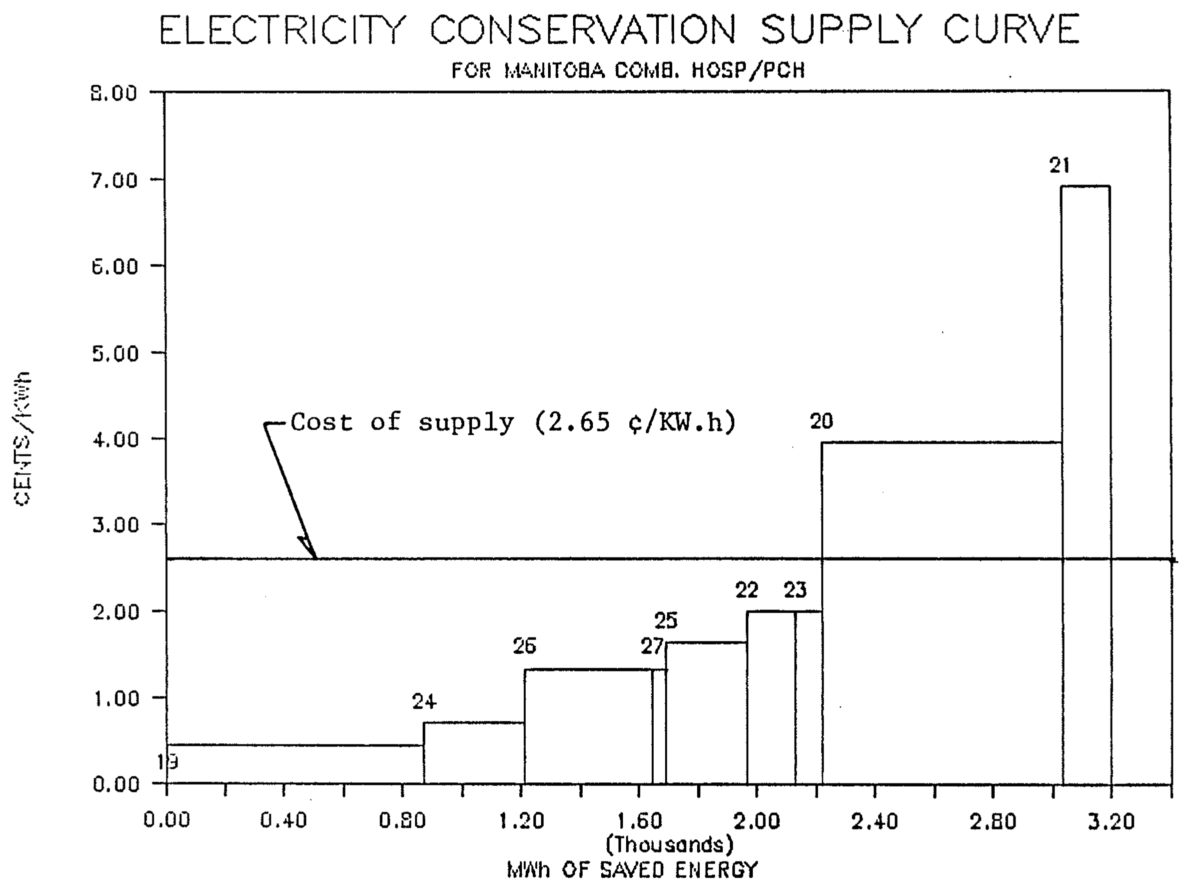


Figure 21. Electricity Conservation Supply Curve for Manitoba Combination Hospital/Personal Care Homes (interactive effects not included).



Limitations to Interpreting the Supply Curves of Conserved Energy

Limitations include:

1. The curves in this study do not take into account the interactive effects mentioned earlier. As a result the potential for electricity conservation may be overstated.

2. The accuracy of the energy savings calculations are dependent upon the accuracy of the energy baseline (among other factors). The energy baseline was derived from estimates of Energy Use Indices and of floorstock. The energy use indices were derived from the energy bus audits which in many instances had little information broken out on some end-uses, such as motors. For these reasons, the accuracy of the energy savings is limited by the large number of previous estimations, and by the failure of the energy bus audits to consistently break out detailed information.

3. The cost/unit of saved energy is deemed to be fairly accurate where costs were able to be determined for Manitoba. In some instances the costs used were from Engineering Interface Ltd. (1988), and this may pose some limitations as costs may not be exactly the same in Ontario as in Manitoba.

The above discussion of limitations indicates the need for accurate data in all portions of studies dealing with conservation supply curves.

Chapter Five: Conclusions, Recommendations and Limitations

Conclusions

Electric Utilities in Canada have recently begun to look for ways to reduce the need for, or delay the construction of, costly new electricity generating structures. This report approaches this problem by developing parameters necessary for forecasting long-term energy demand within the Manitoba Health Care subsector, a portion of the Manitoba Commercial sector, and by estimating the potential energy savings which might be realized through the modification of the way in which energy is used. The latter part of this approach is part of what is known as Demand Side Management (DSM). DSM refers to efforts by utilities to control or change the quantity and timing of their customers consumption to avoid costly capacity or supply acquisition. This balancing of the mix of supply and demand side alternatives is called Integrated Resource Planning (IRP). This report contributes to the energy planning and end-use computer modelling efforts conducted towards integrated resource planning in Manitoba in the following ways: (1) The study develops parameters necessary for long-term energy demand forecasting within the framework of an end-use computer model, for the Manitoba Health Care subsector; and (2) The study assesses the potential for Demand Side Management in the form of energy conservation within the Manitoba Health Care subsector. The demand side alternatives which this report specifically looks at, deal with technological change, such as improved energy consumption efficiencies within electrical end-uses, an example of which is electric motors.

The first part of the above stated contribution towards integrated resource planning in Manitoba, is the estimation (in chapter 3) of parameters which describe the energy consumption and physical characteristics of the Manitoba Health Care subsector. These parameter estimates, taken together, are called the "energy baseline" for the Manitoba Health Care subsector. The baseline was constructed for the time period 05/87 to 04/88, but it also includes past and future estimates of floor area in the health care subsector.

The parameter estimates which make up the baseline are to be used by the Manitoba Department of Energy and Mines as inputs to an energy demand forecasting end-use computer model as part of their long-term energy demand forecasting program for the Manitoba Commercial sector. The computer model to be used in the forecasting is called COMMEND - the Commercial End-use Planning System.

Table 21 is a summary of the parameters which have been estimated (and those which have not been) in this study to serve as inputs to COMMEND. The location of the estimated parameter within the body of the report is also noted in this table. It is important to note that COMMEND provides endogenous values for those parameters which could not be estimated. This study does not assess the endogenous values used by COMMEND, since it has already been determined that the end-use model will be used for energy forecasting by the Manitoba Department of Energy and Mines. It should be noted that COMMEND provides a selection of endogenous values for specific parameters, the choice of which is determined by variables such as subsector (eg., health, offices), building type, and fuel type. A limitation of using endogenous values is that they may have been developed for situations which are different from those in Manitoba, and may therefore result in an inaccurate forecast. It may be that an accurate forecast requires not only a good computer model, but also an experienced forecaster who can assess the endogenous values and determine if they are appropriate for the forecast region.

Table 21: Data Requirements of COMMEND		
Model Component	Data Requirements	Estimated in Study?
Floor Space Additions (A) (A_t^1*d[T-t] in the central equation)		
	1. Subsector floorstock in base year.	Y
	2. Average ratio of floor area/bed in base year (based on different size hospitals).	Y
	3. Estimated annual growth rate.	Y
	4. Historical floorstock estimates.	Y
	5. Future floorstock estimates.	Y
	6. Average floorstock additions estimates.	Y

Continued on next page.

Energy Use Indices (e_t or EUI) ($e^t_{i,k,l}$ in the central equation)		
	1. Floor area data for a sample of buildings and subsector floorstock by vintage.	Y
	2. Energy consumption (KW.h) by fuel type.	Y
	3. Monthly utility sales data.	Y
	4. End-use equipment penetrations.	Y*
	5. Engineering and econometric data	
	-short-run and long-run fuel price elasticities.	N
	-end-use equipment costs	Y
	-end-use equipment lifetimes	Y
	-end-use equipment efficiency	Y
Fuel Shares (a_t or S) ($a^t_{i,k,l}$ in the central equation)		
	1. Floor area data for a sample of buildings and subsector floorstock by vintage.	Y
	2. Fuel shares by building type and end-use for a base year.	Y
	3. Frequency distribution of population discount rates and price expectations for each fuel and end-use.	N
	4. Monthly utility sales data.	Y

Utilization (U) ($U^t_{i,k,l}$ in the central equation)	1. End-use equipment penetrations.	Y*
	2. Changes in existing buildings and equipment penetrations in new building stock.	N
	3. Historical and forecast average fuel price data.	N

Notes: * indicates the data was not estimated for Manitoba, but was obtained from Engineering Interface Ltd.'s Commercial/Institutional Buildings: Electrical Energy Technology Study (1988).

The second part of the contribution towards integrated resource planning in the province is the assessment of the potential for energy conservation, and in particular electricity conservation in the Manitoba Health Care subsector. To this end, nine different electrical end-use conservation methods were theoretically applied to the previously estimated "energy baseline" to determine how much electrical energy could be saved through conservation efforts within the Manitoba Health Care subsector. The resulting potential energy savings are presented in the form of "electrical energy conservation supply curves" in Appendix F, and in the form of "composite electrical energy conservation supply curves" in Figures 19, 20, and 21. Table 20 presents a summary of the conservation measures assessed and the estimated potential energy savings associated with each measure. The table also relates the block numbers on the conservation supply curves to the individual measures.

The composite curves in Figures 19, 20 and 21 illustrate that there is a significant potential quantity of electrical energy which can be saved through conservation efforts in the Manitoba Health Care subsector at a cost per unit of energy below that of supply (using a calculated cost of supply of 2.65 cents/KW.h). The size of the energy potential for the entire Manitoba Health Care subsector cannot be stated in absolute terms due to the inability of this study to take into account interactive effects. However, the size of the potential for energy savings due to just one of the conservation measures assessed in this study, Energy Efficient Fluorescent Lighting - Level One (8,220 MW.h at 0.45 cents/KW.h), indicates that there is good reason to carry out more research into the impact of energy conservation on energy demand in Manitoba's Commercial Sector.

Limitations and Recommendations

Limitations on the first part of the study, that part dealing with the estimation of energy consumption and physical parameters for the Manitoba Health Care subsector to be used as inputs to COMMEND, were due in part to the small sample size of energy audits (which contained the data on energy consumption and physical characteristics) used in estimating the parameters. The small sample size makes it impossible to state with certainty that the estimated parameters are statistically valid, although in most instances, comparisons with estimated values from other studies indicate the estimates in this study are within an acceptable range.

A limitation is also placed on the first part of the study as a result of using population as a scale variable when forecasting and backcasting the Manitoba Health Care subsector floorstock. As noted in Chapter 3, population is not an accurate proxy for back- and forecasting floorstock due to the changing age structure of the population and the declining rate of growth. Population projections for the province of Manitoba show a steadily declining growth in population and a decline in total population after 1998, making population a poor selection for scale variable when forecasting floorstock. Past population figures are available for Manitoba for backcasting floorstock. However, there are no past floorstock figures available which can be used to check and verify the backcast figures and, hence, it is not known if these backcast figures are correct.

Limitations on the second part of the study, that part dealing with development of the Electrical Energy Conservation Supply Curves, are also due in part to the small number of energy audits, from which the average values for Energy Use Indices and Fuel Shares were estimated. The large standard deviations associated with many of these estimates indicates the possibility of large estimation errors. As noted in this study, however, Esler (1987) found in her study (with a much larger sample) that the energy audits are representative of the population. Also, comparisons of the EUI values with those from other studies indicate they are within an expected range of values.

Another limitation of the second part of the study is that it doesn't assess all conservation measures which have the potential to save electrical energy, nor was it able to assess conservation measures which conserve other forms of energy such as natural gas and fuel oil. The quantity of saved energy presented in Table 20 is, therefore, probably understated in terms of the amount of energy (considering all fuel types) with the potential to be saved in the Manitoba Health Care subsector.

The supply curves of conserved electrical energy presented here are to be considered preliminary in nature due to the inability of this study to take into account "interactive effects", a limitation described in Chapter Four. This limitation means that the quantity of electrical energy which could potentially be saved in the Manitoba Health Care subsector, as presented in Table 20, is probably overstated. However, the study does not estimate the potential energy savings for all possible conservation measures and for all fuel types, which would be expected to greatly increase the potential energy savings.

A limitation is also placed on the assumptions used regarding behavior of energy users. Although the theory used in these calculation is correct, it is possible that the user response will not follow the logic. That is, in the case of fluorescent tubes, users see negligible labour costs and a relatively certain return on their investment in under five years, but in the case of the ballasts, the assumed life is 20 years, and there is a question as to whether these new and unproven "energy efficient ballasts" will have a 20 years life in reality. Therefore, users may not follow the same logic as the theory used in this study assumes, and only small changes in the assumptions could wipe out the possible energy savings. It may be necessary for government or utilities to supply incentives to energy users to adopt the energy conservation measures.

A number of recommendations are suggested as a result of the above mentioned limitations.

1. It is recommended that much more data on end-use energy consumption and physical characteristics in health care facilities (eg., more energy audits) be collected. This would facilitate categorizing the data into vintage categories and single fuel - multiple fuel categories, and would add greater statistical validity to the estimated parameters.

2. It is recommended that future energy demand studies gather data on present and future employment in the

economic sector under study, and to assess its use as a scale variable for back- and forecasting purposes.

3. It is recommended that the Manitoba Health Services Commission begin to tabulate the annual floorstock additions to health care facilities in Manitoba, to facilitate future energy demand studies in this sector.

4. It is recommended that future researchers acquire an energy model capable of taking into account "interactive effects". This will allow energy planners to state with confidence, the potential for energy conservation in Manitoba's Commercial sector.

Possibilities for Future Research

Since end-use models are new to Manitoba, and an extensive data base for the various Commercial subsectors is still in the beggining stages, much work is still to be done before this type of model can be effectively implemented for forecasting. Specifically, the Health Care subsector could be better characterized if the following research was undertaken:

- Research into utilization (which includes the effects of price elasticity and changes in equipment efficiecy).

- Research into determining equipment penetration rates for Manitoba.

- Research into establishing a distant year floorstock for the various Commercial subsectors so that the available scale variables used in this study can be assessed.

References Cited

Journal Articles

Burgess, David F. "The Social Discount Rate for Canada: Theory and Evidence." Canadian Public Policy, Summer 1981: 383-394.

Energy Resources Conservation Board. "Energy Conservation, a Major Factor in ERCB Projections." Energy Conservation Update, Feb/Jan 1987.

Grusky, Scott T. and Fereidoon P. Sioshansi. "Beyond Demand Side Management: Positioning Strategies for Electric Utilities." Public Utilities Fortnightly, August 20 1987: 23-28.

Public Utilities Fortnightly, Editorial. "Least-Cost Planning: A National Perspective." March 19, 1987:13.

Squitieri, Ray, Oliver Yui and Craig Roach. "The Coming Boom in Computer Loads." Public Utilities Fortnightly, Dec 25, 1986.

Sumner, M.T. "Benefit-Cost Analysis in Canadian Practice." Canadian Public Policy, Spring 1980: 389-393.

Books

Canada. National Energy Board. Canadian Energy Supply and Demand: 1985-2005. Ottawa: Supply and Services, October 1986.

Chateau, B. and B. Lapillonne. Energy Demand: Facts and Trends. New York: Springer-Verlag, 1982.

Meier, A., J. Wright, and A.H. Rosenfeld. Supplying Energy Through Greater Efficiency. Berkeley: University of California Press, 1983.

Munasinghe, M. and G. Schramm. Energy Economics, Demand Management and Conservation Policy. Berkshire, England: Van Nostrand Reinhold Co., 1983.

Conference Papers, Technical Reports, Brochures, Theses, etc

Canada. Energy, Mines and Resources. Building Energy Technology Transfer Program (BETT). Building Population Demographics and Energy Consumption for Health Care Facilities in Canada, A Research Report. Ottawa: Supply and Services, March 1983.

Canada. Statistics Canada. A Prognosis for Hospitals: The Effects of Population Change on the Need for Hospital Space, 1967-2031. Cat. No. 83-520E. Ottawa: Supply and Services, 1977.

Canada. Statistics Canada. Hospital Statistics, Preliminary Annual Report, 1985-86. Cat. No. 83-217. Ottawa: Supply and Services, 1987a.

Canada. Statistics Canada. List of Canadian Hospitals 1987. Cat. no. 83-20. Ottawa: Supply and Services, 1988.

Canada. Statistics Canada. List of Residential Care Facilities in Manitoba. Cat. no. 83-221 Annual. Ottawa: Supply and Services, 1987b.

Canada. Statistics Canada. Population Projections for Canada, Provinces and Territories 1984-2006. Cat. no. 91-520. Ottawa: Supply and Services, May 1985.

Canada. Statistics Canada. Quarterly Report on Energy Supply and Demand in Canada.

Electric Power Research Institute (EPRI). An Implementation Guide for the EPRI Commercial Sector End-Use Energy Demand Forecasting Model: COMMEND. Volume 1: Model Structure and Data Development. EA-4049-ccm v.1. Research Project 1216-6. Prepared by Georgia Institute of Technology. Atlanta, Georgia, June 1985.

Electric Power Research Institute (EPRI). COMMEND: Commercial End-Use Energy Planning System: Tools for Demand Side Planning. Palo-Alto, California, 1987a.

Electric Power Research Institute (EPRI). Commercial End-Use Data Development Handbook: COMMEND Market Profiles and Parameters. Volume 2: COMMEND Data and Parameter Development Techniques. EM-5703 v.2. Research Project 2863-1. Prepared by Regional Economic Research, Inc. San Diego, California, April 1988.

Electric Power Research Institute (EPRI). Moving Towards Integrated Resource Planning: Understanding the Theory and Practice of Least-Cost Planning and Demand Side Management. EM-5065. Project 2548-3. Pal Alto, California, February 1987b.

Engineering Interface Ltd. and Marbek Resource Consultants Ltd. Commercial/Institutional Buildings: Electrical Energy Technology Study. Toronto: Ontario Ministry of Energy, February 1988.

Esler, Nancy. Requirements for End-Use Modelling and Least Cost Planning in Energy Resources Management: A Case Study of End-Use Data Collection and Analyses for the Commercial Sector in Manitoba. Master of Natural Resources Management Thesis (Report No. 62), Simon Fraser University, 1987.

Faraci, E.J. and Associates Ltd., Research Division. Energy Index Evaluation of Manitoba Health Care Facilities (ENERHOSP). Winnipeg, 1984.

Jaccard, Mark. "Description and Analysis of Energy End-Use Modelling and Forecasting." Seminar for the Manitoba Ministry of Energy and Mines. January 21, 1987, Winnipeg, Manitoba.

Manitoba. Commission of Inquiry into Manitoba Hydro. Commission of Inquiry into Manitoba Hydro, Final Report. December 1979.

Manitoba. Health Services Commission. Annual Report 1986-87. Winnipeg, June 1988a.

Manitoba. Health Services Commission. Annual Statistics 1986-87. Winnipeg, 1988b.

Manitoba. Health Services Commission. Personal Care homes 1988 Listing. Winnipeg 1988c.

Manitoba. Health Services Commission. Rural Health Facilities 1988 Listing. Winnipeg 1988d.

Manitoba. Health Services Commission. Urban Health Facilities 1988 listing. Winnipeg 1988e.

Manitoba. Manitoba Hydro and Ministry of Energy and Mines. End-Use Models for Least Cost Energy Planning. Winnipeg, Summer 1987.

Manitoba. Ministry of Energy and Mines. The Manitoba Energy Demand Model, by G. Chuchman. Winnipeg, November 1983.

Marbek Resource Consultants Ltd. Energy Efficient Motors in Canada: Technologies, Market Factors and Penetration Rates, Final Report. Ottawa: Energy Conservation Branch, Energy, Mines and Resources Canada, November, 1987.

Marbek Resource Consultants Ltd. Electricity Conservation: Supply Curves for Ontario, Final Report. Toronto: Ontario Ministry of Energy, August 1987.

A. Meier. Supply Curves of Conserved Energy. Ph.D. Dissertation, University of California (Berkeley), 1982.

Ontario Hydro. Analysis of Energy Use in Ontario's Hospitals. Ontario Hydro 1985.

Ontario Hydro. Ontario Hydro Memorandum - Subject: Visit to Ministry of Health. Ontario Hydro April 10, 1984.

Treasury Board. Benefit-Cost Analysis Guide. Ottawa: Ministry of Supply and Services 1976.

Interviews

Kellas, C. Corporate Planning, Manitoba Hydro. Winnipeg, Manitoba. October 6, 1987.

McVicar, Grant. Senior Planning Analyst, Manitoba Department of Energy and Mines, Winnipeg, Manitoba. April 24, 1989.

Webb, K. Energy Management Division, Manitoba Ministry of Energy and Mines. Winnipeg, Manitoba. June 25, 1987. Interview from Esler 1987.

Published Data

Canada. Statistics Canada.

83-520E A Prognosis for Hospitals: The Effects of Population Change on the Need for Hospital Space, 1967-2031.

83-217 Hospital Statistics, Preliminary Annual Report, 1985-86 (Annual).

83-20 List of Canadian Hospitals 1987 (Annual).

83-221 List of Residential Care Facilities in Manitoba (Annual).

57-003 Quarterly Report on Energy Supply and Demand in Canada (Quarterly).

91-520 Population Projections for Canada, Provinces and Territories 1984-2006.

Canadian Economic Observer. Historical Statistical Supplement 1987, Catalogue 11-210. Ottawa: Minister of Supply and Services Canada, 1988.

Dimensions. Industry Trends, 1951 - 1986, Catalogue no. 93-152. Ottawa: Minister of Supply and Services Canada, 1988.

APPENDICES

APPENDIX A: SAMPLE OF ENERGY-OUT SUMMARY

Energy Audit " Energy Out" Summary Format

Energy Out	kWH/YR.	$/YR.	% of Total $
.1 Heating (Light Fuel Oil)			
Transmission	226,000	5,650*	39.0
Infiltration	34,800	820*	5.7
Internal Heat Gain	-58,000	0	-
Stack Losses	109,000	3,480	24.0
.2 Electrical/Mechanical			
Lighting	35,700	1,700	11.7
Nursery School Heating	21,900	980	6.8
Electric Heat	12,000	750	5.2
Domestic Hot Water	3,000	145	1.0
Car Plugs	1,200	60	0.4
Fans, Motors and Misc. Electrical Equipment	29,000	910	6.3
.3 TOTAL ENERGY OUT	414,600 kWh	$14,495	100

* Reduced by the value of the internal heat gain from "free" sources, e.g. lights, solar, people, etc.

SOURCE: WEBB, 1987 (as cited in Esler 1988)

APPENDIX B: METHODOLOGY FOR WEATHER ADJUSTING

METHODOLOGY FOR WEATHER-ADJUSTING ENERGY CONSUMPTION DATA (Esler 1988:139)

A. GENERAL

There are a variety of ways in which to adjust energy consumption data to reflect consumption in a "typical year." One of the most common and simplistic approaches involves using 18 degree Celsius degree day data (which are readily available from Environment Canada) as the basis for normalization:

$$\text{Adjusted fuel consumption} = \text{Actual fuel consumption} * \left(\frac{\text{Base year DegreeDays}}{\text{Measured year Degree Days}} \right)$$

The choice of base year for this calculation depends on the application of the weatherized data. Choosing a specific base year only reflects energy consumption in that year, which may or may not be a "typical year." For the purpose of long-term end-use modelling, it is more relevant to adjust consumption data to a long-term average. The weatherization formula becomes:

$$\text{Adjusted fuel consumption} = \text{Actual fuel consumption} * \left(\frac{\text{Average Degree Days}}{\text{Actual Degree Days}} \right)$$

Weather adjustments are usually only necessary for heating and cooling end-uses. Generally, the base load, comprised of lighting, cooking and other non weather-sensitive end-uses, is not affected by outside temperature. Lighting is an important exception, since it can contribute significantly to heating and cooling loads. For example, a severe winter may result in increasing consumption of natural gas for heating, but this is not necessarily proportional to the change in temperature, due to the influence of lighting. Since the relationship between lighting and weather-sensitive loads is uncertain, it was not considered in the analysis of school energy consumption. Although this could be a limitation to the weather adjustment, engineers estimate that at the annual consumption level of analysis, it is difficult to assess the nature of these relationships (Webb, 1987).

In adjusting school consumption to reflect long-term average weather conditions, only the heating and ventilation portion of total consumption was normalized. Schools were weather-adjusted individually based on degree days within their location zones recorded at the time of the energy audit. Cooling was not addressed in this study since the audits do not provide enough data on air-conditioning penetrations and since air conditioning can be anticipated to have low penetrations in schools, which are generally closed during the summer.

One limitation to the weather-adjustment of school consumption is that since end-use consumption was analyzed on an annual basis in the audits, only annual consumption could be weather-adjusted. It would be more meaningful to analyze consumption on a monthly basis in future end-use analysis.

B. PROCEDURE

The weather-adjustment procedure followed for schools used thirty-year average degree days to normalize heating and ventilation consumption. These average degree days were obtained for several centers within each geographical zone identified in the audits, based on geographical area coefficients derived in another study (McVicar and Carroll, 1985). These coefficients describe fifty-year average degree days in major Manitoba centers relative to degree days in Winnipeg. The average coefficient for each zone was then multiplied by Winnipeg's thirty-year average, to derive the base for normalizing school energy consumption.

The method for estimating average degree days proved to be relatively accurate when compared to actual thirty-year averages for a sample of centers. The difference between thirty and fifty year averages was therefore considered to be negligible. The use of average coefficients for particular zones ignores potentially large degree day variation in larger zones, particularly the North, South-west and Parklands, by concealing variation within averages. Nonetheless, it was considered adequate for this analysis. The coefficients are presented in Table 15.

Thirty-year average degree days for Manitoba zones

ZONE	CENTER COEFF.	AVE. COEFF.	WINNIPEG 30-YEAR	ZONE 30-YEAR
1. WINNIPEG	1.00	--	10661.6	10661.6
2. SOUTH-CENTRAL				
Roblin	1.14	1.00	10661.6	10661.6
Morris	0.99			
Morden	0.96			
Emerson	0.92			
3. SOUTH-EAST				
Beausejour	1.01	1.03	10661.6	10981.5
Niverville	1.03			
Pinawa	1.07			
Pine Falls	1.05			
Steinbach	1.01			
Vita	0.99			
4. SOUTH-WEST				
Melita	1.00	1.04	10661.6	11088.1
Neepawa	1.03			
Brandon	1.08			
Virden	1.01			
Boissevain	0.98			
Minnedosa	1.11			
Souris	1.04			
Rivers	1.03			

ZONE	CENTER COEFF.	AVE. COEFF.	WINNIPEG 30-YEAR	ZONE 30-YEAR
5. NORTH-CENTRAL				
Portage La Prairie	0.99	0.99	10661.6	10555.0
6. INTERLAKE				
Arborg	1.13	1.07	10661.6	11407.9
Stonewall	1.04			
Selkirk	1.01			
Gimli	1.06			
Eriksdale	1.08			
Gypsumville	1.11			
Stony Mountain	1.03			
7. PARKLANDS				
Swan River	1.11	1.08	10661.6	11514.5
Russell	1.11			
Dauphin	1.08			
Ochre River	1.02			
8. NORTH				
Churchill	1.66	1.28	10661.6	13646.9
Flin Flon	1.17			
Lynn Lake	1.38			
Gillam	1.08			
Brochet	1.48			
Grand Rapids	1.20			
The Pas	1.00			
Wabowden	1.28			

APPENDIX C: SUMMARY OF END-USE PENETRATIONS

Current Penetration of Technology, Pc (%) - Percent of each Measure found in Current Building Stock

Engineering Interface Ltd. (1988:Appendix B)

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	10	10	10	10	10	10	10	10	10	10	10	10
High Efficiency Unitary Cooling	10	10	10	10	10	10	10	10	10	10	10	10
Low Wattage Par Incandescent	5	5	2	1	5	10	10	20	5	2	2	2
Screw-In Fluorescent	5	5	5	1	5	10	5	10	10	5	5	2
Energy Efficient Fluorescent	35	20	15	5	10	20	20	20	10	5	10	15
Energy Efficient Ballasts	2	2	1	1	1	3	1	2	1	1	1	1
High Efficiency Luminaires	1	1	1	1	1	1	1	1	1	1	1	1
Light Switching	80	60	60	70	20	20	20	20	40	30	35	20
Lighting Automation	10	10	10	0	10	10	10	10	10	10	10	10
Occupancy Lighting Controls	0	0	0	0	0	0	0	0	0	0	0	0
Daylighting	20	10	10	0	10	5	5	5	10	5	10	15
Energy Efficient Motors	2	3	3	0	0	3	1	1	1	1	1	1
Variable Speed Drives	1	5	1	0	0	5	1	1	1	0	0	0
Energy Management Control System	25	35	20	1	10	30	25	25	15	10	10	10
Air Balancing	5	5	10	1	1	15	5	5	5	1	1	1
Water Balancing	5	5	10	1	1	15	5	5	5	1	1	1
Power Factor Correction	1	1	1	1	1	1	1	1	1	1	1	1
Cogeneration	1	2	1	0	0	0	0	0	0	0	0	0

Penetration of Technology in the Year 2000
without Initiatives, P (%) - Percent of each Measure found in 2000 Building Stock Engineering Interface Ltd. (1988:Appendix B)

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	20	20	20	20	20	20	20	20	20	20	20	20
High Efficiency Unitary Cooling	15	15	15	15	15	15	15	15	15	15	15	15
Low Wattage Par Incandescent	20	25	25	4	20	40	30	60	40	20	20	10
Screw-In Fluorescent	15	15	7	3	15	30	40	60	15	7	7	7
Energy Efficient Fluorescent	65	45	35	15	25	45	45	45	25	15	25	35
Energy Efficient Ballasts	10	10	5	5	5	15	5	10	5	5	5	5
High Efficiency Luminaires	10	10	10	10	10	10	10	10	10	10	10	10
Light Switching	80	60	60	70	30	35	35	30	45	35	40	30
Lighting Automation	20	20	20	5	20	20	20	20	20	20	20	20
Occupancy Lighting Controls	5	5	5	5	5	5	5	5	5	5	5	5
Daylighting	25	12	12	5	12	7	7	7	12	7	12	20
Energy Efficient Motors	10	15	15	5	5	15	5	5	5	5	5	5
Variable Speed Drives	5	20	5	4	4	20	5	5	5	4	4	4
Energy Management Control System	45	55	40	20	30	50	45	45	35	30	30	30
Air Balancing	10	10	15	5	5	20	10	10	10	5	5	5
Water Balancing	10	10	15	5	5	20	10	10	10	5	5	5
Power Factor Correction	5	5	5	5	5	5	5	5	5	5	5	5
Cogeneration	5	10	5	0	0	0	0	0	0	0	0	0

Penetration of Technology in the Year 2000
with Initiative, P' (%) Percent of each Measure found in 2000 Stock Engineering Interface Ltd. (1988:Appendix B)

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	40	40	40	40	40	40	40	40	40	40	40	40
High Efficiency Unitary Cooling	40	40	40	40	40	40	40	40	40	40	40	40
Low Wattage Par Incandescent	30	40	40	6	30	60	45	90	60	30	30	15
Screw-In Fluorescent	25	25	10	5	25	40	60	90	25	10	10	10
Energy Efficient Fluorescent	85	70	60	25	40	70	70	70	40	25	40	60
Energy Efficient Ballasts	25	25	20	20	30	20	25	20	20	20	20	20
High Efficiency Luminaires	25	25	25	25	25	25	25	25	25	25	25	25
Light Switching	80	60	60	70	50	50	50	50	50	50	50	50
Lighting Automation	40	40	40	10	40	40	40	40	40	40	40	40
Occupancy Lighting Controls	25	25	25	25	25	25	25	25	25	25	25	25
Daylighting	50	25	25	10	25	20	20	20	25	20	25	40
Energy Efficient Motors	30	50	50	25	25	50	25	25	25	25	25	25
Variable Speed Drives	25	50	25	20	20	50	25	25	25	20	20	20
Energy Management Control System	65	70	60	40	50	65	60	60	55	50	50	50
Air Balancing	50	50	60	40	40	70	50	50	50	40	40	40
Water Balancing	35	35	40	30	30	45	35	35	35	30	30	30
Power Factor Correction	40	50	50	20	20	40	30	30	40	30	30	30
Cogeneration	25	50	25	5	5	15	5	10	5	5	5	5

APPENDIX D: CONSERVATION MEASURES

The following information on the various conservation measures was used to analyze their costs and impacts for each of the three building types -HOSPITALS, PERSONAL CARE HOMES, AND COMBINATIONS.

Fluorescent Lighting

The standard unit of analysis of energy conservation in fluorescent lighting is the four-foot two-40W lamp luminaire with a 16W ballast.

The Level One measure for fluorescent lighting consists of replacing the 40W lamps with energy efficient lamps drawing 34W and of replacing the 16W ballast with an energy efficient ballast drawing 10W. Combined with the ballast savings due to the lower wattage lamps, the total savings are about 21% of the baseline technology (40W lamps, 16W ballast). The lighting level is reduced 7% to 12% (Marbek 1987:29). A $0.74 premium and 5 year lifetime are assumed for the lamps and a $3.06 premium and 20 year lifetime are assumed for the ballast (based on calculations).

The Level Two measure for fluorescent lighting noted here was not assessed in this study but is included for interest and for future studies. It includes adding an annodized aluminum reflector to the luminaire. This allows half of the lamps to be eliminated. The remaining lamps are replaced with high output 40W lamps (which draw 48W) to ensure lighting levels are maintained. The ballast is replaced with a 10W ballast. The premium of the lamps is $11.20 with a 5 year lifetime. The ballast has a premium of $68.01, with a lifetime of 20 years, and the reflector has a premium of $48 with a lifetime of 20 years.

The Level Three measure for fluorescent lighting includes installation of electronic, dimmable ballasts with photocell controls, reflectors and high output 40W lamps (which draw 48W). The premium for the lamps is $11.20 with a 5 year lifetime, the premium for the ballast is $65 (Marbek 1987:30) with a 20 year lifetime, the premium for the reflector is $48 with a 20 year lifetime, the premium for the dimmer is $20 with a 20 year lifetime, and the premium for the photocell controller is $50/fixture (installed cost) with a 20 year lifetime.

Compact Fluorescent

The Compact Fluorescent measure consists of replacing incandescent bulbs (ave. wattage of 100W) with 22W fluorescent compact lamp. The premium is $27 with a 10,000 hour (2.5 years) lifetime

Motors - Balancing

The cost and savings figures from Marbek (1987) and Engineering Interface Ltd. (1988) were used to compute fan and pump motor electricity savings due to air and water balancing.

Energy Efficient Motors

The cost and savings figures from Marbek (1987) and Engineering Interface Ltd. (1988) were used to compute electricity savings due to replacement of electric motors by energy efficient motors.

Motor Scheduling (Energy Management Control Systems)

Costs per unit floor area and electricity savings for motor scheduling are taken from Marbek (1987).

Cooling

Two cooling measures were assessed in this study - High Efficiency Central Cooling, and High Efficiency Unitary Cooling. The baseline technology was considered to be a standard selection chiller. The cost and energy savings for these measures were obtained from Marbek (1987).

APPENDIX E: DATA BASE SUMMARY

The following ENERGY TECHNOLOGY DATA BASE does not include interactive effects which exist between conservation measures.

The technical potentials in the following summary are taken from Engineering Interface Ltd, 1988, and are the current market penetration and the expected penetration rates in the year 2000. It is important to note that the calculations in the body of this report used total technical potential (P = 1.0). This assumes that all existing inefficient equipment will be replaced by efficient equipment.

Measure: Level one fluorescent lighting
End-use: Lighting
Building sector: Hospital
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 36,422,240 KWh
Applicability (A): 0.82
Energy Savings (S): 0.21
Current Market Penetration (Pc): 0.15
Market Penetration in 2000 (P): 0.35
Cost per KWh: 0.45 cents

Measure: Level two fluorescent lighting
End-use: Lighting
Building sector: Hospital
Fuel type: Electric
Vintage: All existing building Stock
Baseline energy use (BE): 36,422,240 KWh
Applicability (A): ?
Energy Savings (S): 0.45
Current Market Penetration (Pc):
Market Penetration in 2000 (P):
Cost per KWh: 2.93 cents per KWh

Measure: Level three fluorescent lighting
End-use: Lighting
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 36,422,240 KWh
Applicability (A): 0.25
Energy Savings (S): 0.48
Current Market Penetration (Pc): 0.01
Market Penetration in 2000 (P): 0.10
Cost per KWh: 3.96 cents per KWh

Measure: Compact fluorescent
End-use: Lighting
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 36,422,240 KWh
Applicability (A): 0.03
Energy Savings (S): 0.63
Current Market Penetration (Pc): 0.05
Market Penetration in 2000 (P): 0.25
Cost per KWh: 6.90

Measure: High efficiency central cooling
End-use: Space cooling
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 15,681,327 KWh
Applicability (A): 0.83
Energy Savings (S): 0.18
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.20
Cost per KWh: 2.00

Measure: High efficiency unitary cooling
End-use: Space cooling
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 15,681,327 KWh
Applicability (A): 0.22
Energy Savings (S): 0.12
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.15
Cost per KWh: 2.00

Measure: Energy efficient motors
End-use: Motors
Building sector: Hospitals
Fuel type:Electric
Vintage: All existing building stock
Baseline energy use (BE): 25,919,082 KWh
Applicability (A): 0.82
Energy Savings (S): 0.07
Current Market Penetration (Pc): 0.03
Market Penetration in 2000 (P): 0.15
Cost per KWh: 0.71

Measure: Motor scheduling
End-use: Motors
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 25,919,082 KWh
Applicability (A): 0.19
Energy Savings (S): 0.20
Current Market Penetration (Pc): 0.20
Market Penetration in 2000 (P): 0.40
Cost per KWh: 1.63

Measure: Motor balancing - Air
End-use: Motors
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 25,919,082 KWh
Applicability (A): 0.33
Energy Savings (S): 0.25
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.15
Cost per KWh: 1.34

Measure: Motor balancing - Water
End-use: Motors
Building sector: Hospitals
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 25,919,082 KWh
Applicability (A): 0.07
Energy Savings (S): 0.15
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.15
Cost per KWh: 1.34

Measure: Level one fluorescent lighting
End-use: lighting
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 19,074,824 KWh
Applicability (A): 0.56
Energy Savings (S): 0.21
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.25
Cost per KWh: 0.45

Measure: Level two fluorescent lighting
End-use: Lighting
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 19,074,824 KWh
Applicability (A):
Energy Savings (S): 0.45
Current Market Penetration (Pc):
Market Penetration in 2000 (P):
Cost per KWh: 2.93

Measure: Level three fluorescent lighting
End-use: Lighting
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 19,074,824 KWh
Applicability (A): 0.25
Energy Savings (S): 0.48
Current Market Penetration (Pc): 0.01
Market Penetration in 2000 (P): 0.10
Cost per KWh: 3.96 cents per KWh

Measure: Compact fluorescent
End-use: Lighting
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 19,074,824 KWh
Applicability (A): 0.05
Energy Savings (S): 0.63
Current Market Penetration (Pc): 0.05
Market Penetration in 2000 (P): 0.20
Cost per KWh: 6.90 cents per KWh

Measure: High efficiency central cooling
End-use: Space cooling
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 7,672,555 KW.h
Applicability (A): 0.22
Energy Savings (S): 0.18
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.20
Cost per KWh: 2.00 cents per KWh

Measure: High efficiency unitary cooling
End-use: Space cooling
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 7,672,555 KW.h
Applicability (A): 0.67
Energy Savings (S): 0.12
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.15
Cost per KWh: 2.00 cents per KWh

Measure: Energy efficient motors
End-use: Motors
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 18,488,725 KWh
Applicability (A): 0.60
Energy Savings (S): 0.07
Current Market Penetration (Pc): 0.00
Market Penetration in 2000 (P): 0.05
Cost per KWh: 0.71 cents per KWh

Measure: Motor scheduling
End-use: Motors
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 18,488,725 KWh
Applicability (A): 0.28
Energy Savings (S): 0.20
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.30
Cost per KWh: 1.63 cents per KWh

Measure: Motor balancing - Air
End-use: Motors
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 1,848,8725 KWh
Applicability (A): 0.20
Energy Savings (S): 0.25
Current Market Penetration (Pc): 0.01
Market Penetration in 2000 (P): 0.05
Cost per KWh: 1.34 cents per KWh

Measure: Motor balancing - Air
End-use: Motors
Building sector: Personal care home
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 18,488,725 KWh
Applicability (A): 0.02
Energy Savings (S): 0.15
Current Market Penetration (Pc): 0.01
Market Penetration in 2000 (P): 0.05
Cost per KWh: 1.34 cents per KWh

Measure: Level one fluorescent lighting
End-use: Lighting
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,865,800 KWh
Applicability (A): 0.69
Energy Savings (S): 0.21
Current Market Penetration (Pc): 0.13
Market Penetration in 2000 (P): 0.30
Cost per KWh: 0.45 cents per KWh

Measure: Level two florescent lighting
End-use: Lighting
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,865,800 KWh
Applicability (A):
Energy Savings (S): 0.45
Current Market Penetration (Pc):
Market Penetration in 2000 (P):
Cost per KWh: 2.93 cents per KWh

Measure: Level three fluorescent lighting
End-use: Lighting
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,865,800 KWh
Applicability (A): 0.25
Energy Savings (S): 0.48
Current Market Penetration (Pc): 0.01
Market Penetration in 2000 (P): 0.10
Cost per KWh: 3.96 cents per KWh

Measure: Compact fluorescent
End-use: Lighting
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,865,800 KWh
Applicability (A): 0.04
Energy Savings (S): 0.63
Current Market Penetration (Pc): 0.05
Market Penetration in 2000 (P): 0.23
Cost per KWh: 6.90 cents per KWh

Measure: High efficiency central cooling
End-use: Space cooling
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 1,935,846 KWh
Applicability (A): 0.53
Energy Savings (S): 0.18
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.20
Cost per KWh: 2.00 cents per KWh

Measure: High efficiency unitary cooling
End-use: Space cooling
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 1,935,846 KWh
Applicability (A): 0.45
Energy Savings (S): 0.12
Current Market Penetration (Pc): 0.10
Market Penetration in 2000 (P): 0.15
Cost per KWh: 2.00 cents per KWh

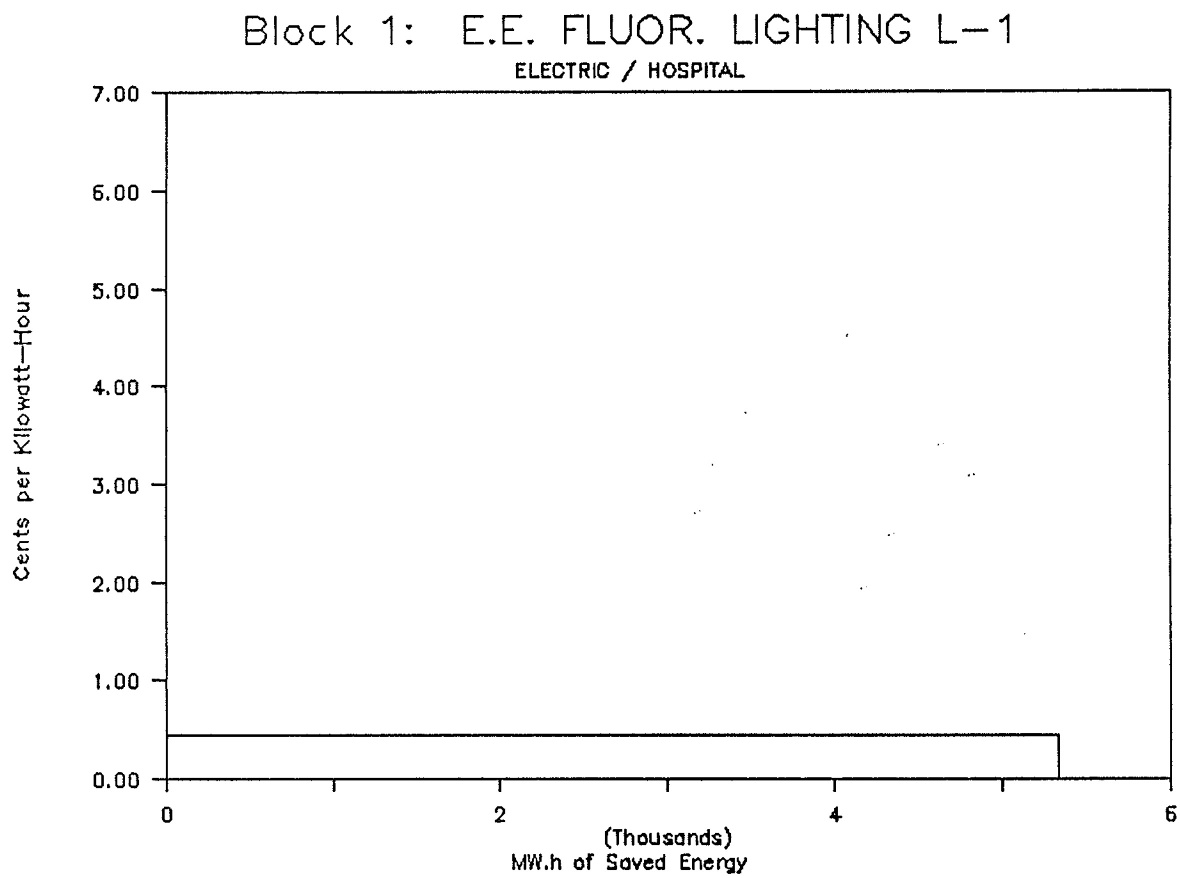
Measure: Energy efficient motors
End-use: Motors
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,917,423 KWh
Applicability (A): 0.71
Energy Savings (S): 0.07
Current Market Penetration (Pc): 0.02
Market Penetration in 2000 (P): 0.10
Cost per KWh: 0.71 cents per KWh

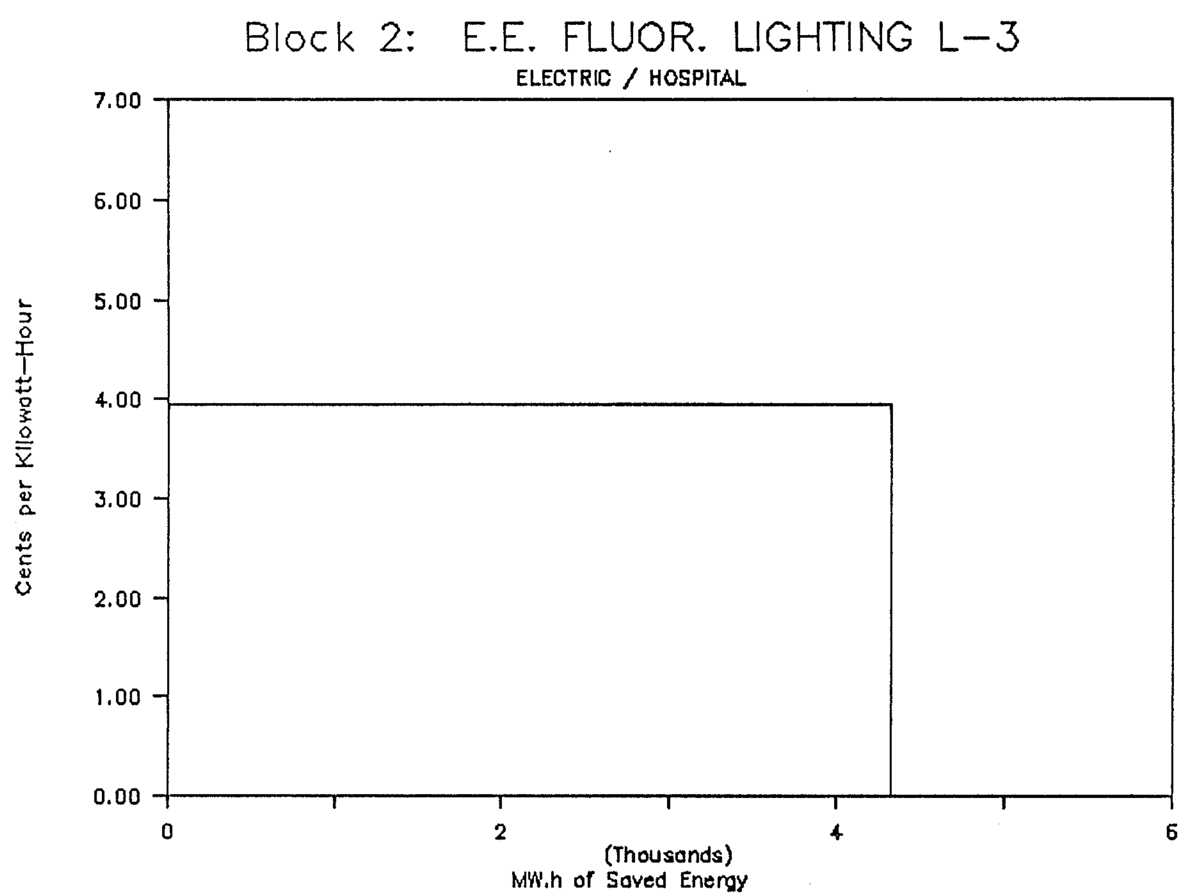
Measure: Motor scheduling
End-use: Motors
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,917,423 KWh
Applicability (A): 0.24
Energy Savings (S): 0.20
Current Market Penetration (Pc): 0.15
Market Penetration in 2000 (P): 0.35
Cost per KWh: 1.63 cents per KWh

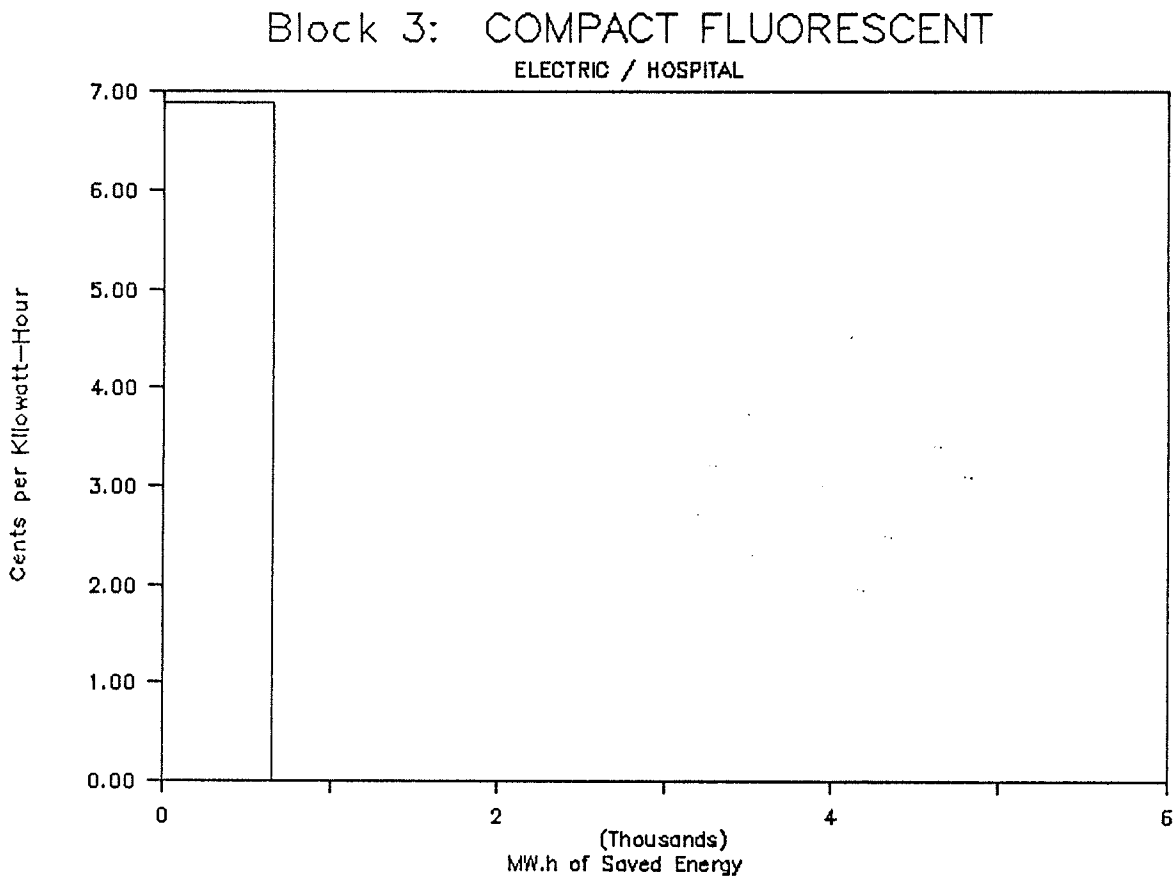
Measure: Motor Balancing - Air
End-use: Motors
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,917,423 KWh
Applicability (A): 0.27
Energy Savings (S): 0.25
Current Market Penetration (Pc): 0.06
Market Penetration in 2000 (P): 0.10
Cost per KWh: 1.34 cents per KWh

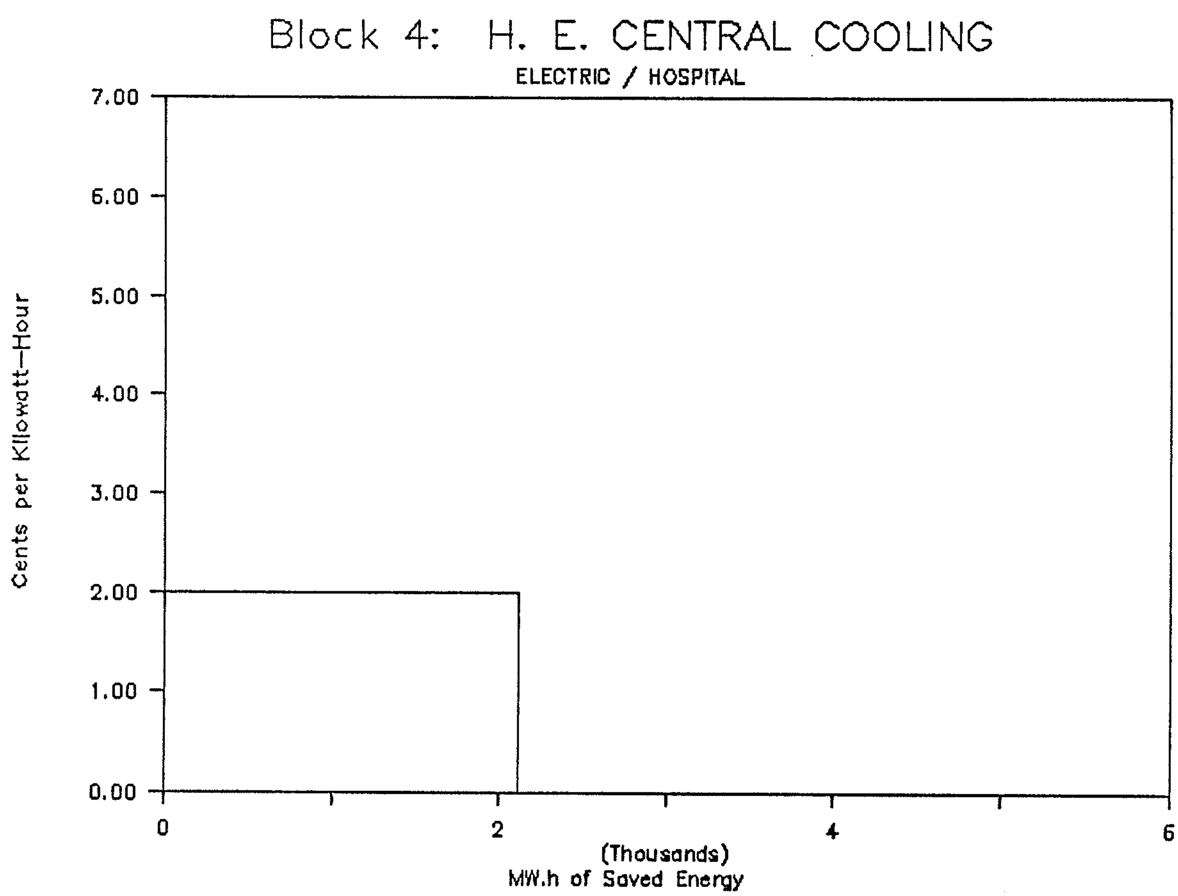
Measure: Motor balancing - Water
End-use: Motors
Building sector: Combination Hosp/PCH
Fuel type: Electric
Vintage: All existing building stock
Baseline energy use (BE): 6,917,423 KWh
Applicability (A): 0.05
Energy Savings (S): 0.15
Current Market Penetration (Pc): 0.06
Market Penetration in 2000 (P): 0.10
Cost per KWh: 1.34 cents per KWh

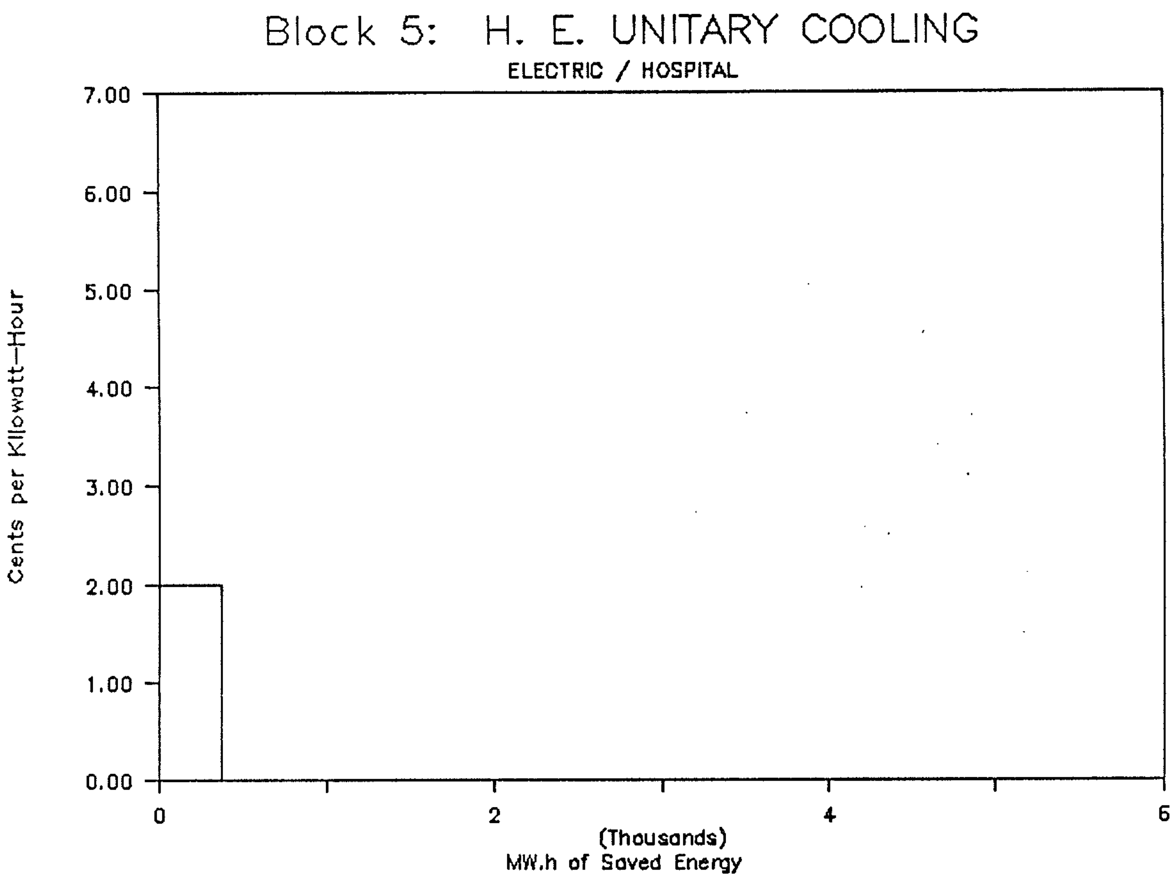
APPENDIX F: SUPPLY CURVES OF CONSERVED ENERGY

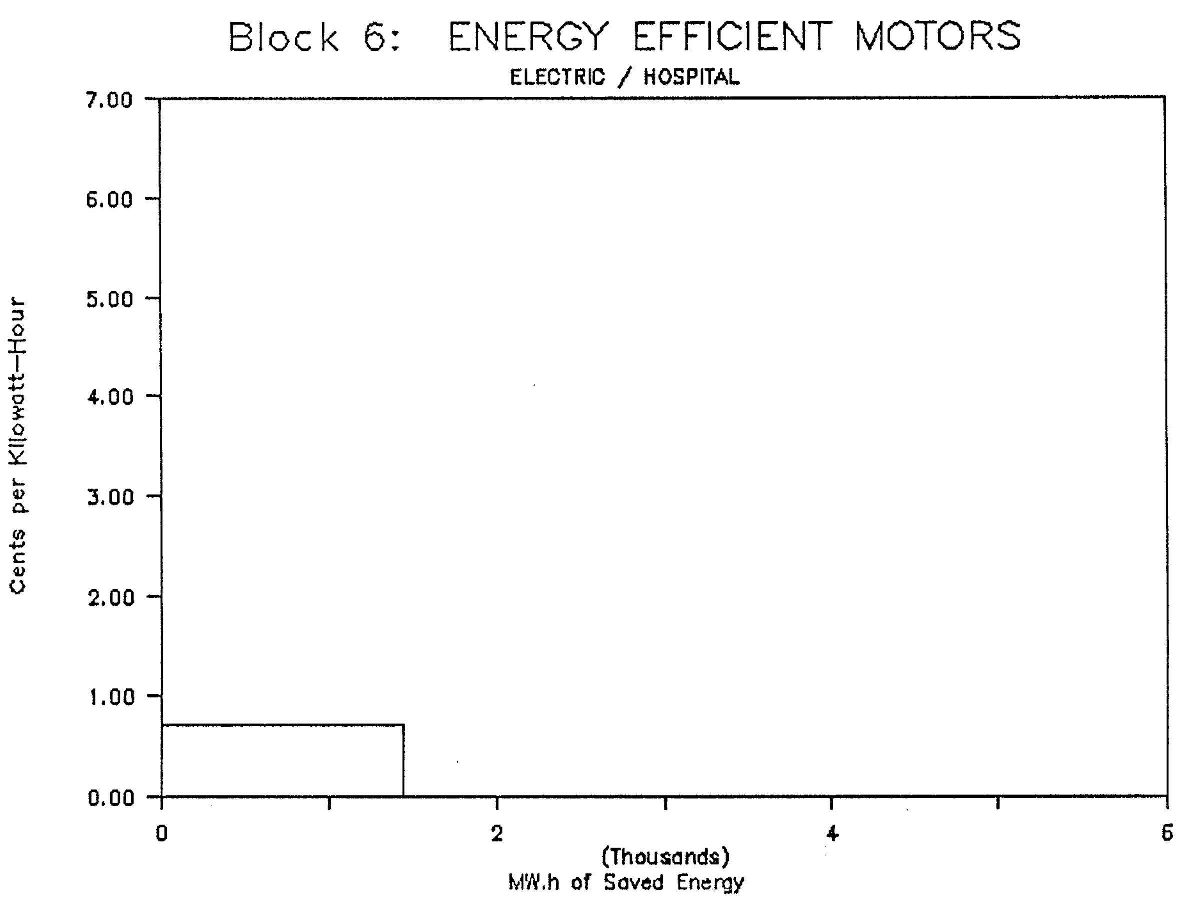

Block 1: E.E. FLUOR. LIGHTING L-1
ELECTRIC / HOSPITAL
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Cents per Kilowatt-Hour
0
2
4
6
(Thousands)
MW.h of Saved Energy

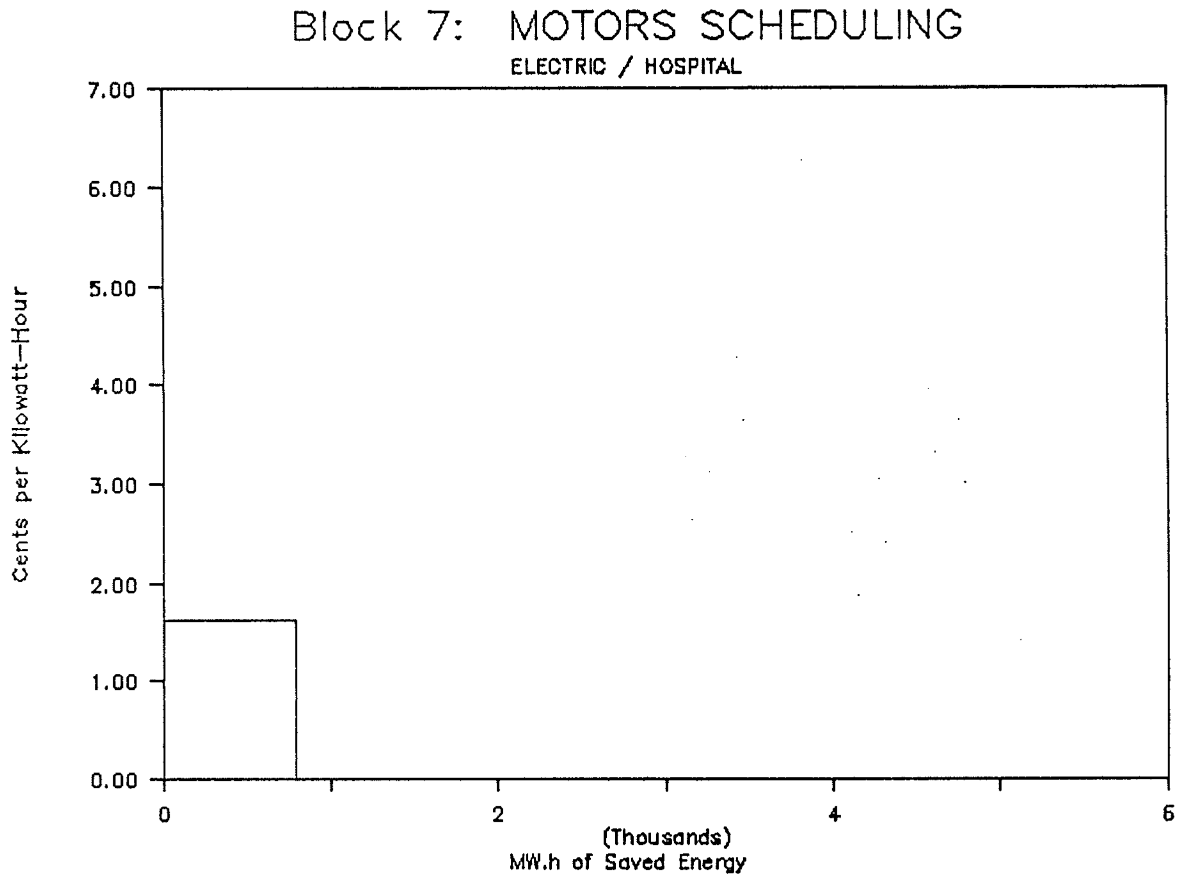

Block 2: E.E. FLUOR. LIGHTING L-3
ELECTRIC / HOSPITAL
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Cents per Kilowatt-Hour
0
2
4
6
(Thousands)
MW.h of Saved Energy

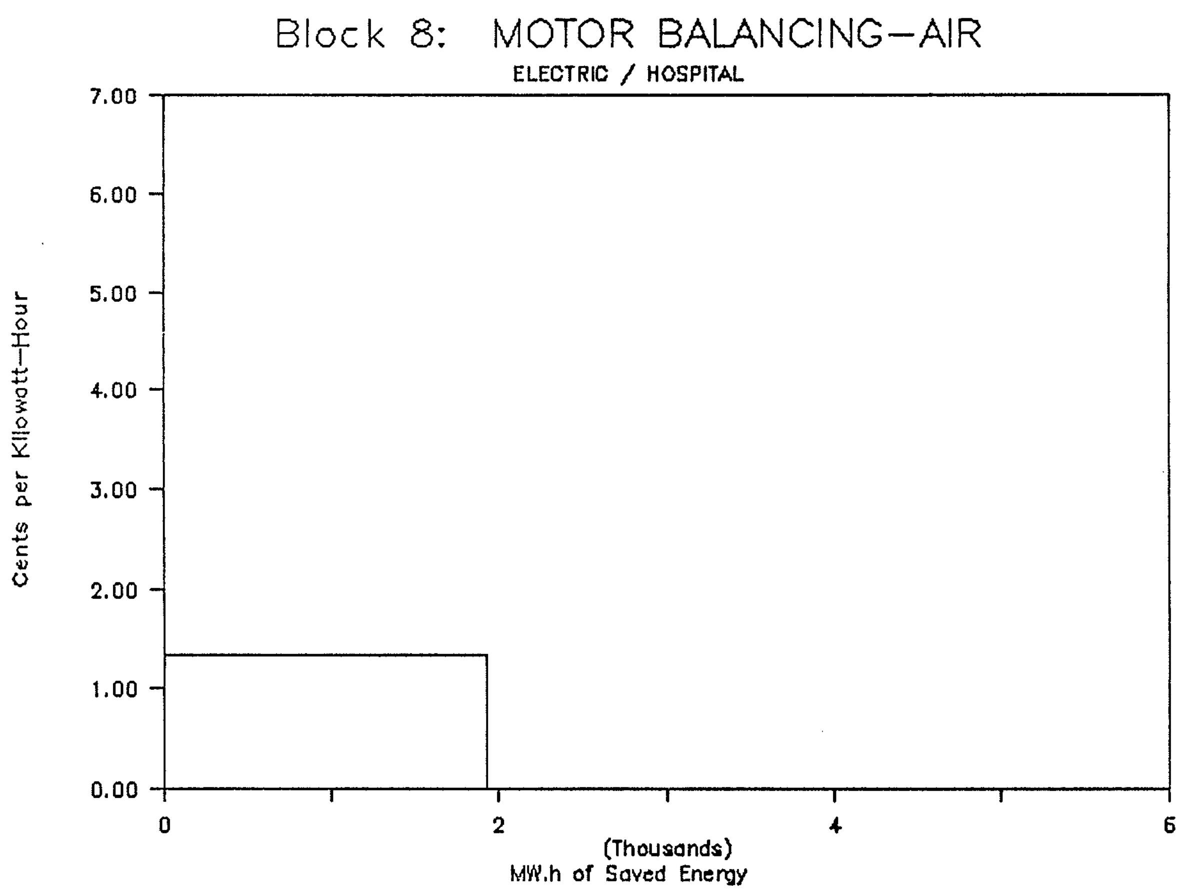

Block 3: COMPACT FLUORESCENT
ELECTRIC / HOSPITAL
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 4: H. E. CENTRAL COOLING
ELECTRIC / HOSPITAL
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 5: H. E. UNITARY COOLING
ELECTRIC / HOSPITAL
Cents per Kilowatt—Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy

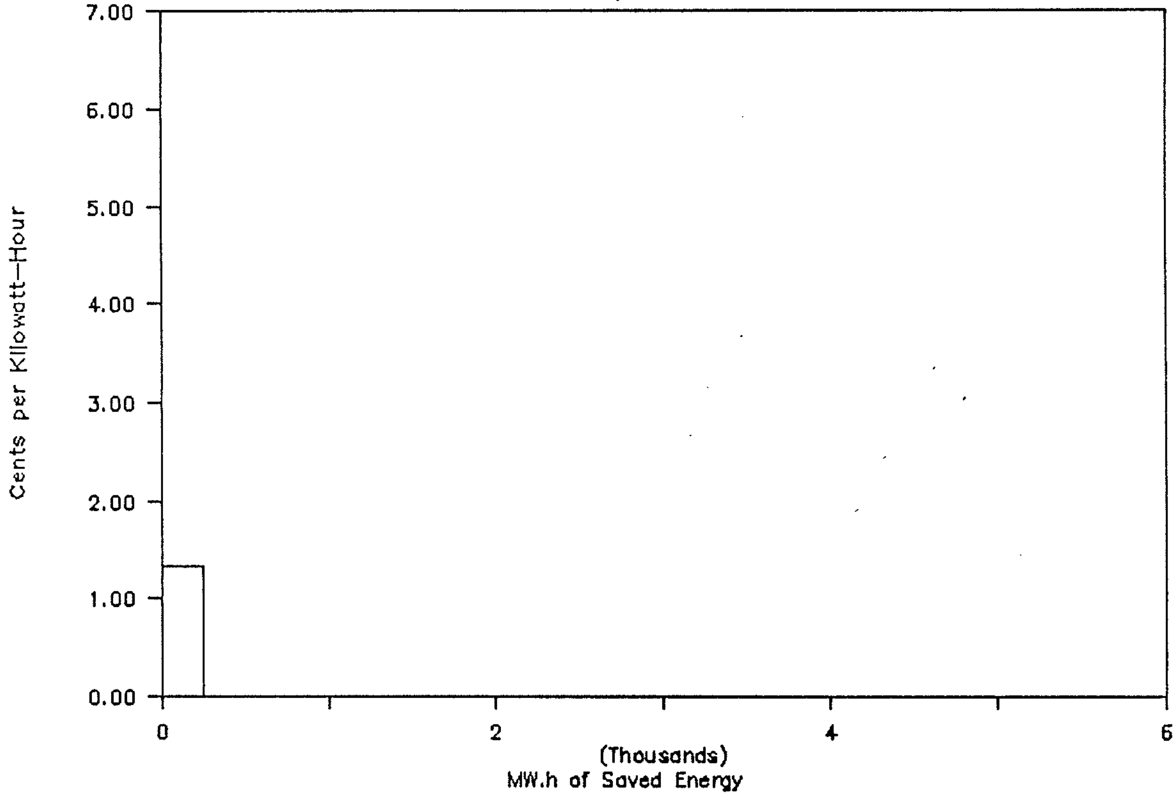

Block 6: ENERGY EFFICIENT MOTORS
ELECTRIC / HOSPITAL
Cents per Kilowatt—Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 7: MOTORS SCHEDULING
ELECTRIC / HOSPITAL
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 8: MOTOR BALANCING-AIR
ELECTRIC / HOSPITAL
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy

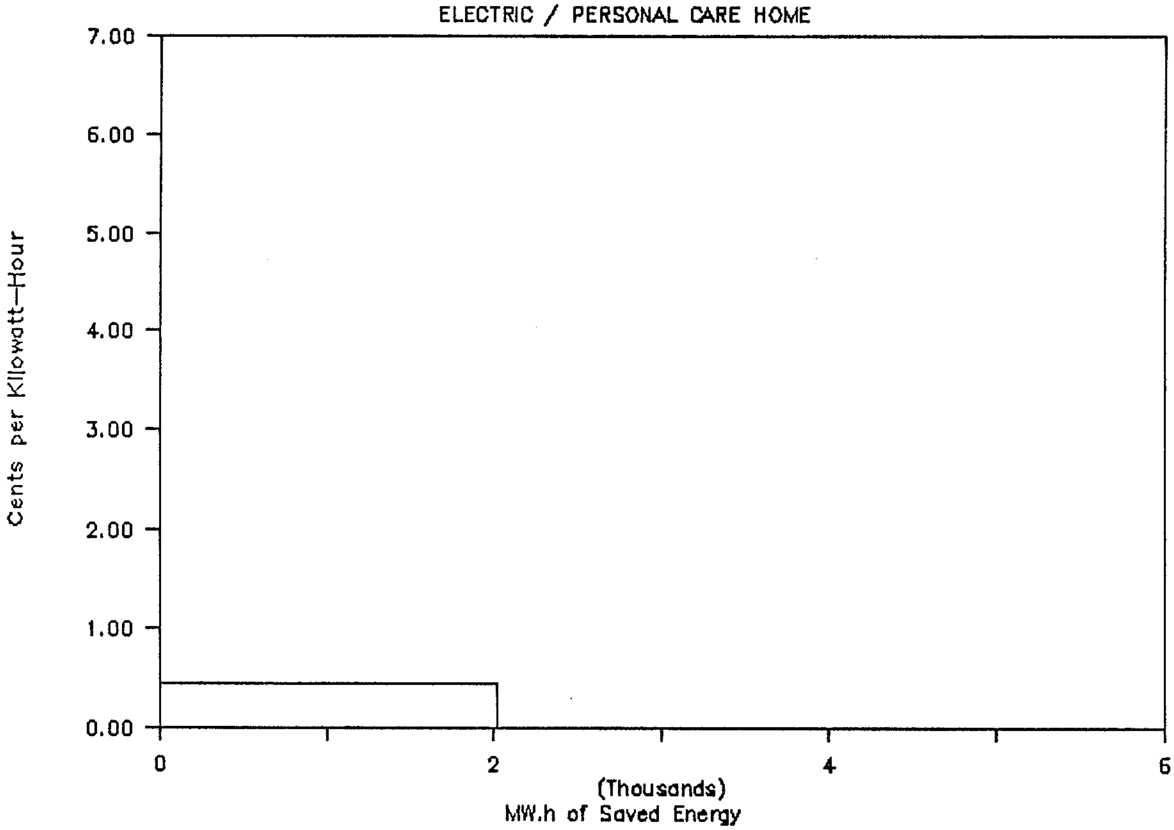
Block 9: MOTOR BALANCING—WATER

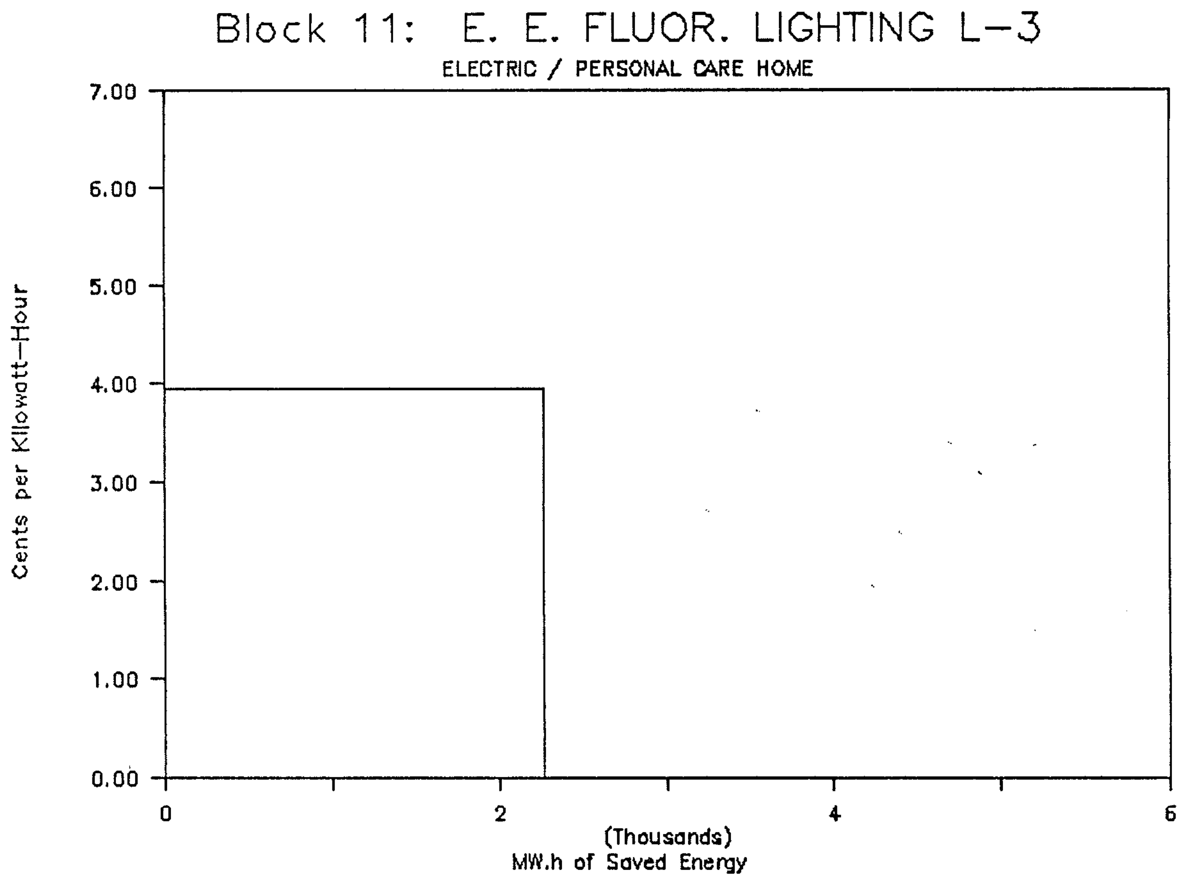
ELECTRIC / HOSPITAL

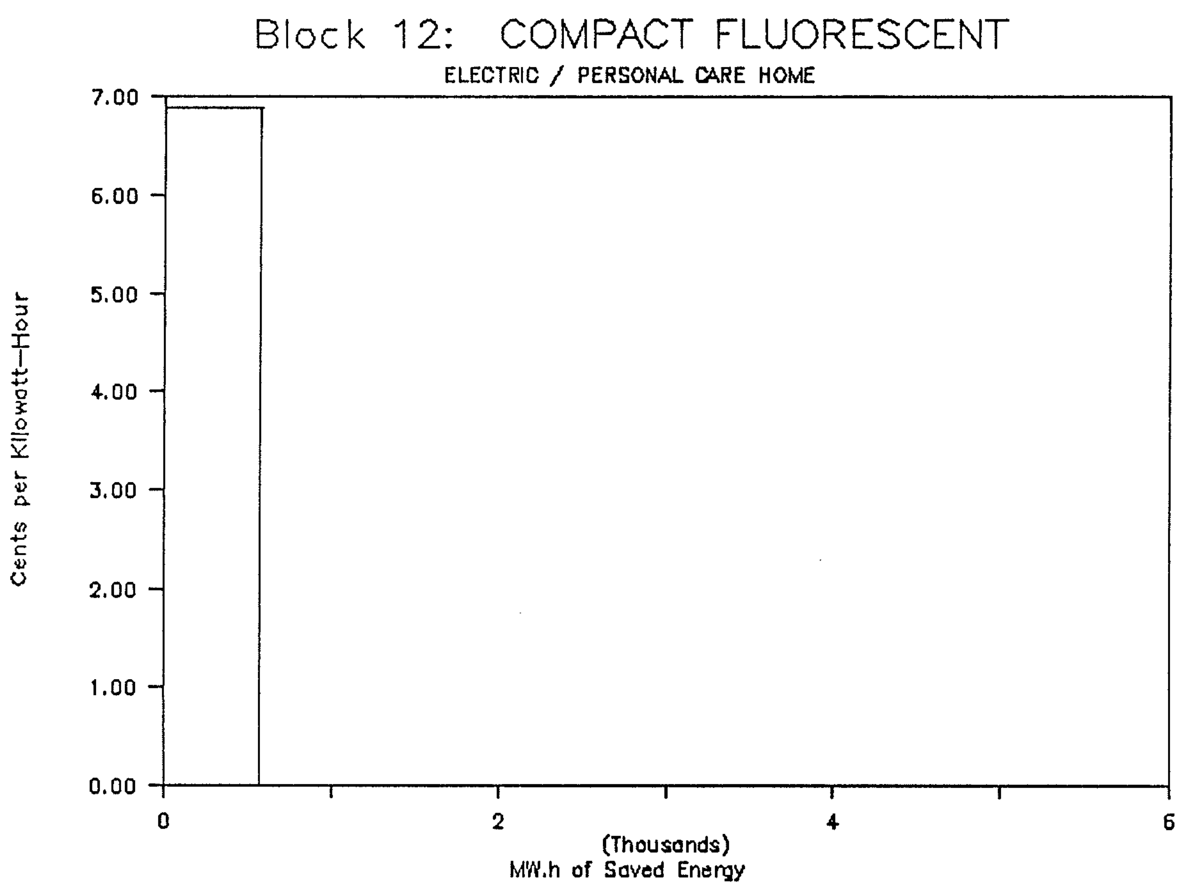


Block 10: E. E. FLUOR. LIGHTING L-1

ELECTRIC / PERSONAL CARE HOME

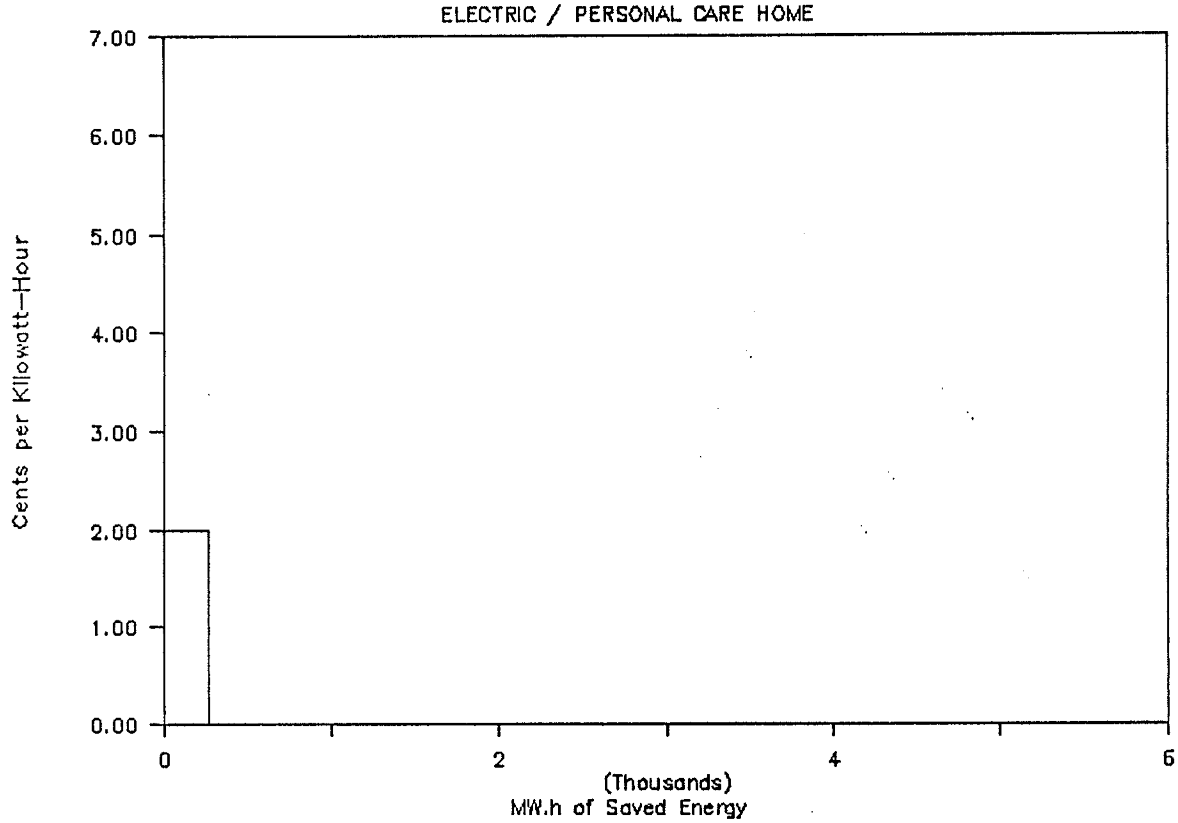



Block 11: E. E. FLUOR. LIGHTING L-3
ELECTRIC / PERSONAL CARE HOME
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 12: COMPACT FLUORESCENT
ELECTRIC / PERSONAL CARE HOME
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy

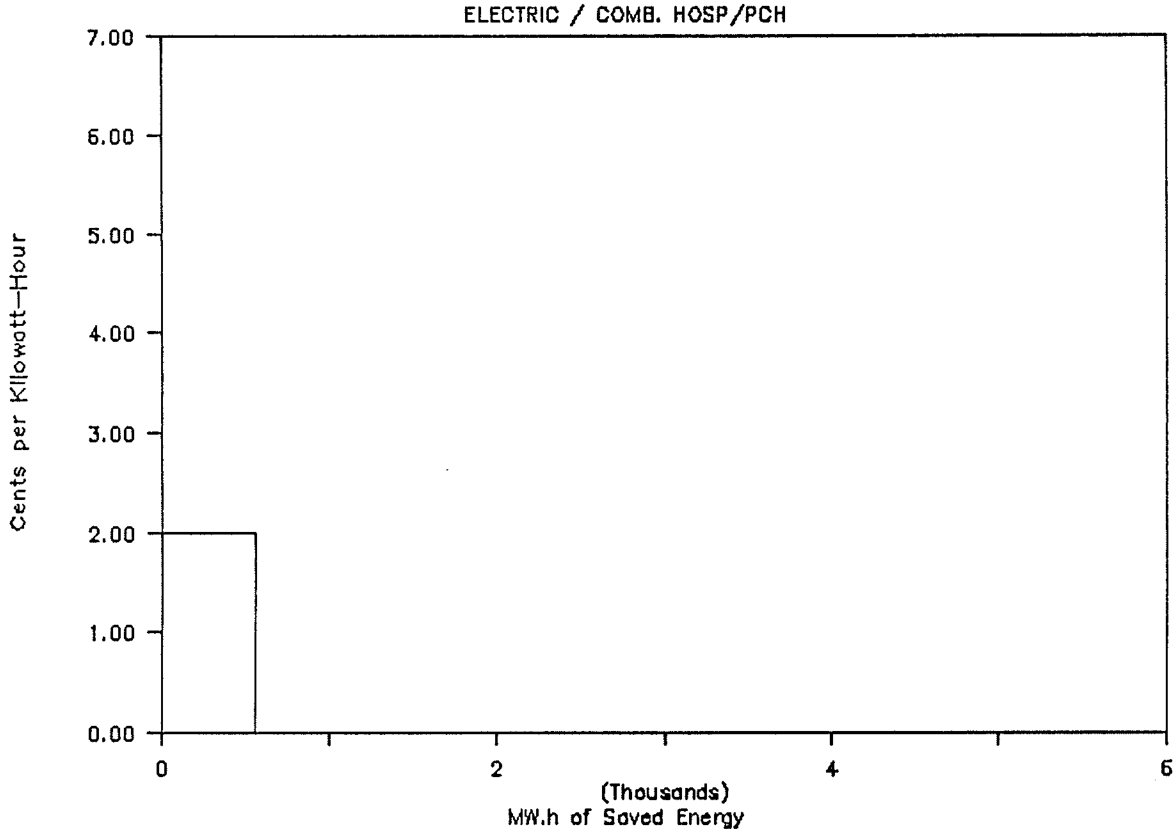
Block 13: H. E. CENTRAL COOLING

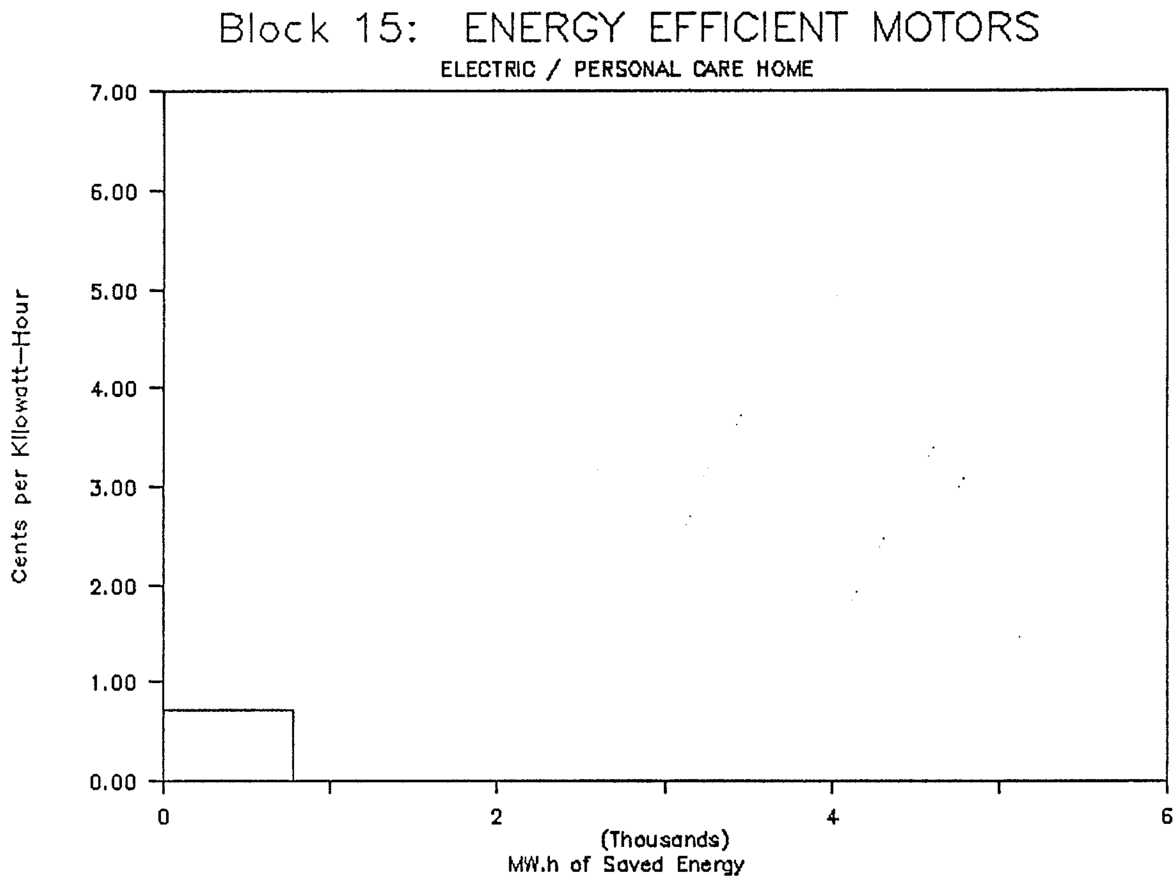
ELECTRIC / PERSONAL CARE HOME

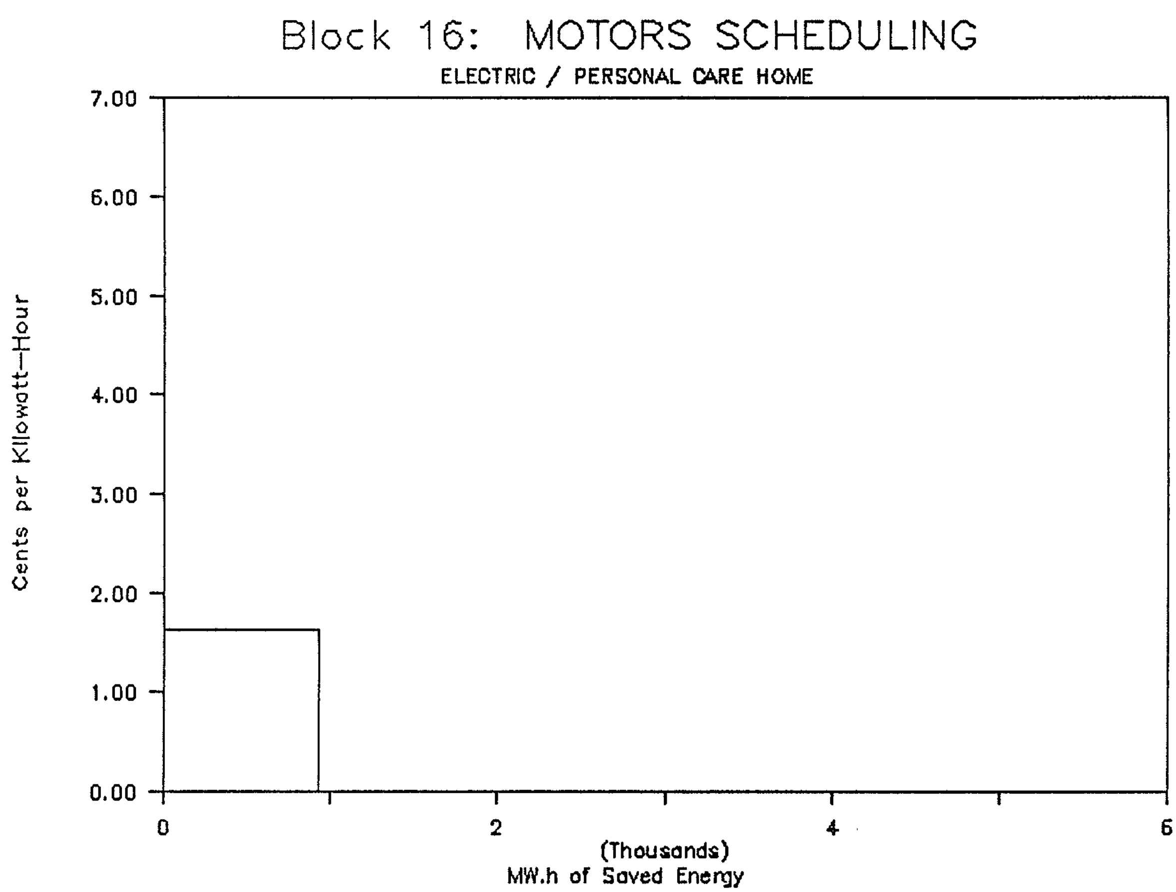


Block 14: H.E. UNITARY COOLING

ELECTRIC / COMB. HOSP/PCH

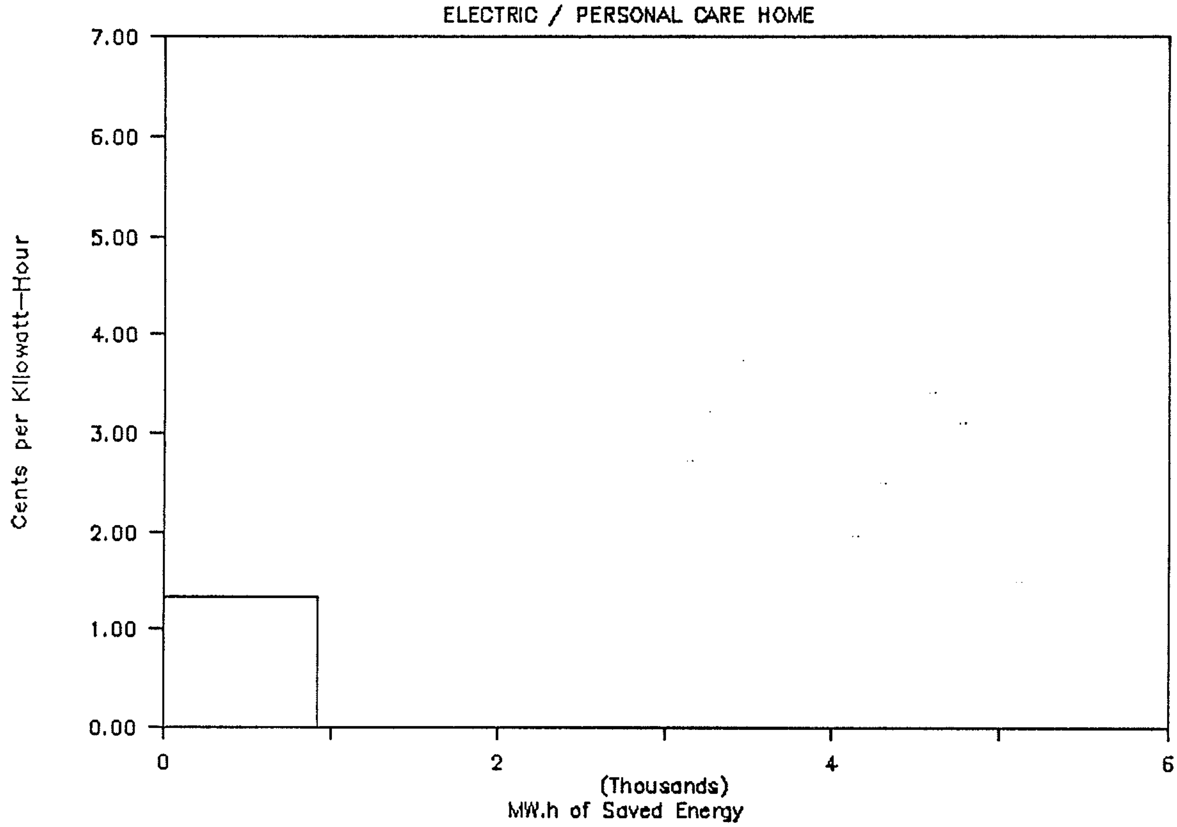



Block 15: ENERGY EFFICIENT MOTORS
ELECTRIC / PERSONAL CARE HOME
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 16: MOTORS SCHEDULING
ELECTRIC / PERSONAL CARE HOME
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy

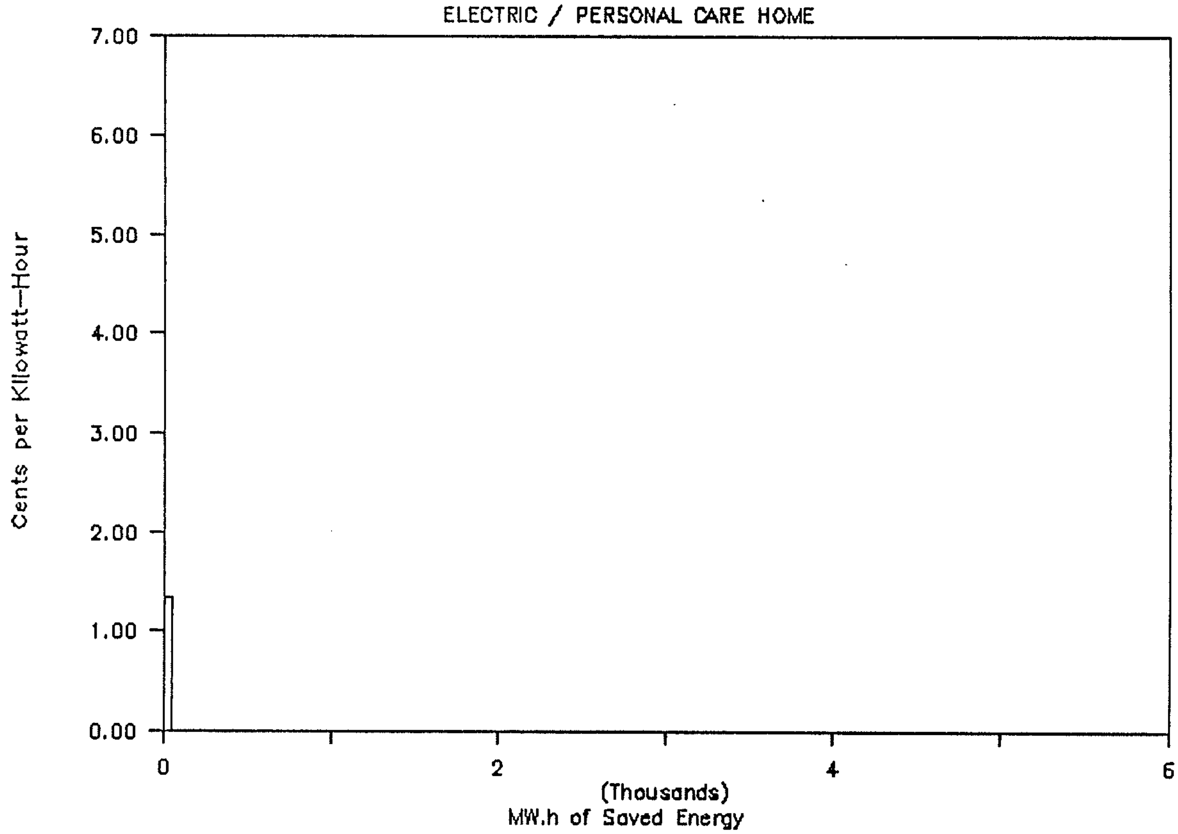
Block 17: MOTOR BALANCING–AIR

ELECTRIC / PERSONAL CARE HOME



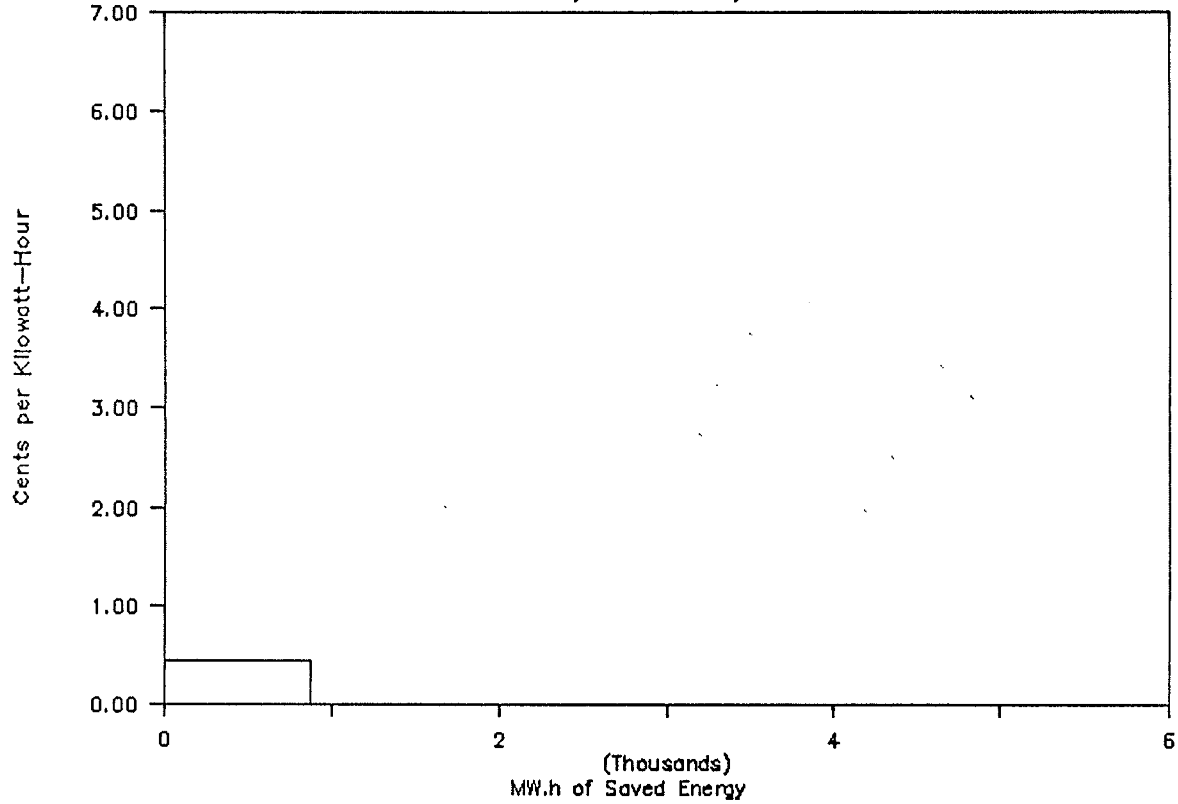
Block 18: MOTOR BALANCING–WATER

ELECTRIC / PERSONAL CARE HOME



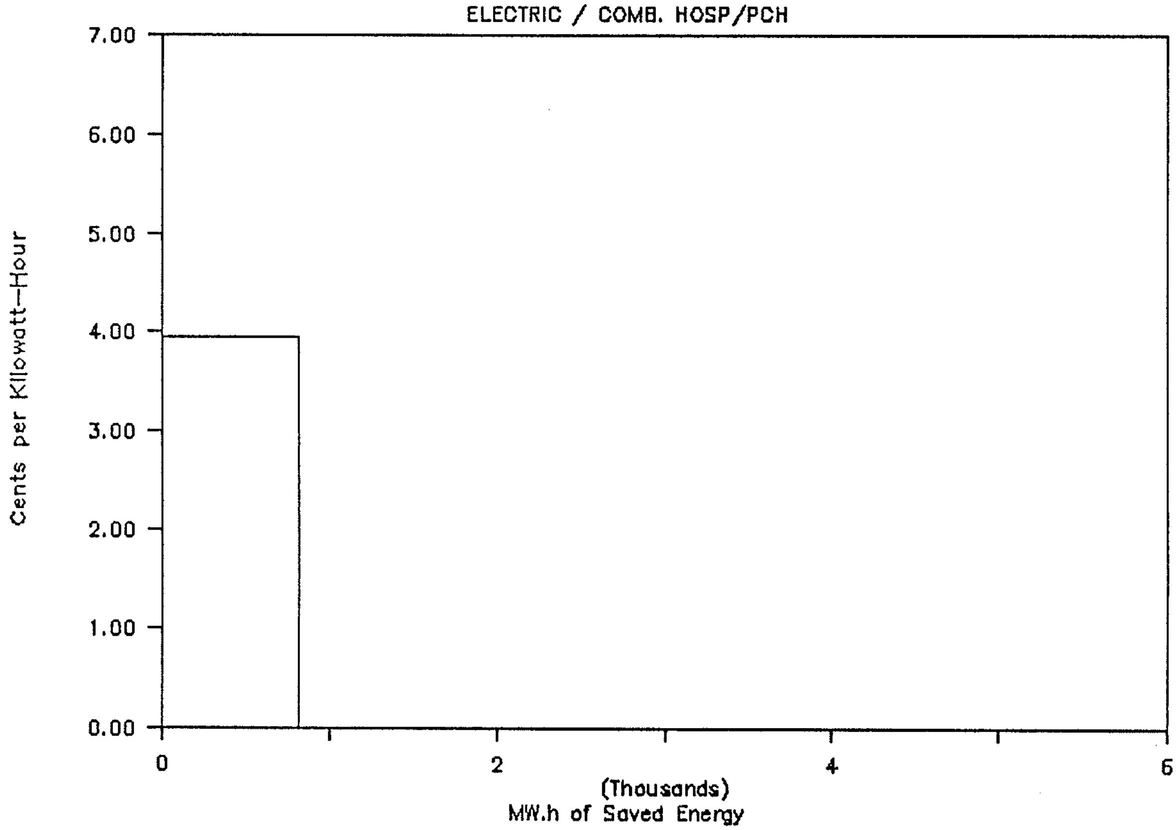
Block 19: E. E. FLUOR. LIGHTING L-1

ELECTRIC / COMB. HOSP/PCH



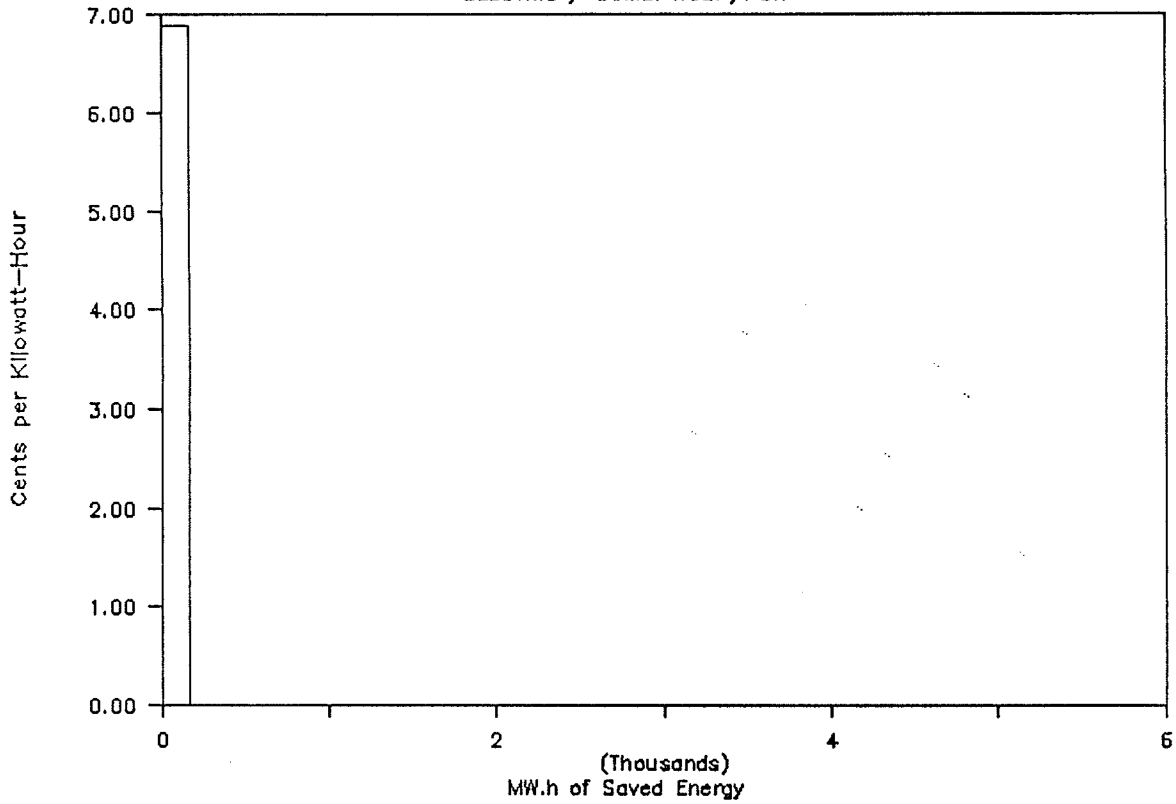
Block 20: E. E. FLUOR. LIGHTING L-3

ELECTRIC / COMB. HOSP/PCH



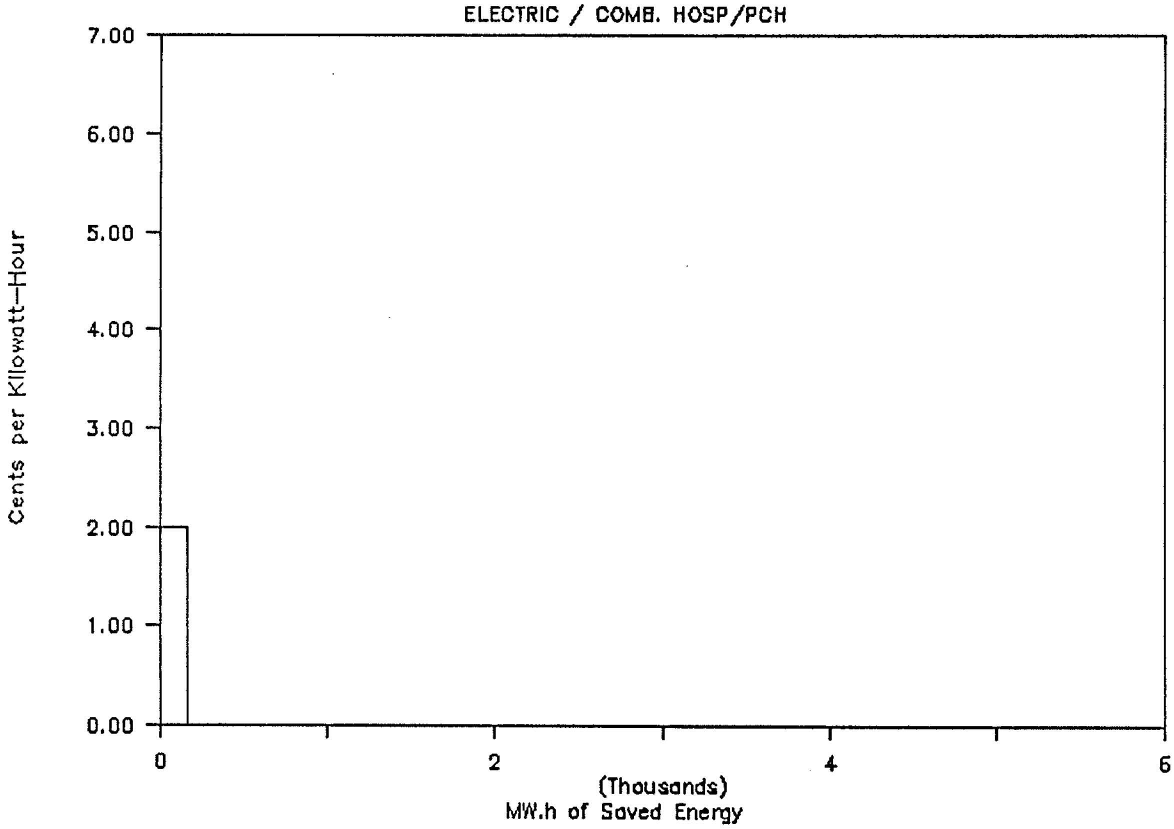
Block 21: COMPACT FLUORESCENT

ELECTRIC / COMB. HOSP/PCH



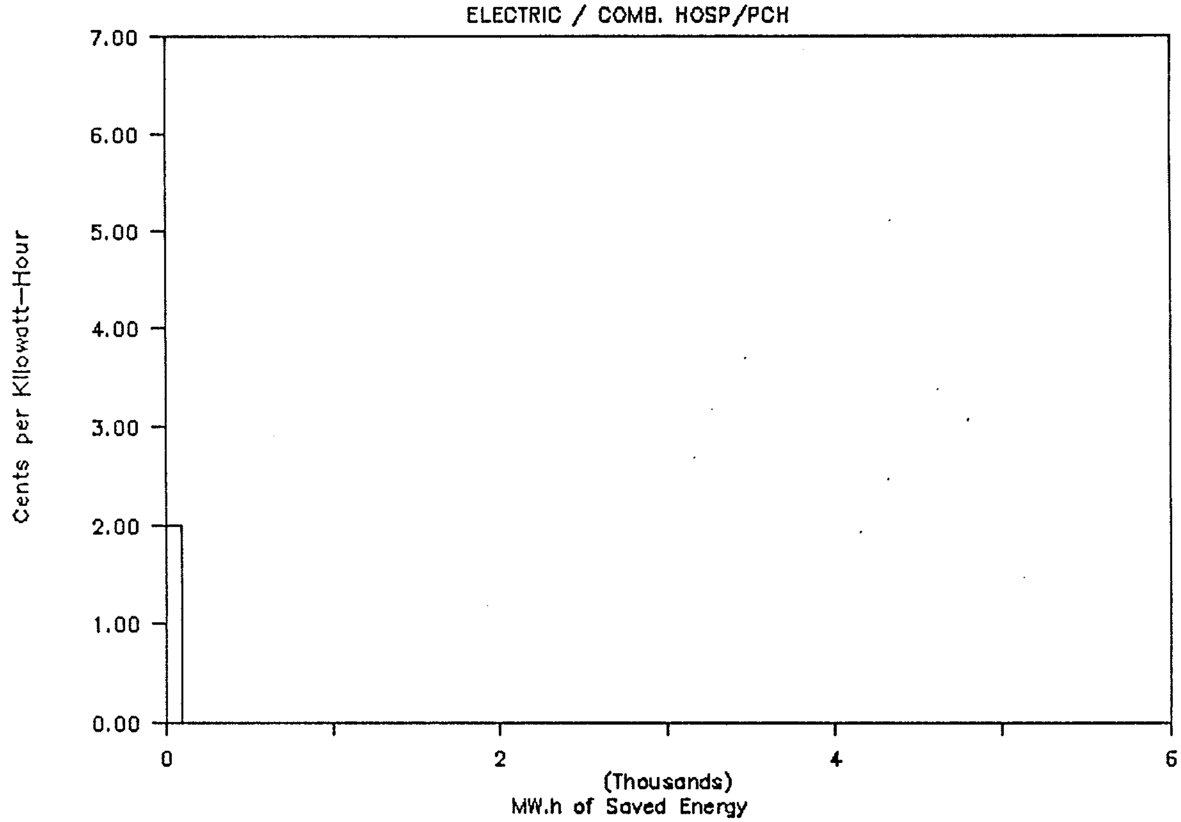
Block 22: H. E. CENTRAL COOLING

ELECTRIC / COMB. HOSP/PCH



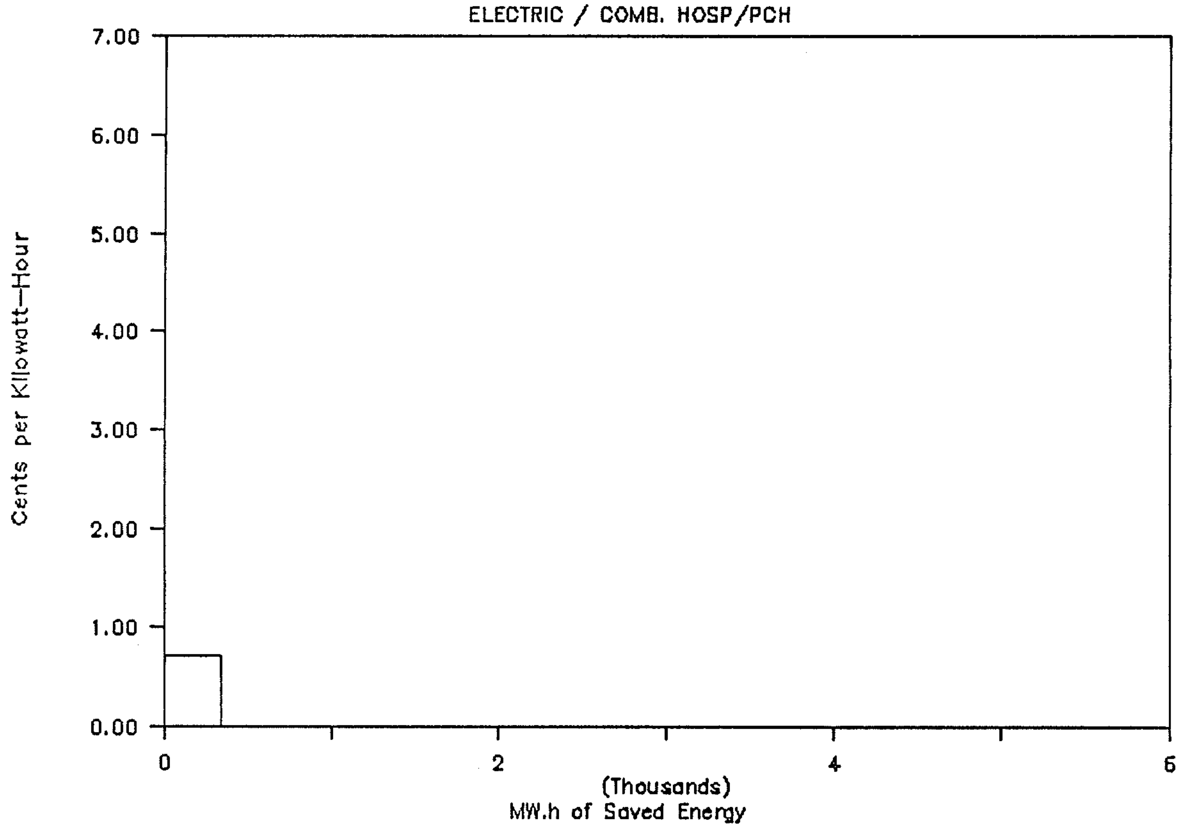
Block 23: H. E. UNITARY COOLING

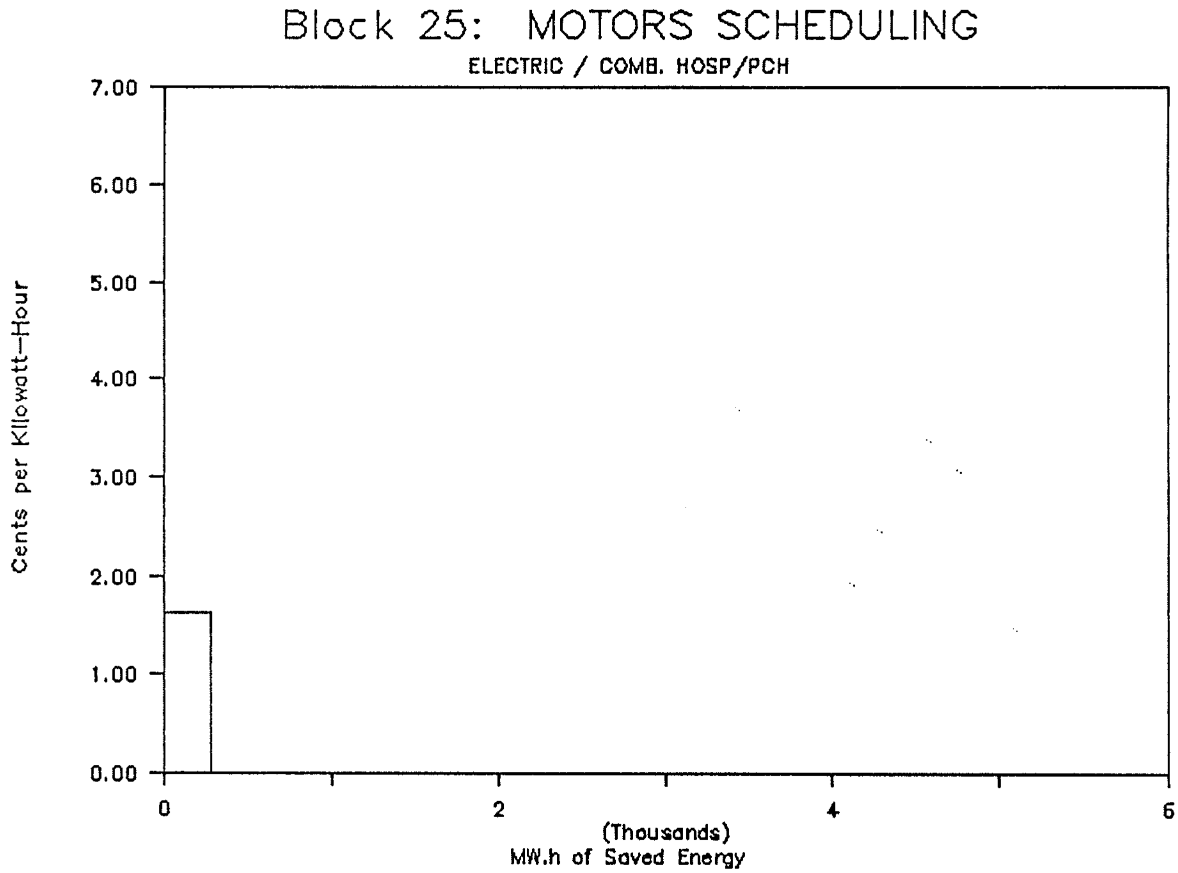
ELECTRIC / COMB. HOSP/PCH

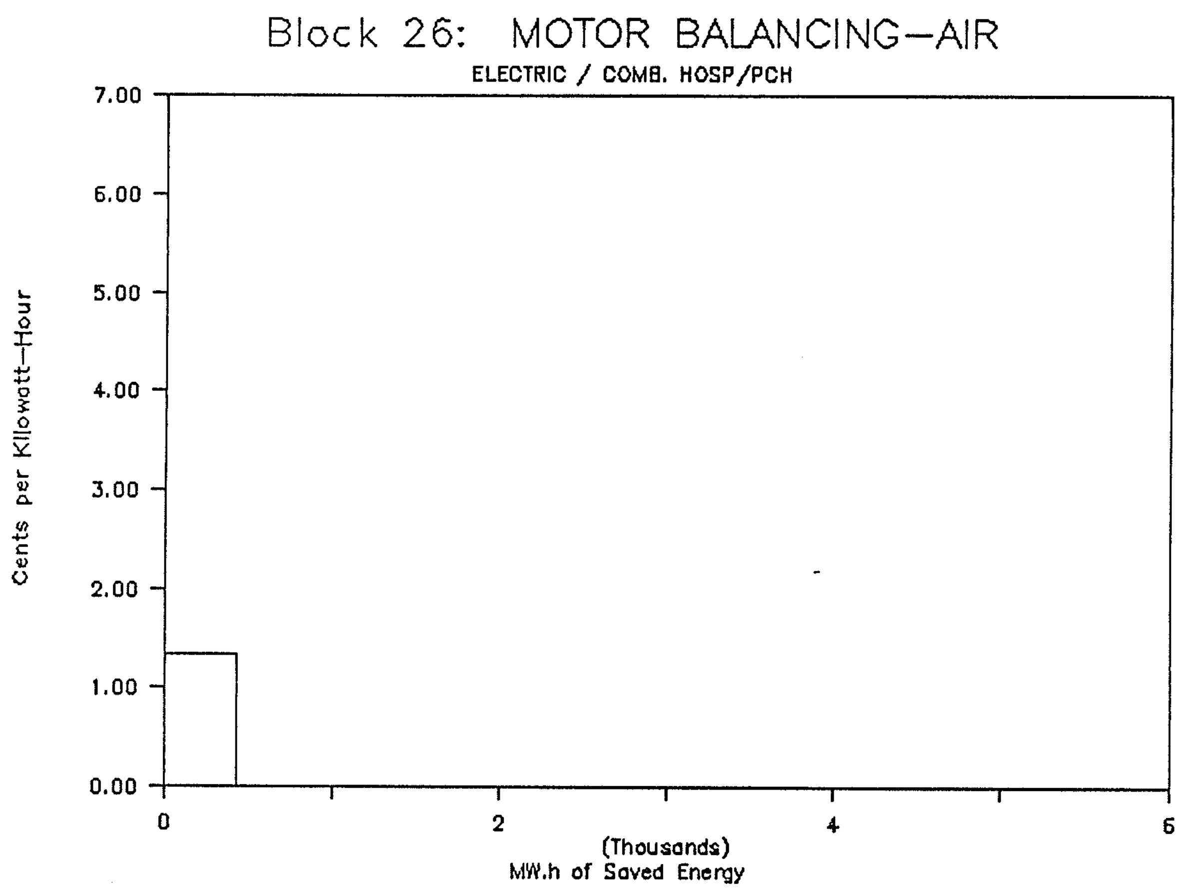


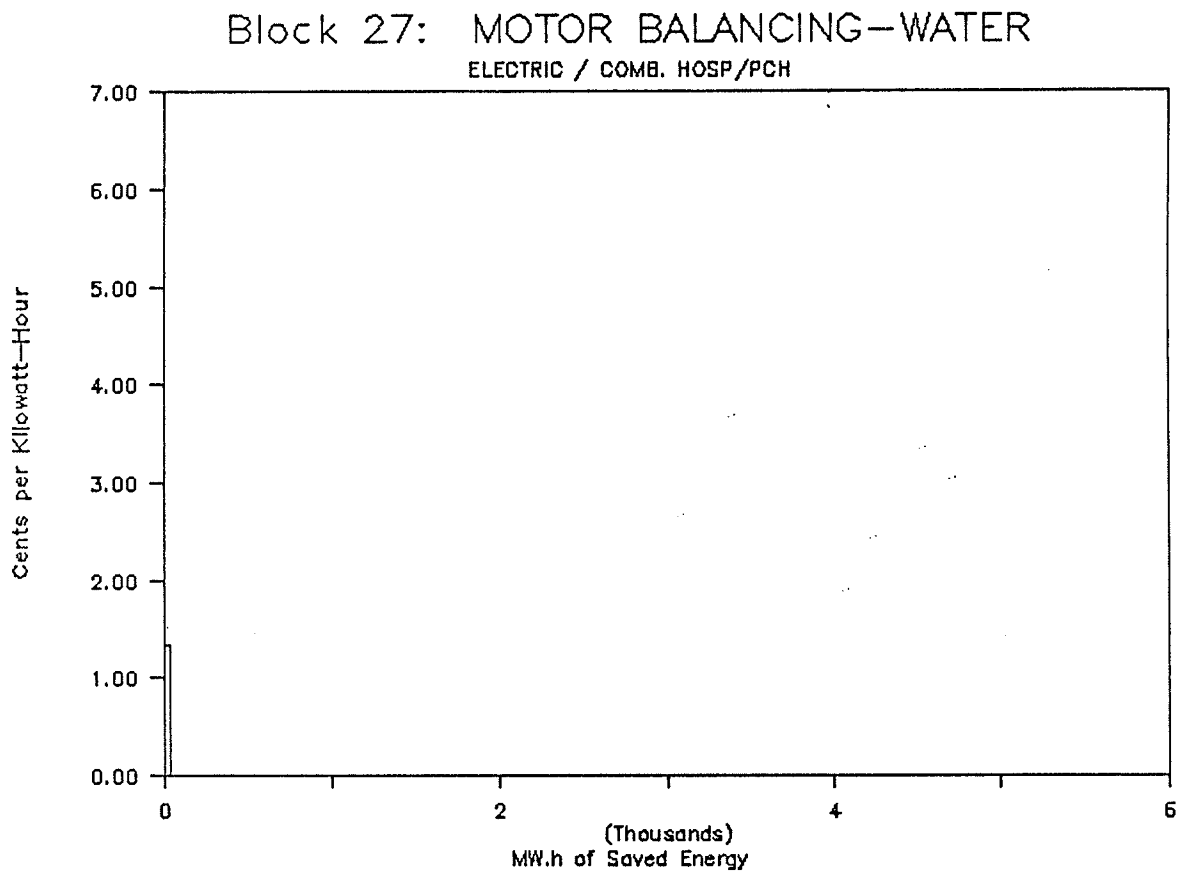
Block 24: ENERGY EFFICIENT MOTORS

ELECTRIC / COMB. HOSP/PCH




Block 25: MOTORS SCHEDULING
ELECTRIC / COMB. HOSP/PCH
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 26: MOTOR BALANCING-AIR
ELECTRIC / COMB. HOSP/PCH
Cents per Kilowatt-Hour
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
(Thousands)
MW.h of Saved Energy


Block 27: MOTOR BALANCING—WATER
ELECTRIC / COMB. HOSP/PCH
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Cents per Kilowatt—Hour
0
2
4
6
(Thousands)
MW.h of Saved Energy

APPENDIX G: ACRONYMS AND ABBREVIATIONS

A	Applicability Factor
BE	Baseline Energy
BETT	Building Energy Technology Transfer Program
CCE	Cost of Conserved Energy
Comb.	Combination
COMMEND	Commercial End-use Planning System
DSM	Demand Side Management
EI	Energy Intensity
EIL	Engineering Interface Ltd.
EPRI	Electric Power Research Institute
ES	Energy Savings
EUI	Energy Use Indices
GDP	Gross Domestic Product
Hosp	Hospital
HVAC	Heating, Ventilation and Air Conditioning
ICG	Inter-City Gas
IRP	Integrated Resources Planning
KW.h	Killowatt-hour
LCP	Least Cost Planning
MHSC	Manitoba Health Services Commission
MW.h	Megawatt-hour
P	Market Penetration
Pc	Current Market Penetration
PCH	Personal Care Home
RCH	Residential Care Home
S	Fuel Share
SIC	Standard Industrial Classification