ENERGY ECONOMICS IN OFFICE BUILDINGS

by

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ABSTRACT

ENERGY ECONOMICS IN OFFICE BUILDINGS

The central hypothesis to be tested by this thesis can be stated as follows: A relative increase in the expense of energy consumed in a commercial office building has the effect of reducing the value of the office building. A second and parallel hypothesis in the policy area was also tested as follows: The price mechanism operating on the demand for energy in the commercial office building market serves the public interest in encouraging energy conservation.

Commercial building energy usage, energy pricing and policy are explored in detail in Chapter I. The relative place energy holds in the expense of operating a commercial building as well as the place energy consumption holds in the commercial office sector is explored. These studies lead to the conclusion that energy expense and energy consumption are important respectively in these areas. It is also shown that it is in the national interest to reduce the consumption of non-renewable energy sources. Technical capabilities were then reviewed and it is established that it is feasible to reduce the consumption of energy in both existing and new commercial office buildings.

Chapter II studies the importance of energy cost in determining value in a theoretical model. A hypothetical building is established and the parameters from this building are used is a net present value model. Using a set of technical forecasts converted to growth rates of energy expense, it is demonstrated that the internal rate of return, being an accepted scale of value, was not sensitive to changes in the cost of energy consumed.

An empirical study of energy and market values was the subject of Chapter III. A model of commercial building value was established as follows:

V = f (lot size per unit area, income per unit area, energy consumption per unit area, number of parking stalls per unit area, number of stories, type of construction, presence of air conditioning, quality, age, parking underground, presence of an elevator, sales date and location)

Information on energy was obtained from B.C. Hydro computer files and all other data was obtained from the files of the B.C. Assessment Authority.

The regression results from the empirical study are analyzed in Chapter IV to determine the significance of energy in determining market value. Indefinite results were achieved for the energy variable coefficient, but the regression model proved to be significant, and the R^2 show that the model is a good predictor of value.

It is evident that a degree of multicollinearity is present in the data, and an additional regression is included using a model with highly correlated variables removed. The results of this regression indicate that the degree of multicollinearity was not responsible for the indefinitive results. It is concluded that the market value of a commercial office building is not affected to a significant extent, by an increase in the consumption of energy. The central hypothesis is therefore not supported by the empirical results.

Energy policy is reviewed in Chapter V. This review includes a number of available policy tools available to government. The chapter concludes that pricing policy alone is likely inadequate to reduce energy consumption.

In the concluding chapter, the central hypothesis is rejected. This conclusion is supported by both the theoretical and the empirical analyses. The second policy hypothesis is also rejected, and a number of possible policy measures are suggested.

Thesis Supervisor

I N D E X

CHAPTER I

INTRODUCTION TO COMMERCIAL BUILDING ENERGY USAGE, ENERGY PRICING AND POLICY

The theme of this thesis is the analysis of the effect of energy consumption on the market value of commercial office buildings in Canada. An attempt is made to determine if energy conservation measures are reflected in commercial values and to link any relationship to national and provincial energy policy.

The importance of this study can be demonstrated by reference to both the private and public sectors of the economy. In the private sector, a prerequisite for a successful investment has been shown to be accurate information about the present and future amounts of income, value and operating expense. This study will provide information to the private sector which will allow better decisions to be made when considering expenditures on plant and equipment for the purpose of using or conserving energy (e.g. capital expenditure and operating expenses).

In the public sector, governments at local, regional and national levels in both Canada and the United States can make use of the results of this study to evaluate the impact of the price mechanism in controlling the demand for energy in commercial office buildings. This could be one tool for formulating policy relating to the control of energy usage in the commercial sector.

The central hypothesis to be tested can be stated as follows: A relative increase in the expense of energy consumed in a commercial office building has the effect of reducing the market value of the office building.[1] This hypothesis is developed theoretically and tested empirically to determine whether a relationship between energy expense and market value exists and if it exists, to determine the strength of the relationship. The timing of the adjustment in value to the changes in the relative costs of energy depends in part on the contractual relationship between landlord and tenant, e.g. leases. The empirical work is based on a sample of commercial office buildings in the Greater Vancouver area.

To the extent that the relationship exists as described in the hypothesis, and commercial office building owners and future investors show a significant interest in energy usage, a second hypothesis in the policy area is tested. This hypothesis is that: The price mechanism operating on the demand for energy in the commercial office building market serves the public interest in encouraging the conservation of energy. This hypothesis considers that energy is a scarce resource, and that conservation of energy is in the public interest.

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1 The measurement used in this study is the amount of energy in kilowatt hours per square foot per year (KWH/FT^2/YEAR) consumed by a commercial building. An increase in energy expense may be caused by an increase in the quantity or an increase in the price per unit of the energy.

The following supplementary questions will be addressed:

(1) Do commercial buildings in Canada consume a significant amount of energy when related to total levels in all sectors in Canada?

(2) In the economics of building operations, is energy consumption significant relative to other costs?

(3) Is it technically possible to achieve a significant reduction in the amount of energy consumed by commercial buildings?

(4) If the office building market does not value energy conservation at the same level as society generally, are policy measures necessary?

(5) What policy measures are available to legislators to promote a decrease in consumption of energy in commercial buildings?

(6) Can these policies have the desired effect of reducing energy consumption without undesirable secondary implications?

Each of the hypotheses and supplementary questions will be developed further throughout the thesis.

In general, the theoretical information used as background for this thesis originated in the United States. An effort has been made to incorporate factors relating to the Canadian situation as much as possible using Canadian data and publications as information sources when available. It is necessary to measure the extent to which commercial buildings contribute to the total demand for energy in various forms in Canada so that the importance of this sector may be put in perspective. Further, both the current state of the art in reducing energy consumption from historic levels, and the attitudes and efforts of building owners towards reducing energy consumption are considered.

DO COMMERCIAL BUILDINGS IN CANADA CONSUME A SIGNIFICANT PORTION OF TOTAL ENERGY CONSUMED?

The National Energy Board has published information showing that Canada will eventually become self-sufficient in some forms of energy, but will be heavily dependent on imports in others. Canada seems most vulnerable in the supply of crude oil, particularly in the Eastern provinces. Net import figures for crude oil, published by Energy Mines and Resources (E.M.&R.), National Energy Policy (1980), indicate that by 1985, 16 percent of demand will be met by imports. It is questionable whether this figure will be lower by 1990 despite assurances of the federal government. Natural gas estimates released by the National Energy Board in Canadian Natural Gas - Supply and Requirements (1979) project a shortfall in production starting in 1992. This shortfall is projected to increase to 52 percent by the year 2000, but the shortfall varies according to the type of energy. Hence conservation and inter-fuel substitution may both be goals of national importance.

According to the Building Owners and Managers Association (BOMA) (1980), a breakdown of the sources of energy used to heat, cool and ventilate commercial buildings shows that approximately 40 percent of the consumers use oil, 30 percent use gas, and 30 percent use electricity. This amounted to 11 percent of the oil consumption in Canada, 19 percent of the natural gas, and 25 percent of the electricity. On average, commercial buildings use 13 percent of the total energy from all sources consumed in all sectors.

Considering the extent of consumption by commercial buildings, a substantial reduction in the usage of oil and natural gas will have a significant effect on the levels of imports and the levels of projected shortfalls.

There are questions concerning a reduction the usage of electrical energy either through a reduction in the demand or through inter-fuel substitution. In Energy Futures for Canadians, Gander and Belaire (1978) projected that the use of nuclear power for generating electricity would account for 36 percent of the total capacity in Canada by 1992. The current concerns relating to uranium mining and the public safety aspects of nuclear power generation, combined with the excessive costs involved in the construction of nuclear plants, lead to the belief that efforts made to reduce reliance on electrical power in the commercial sector would be considered to be a significant benefit to society.

A reduction in the use of energy generally, and in commercial buildings in particular, would have other beneficial effects. First is the advantage of reducing the country's reliance on imported oil since office buildings rely heavily on this source of energy (40 percent of offices use oil for heating). Reductions in the use of natural gas and electricity may also affect the balance of payments indirectly, but the direct import of oil is much more significant than the indirect effect of natural gas and electricity combined. (As a consequence the focus is on the "oil" issue). This would alleviate, in some measure, the inherent problems of shortage of domestic supply and the problems generated by an adverse balance of payments. Second, the preservation of all domestic non-renewable resources for future generations is considered to be an important policy objective and any reduction in aggregate office demand for energy would contribute to this policy.

Alternative Sources of Energy

Reliance upon alternative sources of energy has been suggested to bring about a change in the consumption pattern for oil, natural gas and electricity with the substitution of renewable energy sources for commercial buildings. Solar radiation, geothermal energy and wind energy are three <u>renewable</u> energy sources which have, in isolated instances, been used as substitutes for non-renewable sources in buildings. Use of such substitutes has been primarily experimental and the replacement of conventional energy sources by such renewable sources has not made significant in roads at this time.

It has been suggested that inter-fuel substitutions will forestall the domestic shortgage of oil and ease the burdens arising from importing oil. A summary calculation of an attempt to make up the oil deficit by the year 1990 by substituting surplus natural gas shows that, after substituting the natural gas surplus, there still remains an approximate shortfall of 50 percent. This heavy reliance on natural gas is therefore a very short term solution.

The substitution of electricity for oil or natural gas would, as mentioned previously, require heavy reliance on nuclear power, with the problems inherent in this method. The substitution of another non-renewable resource in the form of coal, or gas manufactured from coal, holds some promise for complementing and perhaps replacing oil. It is noted, however, that while the requisite technology is available, the coal reserves of Canada are limited. Some estimates (Williams, 1980) suggest the life of proven coal reserves will not extend beyond the year 2035, (based on projected levels of increase in the use of coal).

Stobaugh and Yergin (1978), suggest that the use of conservation measures, as opposed to finding new sources of energy, is the only reasonably method of reducing the consumption of energy in buildings. In describing conservation, Stobaugh and Yergin state:

> There is a source of energy that produces no radioactive waste, nothing in the way of petro-dollars, and very little pollution. Moreover, the source can provide energy that conventional sources may not be able to furnish. (page 136)

They point to a trend in the United States where substantial reductions in the amount of energy used in both private and government buildings have been achieved. Cost considerations over the life-cycle of a building, rather than the historical practice of using first-time capital cost calculations, is gaining greater usage. Savings through conservation do not require major technological breakthroughs and, in most cases, do not require major changes in lifestyles. The major barriers to the conservation of energy are found to be institutional, political and social. A government policy designed to champion the cause of conservation may help to overcome some of these obstacles.

Three types of conservation programs are cited by Stobaugh and Yergin. The first two, involuntary curtailment due to supply interruption and externally imposed measures which require a major lifestyle change, are considered undesirable. Instead the method called "productive conservation" is to be encouraged. Productive conservation refers to those measures which encourage changes in the existing capital stock and promise changes in behaviour which encourage the use of less energy in an economical and socially non-disruptive manner.

A problem with productive conservation derives from its fundamental characteristics --- it is a highly fragmented approach. It implies the need for discipline and constant monitoring at the individual level. At the time of the 1973 oil crisis, experts of the day, who promote the expansion of energy production in oil, nuclear power, coal and gas, developed a unified, hence powerful voice. Conservationists, although currently receiving government and popular support, are not as well organized, hence not as powerful. As a consequence, conservation is often relegated to the background in favour of more glamorous and exciting energy solutions.

In the Report on Energy from the Association of Professional Engineers of British Columbia (1978), a recommendation was made that there must be an ongoing commitment to conservation on the part of government and every citizen. In a description of the North American situation, the editors state:

> It has been mentioned many times in the press that Canada and the U.S. are the two most energy intensive nations in the world. Although living spread out along a narrow strip in a cold climate increases our needs for transportation and space heating, our energy consumption is excessive. This is largely due to our love of large cars and occupation of well heated but poorly insulated buildings, the ready availability and low price of energy, especially petroleum products. (Page 12)

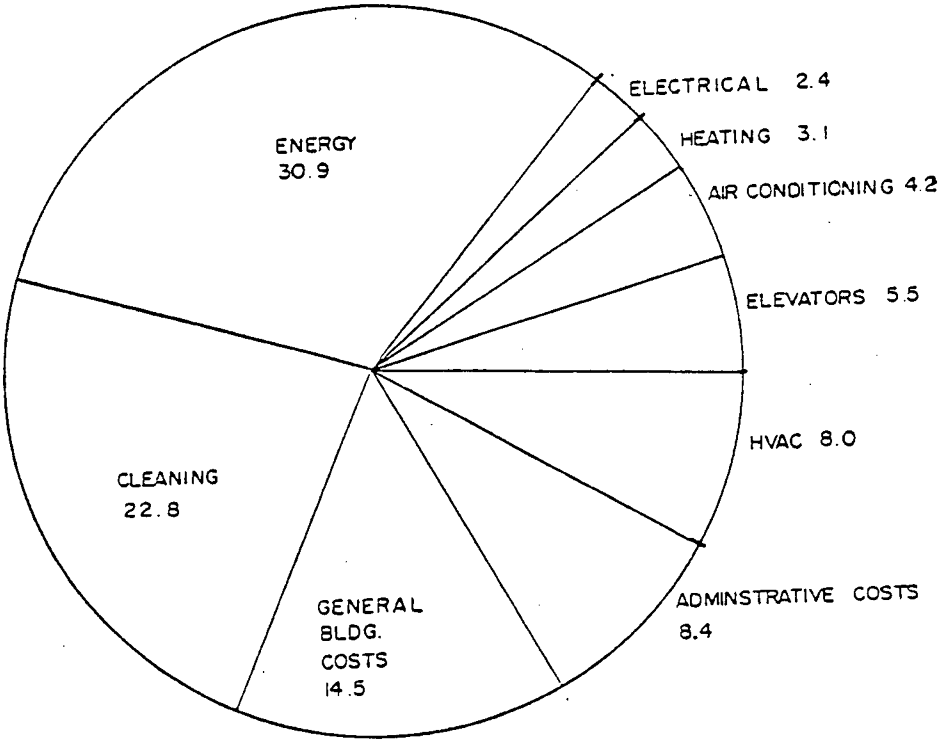
IN THE ECONOMICS OF BUILDING OPERATIONS, IS ENERGY CONSUMPTION SIGNIFICANT RELATIVE TO OTHER COSTS?

Various studies have been initiated to determine levels of energy consumption in different building structure types. Two examples include the Ontario Hydro (1978) survey of 80 buildings in Toronto, and the Building Owners' and Managers' Association (B.O.M.A.) study of buildings in a selection of cities in Canada in 1977. The Ontario Hydro study reports that energy consumption in buildings range from a low of 19.0 $KWH/ft^2/year$[1] to a high of 87.0 $KWH/ft^2/year$. By generally accepted standards, this represents an excessive range. The buildings at the high end of the range are judged, by contemporary standards, to be unacceptably high. B.O.M.A. reported an even wider range in per unit usage, from 18.0 to 169.0 $KWH/ft^2/year$. B.O.M.A. also noted that energy costs for office buildings averaged 30.9 percent of the total variable costs, excluding maintenance,

1 Energy is measured in kilowatt hours per square foot per year ($KWH/FT^2/YEAR$) as a standard in Canada.

repairs and material purchase, of the building. The breakdown of variable costs in a typical office building is illustrated in Figure 1.1[1] It can be seen that energy is the most significant variable cost.

Cleaning, at 22.8 percent, is relatively high but this variable includes high labour cost.



BREAKDOWN OF INDIVIDUAL VARIABLE COSTS

Figure 1.1

SOURCE: BUILDING OWNERS AND MANAGERS ASSOCIATION DOWNTOWN AND SUBURBAN OFFICE BUILDINGS EXCHANGE REPORT (1980)

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1 Energy costs include the utility costs principally for natural gas, oil and electricity. The electrical (2.4 percent), heating (3.1 percent), air conditioning (4.2 percent), elevators (5.5 percent) and heating, ventilating and air conditioning (HVAC 8.0 percent) refer to the percentages of variable costs for system maintenance.

Further, the Ontario Hydro study provides information on average consumption. Average consumption in 1977 was 44.4 KWH/ft^2/year in the sample of buildings in the Toronto area. A follow-up survey the following year confirmed that average consumption was in the 40-45 KWH/ft^2 range. A B.C. Hydro study of seven buildings in Vancouver for the year 1979 reported the average consumption to be 68.3 KWH/ft^2. A more recent survey by the British Columbia Building Corporation (B.C.B.C.), including 110 buildings under its control, reported an average annual consumption of 40.4 KWH/ft^2/year. The minimum consumption in this study was 12.4 KWH/ft^2/year, the maximum was 160.7 KWH/ft^2/year[1], and the average was 40.4 KWH/ft^2/year. (See Table 1.1)

TABLE 1.1

STUDY	AVERAGE CONSUMPTION KWH/ft^2/year	HIGHEST CONSUMPTION KWH/ft^2/year	LOWEST CONSUMPTION KWH/ft^2/year
ONTARIO HYDRO	44.4	87.0	19.0
BOMA	48.6	169.0	18.0
VANCOUVER	68.3	157.6	20.1
BCBC	40.4	160.7	12.4

1 Studies comparing consumption in different climatic conditions, although allowing for a difference in degree-days, indicate a very small difference in the total unit energy consumption.

Referring to Table 1.1, these four studies confirm that there exists a wide range of energy consumption per square foot. Further, these ranges cannot be explained by reference to geographic location since wide variations in consumption were found in each study. These facts, combined with expense data provided in the BOMA study, confirm that, on average, energy is the single largest operating expense item. Furthermore, in a large portion of the buildings, those with above average consumption of energy costs, expressed as a portion of total cost, will greatly exceed the BOMA average.

IS IT TECHNICALLY POSSIBLE TO ACHIEVE A SIGNIFICANT REDUCTION IN THE AMOUNT OF ENERGY CONSUMED IN COMMERCIAL BUILDINGS (THE CONSERVATION ISSUE)?

In relation to the existing stock of buildings, how far if at all can the average consumption of energy be reduced? How far below the current 40 KHW/square foot/year average unit consumption can either a retrofitted building or (a building renovated for energy efficiency) improved operating procedures reduce energy consumption?

In order to determine what is technically possible, it is first necessary to briefly outline those factors that will influence energy consumption. The major factors which will determine annual energy consumption include:

(1) Desired internal temperature during occupation (by heating or cooling).

(2) Total square footage to be conditioned (heated or cooled).

(3) Number of days per year and hours per day at the desired internal temperature.

(4) Permitted internal temperature while unoccupied.

(5) Physical characteristics of the building, e.g. insulation, type of construction material, building design, glass area, etc.

(6) Climatic conditions.

(7) Management of climate control systems, e.g. are permitted unoccupied temperatures achieved efficiently.

A number of studies have attempted to determine whether significant reductions in energy consumption are possible. One study, sponsored by the National Research Council (NRC), and carried out by Vinto Engineering Ltd. (1978), performed extensive energy simulation studies on four office buildings (an explanation of these simulation methods occurs later in this section). The purposes of the study were threefold:

(1) The energy simulation program was to be tested for reliability by comparing it with actual consumption.

(2) A typical office building was analyzed to determine the effects of climate, size, shape and period of occupancy on energy consumption in order to explain the wide spreads in unit consumption figures.

(3) The potential reductions in the energy consumption of existing buildings was investigated through the application of pre-determined, low-cost energy management programs.

The test of the simulation program proved successful: the stimulated consumption figures were within three percent of the actual figures confirming the accuracy of the simulation methods.

The NRC study reported that the factor having the greatest effect on energy consumption was the hours of work per day. This was followed by the number of work days per year. The most important physical parameter was found to be the ratio of outside surface area of the building to floor area. The variables which were found to be the least significant were climate, internal heating levels and, only slightly more important, internal cooling levels.

The implementation of simulated changes to systems to determine reduced energy usage started with a group of items requiring no capital outlays. These included: shut-down of mechanical and electrical systems from 6:00 p.m. to 7:00 a.m. on workdays, and all day on non-workdays; thermostat settings of 21°Celcius from October 1st to May 31st, and 24°Celcius from June 1st to September 30th; removing tubes from light fixtures to reduce lighting energy to 2.5 watts/square foot; and resetting service water temperatures to 43°Celcius. The addition of these modifications to the base model decreased the annual equivalent energy consumption by 50 percent, with little increase in capital cost.

Changes to systems requiring minor capital expenditures were studied. These included: air quantity adjustments, fixture changes, rewiring and ballast removal, reduced outside air ventilation rates, and elimination of reheat using radiators. The addition of these minor-cost items had the effect of improving the total energy reductions, including the no-cost items, to 60 percent.

This process was repeated on two other buildings of different size and system types. Reductions in consumption varied from 57 to 60 percent. A fourth building was checked and was found to be operating at a minimum of 23 KWH/square foot/year, and it was found that, without sophisticated and high cost revisions, lower consumption was not possible. This fourth building had a system for heating and air conditioning similar to the other three. Lighting levels were also equivalent. Considering that there were no sophisticated solar systems or heat storage systems, the low figure of 23 KWH/square foot/year may be considered a minimum[1], and the control and operation of the systems used as a model. The reductions in consumption in the

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1 The methods of achieving consumption figures less than 23 KWH/square foot/year are considered uneconomical since this required more sophisticated equipment and systems.

three buildings where system revisions were simulated yielded final figures of 40 KWH/square foot/year, for one building, and 24 KWH/square foot/year for the other two buildings.

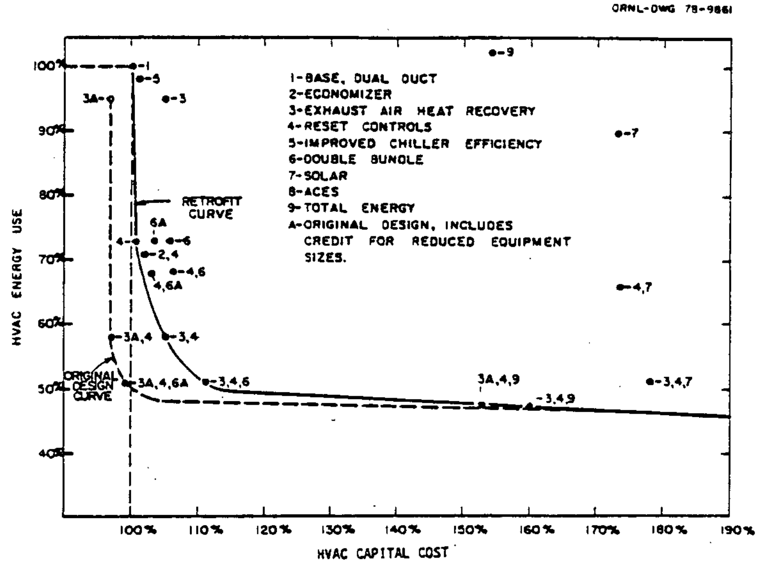
For comparison purposes, the consumption figure for Vancouver's provincial court house and office complex is predicted to be 35 KWH/square foot, while the consumption figure for the new Ontario Courthouse in Energy Management Canada (1980) is predicted to be 13 KWH/square foot/year. Actual consumption figures for these buildings should be available soon, and will attract some interest.

A paper by the American Institute of Architects, (1979) "A Nation of Energy Efficient Buildings by 1990", concludes that the potential saving for existing buildings is 30 percent (from 40 KWH/square foot/year to 28 KWH/square foot/year) and for new buildings, a saving of 60 percent (from 40 KWH/square foot/year to 16 KWH/square foot/year) could be achieved. These estimates are based on case studies of office buildings in major American cities from 1976 to 1978.

Technical Standards for Energy Efficient Buildings

Studies of various programs of retrofit and investment in energy conserving devices is reported by Jackson (1979). Reproduced in Figure 1.2 is a graphical representation of the benefits in energy reduction compared to expenditures of capital funds.[1]

The results of this study, shown in Figure 1.2 indicate that significant reduction in energy consumption can be achieved with small capital investments (e.g. a 10 percent increase in capital cost achieves a 50 percent reduction in energy use), but that the returns from additional capital diminish dramatically.



Space heating and air conditioning energy use vs capital cost for typical office building with dual duct system.

FIGURE 1.2

SOURCE: JACKSON, J.R., An Econometric-Engineering Analysis Of Federal Energy Consumption Programs, U.S. Dept. of Commerce, January, 1979.

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1 In Figure 1.2, the term "dual duct system" refers to an all air heating-cooling system commonly used for office buildings. HVAC is an industry abbreviation for heating, ventilating and air conditioning.

Guidelines for the design of new commercial buildings are available to the industry from the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). ASHRAE is a technical organization, recognized as the standard setting agency in the mechanical design, construction and manufacturing industries. In the 1978 Applications Handbook, ASHRAE, provided a description of the important energy conservation considerations for new building design. This handbook suggests setting temperature standards within a range of 2.3°Celcius in summer (23.3°Celcius to 25.6°Celcius), and 2.2°Celcius in winter (21.1°Celcius to 23.3°Celcius). The report also suggests ventilation rates for outside air which have been reduced to consume less energy. ASHRAE (1980) indicates that many dynamic[1] conservation measures presently in use are more appropriate than the passive measures currently used in building design.

Clearly a range of energy conservation methods can be employed in commercial buildings. The building's structural "envelope" is as important as either the type of mechanical system or the type of control system. In order to analyze the energy problem, computer simulations have been developed where the thermal behaviour of a commercial building can be simulated

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1 Dynamic measures are those that require mechanical means of energy movement (e.g. pumps and fans).

using one of a number of programs available. In Canada, the program most commonly used is the Energy Systems Analysis (ESA) program by Merriwether (1976) which, up to early 1980, was supported by Public Works Canada, and could be used without royalty charge. Computer simulation techniques are used on new designs to determine the effect on energy conservation of different materials and equipment. Similar techniques are used on existing building to determine the extent and economics of retrofit programs.

Another method of analysing the energy efficiency of the existing stock of commercial buildings is the use of infrared photography to produce "thermograms". A description of the technique and pictorial results is shown in the National Geographic's, "Special Report on Energy", (1981). The location of maximum energy loss in a building can be located from such photographs; then action taken to reduce the losses through remedial techniques including insulation, reduction in outside air infiltration or double-glazing.

Pricing Mechanisms and Their Effects on Consumption

A reduction in the cost of energy in a building can be achieved in ways that have little effect on the total amount consumed. These systems take advantage of the method of billing for electrical energy. Commercial electric meters indicate both consumption, as the amount of energy actually consumed, and the peak level of energy used over a set period of time. This peak level of energy used at any point in time during the billing period is referred to as the "demand level" for billing purposes. If the peak level of energy consumption was 1000 KW and the demand billing period was six months, the amount of "demand billed" or that period would be based on 1000 KW of electricity for the entire period. To eliminate short duration surges of power caused by motor start-up, the peak level must last at least fifteen minutes to be considered in calculating the demand billing for the six month period. Hence, a reduction of the peak level of demand (when consumption is at its highest level), can effect substantial savings in demand charges over the entire six-month period because the demand billing would then be based on a lower peak.

For example, consider this oversimplified case illustrating demand peaks.

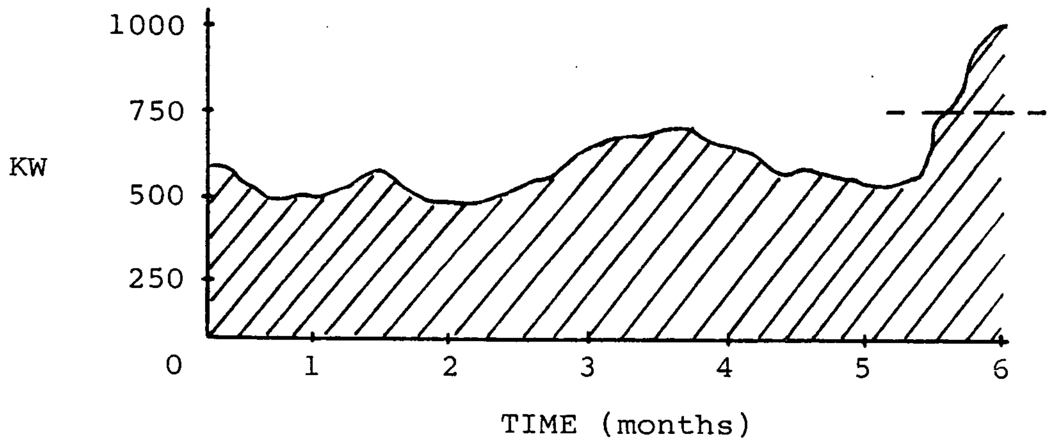

FIGURE 1.3
ELECTRICAL ENERGY USAGE

During the billing period from month one to month six, the peak level of consumption was one thousand (1000) kilowatts, and this level multiplied times the demand charge per kilowatt determines the demand billing. The shaded area in the graph is an indication of the consumption, which is billed on the basis of the total kilowatt hours (KWH) multiplied times the unit rate per kilowatt hours. A reduction in the level of consumption during the last two weeks of month six therefore, would reduce the demand billing level to 750 KW, or a 25 percent reduction, while the consumption in KWH was not significantly reduced.

Included in current technology are systems which utilize thermal storage for the purpose of "peak shaving" or reducing demand. Heat and cool storage allows the equipment, usually electrically-driven chilled water units, to run during off-peak periods, storing the cold or hot water in large underground tanks to be used during peak periods. This type of system saves on the consumption of energy and reduces demand. Heat rejected from the water chiller is stored when cooling is required in the daytime and is then circulated to heat the building at night. The storage of cool water during the night can reduce demand charges, and allow for more efficient machine operations. This allows a reduced sized refrigeration machine to operate on a continual basis, producing higher efficiencies. When maximum cooling is required during daytime, both the cold water from the refrigeration machine and the stored cool water are circulated to cool the building.

As previously discussed, the optimal temperature swing allowed by ASHRAE standards was stated to be 2.3°Celcius in the summer. A simpler method has been developed to store cooling in a commercial building using the mass of the building. The technique starts by allowing the equipment to cool the building during off-peak times to minimum temperature. During peak periods, the capacity and the consumption are reduced and the space and mass temperatures are allowed to increase to the maximum temperature. This method of storage has proven to be very effective in reducing overall demand.

Peak load shedding methods used for limiting peak demand include the shut-down, or reduction in capacity of non-essential loads during peak periods. Air moving equipment, pumps and domestic water heaters may be turned off for the 1 - 1-1/2 hours in the afternoon when systems are creating expensive peak loads. This action reduces peak load demand with a minimum discomfort to occupants.

One of the more interesting technical areas of reducing consumption in buildings is the use of "low-grade" heat, meaning heat at lower temperatures. Low-grade heat is produced in a building using various heat reclaiming methods, which include heat from exhaust air systems, heat available from thermal storage tanks produced by solar collectors, or heat rejected from water chilling equipment, and heat reclaimed[1] from flue gases. Manufacturers have developed air-to-water heat transfer units with much larger contact surfaces to allow use of this low grade heat in direct space or ventilation air heating.

Technically feasible and currently economical methods of using low-grade heat to reduce energy consumption include heat pump systems. Small systems using air-to-air transfers can use the heat from the outside to heat spaces to comfortable temperatures. These systems are efficient, with a coefficient of performance[2] greater than unity at exterior temperatures down to about minus 18° Celcius. To reduce unnecessary wear on equipment, since energy is not gained, it is more economical to switch control to electrical-resistance heating at this point. The reverse cycle of the heat pump provides cooling, rejecting heat to the outside air.

In large commercial buildings, and in areas where there are low-grade heat "sinks", such as lakes or hot springs,

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1 The use of "sorption" systems to produce cooling are also being considered. Coellner (1980) describes the reactivation of a sorption dehumidifier using inexpensive energy such as solar hot water, waste steam, or recovered exhaust heat. These systems use a bromide solution termed the desiccant, which produces cooling by absorbing moisture. The desiccant is regenerated using low-grade heat. Cooling can therefore be produced by substituting a low-grade heat source for electrical power.

2 The coefficient of performance is the ratio of the amount of heat produced divided by the electrical energy used.

the water-to-air "heat pump" is feasible. These units can also work on the reverse cycle, and reject heat to the heat sink. When the condenser water circuit is maintained at about 24°Celcius, heat pumps on one side of a building may be taking heat from the circuit while units on the opposite side or the interior may be rejecting heat. The coefficient of performance of these small water-to-air units is about 2.2.

There are a number of interesting heat reclamation methods which are marginally feasible using presently accepted discount rates. The "Q-Dot" unit is a patented sealed tube unit, with a wick material adhered to the wall of the unit. When heat is applied to one end, the heat is immediately transferred to the other end by the vapour. Liquid is returned to the wick providing a continuous loop. Banks of these tubes are installed to transmit waste heat from contaminated exhaust air streams to colder incoming air streams used to ventilate the space. Another method used with air streams that are not contaminated to the same degree is the thermal wheel. A large wheel infilled with a thermal mat is rotated between two air streams. The mat picks up the heat from one side and is rotated to the opposite side where the cooler air is heated.

The relatively sophisticated techniques available for new buildings have been shown, in current technical literature, to achieve a reduction of 80 percent in energy consumption. To achieve this reduction, the addition of complex automation

automation devices are necessary for control. Computer-based systems have been developed by the major control companies and are available to the industry with the necessary software to achieve the desired ends. A significantly lower amount of energy can be consumed using different methods of operation with the same system. The addition of computers to systems which employ conventional functions, such as monitoring set-point and on-off functions, has allowed optimization of equipment running times and selection of set-points. Conventional control systems adopted for computers do have limitations, specifically in the area of optimizing control strategies. Where systems are very complex and the conventional system costs are high, the new generations of Direct Digital Control (D.D.C.) systems are employed. A D.D.C. control system uses a central computer to replace conventional building systems controls, allowing complex optimal strategies to be implemented at low marginal cost.

This section started by posing the question: Is it technically possible to achieve a significant reduction in the amount of energy consumed in commercial buildings (the conservation issue)? It has been demonstrated that a variety of technically feasible actions may be taken which will reduce energy consumption either without altering the climate conditions experienced by occupants or changing the conditions to what is deemed to be outside an "acceptable" range. However, these programs may face some resistance either because of actual or perceived changes in comfort. These "people problems" are the subject of the next section. In this regard we are concerned with occupants who are tenants, owners or visitors to the office building. Hence, contractual arrangement must be considered.

Occupant Problems in Conservation

Energy conservation is not without problems. Building owners have found that where energy conservation techniques affect occupant comfort, controls are resisted either legally through existing leases or physically through lack of co-operation. Hours of equipment operation and peak shaving programs can be points of disagreement and frequently hours of operation are specified in lease contracts. Reducing space temperatures in the winter and increasing the temperature in the summer has also met with a considerable amount of occupant resistance and again matters of interior climate control are frequently cited in lease contracts. Reductions in lighting levels in common areas and lease space have received criticism where over-zealous or cost-conscious owners and managers have reduced lighting levels below desired levels (but perhaps still within "acceptable levels"). In addition, in cases where the amount of outside air has been reduced, complaints about high odour levels, headaches from high concentration of carbon dioxide and lack of oxygen have been received. In some cases the complaints are well founded in that physical as opposed to psychological problems occured. In other cases however, the air ventilation was reduced, but set within "acceptable standards" and complaints were still received.

Resistence from occupants coupled with uncertainty as to future fuel costs, are factors cited by Brace (1981), President of Honeywell, to explain why only two percent of commercial building owners have implemented a full energy conservation program. The fact that most commercial leases provide that energy costs are passed on to tenants is given as one reason for the current apathy among building owners. To take advantage of the potential conservation in commercial buildings, Brace calls for "a national energy conservation program that has teeth in it". This can be taken as a call for more regulation.

COMMERCIAL BUILDING ENERGY USAGE, ENERGY PRICING AND POLICY: A SUMMARY

It has been shown that:

(1) Energy use in office buildings account for a significant portion of the oil, natural gas and electricity used in Canada.

(2) Oil constitutes the single most frequently used source of energy used in office buildings, and given our reliance on oil imports, this use contributes in a significant way to our national oil shortage.

(3) Energy costs are the single largest (variable) operating expense and any economies in this expense item could prove significant.

(4) The use of energy in commercial office buildings can be reduced through technical and management conservation techniques.

The available technology for reducing the energy used in buildings, most of which has been described here, has progressed to the point that the consumption of energy in new, creatively designed commercial buildings is a small fraction of the historic energy use for older buildings. Moreover, office can be built which no longer require a separate heat source[1].

The important questions related to energy policy will be postponed to Chapter IV of this thesis, since the policy solutions will depend, in large part, on the efficiency of the market as a means to control the use of energy, the timing of the use of energy (e.g. demand billing), and the type of energy used through the price mechanism. Reliance on the price mechanism will be explored in the theoretical and empirical studies in the following chapters. The next chapter [INVESTMENT ANALYSIS: A MODEL OF PRICE DETERMINATION] considers energy conservation in a commercial office building from a theoretical approach.

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1 For example, buildings with a means to store excess heat from one period of time for use when heat is needed are being designed without a heating source (e.g. a boiler).

CHAPTER II

INVESTMENT ANALYSIS: A MODEL OF PRICE DETERMINATION

In Chapter I, we demonstrated the importance of energy in the economics of office building operation. It was noted that energy costs represented the largest variable item in the operation of a commercial office building. Moreover, it was noted that investors will face consumer resistance to efforts to reduce energy consumption. Of perhaps greater importance were the observations that levels of energy consumption in commercial buildings varied over a very wide range. The apparent lack of control suggests either investors don't care about energy cost or they don't know the significance of energy cost.

Articles by Haney, Crask and Isakson (1978) and Isakson and Haney (1978) are significant in that they report survey evidence indicating a low level of awareness of the effects of energy expense in the analysis of either existing or future office projects. Given the significance of energy expenses, this low level of awareness is of concern. Improvements in methods of analysis are being developed in a number of fields including appraisal and investment analysis. These improvements are such that they may force investors to be more explicit in their assumptions concerning all capital and ongoing costs, and in particular, energy costs.

Using computer programs which simulate the physical operation of a new commercial building to determine the energy expense, technical data are generated which can be incorporated into the methods of investment analysis used by investors and analysts. Since the physical components of the building can be varied, it is possible to test different combinations of construction and energy management so that the construction of new commercial buildings and management of both new and existing buildings can be carried out to minimize energy expense within realistic cost-benefit limits.

Given these technical means of forecasting energy data, the question is "how can this information be used in rigourous cost/benefit analysis for the purpose of investment analysis?" Given the improved forecasting activities concerning energy consumption, how can this improved knowledge be put to use? (And how might it be put to use?) Clearly, one way the information may be used is as an input to the currently used models of investment analysis for both new and existing buildings.

For the purpose of this thesis, we will choose to demonstrate how this technical knowledge for forecasting energy consumption can be incorporated into a net present value model of investment analysis. While the net present value model is not the only method of investment analysis used in the market today, it is perhaps the most widely published.

Applying the Models

The basic net present value model[1] is set out as follows:

$$NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t} + \frac{R_n}{(1+r)^n} - E_o$$

WHERE:

WHERE:	NPV	=	Net present value of the investment
	N	=	Holding period
	CF_t	=	Net benefits, measured as cash flows, realized each period
	R_n	=	Reversion cash flow in year of disposition
	E_o	=	Original dollar equity investment
	r	=	Appropriate discount rate
	t	=	1, 2, 3, ... N years in holding period

For purposes of this thesis, this basic model can be rewritten as follows:

$$NPV = \sum_{t=1}^{N} \frac{NOI_t}{(1+r)^t} - \frac{EN_t}{(1+r)^t} + \frac{R_n}{(1+r)^N} - E_o$$

WHERE:	NOI_t	=	Net operating income in period before deducting energy costs (This represents the gross revenues recovered by the property owner less the owner's share of operating expenses exclusive of energy)
	EN_t	=	Energy costs of period to be borne by the property owner

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1 A variation of the net present value model may also be used in analysis, where the net present value is set at zero, and the model is solved for the rate of return, called the internal rate of return (IRR).

Re-writing the basic model in this form more clearly shows the role of ongoing energy costs. Moreover, while it is not central to this thesis, the analysis of new capital expenditures designed to adhere energy efficiency could be analyzed using a variation of this model. This (re-written) model can be used to analyze the influence of ongoing energy expense on net present value. The operating savings of a specific investment can be estimated by an analysis of the life cycle cost-benefit of the investment using this model.

The net present value model is used to determine the role of energy operating cost in the analysis of office buildings and the sensitivity of net present value to changes in any variable but specifically energy expense.[1]

By establishing the role of energy operating expenses in a model of investment analysis, it is possible to demonstrate the effect of energy expense, on either yields (r percent) or net present values. For investors seeking a specific and predetermined yield variations in energy expense must be reflected in the net present value. Given individual expectations concerning yields (r percent) and given the forecast for non-energy variables (rents and other expenses and residual values) changes in present value occasioned by energy expenses will ultimately be

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1 The change in energy expenses can occur through a change in the price of energy, or a change in the level of consumption through conservation measures.

reflected in how much investors will bid for properties, and how little current owners are prepared to accept. These bid and asked prices will ultimately determine market values. Hence, if energy expenses are deemed to be important by investors, they should be reflected in lower bid and asked prices, and hence lower market values.

Using a net present value model with average data from a hypothetical office building, the extent of energy sensitivity can be analysed and its impact on market value can be explored.

Total energy cost for the hypothetical building will be forecasted (the technical forecast) based on three scenarios. These forecasts will be based on historical data provided by B.C. Hydro, to determine the estimated most probable rate, most optimistic rate and most pessimistic rate of increase of the cost of energy. Nominal growth rates for energy expense are assumed at 10 per cent, 14 per cent and 20 per cent. These technical forecasts will then be used in the net present value model.

The hypothetical building selected is an average of buildings used in three recent research and publication standards[1], and is chosen as representative of the most common form of office building in Canada.

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1 (a) the "1977 Downtown and Suburban Office Building Experience Exchange Report" published by the Building Owners and Managers Association (BOMA);
(b) the study by Ontario Hydro (1978) in their study "Energy Use in Office Buildings"; and
(c) the "Standard Test Building Specifications for International Energy Agency Comparison of Building Energy Analysis Computer Programs" published by the National Research Council.

The hypothetical building selected is a 12 story, rectangular, 110,000 square foot building, with 35 per cent of the exposed wall surface as windows. Lighting to 4.5 watts per square foot is used. The mechanical systems, insulation, window types and roof system comply with the requirements of ASHRAE 90-1975. ASHRAE 90-75 is the standard adopted by most of the American states and by the Canadian Government for building design to conserve energy.

The consumption figures are taken from an average of the research standards for the building, and are used to establish the energy costs in the years 1974 to 1980. They are as follows:

Annual Electrical Consumption .. 1,208,900 kwh

Annual Gas Consumption .... 1,759,156 kwh (equivalent)

The peak loads used for calculating demand charges are 254 kw per month.

Calculations of monthly consumption were based on an assumption of equal use per month rather than the alternative of using a percentage for each month indicating a variation for seasons. Monthly data for a typical year were calculated both ways, and the simplified version varied by less than 1 per cent, so the results based on the equal per month assumption should not be distorted.

In order to establish the relative or percentage changes in net present value occasioned by changing energy consumption figures for other revenue and expense components in the analysis have been estimated from information contained in Experience Exchange Reports [BOMA, 1980]. The net operating income figure, as an average of eight buildings in the Vancouver area, are reported at $4.29 per square foot per year with operating expenses at $4.59 per square foot per year. Energy costs from the previously mentioned analysis are, in the year 1981, $0.35 per square foot per year. This energy cost figure is significantly less than the average in Vancouver based upon BOMA data (which were given at $0.83 per square foot per year). The figure used ($0.35) considers that the latest standards of energy efficiency have been applied to the theoretical building.

The model used to establish the sensitivity of net present value to changes in energy costs is the basic model explained earlier. It assumes that the discount rate (r) is already adjusted for differences in risk and further assumes that an allowance for variations in inflation is included in the discount rate, (r per cent per annum for "N" years). Furthermore the technical data for energy consumption will be used to forecast the annual energy expense and a separate rate of increase will be estimated for operating income before energy expense.

Hence the restated model becomes:

$$NPV = \sum_{t=1}^{N} \frac{NOI(1+a)}{(1+r)^t} - \frac{EN(1+b)}{(1+r)^t} + \frac{R_n}{(1+r)^N} - E_o$$

WHERE: a = per annum increase in NOI (estimated from industry data)

b = per annum increase in energy expenses (estimated the technical energy data supplied by B.C. Hydro)

It is assumed that the project has no debt and the net operating income and reversion flows are after taxes. The assumptions concerning debt and income tax are used for convenience only, and do not detract from the generality of the conclusions. The office building is assumed to be sold at the end of year 5.

For the purposes of this illustration, the equity investment in year 1 is estimated to be $10,200,000 and a year 1 net operating income of $1,277,000 is used (based on average BOMA data).

Further estimates required to complete the specifications of the model are:

Annual Escalation Rates		
Operating Expense flows (a)	=	10 per cent
Energy costs (b)	=	10 per cent
Discount Rate (r per cent) assumed	=	15.5 per cent
Residual Value (R_n) assumed	=	$17,030,000

For purposes of sensitivity analysis, the rate of escalation in operating expenses (NOI) is changed from 10 per cent to 12.5 per cent and 15 per cent. Similar changes to 14 percent and 20 per cent are analysed for energy cost. To establish a base unit energy cost for the purposes of these analyses, a review of current energy pricing is included.

To compare energy costs in British Columbia to other areas, the commercial electrical rate over 30,000 kwh per month of 1.60 cents per kwh should be used. Rate comparisons published by Curtis (1980) show this rate to be typical of the pacific northwest region. Where energy costs are more dependent on the cost of oil, as in Iowa and New York, rates of 5.2 cents/kwh and 7.6 cents/kwh are prevalent.

In predicting future energy costs over the next 5 years, it can be assumed that the lowest possible increase will be at the rate of inflation (b=10 per cent). This is the policy of B.C. Hydro and Power Authority. It is more likely that due to projected demand increases, leading to the need to develop more expensive resources to generate energy, the rate of increase will exceed the rate of inflation. Using a scenario as outlined in a number of publications, including National Research Council - United States (1979), a pessimistic estimation of energy costs based on accelerated demand and higher costs will set the rate of increase substantially higher than the rate of inflation. An exact estimation of the rate of increase is not possible, due to uncertainty in the area of both demand and government policy.

For the purposes of this paper, the most likely increase in energy costs will be at the rate of 4 percent above the rate of inflation (b=14 percent). The optimistic level of increase will be at the rate of inflation (b=10 percent), and the most pessimistic, or worst case, will be at a rate of 10 percent above the rate of inflation (b=20 percent).

Net present values for the three rates of increase of both net operating income, including energy (NOI) (a=10 percent, 12.5 percent and 15 percent) and changes in the rate of increase of energy were calculated (a=10 percent, 14 percent and 20 percent), with results given in Table 2.1. The sensitivity of the net present value to changes in the cost of energy were calculated.

TABLE 2.1

NET PRESENT VALUE OF HYPOTHETICAL BUILDING

Energy Acceleration Rate	Operating Income Escalation Rate (%)		
	a=10%	a=12.5%	a=15%
b_1=10%	$-540,000	$255,000	$1,091,000
b_2=14%	$-553,000	$242,000	$1,079,000
b_3=20%	$-574,000	$221,000	$1,057,000

For example, as the rate of increase of energy costs goes from 10 percent to 14 percent, the net present value declines from $-540,000 to $-553,000 or 2.41 percent.

The results shown in Table 2.2 show that sensitivity of net present value to changes in the acceleration of energy costs is very dependent on the scale of the net present value itself.

TABLE 2.2

ELASTICITY OF NET PRESENT VALUE

Change in Energy Acceleration Rate	Operating Income Escalation Rate (%)		
	a_1=10%	a_2=12.5%	a_3=15
(b_2-b_1)=4%	-.32	-.71	-.17 %
(b_3-b_2)=6%	-.34	-.79	-.18

From Table 2.2, for example, the elasticity of the net present value, at a change in energy acceleration rate of 4 percent, increases from -0.32 to -0.71 and reduces from -.071 to 0.17 as the operating income escalation rate is increasd from 10 percent to 12.5 percent and from 12.5 percent to 15 percent.

In order that this dependence on the <u>level</u> of the net present value be removed, the internal rates of return were calculated for the rates of change of operating income (NOI) and energy costs (EN).

The internal rate of return is defined as that rate (r) which provides a net present value of zero. In other words:

$$0 = \sum_{t=1}^{N} \frac{NOI(1+a)}{(1+r)^t} - \frac{EN(1+b)}{(1+r)^t} + \frac{R_n}{(1+r)^N} - E_o$$

The results of the internal rates of return calculations are shown in Table 2.3 and the sensitivity is shown in Table 2.4

TABLE 2.3

INTERNAL RATES OF RETURN CALCULATIONS

Energy Escalation Rate	Operating Income Escalation Rate (%)		
	a_1=10%	a_2=12.5%	a_3=15%
b_1=4%	14.13%	15.95%	17.77%
b_2=6%	14.10%	15.93%	17.75%
b_3=20%	14.06%	15.89%	17.72%

As an example, for an energy escalation rate of 14 percent and an operating income escalation rate of 12.5 percent, the internal rate of return is calculated at 15.93 percent for the hypothetical building.

TABLE 2.4

ELASTICITY OF INTERNAL RATES OF RETURN

Change in Energy Acceleration Rate	Operating Income Escalation Rate (%)		
	a_1=10%	a_2=12.5%	a_3=15%
(b_2-b_1)=4%	.029	-0.18	-0.15
(b_3-b_2)=6%	.025	-0.17	-0.14

To produce a more meaningful measure of sensitivity, elasticities of the internal rates of return were calculated in relation to changes in energy costs and changes in other costs. The results again showed that the change of the internal rate of return was only mildly sensitive (elasticities of between -.014 and +.029) to major changes in the escalation rate of energy costs independent of the changes in other costs.

There are a number of possible reasons why changes in energy costs are not important determinants of changes in net present values or internal rates of return. It is most likely that energy is not a major component of the overall expenses of operating a building relative to other expenses. In addition, small changes in the internal rate of returns may be very important compared to large changes in the cost of energy, leading to a low sensitivity.

ENERGY COST AND NET PRESENT VALUE: A SUMMARY

In this chapter we have developed a model to demonstrate the role of energy operating cost on the net present value on commercial buildings. Given the set of technical forecasts or growth rates of energy cost presented, it is demonstrated that the net present value or internal rate of return, and hence market value was not highly sensitive to changes in the forecasted cost of energy consumption. However, the question remains whether differences in the level of energy consumption will be reflected in the market value of commercial office buildings.

In the next chapter, we will attempt to determine whether different levels of energy consumption influence market value for a sample of actual office buildings. The empirical study looks at the effect that the level of energy operating expense has on the market value of an office building, and specificially whether a reduction in the level of energy used (through investment in equipment or plant) has the effect of increasing the market value of the building.

CHAPTER III

EMPIRICAL STUDY: ENERGY AND MARKET VALUES

Regression Analysis

In the previous chapters, a analytical model was developed which demonstrated the sensitivity of a change in the level of energy expense on the net present value, and hence on market values of real property. This model was analyzed using a "best efforts" forecast of future energy costs and all other costs and benefits (rents) associated with the ownership of commercial property. In this chapter a sample of commercial office properties will be analyzed to determine whether variations in either the level of or the rate of change in energy cost are reflected in market prices.

Readers will recall that the analytical model introduced in the last chapter was as follows:

$$NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t} + \frac{R_n}{(1+r)^n} - E_o$$

In order to demonstrate more clearly the role of energy costs, this model was re-written in a form which isolated energy costs.[1]

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1 With no debt and in equilibrium, Market Price = NPV + E_o [and in equilibrium expected NPV = 0]

Hence, the re-written model is as follows:

$$\text{PRICE (P)} = \sum_{t=1}^{N} \frac{NOI_t}{(1+r)^t} - \frac{EN_t}{(1+r)^t} + \frac{R_n}{(1+r)^N}$$

WHERE: PRICE = E_O
(assumes no debt and equilibrium conditions prevail, bid = asked)

To estimate the relative importance of energy in a market value model, a model is developed to show how real estate markets capitalize energy savings into value. The method of estimating the effect of changes in energy costs on value is multiple regression analysis.

Multiple regression analysis (MRA) employs historical data for both prediction and structural analysis. The availability of computers has made possible the incorporation of very large data bases in empirical models, either to test hypotheses or to predict values of specific variables.

The construction of MRA models in real estate appraisal has been the subject of a large body of literature, particularly in the area of residential appraisal. Research in the area of commercial analysis is less well documented, but most of the information contained in papers concerning residential appraisal can be applied in the commercial area.

Within the literature concerning residential appraisal, a detailed description of multiple regression analysis, using least-squares technique, is presented by Church (1975). The motivation for developing this multiple regression analysis model for mass appraisal stems from the legal requirements for frequent assessment of all property. The model used by Church establishes the equation for the quantity demanded (which depends on the various attributes of the house) and sets this equal to the quantity supplied. In its intermediate form, this model (called the structural model) can be stated as follows:

$$P_h = \frac{(F_1-H_3)}{(H_2-F_2)} + \frac{(F_3-H_3)}{(H_2-F_2)} C_1 + \frac{F_{(n+2)}-H_{(n+2)}}{(H_2-F_2)} C_n + e$$

where $H_2 > 0$ and $H_2-F_2 > 0$
$H_2 > 0$

P_h = Price
F = Supply Coefficient
H = Demand Coefficient
C = Independent Variable Coefficients
e = Random Error Term

Each coefficient in the equation has both supply and demand factors, which may be either positive or negative, and the sign of the variable resulting from empirical analysis may be difficult to explain. The estimated coefficients of the independent variables are then combined to provide the closest fit between the observed data and the regression equation.

This intermediate form of the equation is further simplified to what is traditionally called the reduced form of the

the equation. This further simplification is possible assuming that equilibrium conditions exist in real estate markets (i.e. Demand equals Supply).

$$P_n = A + B_1C_1 + B_2C_2 + \text{----} B_nC_n + e$$

WHERE:

$$A = \frac{F_1 - H_3}{H_2 - F_2}$$

$$B_1 = \frac{F_3 - H_3}{H_2 - F_3} \quad \ldots\ldots \text{ etc.}$$

e = random error term

PRICE = Independent variable

C_i = Dependent variable

i = 1, 2, 3, ... n

and C_i represents those factors which will reflect either net operating income (NOI), energy cost or the reversion value.

It is this reduced form of the equation which is used to empirically test our model.

Various problems and limitations with the use of multiple regression analysis are described in the conclusion to Church's article. One obvious limitation arises because of the limit on the number of the characteristics in the equation. To overcome this problem the characteristics to be included can be determined in a number of ways, such as through the use of stepsion[1]. This process ensures that the most statistically significant characteristics are included in the model.

A second problem described by Church relates to the interaction effects of the characteristics. Interaction occurs when the use of two or more variables produces an effect which is different from the sum of the individual effects of the separate events. Where there is high correlation among independent variables, the separate effects of the variables cannot be distinguished.

A similar, but separate problem, is called multicollinearity. Multicollinearity is defined by Gau and Kohlepp (1979) as follows:

> "...the lack of statistical independence of the explanatory variables."

The methodology utilized with least-squares regression analysis is based on the assumption that the explanatory (independent) variables are linearly independent. Where this assumption is violated, multicollinearity is present in the data set. Throughout this study, tests will be applied to determine whether the variables are highly correlated and whether multicollinearity is sufficient to represent a problem.

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1 This statistical technique incorporates the method of accepting the entry of variables in the equation individually according to "t" test significance to minimize interelation.

Grether and Mieskowski (1974) provides a good analysis of the process of selection of independent variables in residential regression analysis which are used, in part, to select variables for this commercial building model. Grether and Mieskowski postulate that the price of the house can be predicted on the basis of its physical characteristics. Grether and Mieskowski separated the variables into three categories:

1) structural characteristics,
2) lot characteristics, and
3) neighbourhood characteristics.

The authors concluded that, given the statistical results of the reduced form linear regression, it appears possible to estimate the magnitude of structural and neighbourhood effects using a limited number of controls for the attributes of the property.

The list of variables used by Berry and Bednarz (1975) was much shorter than those used by Grether, but they included structural characteristics, neighbourhood variables and a location variable. Collinearity between variables such as house size and lot size and high income neighbourhoods and air conditioning, were ignored, as it was stated that these must be included in a minimum set to retain the explanatory power of the regression model.

A more specific topic was researched by Morton (1976). Morton presented information on the stratification techniques related to the accuracy of regression analysis for residential properties. Two samples of properties were narrowly stratified and two were widely stratified.[1]

Better results were obtained using the widely stratified sample. The higher standard error found for the widely stratified sample was justified by showing a better relationship when the standard error is compared with the standard deviation of the dependent variable.

Structural Equations to Test Energy Hypotheses

For the purposes of this study an initial sample of 100 office buildings was drawn from the files of the British Columbia Assessment Authority. In statistical terms, the universe for this study is all buildings in the Greater Vancouver area with the attribute of exclusive office use, having no retail, restaurant or residential components. From this universe those buildings sold during the years 1978 to the first quarter of 1981 were chosen. This time period was selected since data were available from both the Assessment Authority and from B.C. Hydro during this time. Property records prior to 1978 lacked the detail required for this analysis. Therefore it is necessary to assume that there is no systematic difference between the sample selected and the universe. In other words, there is

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1 Wide and narrow stratification refers to the degree of homogeniety in physical characteristics.

no difference in the characteristics, energy consumption or market values of those properties in the sample (which sold in the years 1978-79) and those properties which did not qualify for the sample. This assumption is necessary since the market value is the dependent variable in the regression equation and the best estimate of market value is the sales price.

The initial sample was then reduced in size by matching the buildings for which data on energy consumption could be obtained from the British Columbia Hydro and Power Authority. Due to the unavailability of energy data on some buildings, the sample was further reduced to include those buildings which sold during the designated time and for which energy data were available. It is assumed that the lack of energy data for some 27 out of 100 buildings would not systematically modify the accuracy of the sample.

Data obtained from the British Columbia Assessment Authority for the 73 remaining properties consist of a buildings characteristics. These include:

a) physical dimensions measured in feet, including length, width and height of outside surface;

b) net rentable area in square feet measured inside;

c) lot size in square feet;

d) property location;

e) building use, i.e. office, retail outlet;

f) actual age since construction;

g) effective age since construction on last major renovation;

h) type of construction material;

i) number and location of parking stalls;

j) presence of elevators;

k) gross and net income information;

l) sales price; and

m) sales data.

The data were carefully gathered by the Assessment Authority and updated as buildings were renovated.

The data obtained from B.C. Hydro consist of annual consumption totals for both electricity and natural gas.

In addition information concerning the debt structure of a sub-sample of property was obtained. These data concerning debt were obtained from the British Columbia Land Title Office. These data were obtained for 24 properties out of the total sample of 73 properties. The regression analysis is included to determine if the addition of the debt information had an effect on the market value model as it relates to the energy consumption variable.

Each property in the total sample is represented with 15 variables, while the sub-sample of 24 properties has an additional 4 variables per property relating to the debt structure.

The reasons for adopting these variables, along with greater descriptive details for each variable, are described in the following section.

DESCRIPTION OF VARIABLE

Market Value (V-1)

The market value (sales price) of commercial office buildings is the dependent variable in the regression equation. The market value is taken as the actual sale price of the real property (in dollars) taken from files at the British Columbia Assessment Authority.[1] All non-arm's length transactions were excluded. For the purposes of this sample, properties were excluded if the Assessment Authority believed the sale to be non-arm's length.[2] Furthermore, buildings which were in locations of imminent re-development were also excluded, since the inflated value of the land would distort the regression results. Approximately 30 percent of all sales transactions were excluded for these two reasons.

Net Rentable Area (V-2)

The net rentable area of each building in the sample is the first independent variable, and is measured in square feet.[3] This measurement of area excludes basement areas which

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1 Information on variables is taken from Assessement Authority files unless otherwise noted.

2 A non-arm's length transaction is one where there are other than monitary consideration included in the property transfer. For example, where a sale takes place within a family or between two subsidiaries of the same company.

3 Imperial measures is used, as data from all sources were consistent.

are used for storage. The net rentable area is used to transform other variables which are dependent upon building size. (The SCALE Factor)

Lot Size (V-3)

The size of the lot is calculated in square feet from dimensions in the Assessment Authority files. The lot size is assumed to have an effect on the reversion value (R_n) in the regression equation.

Number of Stories (V-4)

The number of stories above grade is included as an independent variable. Where basement areas are shown as storage areas, this are not included as a storey. Below grade areas used as offices are included as a full storey. Below grade areas used for parking are considered to be included in independent variable V-9. Consideration is not given to differences in floor to ceiling heights. The number of stories is assumed to have an effect on income, since high buildings (with elevators) may tend to command higher rents. The variable will also have a minor effect on energy due to building configuration, and on reversion value.

Type of Construction (V-5)

A single variable is included to differentiate between frame construction and masonry or concrete construction. The variable is included to explain any value variation due to this difference in physical construction. Masonary construction would relate to longer life and would effect reversion value. Lower maintenance costs and cheaper fire insurance with masonary will relate to expense, and net operating income. The use of a simple variable (yes-no) to indicate whether the building is masonary construction is referred to as a dummy variable.

Air Conditioning (V-6)

A single dummy variable (yes/no variable) is used to explain the difference in the market value of buildings which have air conditioning. It is expected that this variable will be reflected in the annual income of the property, the reversion value of the property and the energy consumption for the building.

Quality (V-7 and V-8)

To a large extent, the quality of the building is a function of age. In the case of older buildings, extensive renovations may have changed the quality. For this reason, a dummy variable is used to separate poor, average and good quality (00, 01, 10). These quality variables were taken directly from

Assessment Authority files, and represent the judgments of the commercial sector assessors. The variable will have an effect on the annual income and the reversion value.

Effective Age (V-9)

In selecting the variable to be used to represent age, the effective age of the building is selected. The effective age of the building is taken as the number of years from 1981 to either the year of construction, or the year of the last major renovation. The effective age variable will relate to net operating income as well as reversion value. It is assumed that older buildings are less energy efficient.

Parking (V-10)

The market value of an office building is assumed to increase as the number of parking stalls increase. The number of parking stalls within property lines is included as a variable to test this assumption. This variable will affect both the annual income and the reversion value.

Type of Parking (V-11)

To differentiate between on-grade and underground parking, a single dummy variable (yes/no) is included. Underground parking is assumed to add to both the annual income and the reversion value.

Elevators (V-12)

The presence or absence of an elevator, particularly in the two and three storey segment of the sample is expected to have an effect on the market value of the office building. A single dummy variable (yes/no) is included to explain this difference. This variable will relate to energy consumption and the annual income.

Sales Date (V-13)

Due to the secular increase in market value of commercial office buildings, a variable representing the number of months to the sales date from January 1st, 1977 to the sales date is included. It is assumed that this variable will reflect the effect of inflation on market value.

Location (V-14, V-15, V-16)

Assessment Authority experience has separated the city into geographic zones of comparable value. For this equation, the variation between different zones of the city is accounted for by using dummy variables for the following (areas used by the Assessment Authority):

a) Central Business District;

b) Central Business Fringe;

c) Court House Area; and

d) Elsewhere.

It is assumed that the locational contribution to value remains constant within each of these areas, and hence the dummy variable will relate the differences between locations in the annual income and the reversion value.

Gross Income (V-17)

Gross income per year per property in dollars is taken from the Assessment Authority files. This variable required the most judgment in attempting to establish the gross income which the investor in the office building would use in establishing the purchase price.

In over one-half of the sample, where the buildings were near full occupancy, the actual income data are used. Where there was a serious conflict between the actual and the potential income, the potential or economic rents of the building are used. This potential rent or income from the property is calculated by the assessors based on comparable building rentals in effect at that same time in the same area, with a reasonable allowance for expenses, management and vacancies. This method, according to the Assessment Authority, has previously proven to be successful as one of the methods of determining value for assessement purposes.

In some cases it was necessary to adjust this income figure by an annual inflation factor up to the year of sale, where the income data and the sale are from different periods.

Energy Expense (V-18)

Energy consumption, adjusted for changes in unit costs and weather differences to the year of sale, are from the files of B.C. Hydro and Power Authority, and include the costs of power and natural gas. The adjustments for differences in weather between the year the data is available and the year of sale is calculated using differences in the number of degree days for both heating and cooling. Where there has been a demand charge for electrical load, the demand is converted into an equivalent consumption unit to allow comparison. Utility consumption was converted to kilowatt hours as the most convenient unit, and this was used as a proxy for energy expense. Conditions of confidentiality set out by B.C. Hydro to allow the use of customer data were respected, and individual consumption information was left in the Hydro offices.[1]

Debt (V-19)

The total mortgage debt of each property is taken from the files of the Provincial Land Titles Office.

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1 No individual properties and no individual property owners are identified throughout this thesis since no individual records were obtained. The author wishes to express his appreciation to the officials of B.C. Hydro for preparing the aggregate data for use in this thesis.

Debt Payment (V-20)

The debt service costs for mortgages registered upon the property are taken from the Provincial Land Titles Office and converted to an annual figure.

Interest (V-21)

A weighted average of interest rates is used in cases where there is more than one mortgage recorded. Where there is only one mortgage, the contract rate is used.

Mortgage Term (V-22)

In an effort to capture the impact of the time factors for borrowed capital at the time of purchasing a commercial office property, the remaining term of the mortgage (in months) is included as an independent variable. Where there is more than one mortgage, a weighted average of remaining months is used.

Consumer Price Index for Vancouver (V-23)

To adjust factors affected by inflation, the accuracy of the regression equation was compared using a test with the terms market value, energy expense, and income divided by the consumer price index from Statistics Canada as listed in the following as "CPI". This variable is used in the transformation so that inflation dependent variables are reduced to real terms.

The reduced form regression equation is established and variables V-4 through V-9, V-11 through V-16 as previously described, and transformed variables V-25, V-30, V-35, V-40 and V-45 are tested. The transformed variables represent five of the original variables (V-1, V-3, V-10, V-17 and V-18) each converted to a measure per "net rentable area". These transformed variables were then recorded as follows:

DEPENDENT VARIABLE

MARKET VALUE/UNIT AREA (V-25) =
MARKET VALUE (V-1)/NET RENTABLE AREA (V-2)

INDEPENDENT VARIABLES

LOT SIZE/UNIT AREA (V-30) =
LOT SIZE(V-3)/NET RENTABLE AREA (V-2)

GROSS INCOME/UNIT AREA (V-35) =
GROSS INCOME (V-17)/NET RENTABLE AREA (V-2)

ENERGY CONSUMPTION/UNIT AREA (V-40) =
ENERGY CONSUMPTION (V-18)/NET RENTABLE AREA (V-2)

NUMBER OF PARKING STALLS/UNIT AREA (V-45) =
NUMBER OF PARKING STALLS (V-10)/NET RENTABLE AREA (V-2)

A number of regessions were run using the MIDAS package to identify the best possible equation. The results of these equations are discussed in the next chapter of this thesis.

CHAPTER IV

REGRESSION ANALYSIS RESULTS

COMPLETE SAMPLE
(Referred to as DATA-1 in the results)

As a first step in the analysis of energy consumption and its effect on property values, the correlation matrix for the full sample was developed (TABLE 4.1). With one exception, the correlation coefficients have the expected sign (positive or negative). The one exception is, however, of some consequence since it represents the relationship between energy consumption and market value. It was expected that the correlation coefficient would be negative, but in fact it is positive. There are a number of possible explanations for this unexpected result and hopefully some insights will become apparent as the analysis continues. There is evidence of high correlation between the energy variable (V-40) and; the number of stories (V-4) of .4737, the presence of air conditioning (V-6) of .4138 and the presence of elevators (V-12) of 0.4788. This would indicate the likely presence of multicollinearity. These variables are positive determinates of value and may not allow the analysis to separate the effect of energy consumption on market value.

The second step in the analysis involved the least squares regressions using the entire sample and all 16 independent variables. The results of this analysis, as shown in the TABLE 4.2 are statistically significant[1]. Furthermore, the model "explains" 69.3 per cent of the variation in the market value (R^2 = 69.3 per cent).

At the structural analysis level, variables which are significant (over 10 per cent t-test[2]) are distinguished from those which are not significant at the 10 per cent level as follows:

SIGNIFICANT		NOT SIGNIFICANT	
Lot Size	(V-30)	Energy Consumption	(V-40)
Annual Income	(V-35)	Parking Stalls	(V-45)
Quality 1	(V- 7)	Elevator	(V- 4)
Elevator	(V-12)	Masonry	(V- 5)
Sales Date	(V-13)	Air Conditioning	(V- 6)
Location 1	(V-14)	Quality 2	(V- 8)
Location 2	(V-16)	Age	(V- 9)
		Underground Parking	(V-11)
		Location 2	(V-15)

The coefficients from the regression for the significant variables are mostly consistent in sign with the correlation matrix, with the one exception being the first location variable (V-14). However, the degree of correlation between market value (V-25) and location (V-14) is very low and the change in the sign is not assumed to be a problem.

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1 The "F" statistic is an analysis of variance for testing the significance of the regression line. In this regression, the F statistic was 7.91, compared with an F-statistic of 2.11 which indicates a statistical significance at the 5 percent level. The results show that this F-statistic is significant at the 0 percent level.

2 The "t" test is used to eliminate poor predictors of the dependent variable.

The relationship between energy consumption (V-35) and market value (V-20) is positive as was the case in the correlation matrix. The coefficient for energy is 0.136. This result does not agree with the original hypothesis, but it should be noted that the coefficient for energy consumption (V-40) in the model has a "t"[1] statistic of 0.993 which results in statistical significants only at the 32.7 per cent level.[2]

A number of further regressions of the complete sample were run in an attempt to better isolate the energy variable. Eliminating variables with high correlation with energy, the co-efficient of the energy variable was stable and positive as the variables with high correlation coefficient were dropped. Additional regressions were run including the area variable (V-2) and excluding the income variable, however, these regressions had little effect on the R^2 or the coefficient of the energy variable.

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1 The "t" statistic is a measure of the variation of the coefficient of the independent variable from normal distribution.

2 An attempt was made to improve the regression results by incorporating the Consumer Price Index (CPI) for Vancouver. Market Value (V-25) and annual income (V-35) were converted to real terms by dividing by the Consumer Price Index for the month of sale. This regression yielded an R^2 of 65.3 percent compared to 69.3 percent in the original sample and an F-statistic of 6.65 compared to 7.91 in the original sample. It was assumed that the use of the CPI to convert to real terms does not improve the results, and is therefore not used in further regressions.

TABLE 4.1
CORRELATION MATRIX OF THE DATA-1 SAMPLE

VARIABLE	25. VALUE	30. LOT	35. INCOME	40. ENERGY	45. STALLS	4. STORIES	5. MASONRY	6. AIR	7. Q1	8. Q2	9. AGE	11. UG
25.VALUE	1.0000											
30.LOT	.1886	1.0000										
35.INCOME	.4174	-.0225	1.0000									
40.ENERGY	.3153	-.3328	.2153	1.0000								
45.STALLS	.2319	.0625	.2088	.2656	1.0000							
4.STORIES	.1164	-.5663	-.0377	.4737	.0362	1.0000						
5.MASONRY	.0947	-.4124	.0421	.3352	.1514	.2938	1.0000					
6.AIR	.2794	-.2401	.2609	.4138	.2347	.2076	.5248	1.0000				
7.Q1	.0175	.0896	.0826	-.1145	.0666	-.0343	-.1828	-.3305	1.0000			
8.Q2	.2328	-.0089	.0282	.2312	.0807	.0047	.1700	.5616	-.7803	1.0000		
9.AGE	-.2981	.1741	-.3474	-.2903	-.1689	.0551	-.2000	-.3982	-.0429	-.1781	1.0000	
11.UG	.2941	-.2543	.3352	.4406	.4464	.2782	.2802	.3139	.0592	.0936	-.2337	1.0000
12.ELEV	.3250	-.5696	.2386	.4788	.0876	.5512	.4915	.5032	-.1678	.2151	-.1460	.4665
13.DATE	.4900	-.0684	.1380	.1487	-.0046	.0351	.0752	.1122	-.2926	.3532	-.1673	-.0424
14.LOC1	.0651	.5965	.0083	-.0198	.3077	-.3872	-.2986	-.0944	.1121	.0653	.0083	.0928
15.LOC2	.0340	-.0813	.2262	-.0472	-.1172	-.1046	-.0019	-.0799	.2651	-.2069	.0583	-.0129
16.LOC3	-.2795	-.2996	-.0769	-.1273	-.1282	-.0037	.1336	-.0617	-.1213	-.0940	-.0300	-.0843

VARIABLE	12. ELEV	13. DATE	14. LOC1	15. LOC2	16. LOC3
12.ELEV	1.0000				
13.DATE	.2450	1.0000			
14.LOC1	-.2711	-.0723	1.0000		
15.LOC2	-.0851	-.0435	-.2803	1.0000	
16.LOC3	-.0254	-.0564	-.5919	-.1224	1.0000

TABLE 4.2
REGRESSION RESULTS OF DATA-1 SAMPLE

<REG VAR=25,30,35,40,45,4-9,11-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 73 OUT OF 73

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	25122.	1570.1	7.9078	.0000
ERROR	56	11119.	198.56		
TOTAL	72	36241.			

MULT R= .83258 R-SQR= .69319 SE= 14.091

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		.86246	13.112	.65776 -1	.9478
30.LOT	.60330	32.707	5.7776	5.6610	.0000
35.INCOME	.21962	1.8004	1.0688	1.6846	.0976
40.ENERGY	.13150	.13598	.13698	.99271	.3251
45.STALLS	.12232	1704.9	1848.5	.92229	.3603
4.STORIES	.11607	.52612	.60162	.87451	.3856
5.MASONRY	-.00298	-.11583	5.1857	-.22336 -1	.9823
6.AIR	-.06826	-3.1053	6.0645	-.51204	.6106
7.Q1	.25409	12.507	6.3621	1.9659	.0543
8.Q2	.18098	10.005	7.2654	1.3771	.1740
9.AGE	-.21454	-.23027	.14009	-1.6438	.1058
11.UG	.19281	7.6891	5.2291	1.4704	.1470
12.ELEV	.28313	12.816	5.8011	2.2091	.0313
13.DATE	.49120	.77388	.18339	4.2199	.0001
14.LOC1	-.34033	-19.042	7.0306	-2.7085	.0089
15.LOC2	-.05747	-4.4498	10.330	-.43076	.6683
16.LOC3	-.22550	-11.425	6.5961	-1.7321	.0888

STRATIFIED SAMPLE WITH DEBT DATA
(Referred to as DEBT-DATA-1 in the results)

A further regression was run using a sub-sample of 24 properties for which debt information was obtained. This debt information represented an additional four variables.

A summary of results (Table 4.3) show some problems with the correlation matrix. Again, the relationship between annual energy consumption (V-40) and market value (V-25) is positive, consistent with the regression on the complete sample. The outstanding balance variable (V-50) and the payment variable (V-55) are both positively related to market value indicating that increasing debt loads can be supported by properties of higher value.[1] The remaining relationships are as expected except for masonry with a negative sign. In this sample, there is a high inverse correlation (-.716) between the number of stories and lot size. Since both are transformed to a square foot basis, this relationship is assumed to be coincidental due to the small sample size. An expected high positive correlation exists in this stratified sample between the number of storeys and the presences of an elevator, and between annual income (V-35) and market value.

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1 Variations in the outstanding balance/property value (loan/value ratio) and payment/gross income (gross debt service ratio were included in a separate regression to indicate the impact of leverage on value, but were found to have no effect on the energy consumption variables/value relationship.

The regression results for the DEBT-DATA-1 sample in Table 4.4 show an R^2 of 95.32 percent but an test significance of only 19.45 percent (F=3.05). The only variable to have a "t-test" significance at the 15 percent level is annual income.

Although the sample size is small, the debt variables selected are shown not to be significant and it is assumed, for the purpose of this paper, that the results of the complete sample or other stratified samples are not affected by the absence of these debt variables.

TABLE 4.3
CORRELATION MATRIX FOR THE DEBT-DATA 2 SAMPLE

VARIABLE	25. VALUE	30. LOT	35. INCOME	40. ENERGY	45. STALLS	50. OSB	55. PMT	4. STORIES	5. MASONRY	6. AIR	7. Q1	8. Q2
25.VALUE	1.0000											
30.LOT	.1250	1.0000										
35.INCOME	.6458	.1009	1.0000									
40.ENERGY	.4451	-.3749	.3614	1.0000								
45.STALLS	.3178	.0181	.2730	.3724	1.0000							
50.OSB	.4121	-.0449	.2107	.1044	.0911	1.0000						
55.PMT	.4553	-.1019	.2774	.2039	.2011	.9687	1.0000					
4.STORIES	.2103	-.7157	.1391	.4900	.1416	.1345	.2575	1.0000				
5.MASONRY	-.0114	-.4843	-.1444	.3091	.1732	.1386	.1510	.3178	1.0000			
6.AIR	.3946	.0214	.4316	.3487	.3981	.2862	.2759	.0793	.2902	1.0000		
7.Q1	.4418	-.1752	.0661	.2124	.1909	.4317	.4542	.2857	.1451	.1250	1.0000	
8.Q2	.0781	.2487	.3094	.1043	.0900	-.0814	-.1202	-.2666	-.0265	.5477	-.5477	1.0000
9.AGE	-.3373	.1314	-.3486	-.4405	-.2608	-.0319	-.0308	.1520	-.2443	-.4725	-.1860	-.2233
11.LOC1	.4838	-.2994	.4473	.7415	.3519	.0546	.1403	.5296	.2632	.3627	.2902	.0265
12.LOC2	.2102	-.6638	.1731	.3601	-.0028	.1527	.2069	.8764	.3292	.0648	.1296	-.1183
13.LOC3	-.1335	-.3566	-.4674	.3008	-.0107	.1377	.1384	.2028	.2118	-.0817	-.1327	-.0037
14.I	-.0801	.5927	.1503	-.0377	.2417	-.1207	-.1674	-.4040	-.3078	.3536	-.1768	.4303
15.E	.0177	-.0640	.0082	-.0070	-.1568	.0380	.0345	-.1217	.1070	-.2949	.2949	-.1615
16.V16	-.1679	-.1554	-.4735	-.2260	-.2341	.0303	-.0060	-.1111	.1035	-.3241	-.0648	-.3077
21.INT	-.1626	-.0070	-.3652	-.2963	-.2547	.5993	.5085	-.0779	.0478	-.0558	.0607	-.0883
22.TERM	.1028	.0351	.2938	.2174	.2300	-.6527	-.5862	.0234	-.0477	.0828	-.1006	.1150

TABLE 4.3 (continued)

	9. AGE	11. LOC1	12. LOC2	13. LOC3	14. I	15. E	16. V16	21. INT	22. TERM
9.AGE	1.0000								
11.LOC1	-.3275	1.0000							
12.LOC2	.1492	.5737	1.0000						
13.LOC3	-.0557	.0370	.1416	1.0000					
14.I	-.0450	.1026	-.2750	-.3031	1.0000				
16.V16	-.0385	-.3292	-.2101	.4909	-.6417	-.1338	1.0000		
21.INT	.3096	-.3647	.0060	.2863	-.1742	.0870	.3078	1.0000	
22.TERM	-.2531	.2980	-.0487	-.3043	.2088	-.0875	-.2551	-.9712	1.0000

TABLE 4.4
REGRESSION RESULTS FOR THE DEBT-DATA 2 SAMPLE

<REG VAR=25,30,35,40,45,50,55,4-9,11-16,21,22>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 24 OUT OF 24

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	20	7952.6	397.63	3.0538	.1945
ERROR	3	390.62	130.21		
TOTAL	23	8343.2			

MULT R= .97631 R-SQR= .95318 SE= 11.411

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		40.907	93.418	.43789	.6911
30.LOT	.79185	34.198	15.228	2.2457	.1104
35.INCOME	-.02950	-.25519	4.9921	-.51118 -1	.9624
40.ENERGY	.61735	.74187	.54581	1.3592	.2672
45.STALLS	.49748	2712.5	2730.8	.99330	.3938
50.OSB	-.29949	-.58283	1.0720	-.54370	.6245
55.PMT	.39019	60.812	82.849	.73402	.5161
4.STORIES	-.55491	-4.3348	3.7519	-1.1553	.3316
5.MASONRY	-.66739	-17.862	11.507	-1.5522	.2184
6.AIR	.59659	25.834	20.065	1.2875	.2882
7.Q1	.43827	16.579	19.631	.84453	.4604
8.Q2	-.15023	-3.0711	11.668	-.26320	.8094
9.AGE	.01677	.17043 -1	.58670	.29049 -1	.9786
11.LOC1	-.42092	-22.047	27.431	-.80372	.4803
12.LOC2	.71982	74.572	41.520	1.7961	.1704
13.LOC3	-.03711	-.11739	1.8251	-.64317 -1	.9528
14.I	-.54513	-24.743	21.969	-1.1263	.3420
15.E	.31748	15.050	25.954	.57989	.6027
16.V16	.19305	10.214	29.973	.34078	.7557
21.INT	-.16917	-2.0108	6.7638	-.29729	.7856
22.TERM	-.02266	-.27312 -2	.69572 -1	-.39256 -1	.9712

"HOMOGENEOUS" SAMPLE RESULTS

The complete sample is stratified further to produce more homogeneous sub-samples. It is expected that, if the hypothesis is to be supported, the assumption of a negative relationship between energy consumption and value may be present if the office buildings are broken down into groups which are more homogeneous.

The stratification technique used was to split the complete sample in two parts, with as close to an even split as possible. The criteria used for purposes of stratifying the sample include:

a) age;

b) number of stories; and

c) quality of construction.

It was felt that these three criteria provided the best homogeneous groupings for purposes of this analysis.

The following regressions were run and the results summarized in Table 4.5:

a) Age - 10 (buildings of age 10 years and younger)

b) Age - 11 (buildings of age 11 years and older)

c) St. - 2 (buildings of two stories and fewer)

d) St. - 3 (buildings of three stories and more)

e) Age - 15 (buildings of age 15 years and younger
St. - 3 and three or fewer stories)

f) GOOD (Buildings of "good" quality using the Q-1 variable for stratification)

The computer printout of correlation matrices and regression results for these stratified samples are given in Appendix A.

TABLE 4.5
SUMMARY OF REGRESSION RESULTS

SAMPLE	NUMBER OF BUILDINGS	LOT	INCOME	ENERGY	STALLS	STOREYS	MASONARY	AIR	Q1	Q2
DATA-1	73	32.71 *(0.000)	1.80 *(0.098)	0.136 (0.325)	1704.9 (0.360)	0.531 (0.386)	- 0.126 (0.982)	- 3.11 (0.611)	12.51 *(0.054)	10.01 (0.174)
AGE-10	36	25.24 (0.128)	3.17 (0.195)	0.029 (0.896)	717.1 (0.871)	1.81 *(0.072)	11.39 (0.316)	- 4.61 (0.670)	4.99 (0.640)	8.93 (0.420)
AGE-11	36	-0.29 (0.434)	2.03 (0.252)	0.092 (0.707)	1477.2 (0.548)	- 1.14 (0.229)	- 8.18 (0.176)	- 3.56 (0.685)	17.06 *(0.075)	8.19 (0.468)
ST-2	33	40.49 *(0.001)	0.144 (0.949)	+ 0.403 (0.284)	945.2 (0.697)	- 0.90 (0.927)	-11.19 (.1531)	1.77 (0.860)	20.07 *(0.082)	13.37 (0.355)
ST-3	39	39.38 *(0.026)	2.10 (0.277)	- 0.034 (0.876)	3127.4 (0.464)	0.95 (0.283)	8.21 (0.635)	1.44 (0.927)	10.95 (0.328)	10.14 (0.377)
AGE-15 ST-3	35	51.47 *(0.006)	- 0.491 (0.821)	- 0.1191 (0.605)	-5051.5 (0.106)	9.86 (0.110)	8.33 (0.314)	- 5.52 (0.626)	8.31 (0.460)	17.88 (0.227)
GOOD	31	31.56 *(0.028)	- 0.681 (0.799)	0.150 (0.521)	1504.6 (0.678)	0.42 (0.703)	-15.5 (0.238)	0 0	0 0	0 0

SAMPLE	AGE	UG	ELEV	DATE	LOC 1	LOC 2	LOC 3	R	F STAT	CONSTANT
DATA-1	- 0.230 (0.106)	7.69 (0.147)	12.82 *(0.031)	0.774 *(0.000)	-19.04 *(0.009)	- 4.45 (0.669)	-11.43 *(0.089)	69.32	7.91 (0.000)	0.862
AGE-10	- 0.996 (0.384)	- 0.791 (0.911)	12.57 (0.140)	0.635 *(0.033)	0.201 (0.998)	22.20 (0.258)	- 9.40 (0.335)	81.14	5.11 (0.001)	- 7.37
AGE-11	- 0.593 (0.756)	25.19 *(0.025)	8.59 (0.476)	1.025 *(0.003)	-35.13 *(0.001)	-26.34 *(0.062)	- 7.48 (0.470)	81.64	5.28 (0.000)	11.17
ST-2	- 0.298 (0.317)	5.36 (0.659)	- 0.89 (0.960)	0.550 (0.128)	-20.60 *(0.980)	- 0.631 (0.949)	- 1.39 *(0.002)	75.65	3.11 (0.14)	4.29
ST-3	- 0.164 (0.559)	7.37 (0.366)	- 0.361 (0.971)	- 0.977 *(0.009)	-20.17 (0.103)	11.84 (0.539)	-16.12 *(0.073)	75.69	4.06 (0.001)	- 8.95
AGE-15 ST-3	- 0.108 (0.903)	14.54 *(0.067)	3.48 (0.700)	0.850 *(0.007)	-16.48 (0.276)	33.14 (0.129)	-15.22 (0.269)	80.85	4.75 (0.001)	-22.71
GOOD	- 0.870 (0.049)	11.78 (0.198)	20.94 (0.164)	0.348 (0.564)	-20.37 (0.129)	0 0	-16.94 (0.181)	69.56	3.43 (0.009)	55.98

NOTE: THE FIGURES IN BRACKETS BELOW THE VARIABLE COEFFICENTS ARE THE LEVEL OF SIGNIFICANCE OF THE VARIABLE.
THE * INDICATES A VARIABLE WITH A SIGNIFICANCE OF 10% OR LESS

The correlation matrices, similar to that of the complete sample, indicate that there is high correlation between the energy variable (V-40) and other independent variables which are positive determinants of value. These include: the number of parking stalls per square foot, the height of the office buildings and the presence of masonry construction, air conditioning and elevators.

In all cases in the correlation matrices of the stratified sample results there are at least three correlation coefficients which are positive determinates of value which are over 0.4, with the exception of the ST.-2 regression. The presence of this high correlation is an indication that multicollinearity exists in the data set.

An initial indication, referring to the correlation matrices for the complete sample, and the stratified sample, is that the expected negative relationship between energy consumption and market value cannot be proven, since, in all cases the correlation coefficients are positive.

Referring to Table 4.5, the R^2 for the stratified sample regressions are between 69.56 and 81.64, with a highly significant "F" statistic of at least the 0.9 percent level.

This indicates that the data are statistically significant and the model is a good predictor of values.

REGRESSION RESULTS: A SUMMARY

This is a summary of the regression analysis indicating the effect of the energy consumption variable on the market value of office buildings:

TABLE 4.6
ENERGY CONSUMPTION VARIABLE

DATA FILE	ENERGY COEFFICIENT[1]	LEVEL OF SIGNIFICANCE	NUMBER OF BUILDINGS
DATA-1	0.136	32.50%	73
AGE 10	0.029	89.60%	36
AGE 11	0.092	70.70%	36
ST 2	0.403	28.41%	33
ST 3	- 0.034	87.60%	39
AGE 15 ST 3	- 0.119	60.50%	35
GOOD	0.150	52.10%	31

Referring to Table 4.6, the positive relationship exhibited between the energy variable and value has been reversed in the energy coefficient from the regression analysis for two of the stratified samples (ST-3 and AGE 15 ST 3). This gives a further indication that multicollinearity may be a problem. In the regression of these two stratified samples the energy coefficient varies between -0.119 and 0.403 dollars/kilowatt hour

1 The units of the coefficient are dollars/killowatt hour per square foot.

per square foot, and the coefficient turns out to have very low "t" test significance at between 28.41 percent and 89.6 percent.

With the exception of the negative signs in the ST-3 and AGE-15 ST-3 regression, the results do not support the hypothesis as originally stated. In the complete sample, the results of the analysis suggests that the effect of the level of energy consumption is to increase the value of an office building as the energy consumption increases. The stratification of the sample into more homogeneous groupings of age, size and quality, energy consumption, and therefore energy expense, does not appear to have a significant effect on the results of the regression analysis. The first hypothesis, that: An increase in the expense of energy consumed by a commercial office building has the effect of reducing the market value of an office building, is therefore rejected. That the results indicate that no relationship exists between value and energy consumption, is evidenced by the lack of significance of the energy variable in this sample. There are a number of possibilities to account for the lack of significance. One possibility is that the sample is to heterogeneous in terms of size and age of buildings. Furthermore, a lack of information on vacancy rates would tend to distort the results since higher occupancy rates would be reflected in higher market values, and simultaneously in higher increase energy consumption, thereby suggesting that higher energy consumption and costs are positively correlated with higher market values.

One further factor which may contribute to these regression results relates to the contractual lease terms as between landlord and tenant. In this study, energy consumption relates to the entire building, whereas the rental data refers to the contractual rents. <u>To the extent that these lease contracts provide that the tenant bears the responsibility for the energy cost, the landlord (and gross rents used in this study) are simply a neutral conduit</u>. In most cases, floor space is leased on what is termed a "triple net lease". Under the terms of the lease, the tenant pays a basic rent, plus a pro rata share of the cost of utilities, taxes and maintenance. Hence, as tenants have a contractual responsibility for energy costs, a change in energy costs is unlikely to reflect in market values until such time as the lease is renewed. Unfortunately, this cannot be tested with the data available.

Finally, as previously mentioned, these is some indication that multicollinearity distorted the regression results. This possibility was tested by removing the variables which are highly correlated with the energy variable. The positive coefficient for energy remains as can be seen in Appendix B indicating that the effect of multicollinearity is minimal.

Prior to drawing conclusions from these results in terms of the second hypothesis or of their importance to the private and public sectors, a study of the policy questions surrounding energy in general, and office building energy consumption is necessary. The next chapter of this thesis is therefore directed to questions of policy.

CHAPTER V

ENERGY POLICY

In view of the national importance of reducing the consumption of energy and in consideration of both social and economic factors, a review of the various policy measures is presented. This includes policies which are either currently employed or could be implemented in Canada and the United States.

Support for the argument that new policy measures are necessary comes from many sources. There exists a widely-held belief that energy conservation is not very necessary because there is no energy problem at either the national or provincial level. An attitude that "others" will cut back on energy use gives way to the tendency to take the "if they don't, why should I bother?" approach. In a survey carried out by CANADIAN BUILDING (1981), the following results were reported:

1) The cost of energy has not yet risen or been passed on to the consumer to the extent that it might produce a major change in consumption behavior.
2) Energy costs, compared to other expenses, are not first or even second, but fifth in order of importance.
3) There is a lack of understanding about the quantity of energy being used or the rate at which costs are rising.

4) There is little understanding of or information about metering or rate structures, making intelligent decisions about conservation measures impossible.

Lurz (1981) contends that if world market prices were used instead of subsidies, this would bring about an explosion of activity in both new construction and the retro-fit markets that would be of benefit to Canadians as individuals and as a nation.

Writing in Finance & Development Magazine, Quirls (1980) advocates a policy of allowing prices to increase with market demand and supply. Prices, he maintains, should be allowed to increase and the increase passed on to consumers to provide the necessary market signals. He questions the extent to which additional government policies are necessary when market prices reflect the full cost of energy, and the possibility is emphasized of long-run distortions in resource allocation induced by inappropriate policies. He adds that there is little justification for diminishing present tax rates or tariffs on energy products, where these rates have been established. In his opinion, a reduction would lower incentives to conserve energy. He suggests reconsideration of bulk discounts and block pricing of energy, and finds that the use of these pricing methods has decreased for natural gas and fuel oil since 1975, but has increased for electricity.

The following matrix summarizes the possible array of policy vehicles available for the control of energy consumption in commercial buildings.

TABLE 5.1
Policy Instruments Available to Control Energy Use in Commercial Buildings

	Financial	Non-financial
Persuasive	1) Tax incentives 2) Price incentives 3) Subsidies 4) Tax penalties 5) Inter-government funding	1) Education 2) Research, development and implementation
Mandatory	1) Fines 2) Withdrawal of financing	1) Codes 2) Ordinances

Each of these general policy tools will be discussed in the next section of this paper.

Financial Persuasive Policies

Tax Incentives

At the present time, the Canadian government does not have a tax incentive program either to promote conversion to alternate fuels, or for persuading building owners to install conservation equipment.

In the United States, tax incentives are provided by various levels of government to encourage both conservation and inter-fuel substitution. The Energy Production and Conservation Tax Incentive Act (USA 1978) provides a good example of such a policy. A tax credit of 10 percent of the costs can be applied to investments in conservation equipment against taxable profits. The tax credit applies to waste heat recovery equipment, storage systems, heat pipes, automatic energy control systems, combustible gas recovery systems, and preheaters for feedwater using flue gases.

The legislation includes an additional incentive in the form of a tax credit for investment in conversion properties. The extent of this tax was finally established at 10 percent, although in 1977 the government had originally proposed a 40 percent tax credit. To be eligible for the tax credit, expenditures must be used to convert equipment to use substances other than crude and shale oil, refined petroleum products, natural gas, geopressurized methane and liquified natural gas. The fuels which are eligible for the credit include coal, and agricultural and municipal wastes. The credit is given for boilers, burners, production of synthetic fuel, including that equipment which uses a mixture of oil or natural gas in combination with an alternative substance. The installation costs of pollution control equipment became eligible for the tax credit and were applicable to the costs of new equipment installed after 1977. A similar provision also exists in Canada.

Equipment installed to allow the use of renewable resources, including ocean and tidal, solar and wind equipment and geothermal energy was also eligible for the conversion credit. At the time it went into effect, the tax credit program was projected to cause a budget revenue loss to the U.S. federal government of $5 billion by 1985 and a tax credit of $407 million on conversion equipment. This revenue effect was estimated under the assumption that there would be no extraordinary increase in prices of qualifying property.

An additional feature of the Energy Tax Credit is that it is not limited to tax liability, but is refundable where the tax liability is insufficient. This feature allows the credit to take the form of a grant or price incentive to improve the economics of the installation of conversion or conservation equipment.

A further evaluation of the effects of the Tax Credit Program was provided by Kincel (1978). The projected energy saving in 1985 was estimated at 7.7 quads. Looking at the total consumption, the possibility of consumption savings in the commercial sector are much less significant than possible savings in the industrial sector. It was also noted that second order price effects could be expected because industrial interfuel substitutions would make more gas available for other uses.

Klepper (1980) has written a number of articles on issues related to the Energy Conservation and Solar Tax Credits. The Windfall Profits Tax Act (USA, 1979) was added as an amendment to the Energy Tax Credit Act (USA, 1978), and according to Klepper, it makes three significant changes in tax credits for energy conservation expenditure. Purchase of solar or wind energy equipment now qualifies for a special 15 percent tax credit which remains available until 1985. Expenditures on solar energy which provide process heat for commercial application, as well as equipment that generates electricity or is used to heat or cool a building, are eligible. If the solar equipment does not become a part of the building as a structural component, it may qualify for the 15 percent energy credit as well as the regular business investment tax credit of 10 percent. The second change affecting commercial building covers investments in co-generation equipment. This would include equipment that allows a boiler to produce both steam for heat as well as electricity. In his paper, Klepper analyzes owner's attitudes toward the legislation. He finds owners are reluctant to make significant capital investments in new and untested equipment, and unwilling to wait for a 5-year payout. In view of this, he maintains that the tax credit will be unlikely to promote significant investment in energy conservation or conversion properties.

A further review of the National Energy Act (USA, 1978) is provided by Shoup (1979). The act is critized for encouraging energy production in favor of discouraging consumption and he states that the energy code is a close rival to the internal revenue code in complexity. He supports the section of the Act dealing with tax relief inducements, even in light of an upsurge of adverse public sentiment.

Jackson (1979), describes an econometric engineering model which analyzes a number of U.S. federal energy conservation programs. The model emphasizes plant and equipment or capital stock energy demand, and makes use of detailed engineering estimates of energy use by equipment, structure, fuel type and age of capital stock. The model explicitly recognizes that energy is produced by capital goods to provide services demanded. In the short run, the model assumes a fixed capital stock while, in the long run, changes in stock and in the energy using characteristics of the stock are also considered. An example of the model in the short run is provided using the demand for electric space heating.

The quantity of electricity demanded equals the maximum potential demand times a utilization rate that represents actual use relative to potential use. The utilization rate is a function of the price of providing the space heating services. With the stock and the efficiency not fluctuating in the short run, the demand for energy fluctuates only in response to fuel price changes. Using 1970 as a base, baseline projections are developed for commercial energy use and are used as a reference for evaluation of federal conservation programs. The drop in energy requirements of 11 percent on an area-adjusted basis does not seem as significant as previously indicated. The more efficient use of energy is disguised somewhat in this measure because an increase in energy use from increases in air conditioning penetration and increased electromechanical uses offset the more efficient production of end-use services. A drop of 34 percent in energy use is indicated where space heating energy intensity is isolated.

An investment tax credit is assumed to influence efficiency in two ways in the model. The planned investment is assumed to be initiated without the credit, with the cost being reduced by 10 percent[1]. Engineering curves are used to estimate the increase in efficiency that can be expected to follow. Consideration is given to an accelerated program of investments

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1 The 10 percent figure is set by the federal government in the United States.

prior to the 1982 cut-off date. This effect is capture by assuming that planned investments in 1983 and 1984 are undertaken in 1982.

Table 5.2 includes information on grants and tax credits, but comparision of other factors are also of interest.

TABLE 5.2
ENERGY SAVINGS AND CAPITAL COST
IMPACTS OF FEDERAL CONSERVATION PROGRAMS

		ANNUAL ENERGY SAVINGS (QBtu)					ANNUAL CAPITAL COSTS (10^6 1975-$)					PRESENT WORTH OF CUMULATIVE EXPENDITURE, 1978-2000 (10^6 1975-$)	
		1978	1980	1982	1990	2000	1978	1980	1982	1990	2000	Fuels	Capital
1.	Thermal performance standards		0.15	0.39	1.74	4.31		0.39	0.40	0.36	0.57	30.36	2.88
2.	FEMP	0.02	0.03	0.05	0.09	0.16	0.03	0.03	0.03			2.04	0.16
3.	Grants program	0.04	0.12	0.10	0.06	0.04	0.79	0.65				2.01	1.64
4.	Investment tax credit	0.02	0.04	0.10	0.05	0.03	0.06	0.07	0.30			1.38	1.11
5.	Combined programs	0.08	0.34	0.63	1.88	4.33	0.88	1.14	0.73	0.36	0.57	34.77	5.79

SOURCE: JACKSON, J.R., "An Econometric-Engineering Analysis of Federal Energy Conservation Programs in the Commercial Sector", U.S. Department of Commerce, Oak Ridge National Laboratory, 1979.

This table shows that the saving from current levels of energy consumption in Qbtu[1] increases from 0.02 in 1978 to a peak of 0.05 in 1982, falling to 0.03 in the year 2000. The present work of the full saving is estimated at 1.38 billion

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1 A Qbtu is 10^{15} British Thermal Units of energy.

dollars, while the capital expenditures have a present worth of $1.11 billion, indicating that the program would be cost effective.

Studies on tax incentive programs designed to persuade building owners to conserve energy have indicated that such plans are costly to the taxpayer, although the cost of the program would be difficult to assess except for first order and possibly some second order effects. The benefits of a reduced reliance on foreign oil, social costs of using up national non-renewable resources and a reduced reliance on nuclear energy are difficult to quantify. In the view of building owners, the rather simplistic ORNL model developed by Jackson indicates that, based on present values of money and energy, the plan is beneficial. Calculation of life cycle costs of energy conserving property, using the savings due to tax incentives, remains inconclusive because of the uncertainty of the future cost of energy. This fact is born out by the apathy shown by building owners or their insistence on very short pay-out periods. Most of the benefit of the tax incentives programs have accrued to the equipment manufacturers and the installing contractors. Manufacturers of fibreglass insulation, double glass and control system components have experienced a measurable surge in business and profits and, of course, the second order tax effects from this surge are available to the government to offset the cost of the program.

Price Incentives

Policy programs based on permitting free market fluctuations in the price of oil while simultaneously eliminating government subsidies and regulations have been previously discussed. The United States has de-regulated oil prices (1979) but Canada, in the interest of what is termed "fairness to eastern provinces", adopted The National Energy Program (1980), which subsidizes and controls the price of domestic oil. A subsidy equal to the difference between domestic and world oil prices is paid to refineries which use imported oil thus allowing the commercial price of oil to remain artificially low. The program states that price is only one route to conservation and it blames entrenched social and economic patterns which were established when oil was relatively cheap for the need to prevent a rapid price rise.

Empiricle studies have shown that price can be effective in promoting or discouraging the use of an energy source. The effects of price and pricing policy on energy conservation is the topic of a paper published in 1975 by the U.S. Federal Energy Administration. The paper is a very cursory analysis and, in summary, states that higher prices for energy encourage people to conserve. The conclusion is supported by five arguments:

(1) Energy consumption in 1973 and 1974 reversed historical trends and declined while prices rose.

(2) Energy use per person is less in countries where energy prices are higher.

(3) Economic studies have demonstrated that higher prices lead to reductions in amounts of energy consumed.

(4) Opinion surveys indicate that most consumers cite higher costs as a reason for conservation.

(5) Individuals and businesses take specific action to conserve when prices increase.

The intuitively acceptable remarks in the report are followed by a number of reports on price elasticities, most of which are inconclusive.

In economic studies carried out by RAND (1978), researchers are quoted as providing extensive evidence that a 10 percent increase in electricity prices reduces electrical demand by greater than 10 percent, and that a 10 percent increase in natural gas prices reduces demand by more than 20 percent. The report quotes disagreement among researchers as to the magnitude of price-induced conservation, and the conclusion reached is that price increases lead to reduced consumption of energy, implying a downward sloping demand curve.

A report which addresses the question of the proper value for energy used in the development of cost-effective energy conservation performance standards for buildings was published by Weber (1978) for the U.S. Department of Energy. The report was written in response to the Energy Conservation Production Act, (USA, 1978), which set out the development of building performance standards as an ultimate goal. The Act specifically stated that these standards were to provide a balance between savings of energy and costs of standards.

The concept of a Resource Impact Factor (R.I.F.) is developed to address the problem of the social cost of the resource compared with the market value. Discussions concerning the development of standards using R.I.F.'s will be covered later in this paper. Their price effects will be discussed here. The assumption is that standards are to be set at a level which is socially optimal, using the social value of energy.

The underlying purpose of developing a national energy conservation standard is to encourage energy conservation measures in building which are optimal for the nation. The optimal point for the nation, in this regard, will not necessarily coincide with the market induced level. This divergence is considered to exist due to certain distortions in markets for energy resources. What is optimal for the nation may not be optimal for the building owner. In traditional economic theory, perfect competition is said to exist under very restrictive assumptions, where the prices paid for resources are equal to their true social value.

The first divergence between social and market price is unit taxes. A tax on the number of units of gas or kilowatt hours of electricity consumed forces the market equilibrium price to differ from the true social cost of supplying the resource. This is said to be true unless the purpose of the tax is to offset negative environmental effects or excess profits. A situation similar to the unit tax exists where there are too few firms competing in the market, leading to a degree of monopoly power. The resource users will not be guided by the true cost of the resource, since suppliers will tend to restrict the quantity supplied so that the price paid is greater than the true cost of producing the resource.

Externalities or environmental effects are another source of divergence between the price paid for a resource and the social cost of making the resource available to the consumer. These effects are present when a production or consumption process generates a cost or benefit not directly involved in the process. In the case of energy resources, most of the external effects take the form of costs, and are not reflected in the price established by the supply and demand for the energy resource. In the absence of an adequate pollution tax, the effects of pollution are calculated as a part of the social cost of producing energy.

To the extent that the nation is vulnerable because of economic dependence on the security of supply of imported oil, the influence of oil embargos and OPEC price increases must be included in the calculation of R.I.F.'s.

Therefore, for each unit of energy consumed, there is an extra social cost defined in terms of an increased requirement for oil imports and vulnerability to supply interruptions. Although quantifying the impact of import dependency is not presently possible, it is certain that the cost to a nation's economic independence makes the social cost of energy consumption exceed its market cost.

Deviations between the prices paid for resources and their social value grow when price controls are introduced. This situation arises where the price is actually set by legislation or regulation, and not by the forces of the market reflecting the costs of supply and the benefits from use. Whether the objective of such regulation is to make the resource affordable to allow industry to be competitive, or to control excess profits in an industry with little competition, the administered price will generally deviate from the social value of the resource.

Another factor which must be considered in estimating the social value is the effect on market price caused by uncertainty. Because of inadequate information about the long-run scarcity of exhaustible energy resources, present supply and demand forces may lead to equilibrium prices which do not reflect true value, and could result in rates of resource exploitation which are sub-optimal. A similar problem exists because private discount rates are likely to be greater than the social rate. Private energy producers, in this case, will tend to undervalue the future earnings from resources saved for later exploitation, and this will lead to extraction at a rate which is too rapid from a social viewpoint.

It is necessary to describe these factors which affect social value and market price in order to provide some insight into the difficulty of representing the value of a resource at its actual market price as a basis for discussing energy-related policies where economically balanced standards are required. These factors make up a partial checklist which should be considered in the development of quantified R.I.F.'s. Conflicting objectives which may exist in society must be taken into account. Conflicts must be resolved before social values can be determined.

Some hypothetical quantity multipler R.I.F.'s are outlined in the following table.

TABLE 5.3
HYPOTHETICAL QUANTITY MULTIPLIER RIF's

	UNITS NEEDED*	HEATING LOAD (10 Btu)	RIF	IMPACT
Energy Type	(1)	(2)	(3)	(4)=(2)x(3)
Nat. Gas (MCF)	60	36	1.3	46.2
Oil (Gal.)	4.29	36	1.2	43.2
Electric (kWh)	10,548	36	2.0	72.0

* The number of physical units of input of the energy type needed to satisfy the given annual heating load of 36 x 10^6 Btu. The heating system output of 36 x 10^6 Btu was converted to corresponding input requirements by assuming the following energy contents and conversion efficiencies.

(1) Natural Gas: 10^6 Btu/MCF and 60% efficiency.
(2) Oil: 140,000 Btu/Gal. and 60% efficiency.
(3) Electric: 3.413 Btu/kWh and 100% efficiency.

SOURCE: WEBER, S., The Effect of Resource Impact Factors on Energy Conservation Standards for Buildings; (National Bureau of Standards: Washington, D.C., September 1978) page 32.

Also presented are hypothetical price multiplier R.I.F.'s.

TABLE 5.4
HYPOTHETICAL PRICE MULTIPLIER RIF's

	ACTUAL PRICE ($/Unit)	EFFECTIVE PRICE* ($/10 Btu)	RIF	SOCIAL PRICE ($/10 Btu)
Energy Type	(1)	(2)	(3)	(4)=(2)x(3)
Nat. Gas (Mcf)	2.00	3.33	2.0	6.66
Oil (Gal.)	.40	4.76	1.5	7.14
Electric (kWh)	.03	8.79	1.1	9.67

* Energy contents and conversion efficiencies for each type are as follows:

(1) Natural Gas: 10^6 Btu/MCF and 60% efficiency.
(2) Oil: 140,000 Btu/Gal. and 60% efficiency.
(3) Electric: 3.413 Btu/kWh and 100% efficiency.

SOURCE: WEBER, S., The Effect of Resource Impact Factors on Energy Conservation Standards for Buildings; (National Bureau of Standards: Washington, D.C., September 1978) page 32.

Weber defines the limitations in calculating social prices (Table 5.4, Column 4). The evidence presented in Table 5.2 indicates the range of RIF's over the major sources of energy. It is noted that electrical energy (generally considered a local source of energy) is assigned a low RIF (1.1) while natural gas and oil (large impact items) are assigned much higher RIF's (2.0 and 1.5). This reflects the growing social concern with the balance of payments issue.

The methods used incorporate a study of cost components rather than quantifying social standards over the life cycle of the property. Constant marginal cost of resources is assumed, regardless of the total level of resource use. Second, it is assumed that the temperature base for calculating degree days did not change with increases in prices. Weber concludes that, as R.I.F. values rose, the maximum energy consumption rate allowed by the socially optimal standard would be reduced.

Since price affects energy use, it is worth investigating how energy tariff schedules may be constructed. Intuitively one would expect that level prices or prices which increase according to the amount of energy used would promote conservation. Charges to consumers have historically been based on decreasing block pricing for both electricity and natural gas. Consumption in larger blocks is charged at lower rates.

In Canada, private discussions with personnel at B.C. Hydro have indicated a trend, which will take 10 to 15 years from now to complete, toward reducing block pricing and eventually developing a level price system at set rates per KWH or BTU.

Commercial users of power have been faced with demand charges so, where block or stepped rates tent to encourage consumption of electrical energy, the demand charges will have a dampening effect. Instituting demand charges [See Chapter I], however, do not significantly reduce the total consumption of power, for example, power generated by non-renewable resources. Instead, demand billing reduces the peak demand, and this in turn will have the effect of reducing the total amount of generating capacity required. This effect of demand billing can be seen from the previous explanation of demand metering. In the area of nuclear energy, or new coal-fired generating plants, the new plants may not be required as early when utilizing a policy of demand pricing of electrical energy as would be the case with other pricing models.

Time-of-day and seasonal demand pricing of electricity are similar methods of altering demand by spreading peak demand over longer time periods. These methods are explained in an article by Taylor (1979). Seasonal demand pricing is similar in nature to demand metering and billing presently in use in Canada. Time-of-day (T.O.D.) pricing, although used extensively in Western Europe, has been used in only a few small scale experiments in North America.

Experiements presently underway by the U.S. Federal Energy Administration are expected to generate data showing the effect of T.O.D. pricing on load curves. It is expected that both time-of-day and seasonal pricing will level out the load curve and reduce the requirement for peak-load production of power, just as seasonal demand billing has. In designing a model of the load curve for the demand for electricity, short and long run effects are considered as are the effects of decreasing block tariffs.

Block tariff pricing is simulated in the load curve model by considering that it is similar to a change in income in an economic analysis. In the commercial area, there is a complication introduced by the fact that electricity is sold using a KW charge as well as a KWH charge. The model is developed to forecast the 24-hour load curve for the utility, using basic determinants such as price, temperature, summer and winter sensitive plant, non-weather sensitive plant, and socio-demographic characteristics. The hope is to develop a model which will predict the effect of T.O.D. pricing, and it is expected that the information will be useful to utilities and policy-making bodies in establishing the price of electricity on the basis of consumption, seasonal demand and time-of-day demand.

Subsidies and Grants

The use of subsidies to encourage the installation of energy conserving plants is expected to bring about results which are similar to the tax incentive policies. However, it is assumed that the administration costs of a subsidy program will be considerably higher than for tax incentive policies.

In addition to the effective subsidy given to consumers in the form of lower than world price for oil in Canada (NATIONAL ENERGY POLICY), and the existing subsidy under the Canadian Home Insulation Program (C.H.I.P.), the Canadian government has a subsidy program to promote interfuel substitution which is outlined in the National Energy Program. A grant of $800 or 50 percent of the cost of conversion is available to homeowners for substitutions from oil to gas, electricity or a renewable resource. The program also refers to "other steps" to ensure that conversions from oil to gas occur in the commercial sector.[1]

An Economic-Engineering Analysis of Federal Energy Conservation Programs in the Commercial Sector (Jackson, 1979) presents a theoretical look at grant programs which is similar to the study of the investment tax credit. The paper describes the proposed U.S. federal program of providing matching grants

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1 In the National Energy Program, "other steps" is left undefined.

to states for energy conservation improvements to schools and hospitals. As presented in Table 5.1, the capital cost of the program was expected to total $1.18 billion through 1980. The total energy saving in QBTU was projected at 0.04 in 1978, increasing to 0.12 in 1980, and reducing to 0.04 in the year 2000. Calculations show the present worth of capital at $1.64 billion as the cost of the program, with energy savings estimated at $2.01 billion. The net present worth to the taxpayer, including grants for public buildings, is therefore positive.

Tax Penalties

A paper by Hudson and Jorgensen (1974) provides an overview on various methods of taxing energy use. The tax is described as a wedge between the price paid by consumers and that received by producers. If the tax is added to the sale price, the supply price is unchanged and acts on the demand side only.

An econometric model of macro variables is developed to determine the pattern of economic interactions that result from a given tax specification. The model contains a simulated picture of the inter-industry supply and demand determinants in the U.S. economy. The model is used to analyze the BTU tax designed to reduce fuel consumption[1]. The alternative oil

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1 The BTU tax is a uniform rate energy tax on the BTU content of all fuel sales to the non-energy producing sector.

prices used in the model were $4.00, $7.00 and $11.00 per barrel, and it is expected that some distortion in the results would occur at a 1981 world price. The BTU tax was to be imposed on energy as it emerges from the fuel producer into domestic uses; hence, fuel exports and fuel to general electricity are exempt. The BTU tax rate was estimated for taxes on coal, gas, petroleum and electricity anticipating substantial cuts in intermediate and final use. In the 1980 estimate, service consumption would be reduced by 9.5 percent in response to a $.50/million BTU's tax rate. This rate was estimated to produce tax revenues of $31 billion.

Studies of elasticity by the authors showed that discretionary consumption, described as heating and cooling of housing and gas for cars, was more elastic than industrial use.

Alternative tax policies designed to reduce the use of imported oil to 0.5 million barrels per day, and natural gas to 0 by 1985 were also discussed. One such alternative tax policy the Energy Sales Tax, is a uniform sales tax on all sales from the fuel producing sector. The tax was found to cause a substitution from energy to inputs of labour and capital.

Another example, the Petroleum Tax is a uniform rate sales tax on all petroleum products sold to the non-energy producing sector. The model indicated a reduction in consumption, with little inter-fuel substitution. The model did not indicate a decrease in natural gas demand.

In the model, the effect of the BTU tax was to generate a substantial change in the relative prices of fuel. Prices for coal increased the most at 36 percent, petroleum was second at 35 percent, and electricity the least at 12 percent. Figures for natural gas were not given.

Quirls (1980) favours the use of tax penalties to promote energy conservation. Where taxes are used to speed up an expected response to market-determined price incentives and to correct the problem of balance of payments pertaining to basic energy resources, these policies are appropriate. In order for conservation to take place and to achieve the most efficient combination of resources, the price of the energy-capital combination should rise relative to other expenses.

Using taxes as a substitute for regulation is the topic of a paper by Breyer and Drapkin (1979). Setting the price of energy through regulation is criticized in two major areas. First, policy agencies are unable to determine a price which allows normal profits and ensures sufficient new production. Second, the problem of allocating the resource at the regulated price can be virtually impossible to solve. Standards developed by the Federal Power Commission attempted to allocate natural gas resources by establishing interruptible categories depending on a priority list. The problem was only partially solved by creating a process that allocated gas in a manner similar to television licenses, by using exceptions to the rule to eliminate users. The public interest was determined in each case, and was used as a measure for curtailment.

Breyer and Drapkin suggest that the excess profits tax be used as an alternative to accomplish the same ends as regulation, but more directly. The tax would redistribute excess profits from the producer to the consumer and would avoid the problems caused by regulation. The problem that the policy authority must face is determining what profit is normal and what is excessive. This problem is solved by setting the tax at a level equal to the differences between cost and world market price. This would apply similarly to natural gas and oil. The upper bound of the tax is the free-market price of the product. This is not easy to determine in the case of crude oil and natural gas since these products are not homogeneous; variations occur in grades of crude oil, distance from seaport and time of year differences. The upper bound therefore depends on establishing specific categories. The lower bound is designed to capture windfall profits. It is equal to the difference between the cost of older, cheaper products or domestic products, and the free-market price. Again, categories must be established to account for the heterogeneous nature of the product.

Breyer and Drapkin anticipate no problems in the collection or enforcement of the windfall profits tax, given that categories can be established and agreed to by the tax collector and the producers.

Serious problems are obvious in the use of a tax as a substitute for regulation. However, the problems seem less serious than those accompanying price regulation, particularly since the tax system is able to rely on the market for allocation.

Despite these advantages, the tax system as a substitute for regulation is not expected to be acceptable to the public. The resulting large increases in price would be perceived as large profits for producers, and would produce a political demand for regulation to hold down prices.

As emphasis shifts from regulation to taxation, the corresponding legislative jurisdiction and bureaucratic responsibility presents problems. During the time of transition, regulatory committees would be less familiar with the particular area regulated, and more interested in the general macro effect of taxes.

Examples of taxes are presented by the Government of Canada's recent National Energy Program. Taxes were created to compensate for revenues foregone when a natural gas export tax was not imposed. Taxes were placed on oil and gas in general. The oil tax is called the Petroleum Compensation Charge, and produces a "blended price" of crude oil by subsidizing imported oil. In addition to the tax on oil, the federal government taxes the sale of all natural gas, both domestic and export. The government also maintains a tax on exported oil equal to the difference between the domestic price and the export price. The effect of the tax is to remove the incentive for provinces or producers to export oil.

Mandatory Financial Policy Instruments

Fines

In the United States it can be seen that regulations governing the quantity of energy which may be consumed by a commercial building have already been established at the city, state and federal levels. A total of 15 out of 21 states surveyed by the Federal Energy Administration had energy regulations in 1977. In most cases these regulations applied to new buildings only, and required the pre-submission of building documents and proof that thermal characteristics conformed to the regulations.

The possibility exists that non-compliance with these regulations or failure to meet regulations after initial approval would be subject to review by the judicial systems and fines would be levied as a method of ensuring compliance.

In the future, when the high cost and/or the availability of energy becomes more acute, it is also possible that regulations will be extended to the existing stock of commercial buildings, demanding that these buildings reduce consumption or be subject to fines.

The imposition of fines would require enforcement procedures along with a detection system which would imply the cooperation of fuel suppliers. As with violators of pollution regulations, fines would be levied after an adequate time is allowed for compliance.[1]

This policy measure would only be undertaken when the problem becomes much more acute, and persuasion and code regulations have not elicited the desired response.

Finance Withdrawal

The U.S. federal government has instituted a system similar to the use of fines. A system of grants (negative fines) allow state buildings to be upgraded with energy conserving measures. These grants will be withdrawn unless the state adopts provisions similar to ASHRAE 90-75 (1975) in its building code, requiring all new buildings to meet energy conservation requirements.

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1 It should be noted that these fines are essentially a "poll tax" which is unrelated to energy consumption or energy wasting.

Persuasive Non-Financial Policy Instruments

Research and Development

Research and development in all areas of energy conservation and conversion is seen as one of the most important policy areas. This may include research in technical areas as well as behavioral research.

For example, the Canadian government is conducting 10 ongoing research programs at a total estimated expenditure of $12 million. In the area of conservation, the principal effort is on reliability, practicality and economics of the application of energy conversion processes. By comparison, the government is also spending $160 million in the same period of 1979-80 on nuclear research, including research on nuclear fusion.

Education

Education to conserve non-renewable resources covers a broad range of possibilities. For the most part, efforts in this direction lack concrete, quantifiable and quickly evident results. This may not be the case in "kill-a-watt today" type programs. With this program, occupants of a building are educated to turn off non-essential electrical loads. Other education programs being developed include those designed to convince occupants that it is desirable to adjust clothing instead of space temperature, to close drapes on a nice sunny day to reduce heat gain, or to refrain from opening windows in older buildings to control space temperature during the heating season. These programs will not lend themselves to easy monitoring and evaluation.

Education programs for the general public and for building occupants in commercial buildings are inexpensive relative to retrofit and conversion of building systems, and have proven to be cost-effective in saving energy. Programs of this nature can also have the effect of preparing people to expect less than ideal space conditions due to the activities elsewhere to conserve energy. In this regard, if local governments followed a policy of providing information and support to building owners, it would be beneficial in the short run by achieving immediate reductions in consumption, and in the long run by changing people's attitudes to energy as a "cheap" good.

Programs designed to educate building owners and managers have been developed by governments, and are designed to remove some of the uncertainty surrounding energy cost, as well as to change attitudes towards conservation. An example of this type of program is contained in the Province of British Columbia's Energy Conservation Manual, (undated), published by the Ministry of Energy, Mines and Petroleum Resources, Energy Conservation and Technology Division. The Manual contains information on future energy costs and potential areas for saving. A four-part energy management program is outlined. The first part is the evaluation phase, where an energy audit is recommended. Upgrading operating and maintenance procedures, reducing energy loads and implementing retrofit programs are suggested. The potential savings in each area are described and the manual concludes with operations and maintenance checklists and forms for recording electrical and oil or gas consumption. The document also describes the Energy Bus program. The bus, along with trained engineers and technicians, is available to commercial and industrial energy users to identify areas of energy savings. The program in use is restricted to firms and institutions whose energy consumption costs a minimum of $10,000.

Education programs aimed at building owners should provide information, as explained above, but should also work to change attitudes, and to let owners know that energy conservation is not only economical, but also is one of the requisites of being a good corporate citizen. Providing information to building owners about the current state of energy availability and future pricing should form the basis of an education process to dispel the conventional concept of an inexhaustible supply at an acceptable price.

An area of conservation education which has received little attention and is the key to achieving measurable results is the technical education of operating and maintenance personnel. The state of the art in design has met the challenge, and buildings are being designed which operate a 20 percent of previously accepted consumption figures. Some owners are making substantial investments in plant, with the hope of receiving a return on that investment through reduced consumption of electricity, oil and natural gas. Without trained personnel to operate these systems in an optimal manner, the expected results will not be achieved. It is estimated by building systems designers that it takes four years for trained operating and maintenance people to achieve the full energy saving potential of a commercial building. If a time allowance has to be made to train people on the job, this period can be expected to be doubled to eight years, with the resulting loss in operating efficiency.

While a cost-benefit study of technical education for the operation and maintenance of energy using systems is not available, there is some indication that programs are being developed. Thomson (1980) explains programs at Toronto's George Brown College which cover heating technology, changing attitudes, priorities and energy saving tactics for the public. The course of studies emphasizes theory, to equip students for new advances in building heating technology. The course includes marketing of improvements in energy-efficient units, to allow technicians to go into industry with the necessary skills. The demand for this type of person is evidenced by the fact that the program places 100 percent of its students in jobs at an annual rate of 250 students per year.

Manufacturers will train operating personnel in the use and programming capabilities of computer-based control systems in buildings. This type of program tends to cover their own piece of equipment which limits flexibility. Without trained personnel, the systems can be the cause of energy waste rather than conservation.

In the private sector, organizations have taken the lead in educating their members about the economic advantages of conservation. The American Architectural Institute has a complete course on life-cycle costing, while the Building Owners and Managers Association has a full-time energy division to assist members and to disseminate information. The International Association of Shopping Centre Owners provides educational material; it also presents awards to members for buildings which achieve the highest standard of energy efficiency.

Mandatory Non-Financial Policy Measures

Rationing

In the past, governments have used rationing in times of crisis to distribute a commodity which is in short supply. Policies involving rationing of energy resources, particularly automotive gasoline, have been discussed recently.

A form of rationing was employed in Los Angeles in 1973-74 during the severe shortgage of oil for heating and generating electricity (Acton, 1975). Mandatory curtailment of usage was established based on past usage. Violators were faced with the threat of suspension of utility service. It was reported that the decrease in consumption by residential, commercial and industrial users was greater than legislated, and that there were no recorded cases where rationing limits had been exceeded. In the opinion of Acton, the curtailment plan adopted by Los Angeles was highly successful in the short run, but there are doubts as to whether it would be effective in the long run.

Codes and Standards

Code standards can be viewed from different perspectives. A paper by Phung and Rohn (1979) explores owners' motivation for conserving energy. From the owners' viewpoint, the following question is addressed "should energy conservation be implemented simply because the energy planners foresee a wide gap between energy supply and demand?". Another concern relates to the impact of resource deployment on the earth's environment and about the depletion of non-renewable resources. The paper takes the view of private concerns that energy codes must save money by the adoption of new ways of using energy.

This view is contrasted with later comments about social costs contained in a paper by Brooks (1979). Brooks feels that it is necessary to set standards to encourage economically rational demand responses to high energy prices. The fact that owners are influenced more by first cost than by operating cost, and that it is necessary to anticipate future fuel price increases provides justification for mandatory standards.

The establishment of building codes to promote efficient construction is the policy measure most frequently used by state governments in the United States and the federal government in Canada. In the early stages of the energy crisis caused by the cut-off of OPEC oil, various building codes were established to prescribe the allowable types of construction for commercial buildings. In Canada, the prescription of insulation standards, maximum window areas, infiltration standards and mechanical system standards followed from the publishing of ASHRAE Standard 90-75, Energy Conservation in New Building Design. These standards were adopted by the Canadian government for all federally-funded projects.

Starting with the <u>Energy Policy and Conservation Act</u> (USA, 1975), federal law required that states adopt ASHREA 90-75 or similar standards in order to be eligible for federal funding for the energy conservation plans.

Criticism of prescriptive standards are typified in comments by Erickson (1977). In strong terms, Erickson states that the government had shown an inability to come to grips with the problem. He contends that issues are clouded in a "haze of bureaucratic miasma". Standards, according to Erickson, should be for performance and not technicalities which will vary with each case. This sentiment seemed to be echoed by Public Works Canada in developing a performance type code.

The use opf a performance code is recognized by <u>The National Energy Act</u> (USA, 1977) in a section dealing with buildings, called "<u>The New Buildings Act</u> (USA, 1977)". The <u>Act</u> provides that, by 1979, energy performance standards be developed and that they be implemented no later than August 1981.

Comments on <u>The National Energy Act</u> are contained in a paper by Klepper (1979). Klepper states that the Act establishes energy budgets for a wide range of buildings in seven climatic regions and permits any combination of conservation measures to satisfy the budget.

The case for performance-based codes was taken to court in California, when a non-residential code was adopted in 1976. According to a publication by the Lawrence Berkley Laboratory (1978), the code was challenged by the building industry which argued that, although the state legislature had specified a performance code, the proposed code was in fact prescriptive. The code did permit alternative designs but the difficulty in having alternatives approved appeared prohibitive. The court ordered the state to rewrite the code to include performance energy budgets, and to provide a computer program to calculate energy budgets. The same Lawrence Berkley Laboratory publication recommended that performance codes be adopted as required by the New Building Act. The problem of implementation is mentioned and special staff and facilities are recommended to handle plan checking, inspection and approval of new designs.

In the United States the failure of The New Building Act (USA, 1977) to receive the necessary government backing has led to a continuing debate over prescriptive versus performance type codes. The ASHRAE Standard 90-75 has been updated to ASHRAE 90A-80 with changes outlined in an article by Patterson (1980). The prescriptive sections of the standard have been upgraded but the performance sections remain under review. Standards of equipment efficiency have been increased.

The effects of the proposed model code for energy conservation, which in turn is based on ASHRAE 90-75 in New York City, is studied in a document authored by Flack (1977). The implications with respect to first cost, operating cost, energy consumption and marketability of new office buildings are presented. The study was undertaken to evaluate concerns expressed by building developers that the new code would increase construction costs excessively on new high rise office buildings.

The findings of the study indicated that the code will not measurably increase the cost of constructing new buildings. The second finding was that the new buildings, designed in accordance with the code, will use less energy than comparable existing office buildings which have undergone energy conservation programs. Assuming 85 percent efficiency[1], the code-designed building averaged 63.0 MBTU/FT^2. This is 54 percent less than that achieved in existing buildings. It is also within the 55 MBTU/FT^2 standard recommended by the General Services Administration. The cost of utilities for the New York City area would be reduced by 32 percent, or $0.67 per square foot per year if this standard were achieved[2].

An additional recommendation includes that of sub-metering tenant electrical systems. The report indicates that, although sub-metering is not currently in force, consideration should be given to it in the future since sub-metering generally results in lower tenant electrical consumption.

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1 Efficiency is defined as the net-to-gross area for a rentable basis.

2 Further, for the office building market, a substantial growth is predicted in the manufacture of insulation, double glazing and efficient lighting fixtures.

Where performance codes are contemplated, and in cases where standards in prescriptive codes are designed to yield net positive return to building owners, there has been some discussion concerning the price of utilities which should be included in the analysis. The calculation of the price of a utility, including the social costs involved in delivering fuel to the site as well as normal economic costs, was covered in a previous section. The report by Weber (1978) on Resource Impact Factors makes extensive reference to the inclusion of these factors in the establishment of code standards. The conclusions to that analysis deal with the effect on the economic efficiency of the selected energy conservation standard. The report concludes that, to reflect the national viewpoint, the standard should be based on the social value of types of energy, which can be determined by the private price multiplied by the appropriate resource impact factor (R.I.F.) value. In the case where the R.I.F. value is greater that one, the savings in energy will be greater than when private costs alone are considered.

A paper by Nieves (1980) supports the view that social costs should be considered in determining the choice and cost of fuel in new buildings. This support is based on the assumption that the present market system does not promote optimal choices of energy resources. The social costs mentioned include the value to the producer of special tax incentives, the value of direct and indirect subsidies, administrative costs of regulatory agencies and the cost to society of environmental and health damages. These costs, added to market costs, give the total social cost of the fuel.

In addition to advocating the use of R.I.F.'s to set energy code performance standards, the author further recommends that marginal rather than average costs for the market value of the fuel be used. The use of marginal costs, similar to the use of R.I.F.'s, would also improve the energy performance standards of new buildings, by reducing the reference level of consumption.

A summary of the approaches to Building Energy Performance Standards (B.E.P.S.) is contained in an article by Patterson (1980). Four methods of applying energy performance standards are listed. The first approach is the one favoured by policy makers, namely, mandatory energy performance standards for design. The second and third possibilities are voluntary, including voluntary standards and a "how-to" approach. The fourth and most rigid is the annual building energy use standard.

The first option, using mandatory standards, has been explained previously. An economically sound life-cycle cost method is suggested for the voluntary options with no mention of social costs in calculating fuel costs. The last method, the building annual energy use standard, combines the mandatory performance standards for design with a standard of operation and maintenance which raises questions of availability of personnel, and difficulty in enforcement due to variations in climate and building operation.

The author suggests that B.E.P.S. follow logically from the ASHRAE 90-75 prescriptive standard, by using prescriptive methods to calculate a performance standard.

Ordinances

The best example of an ordinance concerning energy conservation is the mandatory curtailment legislation in Los Angeles in 1973-74 (Acton, 1975). The government passed ordinances which mandated a reduction in energy use by residential, commercial and industrial consumers.

Other possibilities present themselves which relate in part to performance standards. In the case of residential properties, all homes in Portland, Oregon, which are either new or resold, must meet standards by 1982, (Housing and Urban Development, 1977). This amounts to an ordinance against the sale of a house which does not meet the standard. This method could also apply to the commercial sector on the sale of commercial property.

In the case of commercial properties, a more effective ordinance has been suggested for general application. The ordinance would prohibit lending agencies from advancing mortgage financing on commercial buildings which do not meet energy standards.

<u>General Considerations - Energy Policy</u>

Research has been carried out to determine the relative effect of various policy methods designed to reduce the consumption of non-renewable resources in commercial buildings.

The first of these is a study carried out by the Department of Housing and Urban Development (H.U.D.) (1977) on "Energy Conservation Choices for the City of Portland".

The report indicates a saving in the new commercial building area of 42.8 percent by 1995 with the use of state-implemented conservation standards and a revised building code. Using the voluntary method of investment tax credit, it was estimated that the saving would be reduced to about 20 percent. The 42.8 percent reduction would amount to 5.4 percent of total energy use in Portland in 1995. In the area of existing commercial buildings, a weatherization code standard was found to be the most effective, while the voluntary program would be less than 50 percent as effective.

A study by Williams et al. (1976) deals specifically with policy alternatives to achieve energy savings in existing commercial buildings. The policy alternatives suggested were:

(1) a 15 percent tax credit;[1]

(2) a three-year rapid depreciation write-off of retrofit costs; and

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1 Not to be confused with the 10 per cent tax credit currently in use in the United States.

(3) low interest, subsidized loans.

The results of the analysis indicated that where retrofit actions were marginally profitable under present law, implementing the alternative policies would substantially increase profitability. This led to the conclusion that the policy alternatives would yield substantial energy savings.

In general, Williams concluded that the proposed 15 percent tax credit policy provided the greatest economic incentive to retrofit.

In the study carried out in 1977 by the Environmental Research Centre of Washington State University, the voluntary acceptance of various standards were assessed for their ability to reduce energy. The results of this study are shown in Table 5.5.

TABLE 5.5
ECONOMIC RETURNS AND OTHER FACTORS AFFECTING
ADOPTION OF ENERGY CONSERVATION MEASURES, COMMERCIAL SECTOR

	TYPICAL ANNUAL SAVINGS NET OF AMORTIZED COST			
	1976 Prices	Twice 1976 Prices	Qualitative Factors	Estimated Ultimate Adoption
	($/year/1000 sq. ft.)			(percent)
Temperature Setting Change				
72° winter - 78° summer	20-30	40-70	Less comfortable, more approval	40
68° winter - 78° summer	45-75	90-140	Less comfortable, more approval	20
Reduced Infiltration, Ventilation and Lighting	75-210	150-420	Less comfortable, less attractive	20
New Building Construction Standards	170-240	340-480	None	20
Retrofit with Insulation and Double Pane Glass	15-65	90-200	More comfortable	5
Total Energy Systems - Direct Heating	- 250	- 100	Possible reliability problems	0

SOURCE: Washington State University, "NORTHWEST ENERGY POLICY PROJECT", Environmental Research Centre, 1977

It is noted that the research centre estimates that no program will achieve better than 40 percent adoption. Moreover, the programs which provide the least comfort and have the lowest capital cost will have the highest adoption rate.

The report also gives the opinion that since energy costs are a relatively small proportion of a budget, an energy price change has an insignificant impact on total energy consumption, whereas large increases or rationing would require altered life styles. They suggest that where response to economic incentives with positive returns is low, programs of information and education should be implemented.

Given the results of the regression model presented in the last chapter, it would follow that programs of education and information are necessary to promote energy conservation.

ENERGY POLICY: A SUMMARY

It is obvious that the government has available a variety of policy instruments. The available empiricle evidence suggests that some of these policies will be effective in the short run, others will be more effective in the long run, while yet others appear ineffective by themselves. Moreover, the evidence suggests that some combinations of policies will be more effective than the sum of their parts.

The evidence further suggests, at least within the prices established to date, that pricing policy alone is likely inadequate. However, pricing policy combined with an active research and education program may be effective.

CHAPTER VI

CONCLUSIONS

In Chapter I, it was shown that the investment of capital in energy conserving equipment for an average Canadian office building yields an adequate return relative to the investor's discount rate. Given this is true, building owners and managers should devote time and capital to achieve the optimal lower energy consumption level. A review of current periodicals relating to building design and management suggests that this is occuring, since a substantial number of articles and advertisements related to energy are appearing.

To place this investor's interest in perspective, however, the theoretical analysis shows that the hypothetical value of the typical office building, taken as the present value of future benefits, has a very low sensitivity at present price levels, to changes in energy expenses in the range studied (Chapter II). When a change of energy expense was studied relative to the change in internal rate of return, it was found that the return was inelastic with respect to a major change in energy expense. This leads one to the conclusion that even though reducing energy expense is currently the topic of considerable interest, it does not presently play a significant role in increasing the internal rate of return.

This conclusion is supported by the results of the empirical analysis, where the first hypothesis relating an increase in energy expense to market value was rejected (Chapter III). In both the analysis of the complete sample, and in the stratified samples, there is no consistency either in the sign of the variable nor in its magnitude and although multicollinearity is present in the data set. It is concluded that a statistically significant link does not exist between energy consumption and market values, at present price levels.

In looking for the logic to explain this result, one should consider the attitudes towards energy conservation in commercial office buildings. One can start by differentiating between those buildings owned by a developer and leased to tenants, and those buildings owned and occupied by the same management.

A typical developer-owned office building has multiple tenants, leasing floor space under "triple net leases" as previously described. It can be seen, therefore, that in a developer-owned building, the capital expenditure on energy conservation equipment is borne, at least in the short run, by the developer, but the saving in operating expense is received by the tenant. This eliminates the direct incentive from the developer to invest in the reduction of the amount of energy consumed unless he can charge increased rents.

A second area which may be considered is the "Better Manager Syndrome". Given that energy consumption can be reduced in the typical office building from 30 per cent to 50 per cent with minimum capital expenditure, an astute investor will not pay a premium for a building with low energy consumption if he can purchase a similar building with a higher energy consumption and achieve the reduction himself.

There appears to be a number of effects relating to this analysis which counter-balance one another. The increase in market value which accompanies an increase in energy use may be explained by the requirement by occupants for quality services provided through the use of energy. Hence a building that provides these (energy) services may be more valuable. Countering this is the effect of the cost of energy, where a higher price should have the effect of reducing the amount of energy consumed.

To the extent that it is true that Canada faces energy shortages in the short run, whether or not new energy sources are found, and possibly severe shortages in the long run, the conclusions of this study are threefold. First, it is in the national and local interest to reduce the aggregate consumption of energy in both new and existing commercial office buildings. Second, it is in the national interest to promote inter-fuel substitution. Third, the policies employed to date do not appear to have a profound effect on reducing energy consumption.

The Federal Government has available a number of policies which may be combined to produce meaningful energy savings.

The policy measures which could be instituted to achieve this end include:

(1) The price of energy, in the short run, could be established at its social cost, as previously described.

(2) An excess profits tax could be instituted based on the increased prices of energy.

(3) Performance codes, based initially on a method similar to the resource impact factors previously described, could be developed and enforced for all new buildings.

(4) A system of tax incentives could be instituted initially to expedite the retrofit of existing buildings to current standards. This would, after a suitable voluntary period, be supplemented by a mandatory performance code.

(5) Block pricing of electricity and natural gas could be gradually eliminated as the price of energy is increased. Point-of-use metering of electricity by office tenants should be mandatory.

(6) A substantial increase in funding could be provided to technical education facilities to expand programs to upgrade the performance of operating and maintenance personnel.

If the government chose to raise energy prices (and tax excess profits), owners of commercial buildings would seek to pass this price increase on to tenants, assuming an excess demand market, either through expense escalation clauses, net leases, or higher gross rents. The increased price will not, of and by itself, promote energy conservation by landlords. However, in the long run, tenant response to higher rents or occupancy costs occasioned by increasing energy costs will reflect in vacancy rates, net rents, yields to landlords and market values of buildings. Given the existing structure of leases, this may take a long time to achieve.

The use of performance codes for new buildings may, in the short run, place these landlords at a competitive disadvantage vis-a-vis existing buildings (those which do not have to achieve the performance codes). This disadvantage is likely to disappear as this new fixed cost (of achieving performance standards) is incorporated into their bid price for land.

The system of tax incentives for retrofit of existing buildings is not likely to be successful unless the landlord can find a way to negate existing lease contracts and capture the resulting gains for himself. As long as tenants reap the energy cost savings, the landlord has no incentives to undertake retrofitting and it is unlikely that the tax incentives would, by themselves, be adequate. Compulsory use of point-of-use metering would be one method of capturing the benefits for the landlord providing rents could be adjusted to reflect the change in energy use. The cost of energy would, using point-of-use metering, place the responsibility for energy expenses with the user (i.e. the tenant).

The final programs, relating to research and education, are obviously needed.

A closing caveat is offered with respect to the empirical results. The sample used in this study was relatively small, in one case as low as 31 buildings, and widely diversified in both location and quality. It is suggested that further analysis using a larger, more homogeneous sample (if this sample could be found) would provide results with more consistency and statistical significance.

The results of this research are not definitive. While a good deal of effort has gone into the assembly of data in the most accurate possible fashion, the lack of significant results illustrates the problem of estimating the impact of energy costs on the market values of commercial buildings and investors' yields resulting from the ownership of commercial buildings.

Further work is necessary in this subject area. An evaluation of utility rate studies, governmental regulations in investments in energy conservation equipment and personnel training are suggested to evaluate more fully the effects of energy costs and changes in energy costs on building value.

LIST OF TABLES

APPENDIX A

TABLE A.1
CORRELATION MATRIX FOR THE AGE-10 SAMPLE

VARIABLE	25. VALUE	30. LOT	35. INCOME	40. ENERGY	45. STALLS	4. STORIES	5. MASON RY	6. AIR	7. Q1	8. Q2	9. AGE	11. UG
25.VALUE	1.0000											
30.LOT	.0810	1.0000										
35.INCOME	.5129	-.0886	1.0000									
40.ENERGY	.3543	-.1249	.0185	1.0000								
45.STALLS	.4056	.3488	.3439	.3435	1.0000							
4.STORIES	.2281	-.5891	-.1211	.4421	-.1132	1.0000						
5.MASON RY	.3324	-.2210	.1248	.3945	.3135	.2044	1.0000					
6.AIR	.4821	-.0446	.3250	.4704	.3486	.2565	.6145	1.0000				
7.Q1	-.3241	-.1317	-.1364	-.3273	-.1371	.0676	-.3387	-.3279	1.0000			
8.Q2	.5378	.2364	.2445	.3894	.2999	.0191	.2410	.4913	-.7977	1.0000		
9.AGE	-.2972	-.2017	-.4634	.2647	.0248	.3079	.0872	-.0196	.0712	-.1057	1.0000	
11.UG	.3236	-.0154	.3467	.2877	.5852	.0744	.1765	.2729	.0193	.1690	-.0471	1.0000
12.ELEV	.5885	-.3999	.4672	.3333	.2078	.4172	.4752	.5813	-.1348	.2817	.0276	.3714
13.DATE	.5338	-.0651	.2743	.1876	.1046	.0190	.1457	.0942	-.5588	.5464	-.2069	.0217
14.LOC1	.1222	.7091	-.1858	.0558	.4274	-.3056	-.2190	-.0430	.0698	.1669	-.0294	.2351
15.LOC2	.2381	-.0289	.2979	.0230	.1186	-.0550	.0679	.0830	.2119	-.1690	-.2355	.2000
16.LOC3	-.4000	-.3504	.0468	-.1243	-.2191	-.1021	.0697	-.1654	-.1131	-.1240	.0584	-.1468

VARIABLE	12. ELEV	13. DATE	14. LOC1	15. LOC2	16. LOC3
12.ELEV	1.0000				
13.DATE	.2565	1.0000			
14.LOC1	-.2351	-.0612	1.0000		
15.LOC2	.1429	-.1243	-.1787	1.0000	
16.LOC3	-.1048	-.0192	-.6556	-.1048	1.0000

TABLE A.2
REGRESSION RESULTS FROM THE AGE-10 SAMPLE

<REG VAR=25,30,35,40,45,4-9,11-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 36 OUT OF 36

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	15941.	996.34	5.1100	.0005
ERROR	19	3704.6	194.98		
TOTAL	35	19646.			

MULT R= .90080 R-SQR= .81143 SE= 13.964

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		-7.3697	30.425	-.24222	.8112
30.LOT	.34290	25.243	15.865	1.5911	.1281
35.INCOME	.29440	3.1699	2.3607	1.3428	.1952
40.ENERGY	.03345	.29157 -1	.19985	.14590	.8855
45.STALLS	.03767	717.07	4364.1	.16431	.8712
4.STORIES	.40078	1.8140	.95131	1.9068	.0718
5.MASONRY	.23003	11.388	11.053	1.0303	.3158
6.AIR	-.09883	-4.6053	10.638	-.43293	.6699
7.Q1	.10851	4.9910	10.490	.47578	.6397
8.Q2	.18581	8.9280	10.831	.82429	.4200
9.AGE	-.20012	-.99553	1.1182	-.89030	.3844
11.UG	-.02603	-.78917	6.9533	-.11349	.9108
12.ELEV	.33318	12.566	8.1582	1.5403	.1400
13.DATE	.46712	.63510	.27580	2.3028	.0328
14.LOC1	.00362	.20177	12.801	.15761 -1	.9876
15.LOC2	.25838	22.192	19.035	1.1658	.2581
16.LOC3	-.22124	-9.3999	9.5056	-.98888	.3351

TABLE A.3
CORRELATION MATRIX OF THE AGE-11 SAMPLE

VARIABLE	20. VALUE	25. LOT	30. INCOME	35. ENERGY	40. STALLS	4. STORIES	5. MASON RY	6. AIR	7. Q1	8. Q2	9. AGE	11. UG
20.VALUE	1.0000											
25.LOT	.3844	1.0000										
30.INCOME	.2796	.1715	1.0000									
35.ENERGY	.2070	-.4076	.2878	1.0000								
40.STALLS	.1003	-.0748	.1781	.2457	1.0000							
4.STORIES	.0001	-.6058	.0232	.5365	.1398	1.0000						
5.MASON RY	-.1591	-.4287	-.1683	.2142	.0931	.3663	1.0000					
6.AIR	.0466	-.2125	.0568	.2758	.2217	.1849	.4048	1.0000				
7.Q1	.4389	.1623	.4111	.2012	.2037	-.1286	-.0161	-.2782	1.0000			
8.Q2	-.1714	-.0758	-.3313	-.0441	-.0656	-.0041	.0409	.5893	-.7475	1.0000		
9.AGE	-.3527	-.0424	-.1811	-.3182	-.3649	.0833	-.0522	-.3263	-.2950	-.0903	1.0000	
11.UG	.1808	-.3221	.2054	.5875	.3916	.5589	.3019	.2410	.2190	-.1136	-.0750	1.0000
12.ELEV	-.0517	-.6371	-.1184	.5834	-.0066	.7212	.4663	.3721	-.1587	.0877	.1000	.4682
13.DATE	.4200	-.0335	-.0575	.0516	-.1302	.0468	-.0190	.1055	.0597	.0812	-.2269	-.2597
14.LOC1	.0255	.5763	.2195	-.0717	.2322	-.4558	-.3625	-.1140	.1585	-.0403	-.0698	-.0092
15.LOC2	-.0648	-.1611	.2897	-.0456	-.2477	-.1324	.0174	-.1005	.2852	-.2132	-.0151	-.1211
16.LOC3	-.1870	-.2274	-.3489	-.2565	-.0443	.0910	.1347	-.0803	-.1028	-.1136	.1646	-.1613

VARIABLE	12. ELEV	13. DATE	14. LOC1	15. LOC2	16. LOC3
12.ELEV	1.0000				
13.DATE	.1948	1.0000			
14.LOC1	-.2686	-.0672	1.0000		
15.LOC2	-.1870	.0318	-.3780	1.0000	
16.LOC3	-.0697	-.1700	-.5034	-.1211	1.0000

TABLE A.4
REGRESSION RESULTS FOR AGE-11 SAMPLE

<REG VAR=20,25,30,35,40,4-9,11-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 20.VALUE N= 36 OUT OF 36

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	12897.	806.07	5.2817	.0004
ERROR	19	2899.7	152.62		
TOTAL	35	15797.			

MULT R= .90357 R-SQR= .81644 SE= 12.354

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		11.166	20.381	.54786	.5902
25.LOT	.67657	28.162	7.0319	4.0049	.0008
30.INCOME	.26147	2.0283	1.7178	1.1808	.2523
35.ENERGY	.08716	.92334 -1	.24210	.38138	.7071
40.STALLS	.13884	1477.2	2417.3	.61109	.5484
4.STORIES	-.27421	-1.1428	.91945	-1.2429	.2290
5.MASON RY	-.30706	-8.1841	5.8193	-1.4064	.1758
6.AIR	-.09407	-3.5554	8.6325	-.41186	.6850
7.Q1	.39624	17.059	9.0686	1.8811	.0754
8.Q2	.16748	8.1884	11.058	.74049	.4681
9.AGE	-.07217	-.59258 -1	.18788	-.31541	.7559
11.UG	.48897	25.185	10.307	2.4434	.0245
12.ELEV	.16449	8.5938	11.823	.72688	.4762
13.DATE	.61696	1.0251	.29999	3.4172	.0029
14.LOC1	-.66639	-35.130	9.0175	-3.8958	.0010
15.LOC2	-.41353	-26.343	13.306	-1.9797	.0624
16.LOC3	-.16661	-7.4839	10.161	-.73654	.4704

TABLE A.5
CORRELATION MATRIX FOR ST-2 SAMPLE

VARIABLE	25. VALUE	30. LOT	35. INCOME	40. ENERGY	45. STALLS	4. STORIES	5. MASON RY	6. AIR	7. Q1	8. Q2	9. AGE	11. UG
25.VALUE	1.0000											
30.LOT	.6586	1.0000										
35.INCOME	.2597	.1051	1.0000									
40.ENERGY	-.1030	-.1847	.2777	1.0000								
45.STALLS	.0565	.0079	-.1123	-.0151	1.0000							
4.STORIES	.0054	-.2200	.1089	.0138	-.1322	1.0000						
5.MASON RY	-.1419	-.1562	-.1531	.2662	.1039	.0899	1.0000					
6.AIR	.0396	.0295	.1080	.0709	.1168	.0271	.3985	1.0000				
7.Q1	.1270	-.1256	-.0674	.0474	-.1050	.4195	-.0332	-.3889	1.0000			
8.Q2	.0308	.1563	.0827	-.0395	.1937	-.2621	.0429	.6455	-.7746	1.0000		
9.AGE	.1281	.4298	-.0822	-.2371	-.1541	-.3201	-.3135	-.2938	-.0695	.0461	1.0000	
11.UG	-.0127	-.1297	-.0712	.1221	.2808	-.3516	.0959	-.0770	.0770	-.0000	-.2115	1.0000
12.ELEV	-.0393	-.0136	-.0611	.2909	-.1268	.0917	.1715	.1936	.1614	-.1250	-.0487	-.0559
13.DATE	.5087	.2350	.2697	-.3026	.1065	.1257	-.1022	.0350	-.1280	.1703	-.0053	-.0352
14.LOC1	-.0051	.3238	.0073	.1287	.1792	-.0879	-.3551	.0271	-.0271	.2097	-.0011	.1641
15.LOC2	-.0318	-.3625	.2859	.0353	-.2268	.1641	.0959	-.0770	.2887	-.2236	.1543	-.1000
16.LOC3	-.0710	-.1789	-.1119	-.0857	.0116	-.0938	.3068	-.0770	-.1347	-.2236	-.1969	-.1000

VARIABLE	12. ELEV	13. DATE	14. LOC1	15. LOC2	16. LOC3
12.ELEV	1.0000				
13.DATE	-.1278	1.0000			
14.LOC1	.0917	-.1841	1.0000		
15.LOC2	-.0559	.1045	-.6094	1.0000	
16.LOC3	-.0559	.0293	-.6094	-.1000	1.0000

TABLE A.6
REGRESSION RESULTS FOR ST-2 SAMPLE

<REG VAR=25,30,35,40,45,4-9,11-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 33 OUT OF 33

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	10157.	634.83	3.1062	.0147
ERROR	16	3270.0	204.38		
TOTAL	32	13427.			

MULT R= .86975 R-SQR= .75647 SE= 14.296

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT		SIGNIF
CONSTANT		4.2935	30.971	.13863		.8915
30.LOT	.70936	40.487	10.057	4.0256		.0010
35.INCOME	.01631	.14408	2.2075	.65266	-1	.9488
40.ENERGY	.26701	.40317	.36379	1.1083		.2841
45.STALLS	.09854	945.19	2386.3	.39608		.6973
4.STORIES	-.02336	-.89908	9.6175	-.93484	-1	.9267
5.MASON RY	-.35111	-11.190	7.4601	-1.4999		.1531
6.AIR	.04491	1.7652	9.8157	.17984		.8595
7.Q1	.42058	20.067	10.822	1.8543		.0822
8.Q2	.23174	13.373	14.033	.95291		.3548
9.AGE	-.24981	-.29760	.28839	-1.0319		.3174
11.UG	.11167	5.3635	11.933	.44948		.6591
12.ELEV	-.01272	-.89374	17.569	-.50870	-1	.9601
13.DATE	.37261	.55012	.34252	1.6061		.1278
14.LOC1	-.27126	-20.602	18.275	-1.1273		.2762
15.LOC2	-.00646	-.63107	24.408	-.25855	-1	.9797
16.LOC3	.01607	1.3855	21.546	.64302	-1	.9495

TABLE A.7
CORRELATION MATRIX FOR ST-3 SAMPLE

VARIABLE	20. VALUE	25. LOT	30. INCOME	35. ENERGY	4. STORIES	5. MASON RY	6. AIR	7. Q1	8. Q2	9. AGE	10. STALLS	11. UG
20.VALUE	1.0000											
25.LOT	.3401	1.0000										
30.INCOME	.4755	.1633	1.0000									
35.ENERGY	.3752	-.0181	.1204	1.0000								
4.STORIES	-.0130	-.5867	-.1921	.3664	1.0000							
5.MASON RY	.1555	-.0786	.0925	.1650	.1446	1.0000						
6.AIR	.3901	-.0155	.3227	.4936	.0435	.4971	1.0000					
7.Q1	.0342	.0320	.2617	-.0680	.0789	-.3107	-.2071	1.0000				
8.Q2	.3077	.1692	-.0628	.2605	-.1252	.2385	.4799	-.7678	1.0000			
9.AGE	-.5275	-.3049	-.4849	-.2525	.2378	.1109	-.4711	-.1042	-.2819	1.0000		
10.STALLS	.1351	-.1872	.2479	.5274	.5383	.1168	.2310	.3782	-.2490	-.0699	1.0000	
11.UG	.3264	.1023	.4519	.3806	.1331	.2044	.4111	.2045	.0292	-.1716	.4653	1.0000
12.ELEV	.3065	-.2572	.2396	.2608	.3295	.4245	.5367	-.0976	.1967	-.0114	.2178	.3587
13.DATE	.4137	.0867	-.0171	.1649	-.1685	-.0219	-.0011	-.3474	.4225	-.2035	-.2006	-.2358
14.LOC1	.3164	.6709	.1388	.2216	-.2868	.1838	.0951	.0676	.1379	-.1246	.1181	.3679
15.LOC2	.2189	.0452	.2649	-.0012	-.1009	.0377	.0759	.2168	-.1664	-.1178	-.0083	.1845
16.LOC3	-.5207	-.1851	-.1413	-.3332	-.1884	-.3487	-.2673	-.0356	-.1282	.1244	-.2280	-.2499

VARIABLE	12. ELEV	13. DATE	14. LOC1	15. LOC2	16. LOC3
12.ELEV	1.0000				
13.DATE	.1219	1.0000			
14.LOC1	.0577	.2007	1.0000		
15.LOC2	.0889	-.1638	-.1282	1.0000	
16.LOC3	-.4260	-.2284	-.5270	-.1081	1.0000

TABLE A.8
REGRESSION ANALYSIS FOR ST-3 SAMPLE

<REG VAR=20,25,30,35,40,4-9,11-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 20.VALUE N= 39 OUT OF 39

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	15333.	958.29	4.0584	.0014
ERROR	22	5194.8	236.13		
TOTAL	38	20527.			

MULT R= .86425 R-SQR= .74694 SE= 15.366

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		-8.9519	29.872	-.29968	.7672
25.LOT	.45244	39.379	16.548	2.3796	.0264
30.INCOME	.23116	2.1044	1.8883	1.1144	.2771
35.ENERGY	-.03377	-.33700 -1	.21261	-.15850	.8755
40.STALLS	.15698	3127.4	4194.8	.74553	.4638
4.STORIES	.22858	.94993	.86254	1.1013	.2827
5.MASONRY	.10198	8.2106	17.076	.48082	.6354
6.AIR	.01974	1.4437	15.589	.92613 -1	.9270
7.Q1	.20880	10.945	10.930	1.0014	.3275
8.Q2	.18871	10.143	11.254	.90135	.3772
9.AGE	-.12539	-.16363	.27603	-.59280	.5594
11.UG	.19328	7.3749	7.9815	.92400	.3655
12.ELEV	-.00783	-.35502	9.6723	-.36704 -1	.9711
13.DATE	.51960	.97655	.34236	2.8524	.0093
14.LOC1	-.34115	-20.166	11.847	-1.7022	.1028
15.LOC2	.13183	11.839	18.978	.62380	.5392
16.LOC3	-.37315	-16.117	8.5432	-1.8865	.0725

TABLE A.9
CORRELATION MATRIX FOR AGE-15, ST-2 SAMPLE

VARIABLE	25. VALUE	4. STORIES	5. MASONRY	6. AIR	7. Q1	8. Q2	9. AGE	11. UG	12. ELEV	13. DATE	14. LOC1	15. LOC2
25. VALUE	1.0000											
4. STORIES	.3400	1.0000										
5. MASONRY	.1349	.2280	1.0000									
6. AIR	.4004	.3034	.5610	1.0000								
7. Q1	-.2205	-.0413	-.3083	-.4816	1.0000							
8. Q2	.4095	.2140	.3265	.7054	-.8421	1.0000						
9. AGE	-.3230	-.3842	-.2047	-.2798	.1821	-.2303	1.0000					
11. UG	.3333	.0887	.2274	.1817	-.0150	.1162	-.2483	1.0000				
12. ELEV	.5350	.5690	.4282	.5204	-.1271	.2436	-.2797	.3058	1.0000			
13. DATE	.5426	.2602	-.0493	.0812	-.3425	.3773	-.2743	-.1187	.2579	1.0000		
14. LOC1	.0145	-.3863	-.1557	-.0109	.1271	.0035	.2529	.1167	-.2045	-.2028	1.0000	
15. LOC2	.2892	.1673	.1085	.1318	.1869	-.1574	-.2135	.2915	.2533	-.0998	-.2533	1.0000
16. LOC3	-.2286	.2280	.0430	-.1448	-.2263	.0468	-.1292	-.1646	-.0754	.1101	-.8040	-.0934
30. LOT	.2151	-.5256	-.2621	.0239	-.0725	.1060	.3785	.0419	-.2021	-.0713	.7120	-.1658
35. INCOME	.5604	.3489	.1452	.3023	-.3083	.3466	-.5744	.2551	.4235	.4282	-.1301	.3530
40. ENERGY	.3207	.1877	.4212	.4107	-.3621	.4124	-.0645	.2122	.2504	.1247	.0499	.1075
45. STALLS	.0407	-.1343	.1568	.1548	-.2103	.2696	.3235	.3418	-.0488	-.0008	.3325	.0840

VARIABLE	16. LOC3	30. LOT	35. INCOME	40. ENERGY	45. STALLS
16. LOC3	1.0000				
30. LOT	-.5223	1.0000			
35. INCOME	-.0831	-.0397	1.0000		
40. ENERGY	-.0357	.1777	.2669	1.0000	
45. STALLS	-.2811	.3128	-.0096	.1732	1.0000

TABLE A.10
REGRESSION RESULTS FOR AGE-15, ST-3 SAMPLE

<REG VAR=25,4-9,11-16,30,35,40,45>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 35 OUT OF 35

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	16	14213.	888.31	4.7501	.0011
ERROR	18	3366.1	187.01		
TOTAL	34	17579.			

MULT R= .89917 R-SQR= .80852 SE= 13.675

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		-22.705	27.886	-.81419	.4262
4.STORIES	.36839	9.8604	5.8652	1.6812	.1100
5.MASONRY	.23733	8.3309	8.0375	1.0365	.3137
6.AIR	-.11601	-5.5224	11.144	-.49555	.6262
7.Q1	.17529	8.3067	10.996	.75540	.4598
8.Q2	.28261	17.875	14.301	1.2499	.2273
9.AGE	-.02928	-.10839	.87216	-.12427	.9025
11.UG	.41720	14.544	7.4675	1.9476	.0672
12.ELEV	.09179	3.4779	8.8933	.39107	.7003
13.DATE	.58073	.84985	.28081	3.0264	.0073
14.LOC1	-.25597	-16.481	14.671	-1.1234	.2760
15.LOC2	.35090	33.140	20.845	1.5898	.1293
16.LOC3	-.25959	-15.219	13.345	-1.1404	.2691
30.LOT	.59479	51.465	16.395	3.1391	.0057
35.INCOME	-.05419	-.48691	2.1148	-.23024	.8205
40.ENERGY	-.12331	-.11872	.22518	-.52719	.6045
45.STALLS	-.37280	-5051.5	2963.6	-1.7045	.1055

TABLE A.11
CORRELATION MATRIX FOR THE "GOOD" SAMPLE

VARIABLE	25. VALUE	30. LOT	35. INCOME	40. ENERGY	45. STALLS	4. STORIES	5. MASON RY	9. Q2	11. UG	12. ELEV	14. LOC1	15. LOC2
25. VALUE	1.0000											
30. LOT	-.0320	1.0000										
35. INCOME	.3032	.1224	1.0000									
40. ENERGY	.3547	-.3527	.0692	1.0000								
45. STALLS	.0837	.1539	.1285	.1952	1.0000							
4. STORIES	.1874	-.5731	-.2763	.3835	-.2737	1.0000						
5. MASON RY	.2433	-.4830	-.0078	.4538	.1639	.2641	1.0000					
9. Q2	-.5317	.2158	-.5228	-.3551	-.1632	-.0118	-.5110	1.0000				
11. UG	.3798	-.1721	.4470	.3145	.4323	.0643	.3026	-.3026	1.0000			
12. ELEV	.4761	-.6715	.1419	.4219	-.1381	.4455	.4832	-.3257	.3489	1.0000		
14. LOC1	-.0017	.6248	.2714	.0122	.4463	-.5011	-.3485	.0536	.1234	-.3220	1.0000	
15. LOC2	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
16. LOC3	-.1890	-.3150	.1491	-.1146	-.1172	-.0793	.1923	-.1923	.0726	.0455	-.5518	-0.

VARIABLE	16. LOC3
16. LOC3	1.0000

TABLE A.12
REGRESSION RESULTS FOR THE "GOOD" SAMPLE

<REG VAR=20,25,30,35,40,4,5,9,11,12,13,14,16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 20.VALUE N= 31 OUT OF 31

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	12	10391.	865.89	3.4281	.0092
ERROR	18	4546.5	252.59		
TOTAL	30	14937.			

MULT R= .83404 R-SQR= .69562 SE= 15.893

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		55.983	38.250	1.4636	.1605
25.LOT	.49165	31.568	13.179	2.3954	.0277
30.INCOME	-.06075	-.67686	2.6214	-.25820	.7992
35.ENERGY	.15234	.15033	.22987	.65395	.5214
40.STALLS	.09897	1504.6	3565.7	.42196	.6781
4.STORIES	.09091	.42020	1.0849	.38731	.7031
5.MASON RY	-.27629	-15.502	12.710	-1.2197	.2383
9.AGE	-.44522	-.86935	.41211	-2.1095	.0492
11.UG	.30036	11.782	8.8189	1.3360	.1982
12.ELEV	.32371	20.935	14.423	1.4515	.1638
13.DATE	.13735	.34778	.59115	.58831	.5636
14.LOC1	-.35157	-20.374	12.788	-1.5933	.1285
16.LOC3	-.31151	-16.943	12.182	-1.3908	.1812

APPENDIX B

TABLE B.1
REGRESSION RESULTS REMOVING VARIABLES HIGHLY CORRELATED WITH THE ENERGY VARIABLE

<REG VAR=25,30,35,40,45,7-9,13-16>
LEAST SQUARES REGRESSION

ANALYSIS OF VARIANCE OF 25.VALUE N= 73 OUT OF 73

SOURCE	DF	SUM SQRS	MEAN SQR	F-STAT	SIGNIF
REGRESSION	11	22550.	2050.0	9.1332	.0000
ERROR	61	13692.	224.45		
TOTAL	72	36241.			

MULT R= .78880 R-SQR= .62221 SE= 14.982

VARIABLE	PARTIAL	COEFF	STD ERROR	T-STAT	SIGNIF
CONSTANT		4.0434	11.779	.34327	.7326
30.LOT	.48114	22.454	5.2381	4.2866	.0001
35.INCOME	.33598	2.8880	1.0366	2.7860	.0071
40.ENERGY	.29244	.30395	.12726	2.3885	.0200
45.STALLS	.18834	2702.8	1804.5	1.4978	.1393
7.Q1	.28734	15.280	6.5214	2.3430	.0224
8.Q2	.21705	11.443	6.5891	1.7366	.0875
9.AGE	-.10167	-.10753	.13472	-.79821	.4278
13.DATE	.50198	.81211	.17915	4.5331	.0000
14.LOC1	-.41867	-22.648	6.2900	-3.6007	.0006
15.LOC2	-.19703	-14.992	9.5510	-1.5696	.1217
16.LOC3	-.32978	-16.820	6.1648	-2.7283	.0083

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