An Interim Assessment of the Energuide Program

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Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

En français : <u>Évaluation provisoire du programme Énerguide</u>

Disponible à la : Direction des communications
Consommation et Corporations Canada
Ottawa (Ontario)
K1A 0C9

AN INTERIM ASSESSMENT OF THE ENERGUIDE PROGRAM

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Consumer Energy Research: An Annotated Bibliography, 1984 by C. Dennis Anderson and Gordon H.G. McDougall (1984).

An Interim Assessment of the Energuide Program by Peter Tryfos and Ian Fenwick (1984).

Available in both official languages from:

Communications Branch
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Forthcoming

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Cat. No. RG23-76/1984E
ISBN 0-662-12869-9

FOREWORD

This project was funded by the Office of Energy Research and Development, Energy, Mines and Resources Canada, and was initiated and managed by the Strategic Policy Branch, Policy Research, Analysis and Liaison Directorate of Consumer and Corporate Affairs Canada.

It is one of a series of CCAC survey research reports, begun in 1975, entitled Energy Attitude Studies. The studies have as goals assessing and monitoring consumers' attitudes, knowledge and behaviour with respect to energy and resource use, and examining the importance that consumers have placed and continue to place on this aspect of their lifestyle.

This report, by Peter Tryfos and Ian Fenwick, provides an interim assessment of the Energuide Program, which was officially announced on May 16, 1978. The program requires that various household appliances give prominent display to a label indicating their monthly electricity consumption in kilowatt hours under standardized test conditions. This study is based on information contained in the Energuide Directories and focuses on a major objective: changing consumer preferences to increase the purchase of energy efficient products, with particular reference to household appliances.

It should be understood that the findings, interpretations and recommendations of this report are those of the authors and do not necessarily imply their endorsement by Consumer and Corporate Affairs Canada. The purpose of this open publication policy is to ensure that the research environment is conducive to the production of high quality, objective scientific studies.

T. Russell Robinson
Assistant Deputy Minister
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ACKNOWLEDGEMENTS

The authors would like to thank Howard Gaskin and Lisa Creighton of York University's M.B.A. program for their assistance in carrying out this project. They are also indebted to Robin Heighton and Roy Patterson of the Canadian Standards Association (CSA), Robin Lane of Canadian Appliance Manufacturing Co. Ltd. (CAMCo), to the Canadian Appliance Manufacturers Association (CAMA) and a number of appliance manufacturers and retailers for providing valuable information. However, the analysis presented and conclusions reached are the authors' alone, as are any errors or omissions. The project was carried out under the auspices of the Management Science in Marketing Research Group at York University.

SUMMARY

The main objectives of this study are: (a) to analyze trends in the energy consumption of appliance models, and (b) to estimate consumers' implicit evaluations of energy efficiency and of other appliance features.

The appliances considered are refrigerators, freezers, ranges, clothes washers, clothes dryers and dishwashers. The study is based on information obtained from the Energuide directories, manufacturers' and retailers' product literature, and a survey of appliance prices in a major metropolitan area.

Two major conclusions of the study are:

- Most domestic appliances on sale in Canada in 1982 use much less energy than their counterparts at the start of the Energuide program. The average electricity consumption of appliances has declined, and in many cases the decline has been substantial, far exceeding expectations.

- Consumers do appear to value energy efficiency, but perhaps less than rational economic calculus and present economic conditions justify. In consequence, energy conservation programs such as Energuide do not appear to have exhausted the potential for energy conservation improvement.

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INTRODUCTION

Ever since the rapid escalation in energy prices, Canadians have been increasingly advised, exhorted, directed or encouraged to reduce energy consumption by eliminating waste, by improving the efficiency of existing energy-consuming products, by altering life-styles and behaviour toward lower energy usage and by choosing products at least in part on the basis of their energy consumption patterns.

Although consumer interest in energy conservation may be stimulated in a variety of ways (e.g., energy conservation advertising by public and private agencies), information on the energy conservation performance of household durable goods is almost exclusively provided by the Energuide program.

The Energuide program was officially announced on May 16, 1978. The program requires that various household appliances give prominent display to a label indicating their monthly electricity consumption in kilowatt hours (kW•h) under standardized test conditions. Energuide labelling was first introduced for all refrigerators on sale in Canada manufactured after September 30, 1978. The program has subsequently been extended to freezers (manufactured after November 30, 1979), clothes washers and dishwashers (manufactured after October 30, 1980), electric ranges (manufactured after December 31, 1980), and clothes dryers (manufactured after 1981). Determination of appliances' monthly electricity consumption is the responsibility of the Canadian Standards Association (CSA).

Compiled by the CSA and published by CCAC, the annual Energuide Directory (or directories, depending on the year) lists the monthly electricity consumption and selected features for each model tested, classified by brand name and manufacturer or distributor. Directories are available on request through the regional offices of CCAC. This study had access to a draft of the 1982 directory, which covers refrigerators, freezers, clothes washers, clothes dryers, dishwashers and ranges.

The principal objectives of the Energuide program, as announced at the start of the program in 1978 and repeated several times since, are:

1. to enable consumers to compare the energy consumption of available models and to choose from comparable models the one that consumes the least amount of energy;

2. to allow retailers to assist their customers in making purchase decisions based in part on the energy consumption of the featured models; and

3. to encourage appliance manufacturers to improve the energy efficiency of appliances through research, design and development.

It should be noted that many factors influence manufacturers', retailers' and consumers' interest in energy conservation. Although information on the energy conservation performance of household appliances is provided almost exclusively by the Energuide program, environmental trends, economic conditions, changing life-styles and other government programs all influence manufacturers, retailers and consumers in their choice of appliances. To the extent that these other factors cannot be controlled, it is impossible to relate trends in appliances specifically to the Energuide program. Nonetheless, the evidence presented does strongly suggest the direct effect of Energuide.

If the energy used by domestic appliances is to be reduced, two things must happen. Manufacturers must make available energy efficient appliances, and consumers (perhaps influenced by retailers) must buy them. These two activities are not totally independent. Manufacturers are presumably more likely to increase energy efficiency if consumers show that energy efficiency is a valued product attribute. Or, if all manufacturers uniformly increase the energy efficiency of their appliances, consumers will be compelled to purchase efficient models (although concomitant trading up to larger or more "loaded" models could eliminate any aggregate savings). However, it is important to remember that the Energuide program is specifically aimed at both sides of the market, and at the distribution channel. This report examines manufacturers' actions and presents a detailed assessment of consumers' reactions.

An evaluation of the Energuide program involves a number of particular problems.

1. Time frame. Conservation programs are long-range programs, in the sense that their effects will extend over a considerable period. At the time of writing, Energuide had been in existence for only four years, including a protracted initiation period. Even after four years of operation, Energuide labels do not appear on all major household appliances. For this reason, any analysis carried out at this stage must be considered on an interim basis. Nonetheless, such an analysis is important both in providing an interim appraisal of the program and in determining the data necessary for future measurement of its effectiveness.

2. Consumer response. It is the premise of the program that the provision of energy consumption information will not only assist consumers in making wise purchases, but will encourage retailers and manufacturers to design, produce and market energy efficient models. Nearly all the studies conducted so far, however, examine how consumers *say* they will respond or how they do respond in experimental situations.

These approaches, valuable as they are, have two drawbacks. First, they are sample based. Frequently the consumers involved are not actually in the process of buying appliances, or are self-selected as "intending purchasers." Second, there is an inherent danger in relying on consumers' reports of their buying intentions. The difference between intention and action can be considerable. Particularly in the case of strongly normative issues such as energy conservation, there is a well-known tendency for consumers to provide socially acceptable responses (see, for example, Kendall and Fenwick 1979). Artificial experimental situations introduce their own errors of reaction, and laboratory behaviour may not predict actual shopping behaviour.

3. <u>Appliance operating expenditures and household budgets</u>. At present energy prices, the total energy operating cost of all household appliances is relatively small in relation to household income.

There is evidence suggesting that consumers are less likely to engage in a thorough search and pay attention to all the elements of a decision when the alternatives do not differ significantly and the final choice does not have a prominent effect on the household budget. Thus the probability is relatively high that consumer surveys of intended purchases and stated reasons may be quite different from aggregate actual decisions.

4. <u>Appliances are multifeatured products</u>. For each type of appliance, many models are available on the market. They vary in the features they possess, purchase price, and the cost of operation and maintenance. The 1982 Energuide Directory, for example, lists about 700 models of refrigerators. Their features include refrigerator capacity, freezer capacity, usable shelf area, style, colour, the presence or lack of automatic defrosting, the location of the freezer, the number and type of doors, and so on.

Even if the number of units of each model sold were known -- information which firms and industry associations consider confidential for competitive reasons -- the effect of energy conservation programs could not be measured simply by comparing the average electricity consumption of all units sold over time, for these figures would also be influenced by changes in the preferences of consumers with respect to product features.

For example, Claxton and Anderson (1981, p. 16) note a trend towards larger refrigerator sizes, a trend that could explain why the average electricity consumption of refrigerators sold by three producers actually increased between 1978 and 1979 (ibid., p. 19a).

When attempting to estimate the effect of energy conservation programs for household appliances, it is worthwhile to concentrate on the actual aggregate actions of consumers as distinct from stated intentions or experimentally derived inferences. In Chapter III of this report, a statistical model is described which allows estimates to be made of the values which buyers place on individual product features and of buyers' evaluation of energy efficiency. Even more important for practical purposes, these estimates can be made on the basis of available data concerning prices, product features and energy consumption of appliance models, and do not require confidential information on sales by individual models.

The measures described in this report should be considered in parallel with other measures of success of conservation programs. For example, one role of Energuide is to provide information to consumers concerning the energy consumption of appliances. Information is provided through the labels, the directories and the publicity given to the program. A measure of the performance of Energuide in its informational role can be defined as the proportion of buyers or potential buyers who have heard of, understand the purpose of, and/or consider useful the labels and directories. Claxton and Anderson (1981) carried out fairly extensive surveys of consumers and found generally a high degree of awareness of the program. Despite reservations concerning the correspondence between stated and actual intentions, such measures are undeniably useful and should continue to be taken. Considered together with those of the present report, they allow a better understanding of a complicated issue.

The objectives of this report are to:

1. analyze trends in appliances, with particular regard to energy efficiency;

2. estimate consumers' implicit evaluations of product features (including energy efficiency); and

3. form computer data files to allow future evaluation of trends and estimates of consumers' evaluations as required.

Information on appliance models, selected model features and energy ratings was obtained from Energuide directories and more recent unpublished test results of the CSA. Further information on product features and prices was obtained from manufacturers' and retailers' product literature, supplemented by a survey of appliance prices in the Toronto area.

The organization of the report is as follows:

1. Chapter I provides a description and appraisal of some recent studies concerning the potential for energy conservation in the appliance industry.

2. Chapter II analyzes trends in the energy consumption of appliances, based on Energuide directories and CSA files.

3. Chapter III deals with estimates of the market values of product features and energy efficiency, based on information from a survey of retail outlets, Energuide directories and manufacturers' product literature.

4. The final chapter contains the conclusions and policy implications of the study.

Chapter I

POTENTIAL FOR ENERGY SAVINGS IN DOMESTIC APPLIANCES

Several researchers have examined the potential for home appliance energy saving. Three sources are particularly relevant: Cullen (1979), Drapkin (1981) and Lane (1981).

Cullen (1979) reviews a wide range of trade publications and produces estimates of possible energy savings ranging as high as 71% for refrigerators, 75% for ranges, 50% for clothes washers and 16% for dishwashers (not including potential savings in water heating). Many of these savings involve changes in usage conditions (i.e., require consumer motivation and life-style changes) as well as technical product changes.

The second major, independent study of conservation potential was conducted by Ontario Hydro on behalf of the Canadian Electrical Association (Drapkin 1981). This study performed a cost-benefit analysis of the impact of improved appliance energy efficiency. Based on a literature review and inputs from the Research Division of Ontario Hydro, Drapkin defines two categories of potential energy savings (see Table 1). "Technically possible" savings refer to design changes which could be implemented within three years; "research and development" energy savings estimate the effect of design changes which could be implemented over a three- to five-year period, after further research and development. Pooling these two categories -- that is, estimating potential energy savings available within five years -- shows a 56% saving for refrigerators, 31% for freezers, 70% for electric ranges, 65% for clothes washers and 40% for dishwashers (including savings in hot water heating).

In absolute terms, energy savings can be impressive. Cullen (1979) applies his estimates of potential savings to all appliances now owned. This is clearly a crude estimate of potential savings. Improved efficiency of new appliances will take considerable time to affect aggregate stock performance, because existing appliances are long-lived and unlikely to be retrofitted.

Drapkin (1981) presents a more sophisticated analysis based on forecasts of new appliance sales and existing appliance vintages and stocks (forecasts are provided by Statistics Canada from inputs by the Canadian Appliance Manufacturers Association [CAMA]; see Gribble 1980).

Table 1

Potential Energy Savings for Major Household Appliances

Appliance	Energy savings: Technically possible[a] (%)	Research and development[b] (%)	Total annual savings[c] (%)	Total annual savings[c] (kW•h)
Refrigerators	39	25	56	1 013
Freezers	25	8	31	403
Electric ranges	48	37	70	636
Clothes washers	64	3	65	1 038
Dishwashers	23	25	40	839

Source: Drapkin (1981), Table 3.1, p. 9.

[a]Refers to design options which could be implemented over a three-year period.

[b]Refers to design options which could be implemented over a three- to five-year period, after sufficient research and development.

[c]Includes all design changes.

Drapkin compares forecasts of domestic appliance energy consumption based on current industry projections with those based on the implementation of all technically possible design changes within three years. Savings are comparatively modest in early years: 1980 savings are approximately 118 GW•h (0.3% of total consumption), and 1981 savings approximately 581 GW•h (1.2% of total).[1] But by 1986 substantial savings are being achieved: 1986 savings are almost 6 500 GW•h (11.4% of total consumption) and, over the entire period 1980-2005, total energy savings from improved appliance efficiency are over 300 000 GW•h.

The potential impact of improving the energy efficiency of domestic appliances is considerable, although that impact will be small in the short run. It should be noted that, according to the Drapkin projections, the saving is in terms of mitigating a trend towards greater energy use by domestic appliances rather than an absolute energy saving. Also, his results require that manufacturers incorporate techni-

1. 1 GW•h = 1 x 10^6 kW•h.

cally feasible design changes and that consumers purchase these energy efficient models within a three-year period. If all technically possible design changes are not made, or if they are made over a longer than three-year period, potential gains are considerably deferred. If consumers fail to switch to energy efficient models with sufficient alacrity, or react to increased efficiency by trading up to larger or more-energy-consuming models, potential gains will be lost completely. This is presumably the motivation for Drapkin's recommendation that energy efficiency be assured by mandatory efficiency standards, rather than by sole reliance on the Energuide program.

The third analysis of energy-saving potential to be considered here was conducted by the Canadian Appliance Manufacturers Association Technical Committee, Chairman Roger Lane (Lane 1981). This report is a detailed critique of specific elements of the Drapkin study. Lane argues that Drapkin's estimates of technically possible gains in energy efficiency are in several cases inappropriate. In particular, the baseline model by which Drapkin summarizes each appliance group may not be typical of Canadian purchases. As a result, estimated energy savings reflect neither the range of appliances purchased in Canada, nor even the most frequently purchased models. Furthermore, some of the design changes proposed have repercussions that make their acceptance unlikely. For example, installation of 3" insulation in refrigerators would change external dimensions for any given storage capacity, affecting kitchen and cabinet design. Presumably, such refrigerators would not fit many existing kitchen plans. Similarly, a switch to partial, or non-frost-free refrigerators would demand a considerable change in consumer tastes (Lane also questions whether this switch would produce substantial energy savings).

Lane contends that other design "changes" were already implemented in many of the appliances sold in Canada, even as of 1979 (the date of Drapkin's analysis). Some cannot be implemented in Canada alone but must await changes by foreign suppliers (usually U.S. companies). For example, the design of refrigerator compressors is controlled by the specifications of their U.S. producers, not the demands of the smaller Canadian market. On the other hand, Lane finds that by 1981 the majority of dishwashers and freezers sold in Canada already exceeded the efficiency estimated as technically possible by Drapkin.

Table 2 shows the potential improvements in energy efficiency estimated by Lane as technically possible within a five-year period. For each appliance the base to which percentage savings are applied is the "fleet average" model in Canada, using the earliest available reliable estimate of energy usage (usually the earliest Energuide Directory). Where a single fleet average would not make sense, the appliance class is subdivided (e.g., refrigerators are divided into manual and automatic defrost).

Table 2

Potential Energy Savings for Major Household Appliances

Appliance	Base date	Technically possible saving within 5 years (%)	(kW·h/mon)
Refrigerators:			
Manual defrost	1978	31.0	18.0
Frost-free, top freezer, 2-door, 15 cu. ft.	1978	39.0	64.0
Dishwashers	1979	17.7	25.0
Ranges:			
Self-clean	1980	2.2	2.0
Non-self-clean	1980	7.9	5.5
Freezers	1978	47.0[a]	51.0[b]
Clothes washers	1978	26.0[b]	42.0[b]

Source: Lane (1981), Table 3.1, p. 45.

[a]These savings had already been achieved by 1981.

[b]96% of these savings had already been achieved by 1981.

The Lane estimates (Table 2) are considerably different from those suggested by Drapkin (Table 1). Refrigerators and dishwashers are the only appliances for which the two sources come close to agreement. For ranges, Lane estimates at most an 8% saving, Drapkin 48%. Most of this difference results from estimation of the effects of forced air oven circulation. Drapkin contends that this alone will save 35% of the range's energy. However, Lane points out that the oven, the only range component affected by the circulator, is responsible for only 49% of the range's total energy consumption. To save 35% of *total* energy consumption would require that the forced air oven circulator reduce *oven* energy consumption by 71%. It also appears that the oven circulator is not suitable for all oven applications and so is unlikely to be in constant use.

For freezers, Lane shows that 1981 models have achieved almost twice the energy savings estimated by Drapkin. For clothes washers, Lane suggests that only a 26% improvement is possible (including a 25% improvement already made by 1981); Drapkin estimates a 64% technically possible improvement. The main factor here is the effect of moving to front-loading (drum-type) machines, a saving of about 35% of hot water costs. Although Lane does not dispute the energy efficiency of the front loader, he does question the likelihood of consumers and manufacturers switching over to a radically different washing method.

Probably the most definite conclusions to be drawn from these analyses of energy-saving potential is the difficulty of predicting the impact of future design changes. Most differences in forecast energy savings arise not from disagreement about the technical possibilities but from doubts as to consumer acceptance of design changes, and the actual in-use impact of design changes on energy consumption. The difference in freezer energy savings as predicted in 1979 and experienced by 1981 must throw doubt on all estimates of future energy savings.

Chapter II

TRENDS IN APPLIANCES MANUFACTURED

This chapter examines changes that have taken place in appliances' energy consumption since the implementation of the Energuide program. The analysis is based on information in the Energuide directories and covers four years for refrigerators, three years for freezers, and two years for ranges, dishwashers and clothes washers. At the time of writing, clothes dryers had been covered by the program for only one year and so could not be analyzed here.

The Energuide Directories

The Energuide directories list all basic appliance models available in Canada by model number, energy rating and selected features which affect energy consumption. They do not show the date at which a model was first introduced into the Canadian market or when it was first tested for the Energuide program. Appearance in the directory does not guarantee that a model was actually on the market in that year; older models may remain in the directory for some time, although they may not be available in stores.

For the purpose of analyzing trends in appliances manufactured we need to deduce the date of each model's introduction. In most cases this can be done quite easily: if a model number appears in one year's directory but not in the previous year's directory, that model is deemed to be a new introduction. For example, refrigerator Admiral EC1080 is listed in the Energuide directory for 1981 but does not appear in the 1980 directory; therefore, model ED1080 is classified as a 1981 model. For simplicity we refer to models first listed in the 1981 directory as 1981 models. Although some of these models would have been tested in 1980 and some authors refer to them as 1980 models, we prefer to keep the model date in line with the date of the Energuide Directory in which they first appeared.

Three problems can arise with this classification process. First, it is possible that a manufacturer could change a model's features without changing the model number. If this happened our analysis would fail to register the new model. In practice, therefore, we checked that the same model number did indeed possess the same features insofar as these features were listed in the Energuide Directory.

Second, a manufacturer may change the model number without changing any features. For example, a new year's production may be assigned a new number routinely, even though model features are unchanged. In practice, since the Energuide Directory lists only part of the model number (prefixes and suffixes indicating colour, batch or non-energy-related features are not entered in the directory), there are many cases where the Energuide model number changes without any change in features as listed in the Energuide Directory. As a general rule the changed model number was accepted as "new" only if it reflected a model that was substantially different from any previous model used by that manufacturer.

The third problem occurs when a particular brand adopts a model launched sometime earlier. For example, if a manufacturer obtains a contract to supply a retailer's store brand appliances, those appliances will appear in the Energuide Directory under the retailer's brand name as apparently new introductions, even though they are not in fact newly designed. Such brands are in a sense new introductions to the market, never having been sold before in that particular form. Indeed, if the Energuide program is successful in affecting retailers, the models chosen for store branding should be among the more efficient.

Three Data Bases

The domestic appliance industry in Canada is fairly concentrated. Although there are over 20 manufacturers of major electrical appliances, there are only 3 major, full-line producers. However, a multiplicity of brands and models are produced. Table 3 shows the total number of apparently separate models (i.e., Energuide Directory entries) for each appliance. In total the 1979, 1980, 1981 and 1982 Energuide directories list 1 251 apparently separate models of refrigerators (i.e., all exact, or very close, duplications of model numbers have been excluded, as discussed above). The 1980, 1981 and 1982 directories list 508 apparently separate models of freezers. The 1981 and 1982 directories list 682 apparently separate models of ranges, 253 apparently separate models of clothes washers and 301 apparently separate models of dishwashers. The 1982 directory lists 112 models of clothes dryers. These models form *data base 1: all apparently separate models.*

However, as discussed above, this large data base may contain some element of double-counting. Most manufacturers produce a range of versions of each basic model differing in trim, colour, door-opening, internal fittings, etc. If we delete from the full data base all within-brand redundancy (i.e., within each brand delete all but one of the models having identical features in the Energuide Directory), the number of data points is approximately halved (see Table 3). This reduced data base we call *data base 2: distinct models within brands.*

Potential redundancy does not end there. Even data base 2 may contain double-counting. For example, Energuide directories list retailers' store brands as separate brand categories. As manufacturers rarely produce completely separate models for the retailer, these models

Table 3

Number of Models Listed in Energuide Directories

Appliance	Directories	Data base 1: all apparently separate models	Data base 2: distinct models within brands	Data base 3: definitely distinct models
Refrigerators	1979, 1980 1981, 1982	1 251	785	340
Freezers	1980, 1981 1982	508	435	119
Ranges	1981, 1982	682	255	85
Clothes washers	1981, 1982	253	125	80
Dishwashers	1981, 1982	301	77	39
Clothes dryers	1982	112	51	23

are represented more than once even in data base 2. A third, smaller data base can be generated by excluding from data base 2 all but one of the models having identical Energuide Directory listings irrespective of brand. This data base, which we call *data base 3: definitely distinct models*, is the minimum number of separate models on the Canadian market.

For most purposes we prefer the full data base, data base 1: all apparently separate models. It has two major advantages: First, multiple listings will tend to be most extensive for the most popular brands. In effect, therefore, data base 1 contains some weighting by sales. As sales data by model could not be obtained this weighting, although crude, is welcome. Second, the full data base more closely represents the variety of options available to consumers.

Refrigerators

Univariate analysis. The Energuide Directory distinguishes seven types of refrigerators and lists each refrigerator's fresh food, freezer and total volume. Looking first at data pooled over all refrigerator types, we find that in all size categories there have been considerable reductions in average Energuide ratings. The largest absolute fall occurred for refrigerators larger than 15.5 cu. ft. (the most popular size on the market, representing 38% of all units [CAMA 1982]), where average consumption fell by 35 kW•h/mon. The largest percentage fall was in the 9.5-13.4 cu. ft. range (29% of the Canadian market), where average ratings fell 29%. Slightly lower gains were experienced in the small (under 9.5 cu. ft.) units, and much less was gained in the 13.5-15.4 cu. ft. group where over the four years efficiency improved by only 12%.

A clearer picture of trends can be obtained by looking at individual refrigerator types. The *two-door top freezer with automatic defrost (frost-free)* (TF-A) is by far the most popular type. CAMA (1982) estimates this type to have 71% of the Canadian market. In four size categories, average Energuide ratings have fallen dramatically. In the most popular size category (15.5-17.5 cu. ft., representing 29% of the Canadian market, CAMA 1982) the average energy rating has fallen by 24% between the 1979 and 1982 Energuide directories. The only size that appears not to have become more energy efficient is the 13.5-14.4 cu. ft. range (9% of the market).

The second most important refrigerator type is the *single-door manual defrost,* occupying 18% of the Canadian market. Average Energuide rating has declined in all size categories. However, the decline seems to have been least in the most popular sizes. The 9.5-12.4 cu. ft. range, occupying almost 11% of the total Canadian market, has seen only marginal improvements in energy efficiency.

The *side-by-side* (2SS-A and 3SS-A) refrigerators, currently occupying 7% of the Canadian market and expected to grow (CAMA 1982), recorded considerable gains in efficiency. The greatest gains are in the three-door side-by-side (3SS-A) group, where the most popular sizes improved in efficiency by 28%.

Refrigerators: multivariate analysis. The analysis above is limited in that each refrigerator characteristic has to be considered individually and analyzed in discrete units (e.g., size was arbitrarily categorized). The attraction of a multivariate analysis is its ability to consider the simultaneous influences of a number of continuous or discrete variables. The method used here is multiple regression.

Each refrigerator's Energuide rating is regressed against its volume (both fresh food and freezer), type and estimated year of introduction. Multiple regression analysis estimates the contribution of each of these predictors to the appliance's total energy consumption. We are particularly interested in the contribution of year of introduction. If energy efficiency of *comparable models* has increased, year of introduction should have a negative impact on Energuide ratings.

The simplest model for relating Energuide rating to refrigerator characteristics is the linear additive model. This can be written as:

(1) ENER = B0 + B1*FVOL + B2*RVOL + B3*T2 + B4*T3 + B5*T4 + B6*T5 + B7*T6 + B8*T7 + B9*YR80 + B10*YR81 + B11*YR82

where (*) indicates multiplication and

ENER	=	Energy rating (kilowatt hours per month)
RVOL	=	Fresh food volume (cubic feet)
FVOL	=	Freezer volume (cubic feet)
T2-T7	=	Dummy (0,1) variables representing the type of refrigerator (SD-X, TF-A, TF-P, BF-A, 2SS-A and 3SS-A, respectively).
YR80-YR82	=	Dummy (0,1) variables representing the year of introduction of model (e.g., YR80 = 1 if model was introduced in 1980, 0 otherwise; etc.)

Variables T2 through T7 and YR80 through YR82 are dummy variables taking the values 0 or 1 to describe the type and estimated year of introduction of each particular refrigerator. There are no dummies for T1 (SD-M) or for refrigerators introduced before 1980. These become the base or reference cases to which all other refrigerators are compared. So the coefficient B3 shows how much higher the average Energuide rating of a type SD-X refrigerator is compared to a type SD-M. Similarly, the coefficient B9 shows how much higher the average Energuide rating of a 1980 refrigerator is compared to a corresponding pre-1980 model.

If the Energuide program has stimulated manufacturers to produce more efficient refrigerators, the coefficients B9, B10 and B11 should be negative. If manufacturers have continued to improve efficiency since 1979, these coefficients should be increasingly negative, reflecting reduced energy consumption each year.

Notice that the coefficient of year shows the change in energy efficiency of *comparable models*. That is, if all other refrigerator characteristics were held constant, the coefficient of year shows the change in Energuide rating over time. If manufacturers have reacted to the Energuide program by changing the *characteristics* of the appliances produced (e.g., by eliminating the largest sizes) this will *not* show up in our regression analysis. The change in energy efficiency estimated here is a more basic measure of the effects of the program. It shows the gain that has been made in efficiency without consumers having to change the type or size of appliance purchased. The coefficient of year shows the reduction in energy use that can be achieved by consumers simply continuing to buy the same type of appliances. The consumer is not required to change usage habits or sacrifice features to gain this level of energy efficiency.

The strength of multivariate analysis, as compared to the univariate procedures used above, is its ability to estimate energy savings across all appliance sizes and types. This power is purchased at the cost of having to prespecify a particular functional form for the relationship between Energuide rating and appliance characteristics. The linear additive model specified in equation (1) implies that energy rating increases linearly with refrigerator volume and that the effect of increasing efficiency is a constant additive amount, irrespective of refrigerator type or volume. Alternative models can be formulated. In particular, a multiplicative model allows the year of introduction to reduce energy consumption by a constant percentage amount. Thus larger, more-energy-using appliances would be hypothesized to experience a greater absolute kilowatt hour per month improvement in performance. The multiplicative model can be written as:

```
(2)     ENER = B0*(FVOL**B1)*(RVOL**B2)*(B3**T2)*...
               ...*(B9**YR80)*(B10**YR81)*(B11**YR82)
```

where (*) and (**) indicate multiplication and exponentiation, respectively.

Variables are as defined for equation (1). The dummy variables now act as multipliers rather than additive constants. The 1980 refrigerator uses B9 times the energy of a comparable pre-1980 model. If the Energuide program has stimulated manufacturers to produce more efficient refrigerators, the coefficients B9, B10 and B11 should be less than 1. If manufacturers have continued to improve efficiency over the years, the coefficients should be decreasing ($1.0 > B9 > B10 > B11$).

In practice, the multiplicative model is estimated taking logs of both sides of equation (2) and using regression to calculate the coefficients of the resulting linear relationship. Other models can be hypothesized, but the linear and log-linear are used here and prove satisfactory in every case.

Table 4 shows the coefficients obtained by fitting the linear and log-linear models to data for refrigerators, using data base 1 (all apparently separate models). The multiplicative model gives marginally better fit, explaining 82% of the variation in Energuide ratings, versus 75% for the additive model.

Table 4

Refrigerators: Regression Results
(Data Base 1: 1 251 observations)

	Estimated coefficient	
Variable	Additive model	Multiplicative model
INTERCEPT	54.10	55.15
RVOL	2.83	0.08[a]
FVOL	-4.47	0.13
T2	-3.79[a]	--[b]
T3	85.65	1.93
T4	27.70	1.23
T5	89.74	1.79
T6	118.52	2.03
T7	130.49	2.25
Y80	-5.43	0.95
Y81	-23.18	0.84
Y82	-26.79	0.81
	R^2 = 0.75	R^2 = 0.82

[a]"t-value" less than 2; all other "t-values" are greater than 2.

[b]Type SD-X models eliminated from multiplicative regressions as their freezer volume is zero.

The additive model has the wrong sign on freezer volume. This is the result of multicollinearity. Both versions show year of introduction to have the expected effect. In the additive model, the coefficients on the year of introduction are increasing negative, indicating that manufacturers have tended to introduce more efficient refrigerators each year. Specifically, refrigerators introduced in 1980 had Energuide ratings an average of 5.4 kW•h/mon lower than comparable pre-1980 models. Those introduced in 1981 had average Energuide ratings 23.2 kW•h/mon below comparable pre-1980 models. Those introduced in 1982 had ratings on average 26.8 kW•h/mon below comparable pre-1980 models. The annual gain in energy efficiency, all other features held constant, was 5.4 kW•h/mon in 1980, 17.8 kW•h/mon in 1981 and 3.6 kW•h/mon in 1982. Gains were made in all three years, but by far the largest effect occurred in 1981.

The multiplicative model shows a very similar pattern of results. The coefficients on year of introduction are all less than 1.0 and are decreasing, indicating continual reduction in energy usage. Refrigerators introduced in 1980 obtained Energuide ratings which were, on average, 95% of the ratings of comparable pre-1980 models; 1981 introductions were rated at 84% of comparable pre-1980 models; 1982 introductions at 81% of their pre-1980 counterparts. The energy requirements of comparable refrigerators fell by 5% in 1980, 12% in 1981 and 4% in 1982.

Our estimates of the increase in energy efficiency of refrigerators are lower than those expected by earlier studies. Drapkin (1981) estimated as technically possible a 39% improvement in refrigerator energy usage in the three years from 1979 to 1982, for a total saving of 52 kW•h/mon. Lane (1981) estimated a 31% saving (18 kW•h/mon) for manual defrost and a 39% saving (64 kW•h/mon) for top freezer frost-free models, all savings to be realized in the five years from 1979 to 1984. (Lane refers to data from the first Energuide Directory as 1978 data; we call this 1979 or pre-1980 data. For convenience, we have switched Lane's dates to match our terminology.) By contrast, we find savings of 19% from 1979 to 1982 according to the multiplicative model, or a total saving of 26.8 kW•h/mon according to the additive model.

For a manual defrost comparable to that examined by Lane (SD-M, 9.5-12.5 cu. ft.) we estimate only a 3% improvement in energy rating overall. Comparing 1979's least efficient single-door manual defrost of approximately 10 cu. ft. with the most efficient comparable model in 1982 gives an improvement of only 13% (or 7 kW•h/mon). For a frost-free comparable to that examined by Lane we estimate an average improvement in energy consumption of 17%, or 27 kW•h/mon. The most efficient 1982 model of about 15 cu. ft. was 46% more efficient than the worst comparable 1979 model (saving 85 kW•h/mon), but only 8% (9 kW•h/mon) more efficient than the best comparable 1979 model.

Refrigerators: Conclusions. Manufacturers of refrigerators have improved the energy efficiency of comparable models in every year of the Energuide program. By far the largest gains were made in 1981. Refrigerators introduced in 1982 were, on average, 19% (or 26.8 kW•h/mon) more efficient than comparable pre-1980 models. However, efficiency gains vary by type and size of refrigerator. For the most popular type and size (two-door top freezer frost-free, 15.5-17.5 cu. ft., representing 29% of the market), efficiency gains averaged 24%. For the second most popular type of refrigerator (single-door manual defrost) in its most popular size (9.5-12.5 cu. ft.), efficiency gains between 1979 and 1982 averaged only 3%. Although average energy consumption has fallen, and in some categories the range of energy usage has been narrowed, a few apparently inefficient models continue to be introduced.

Freezers

Univariate analysis. The Energuide Directory distinguishes three types of freezers: upright manual defrost (UF-M), upright automatic defrost (UF-A), and chest manual defrost (CF-M). The upright automatic category contains very few models and will be ignored.

Looking first over all types of freezers, we find that efficiency gains have been made in every size category, with the largest percentage improvements in the largest freezers.

For *upright freezers,* 1982 models are clearly more efficient. Savings averaged 34% (35 kW•h/mon) for the under 14 cu. ft. category and 16% (20 kW•h/mon) for the larger 14-18 cu. ft. uprights. There is also a marked trend to smaller upright freezers, providing additional energy conservation benefits. The overall energy usage of upright freezers declined by 31% from 1980 to 1982 (a saving of 36 kW•h/mon).

Among *chest freezers,* 1982 models again tend to be more efficient; there are some dramatic reductions in energy usage, particularly in the largest sizes. For example, in 1980 it was possible to buy a 23 cu. ft. freezer using over 140 kW•h/mon; by 1982 the same capacity was available using only 91 kW•h/mon, a 36% reduction. However, smaller units (under 14 cu. ft.) represent 65% of the market, a share that is expected to grow (CAMA 1982). Here energy consumption still has quite a wide range: 1982 models of this size tend to be more efficient than most of their pre-1981 counterparts, but there are exceptions. The gap between the most efficient pre-1981 model and the most efficient 1982 model is narrow, only 4 kW•h/mon, or 9%. Again there has been a move to smaller units, increasing the conservation effects of greater efficiency. The overall average chest freezer launched in 1982 was rated 21% (17.8 kW•h/mon) below the 1980 average.

Freezers: multivariate analysis. Several regression models were estimated. As with refrigerators we will discuss in detail only the additive and multiplicative models. Table 5 shows the regression results for the two models. Both models explain 81% of the variation in Energuide ratings.

The additive model shows that freezers introduced in 1981 had Energuide ratings 7.9 kW•h/mon lower on average than comparable pre-1981 freezers. Those introduced in 1982 had Energuide ratings 16.2 kW•h/mon below comparable pre-1981 models. Manufacturers reduced freezer energy consumption in both years by about the same amount, 8 kW•h/mon.

The multiplicative model provides very similar results. Freezers launched in 1981 were 10% more efficient than those sold before 1981. Freezers launched in 1982 were 16% more efficient than comparable pre-1981 models. On an annual basis the efficiency gain was 10% in 1981 and 7% in 1982. Although our estimates of energy savings are less than the

Table 5

Freezers: Regression Results
(Data Base 1: 508 observations)

Variable[b]	Estimated coefficient[a] Additive model	Multiplicative model
CONSTANT	70.82	34.81
FVOL	4.41	0.61
FCPTY	-2.28	-0.20
T2	35.51	1.31
T3	-27.22	0.75
YR81	-7.94	0.90
YR82	-16.20	0.84
	R^2 = 0.81	R^2 = 0.81

[a]All "t-values" are greater than 2.

[b]FVOL = freezer volume (cubic feet); FCPTY = freezing capability (kilograms per day); T2 = 1 if upright automatic, 0 otherwise; T3 = 1 if chest manual, 0 otherwise. The Energuide directories define "freezing capability" as "the 'ability' of a food freezer to freeze a specific amount of food in a defined time. As various foods freeze at different rates, a uniform measure has been developed using kilograms of ice produced per 24 hours, as a 'standard unit,' and relates to the amount of food that may be frozen by a freezer in a 24-hour period.

47% suggested as possible by Lane (1981), the difference is totally due to different comparison dates. Lane based his estimates on the consumption of a 12 cu. ft. unit in 1978-79 (as estimated by Drapkin 1981, at 108 kW•h/mon). Bringing our estimate to this base shows that energy gains from 1979 to 1982 for an approximately 12 cu. ft. chest freezer have been 48 kW•h/mon, or 44% -- almost precisely Lane's estimate of technically possible savings.

Freezers: conclusions. Manufacturers of freezers have reduced the energy consumption of comparable models in every year of the Energuide program. However, the greatest improvement apparently occurred just before the program was implemented. Energy usage of comparable models fell by 44% from 1979 to 1982, in contrast to an average fall of only 16% from 1980 to 1982 (the period for which the Energuide program was actually applied to freezers). Efficiency gains made before 1980 are probably not independent of the Energuide program. Awareness of the forthcoming Directory may well have stimulated the introduction of energy-efficient features.

Since 1980 the range of efficiency has narrowed: the gap between most and least efficient freezers launched in 1982 is considerably less than that in 1980. However, within the smaller units in particular, energy consumption of apparently similar models still ranges quite widely. The most efficient freezers have gained in efficiency by almost twice the amount estimated as technically possible in 1979 (Drapkin 1981).

Ranges

Univariate analysis. Our analysis is confined to regular, nonspecialty ranges. The Energuide program has been applied to ranges for only two years; therefore, manufacturers may not have had time to incorporate all available energy efficient features. The Energuide Directory distinguishes two types of ranges: those with self-cleaning ovens (SC) and those with regular ovens (R).

Comparing Energuide ratings of 1982 and pre-1982 ranges with *regular ovens,* we find that very few of the 1982 ranges embody new features. The majority of the models classified as 1982 introductions are identical to earlier models and seem to represent changes in model number only. The new ranges that have been introduced are neither more nor less efficient than the average for pre-1982 ranges. Moreover, the gap between most and least efficient ranges is not very large. For example, 1982 ranges with an oven capacity of approximately 74 L can be obtained which use from 68 kW•h/mon down to 59 kW•h/mon (a difference of 13%). However, the 59 kW•h/mon range is narrower (only 24" wide). The most efficient truly comparable range is rated at 63 kW•h/mon (making the gap between most and least efficient only 7%).

The ranges with *self-cleaning ovens* follow a more clear-cut pattern. New 1982 models are slightly more efficient than most of the pre-1982 models, and also tend to be smaller. However, the most efficient models of all are pre-1982 introductions.

Ranges: multivariate analysis. The linear and multiplicative models are presented in Table 6. As would be expected from the figures discussed above, the regression models show very modest increases in energy efficiency and do not fit the data very well. Neither model can explain more than 41% of the variation in Energuide rating. It appears that other factors, which are not listed as characteristics in the Energuide Directory, have an effect on range energy consumption. These could be other features, or could be particular energy-saving designs only used by some manufacturers. Perhaps less efficient models will be deleted as the program continues and a more rational structure will emerge.

Table 6

Ranges: Regression Results
(Data Base 1: 682 observations)

	Estimated coefficient[a]	
Variable[b]	Additive model	Multiplicative model
CONSTANT	40.74	16.61
OVSPC	0.15	0.17
WDTH	0.44	0.18
SMTP	7.68	1.12
REG	0.73	1.01
YR82	-0.37	0.99
	$R^2 = 0.41$	$R^2 = 0.41$

[a]All "t-values" are greater than 2.

[b]OVSPC = usable oven space (litres); WDTH = width (inches); SMPT = 1 if smooth top, 0 otherwise; REG = 1 if regular clock, 0 otherwise.

Lane (1981) predicts small efficiency gains for ranges, suggesting 2 kW•h/mon to 5.5 kW•h/mon as the improvement attainable by 1985. Drapkin (1981) and Cullen (1979) anticipated much larger increases in efficiency. However, the results reported here are based on the Energuide directories, which specifically exclude forced air convection features. It is these convection features that Lane, Drapkin and Cullen agree are the major source of future energy improvements for this product. Consequently, Energuide ratings cannot be expected to show much change. Presumably convection features are excluded because of disagreement as to their measurement. If the Energuide rating process continues to ignore the effects of convection features, Energuide ratings will not reflect the true consumption of the appliances and could serve to retard adoption of what previous authors suggest is the only major source of efficiency increases for this product.

Ranges: conclusions. For ranges, the Energuide rating is not closely related to product features as presented in the Energuide directories. This suggests that other factors affect energy consumption, either other range features or particular energy-saving designs. However, the variation in efficiency over comparable models is rarely more than 7%.

Overall, manufacturers have made very small improvements in range efficiency. As shown in Table 6, ranges launched in 1982 use 0.37 kW•h/mon less energy than comparable pre-1982 models. The Energuide program has only been applied to ranges for two years, but gains to date are considerably smaller than those recorded in the first two years of the freezer or refrigerator programs. Forced air convection features, suggested as the major source of potential energy saving for this product, are apparently not included in the Energuide rating process. This could retard adoption of this energy conservation feature.

Dishwashers

Univariate analysis. The Energuide program has been applied to dishwashers for only two years and it is probably too early to expect major effects.

A comparison of pre-1982 and 1982 models having an optional hot or cold dry (almost all models are now of this type) shows that 1982 models are more efficient for any given level of hot water usage. For example, in 1982 it was possible to buy a machine that used about 44 L of hot water and consumed 103 kW•h/mon. Before 1982, a dishwasher of that hot water capacity would have required at least 109 kW•h/mon, and could have used as much as 121 kW•h/mon. Efficiency of comparable models in this example has increased by at least 6% and perhaps as much as 20%.

The more striking change, however, is in the *volume of hot water used:* 1982 models use an average 6.2 L less hot water than pre-1982 models. As a result, seven 1982 models get Energuide ratings of less than 104 kW•h/mon, while prior to 1982 only two brands had appliances of this efficiency.

Dishwashers: multivariate analysis. Additive and multiplicative models are reported in Table 7. Both models fit the data well, explaining 92% of the variation in Energuide ratings. Both models show fairly modest gains in energy efficiency.

The additive model estimates dishwashers launched in 1982 to use on average 2.8 kW•h/mon less energy per month than comparable pre-1982 appliances. The multiplicative model estimates the gain to be 2%. These gains are considerably lower than the 23% suggested as technically possible by Drapkin (1981), or the 17.7% estimated by Lane (1981). However, our estimate is from a 1981 base; Lane and Drapkin apparently work from 1978/79 bases. Many energy-saving features anticipated in 1978/79 were already standard by 1981, and are therefore included in our base estimates. For example, optional hot or cold dry was available in over 90% of 1981 models; this feature was expected to save 5 kW•h/mon in 1979.

Table 7

Dishwashers: Regression Results
(Data Base 1: 301 observations)

Variable[b]	Estimated coefficient	
	Additive model	Multiplicative model
CONSTANT	43.90	10.18
HWCON	1.63	0.64
T2	3.41[a]	1.03[a]
T3	-3.32	0.98
YR82	-2.78	0.98
	$R^2 = 0.92$	$R^2 = 0.92$

[a]"t-value" less than 2; all other "t-values" are greater than 2.

[b]HWCON = hot water consumption (litres, normal cycle); T2 = if heat dry cycle only, 0 otherwise; T3 = 1 if heat on/off option available, 0 otherwise.

Also our regression estimates compare similar models; that is, the saving we estimate is for dishwashers having the same characteristics. As we have seen, there has been a marked trend to reduce hot water usage. The energy-saving implications of this are not included in our estimates.

We estimate the overall average Energuide rating of 1982 dishwashers at 109 kW•h/mon. This is 38% lower than Drapkin's 1979 base estimate and 22% lower than Lane's 1978-79 base estimate. In fact, taken over comparable periods, we find greater energy savings than anticipated by either Drapkin or Lane. However, these savings had been made before the Energuide program was applied to dishwashers in 1981.

Dishwashers: conclusions. Efficiency of 1982 dishwashers was about 2% better than comparable 1981 models. However, a trend to lower hot water consumption allowed the average performance of 1982 models to be 7% better than the 1981 average. Comparing our results with earlier studies shows that very major efficiency improvements must have occurred just before the Energuide program was extended to dishwashers. This is not to say that these improvements were not affected by the Energuide program. Indeed anticipation of the first directory may have stimulated manufacturers to adopt energy efficient features. The average performance of 1982 models estimated here is over 30% better than the 1978/79 performance reported in earlier studies. Dishwashers have become more efficient than previous researchers expected.

Clothes Washers

Univariate analysis. The Energuide program has been applied to clothes washers for only two years and it may be too soon to make a firm evaluation of the program's effects. A comparison of 1982 models with those listed in the 1981 Energuide Directory reveals no clear-cut pattern to performance. Models of equal tub capacity vary widely in energy consumption in both years. Some smaller capacity models were introduced in 1982; otherwise there appear to be no major trends. Certainly the front loaders which Drapkin (1981) estimated could save 35% of hot water costs have not been introduced. The 1981 directory listed only one front-loading model. No new front loaders appeared in 1982.

Clothes washers: multivariate analysis. Table 8 presents the additive and multiplicative models. Both fit the data well; neither show any significant increase in efficiency of comparable models over the period 1981-82.

Table 8

Clothes Washers: Regression Results
(Data Base 1: 253 observations)

Variable[b]	Estimated coefficient	
	Additive model	Multiplicative model
CONSTANT	70.95	17.99
CAPAC	0.66	0.44
T2	-52.15	0.54
C2	9.48	1.09
C3	-7.30	0.92
D2-D13[c]	Yes[c]	Yes[c]
YR82	-0.60[a]	1.00[a]
	$R^2 = 0.91$	$R^2 = 0.91$

[a]"t-value" less than 2; all other "t-values" are greater than 2.

[b]CAPAC = tub capacity (litres); T2 = 1 if front loader, 0 otherwise; C2 = 1 if maximum water level selection only, 0 otherwise; C3 = 1 if suds saver model, 0 otherwise.

[c]D2-D13 dummy variables representing wash/rinse temperature selections (coefficients omitted for simplicity).

Clothes washers: conclusions. Once more it appears that the major efficiency gains had occurred before the Energuide program was extended to this appliance. We estimate the overall average consumption for 1982 clothes washers at 100.2 kW•h/mon. Drapkin (1981) estimates a base energy consumption of 132.5 kW•h/mon in 1979; Lane (1981) uses a figure of 161 kW•h/mon in 1978. Neither author gives a source for these estimates, or explains the exact type of washing machine to which they apply. However, if these bases are comparable to our overall average, there has been a considerable improvement from 1978/79 to 1982, of the order of 24%-38%, depending on which 1978/79 figure is used.

Chapter III

CONSUMER REACTIONS

Some Theoretical Considerations

An appliance can be viewed as a collection of features. For example, a refrigerator's features include capacity to store fresh and frozen food, shelving area and organization, number of meat keepers and vegetable crispers, type (one-, two- or three-door, upright or side-by-side), defrost system (manual or automatic), etc. One of these features -- one among many -- is the cost of operating the appliance, which is a function of its electricity consumption.

In a given period of time, a number of appliance models are available on the market. These models can be identified, their prices ascertained and their features enumerated. There is, then, a set of observations on prices (P) and model features (X1, X2, ...), including electricity consumption (Q).

A regression of P against X1, X2, ..., Q provides an estimate of the relationship among these variables:

$$P = B0 + B1*X1 + B2*X2 + \ldots + B*Q$$

Stated in the simplest possible terms, the regression model states that consumers -- on the average, through their purchase decisions in the market -- act as if they are paying $B1 per unit of feature X1, $B2 per unit of feature X2, ..., and $B (presumably negative) per kilowatt hour per month of the model's electricity consumption (i.e., its Energuide rating).

The regression coefficients can be interpreted (see also Ratchford 1980) as the market's unit trade-offs between price on the one hand, and features and operating cost on the other. If, for example, X1 represents refrigerator capacity measured in cubic feet, B1 is an estimate of the price that consumers, on the average, pay for an additional cubic foot of space. Similarly, B can be interpreted as a measure of the weight that consumers attach to energy efficiency. If consumers, on the average, attach any value to energy savings, B should be negative; if not, it should be close to zero.

As shown in Chapter II, however, there is generally a strong relationship between a model's energy consumption and certain of its features, especially size (measured by capacity or volume) and type. Larger models consume more energy than smaller models. Energy consumption also varies with type: refrigerators with automatic or manual defrost, freezers of the chest or upright type, conventional and self-cleaning ranges, regular and suds saver washers, clothes dryers with temperature or moisture sensors, and so on.

What this means is that in choosing a model of a given size and type, a consumer more or less accepts the energy consumption that goes with that size and type. In the extreme case in which all models are made by the same manufacturer under the same technical specifications, there would be a one-to-one correspondence between size and type on the one hand, and energy consumption on the other. It would then be meaningless to talk of the implicit value of energy efficiency, since whatever value exists will be absorbed by the net implicit values of size and type.

Another consequence of the relationship between energy consumption, size and type concerns the estimation of the parameters of the regression of price against product features. Because of the correlation among three of the explanatory variables, it is difficult to identify precisely the individual effects of the variables. Furthermore, the estimates are likely to fluctuate greatly from one sample of observations to another, and to be influenced strongly by outliers and the subsets of variables considered. This is, of course, the familiar problem of multicollinearity.

A distinction must be made, therefore, between the *discretionary* and the *nondiscretionary,* or *implied,* part of energy consumption. To explain more precisely, suppose that energy consumption depends on size only, and that size and type are the only features considered. Let P be the price, X the size and Q the electricity consumption. The model relating price to product features is

(3) $P = B0 + B1*X + B*Q$

We assume that Q consists of a part that is a function of size (the *nondiscretionary* part, QC) and a remainder (the *discretionary* part, QD):

(4) $Q = QC + QD = C0 + C1*X + QD$

Again, the assumption of linearity is made for simplicity only. We define QC as the expected or average energy consumption of all models with the same size X. The parameters C0 and C1 of equation (4) can be estimated by regressing Q against X, and the discretionary part QD by the residuals of this regression. Since the value of nondiscretionary consumption is zero, equation (3) should be replaced by a model relating price to size and discretionary energy consumption:

(5) $P = B0 + B1*X + B2*QD$

The coefficient of QD can be interpreted as the implied value of energy efficiency.

A two-step estimation procedure is therefore suggested. In the first, Q is regressed against X. The residuals of this regression provide estimates of discretionary energy consumption, QD. In the second step, price is regressed against X and QD.

It is reasonable to suppose that, other features being equal, consumers will wish to pay less for models with energy consumption greater than the average (QD > 0), and more for models with less-than-average energy consumption (QD < 0). In other words, it is reasonable to suppose that B2 < 0.

In short, then, the strong relationship among energy consumption, size and type indicates that a two-step approach is preferable for estimating the implicit values of product features and of energy efficiency. In the first step, energy consumption (measured by the Energuide rating) is regressed against the appropriate measure of size and type. The residuals of this regression may be interpreted as estimates of discretionary energy consumption. In the second step, the implicit prices of product features and of discretionary energy consumption are estimated by regressing price against the product features and the residuals of the first step.

Sources of Data

The information for this part of the study came from three sources: a survey of retail outlets in the Metropolitan Toronto area and their advertisements; manufacturers' brochures and product literature; and the Energuide directories.

Survey and advertisements. The survey was conducted between June 1 and June 15, 1982. Research assistants visited a number of appliance retail outlets in the Metropolitan Toronto area and recorded the brand name, model number and price of all the models displayed in their showrooms.

The retail outlets surveyed were large department stores (Eaton's, Simpsons, The Bay, Woolco, Sears and K-Mart) and large furniture/appliance dealers (No Frills, Leon's, Pascal and Stuart's). In addition, similar information was obtained when possible from advertisements by these stores appearing in the Toronto Star, the Toronto Globe and Mail, and catalogues and pamphlets available in the stores or delivered at home.

The retail outlets visited do not constitute a random sample of all appliance stores in Toronto. They include, however, the largest ones, and account, according to industry sources, for approximately 75% of appliance sales in the Metro Toronto area. The remaining sales are made through generally small stores selling appliances exclusively, or in addition to furniture, etc. Most of these stores appear to be owner-managed and generally do not display prices. The stores surveyed were very cooperative, allowing the research assistants free and uninterrupted access to hundreds of models displayed in their showrooms.

The price recorded was that for a white model (coloured models usually sold for $8-$10 more), and was adjusted to include the cost of delivery in Metro. No other charges were included in the price.

Despite the short observation period and the narrow geographical area, the range of observed prices for the same models was impressive. A few examples will illustrate. A Canadian General Electric dishwasher (SMD930V) was found to sell for $700, $604, $631 and $610 -- a range of nearly $100. A Moffat clothes washer (MWG1120) sold for $580 and $530 in two nearby stores. An Inglis clothes dryer (RO80000) had prices of $319, $312, $309 and $350. The price of a Beaumark range (13770) varied from $670 to $780 during this period. A Wood's freezer (E500) sold for $402 and $370 at two branches of the same store. And three recorded prices for the same Kelvinator refrigerator (D17) were $872, $758 and $786.

When more than one price was observed for the same model, the average price was calculated. The results of the survey were summarized in a list of approximately 700 appliance models, brand names and average prices. At an estimated average of about 2 observed prices per model, this represents approximately 1 400 price observations.

Occasionally, a comparison of prices revealed inconsistencies. One found a model with many more features actually selling for less than another model with fewer features. This would be the case when a particular model in a store's line was on sale while the prices of the other models remained at presale levels.

Still, the variation in observed prices is a little surprising, especially in view of the fact that the surveyed retail outlets compete vigorously in price and prominently display and advertise their prices. One suspects that the price variation would have been found even greater had the smaller retail outlets -- which seem to shun price competition -- been surveyed.

Product literature. Having formed a list of about 700 models and prices, the next step in constructing the data base was to obtain as detailed a description of the models as possible. A few features of these models could be obtained from the Energuide directories, but the number was small since the directories list only the principal features affecting energy consumption. Additional information was obtained from brochures and other literature printed by manufacturers to promote their products.

Two general problems were encountered. The first concerns clarity. Although the product literature is generally enlightening and helpful, it does not follow a uniform format for all brands. The second problem was more severe. It became clear as the study progressed that product literature was available only for the latest models. Since nearly one-half of the models for which prices were recorded were of earlier vintage, this meant that only one-half of the observations could be used in the study. The analysis that follows is based on approximately 350 models for which a description of features could be obtained.

Energuide directories. These formed the third source of information and provided descriptions of models according to size, type and other features affecting energy consumption.

Refrigerators

The survey and advertisements provided the prices of 88 refrigerator models sold under 11 brand names. They range in price between $410 and $2 716 with an average price of about $871. Most models -- 61 in number -- had prices in the $500 to $1 000 range; 8 cost under $500, 15 between $1000 and $1500, 1 between $1 500 and $2 000, and 3 more than $2 000. In terms of refrigerator volume, the models vary from 7.70 to 16.05 cu. ft.; freezer volume varies from 0.60 to 10.19 cu. ft. The average refrigerator volume is 11.86 cu. ft., the average freezer volume, 4.43 cu. ft. Energy consumption varies from 43 kW•h/mon to 162 kW•h/mon.

The variables chosen to describe features of refrigerators are listed in Table 9. The brand names of the models are included as explanatory variables on the premise that some of the variation in prices can be explained by the reputation, quality and image of the brands -- even though the same manufacturer may be making appliances under several brand names.

A regression of price against all explanatory variables (type dummies, brand dummies, RVOL, FVOL, ENER and all variables following ENER in Table 9 except TOTVOL) had an R^2 of 0.9834, indicating that about 98% of the total variation in refrigerator prices is explained by the features used in this study. This is a high proportion and lends confidence to the manner in which the product features were described.

The greater the number of explanatory variables, the higher the (unadjusted) R^2, but beyond a certain point it is possible that additional explanatory variables add very little to the explanatory power of the statistical model. Certain features may have negligible value for the average consumer and could thus be omitted with little sacrifice in explanatory power. It is also possible that the estimates of the implicit values of the product features are not entirely consistent with prior expectations. A slight change in the formulation of the statistical model or the description of the features may provide consistent estimates, again with little loss of explanatory power.

Table 9

Refrigerators: Definition of Variables

Variable	Description
PRICE	Average observed price ($), white model, delivery included
RVOL	Refrigerator volume (cubic feet)
FVOL	Freezer volume (cubic feet)
ENER	Energy consumption (kilowatt hours per month)
MEAT	Number of meat keepers
VEG	Number of vegetable crispers
MEATTEMP	= 1 for meat keeper temperature control; = 0 otherwise
BUTTER	= 1 for butter conditioner; = 0 otherwise
EGG	= 1 for removable egg tray; = 0 otherwise
DOORSH	= 1 for adjustable door shelves; = 0 otherwise
GLASS	= 1 for glass shelves; = 0 otherwise
ADJFULL	= 1 for adjustable full shelves; = 0 otherwise
ADJHALF	= 1 for adjustable half shelves; = 0 otherwise
FIXED	= 1 for fixed shelves; = 0 otherwise
DOORHT	= 1 for door heater switch; = 0 otherwise
FRSHELV	= 1 for freezer shelves; = 0 otherwise
FRDRSH	= 1 for freezer door shelves; = 0 otherwise
JUICE	= 1 for juice can dispenser; = 0 otherwise
OPTICE	= 1 for optional automatic ice maker; = 0 otherwise
DOORIW	= 1 for through-door ice and water; = 0 otherwise
WHEELS	= 1 for four wheels; = 0 otherwise
BLACK	= 1 for black panel; = 0 otherwise
TEXT	= 1 for textured steel door; = 0 otherwise
TRIM	= 0,1,2 for none, some and full exterior trim
T1-T7	Dummy variables for type of refrigerator
BR17-BR42	Dummy variables for brand name
TOTVOL	Total volume (= RVOL + FVOL)

Several variations were considered. It was found that the variable TOTVOL (equal to total volume, the sum of RVOL and FVOL) performed very nearly as well as the two variables it replaced. The variables EGG, DOORHT, FRSHELV, FRDRSH, JUICE, OPTICE, WHEELS and TRIM together contributed very little towards explaining price differences and could be dropped from the statistical model. Stated differently, consumers on the average appear to attach negligible value to these features.

As expected, energy consumption is highly correlated to the size and type of refrigerator. The regression of ENER against TOTVOL, T2, T3, T4, T6 and T7 (recall that T1 serves as the base and that there are no observations of a type 5 refrigerator) can be summarized as follows:[1]

$$\begin{aligned} \text{ENER} = 42.640 &+ \underset{(6.53)}{1.492*\text{TOTVOL}} + \underset{(2.87)}{24.410*\text{T2}} + \underset{(4.01)}{29.181*\text{T3}} + \\ &+ \underset{(14.98)}{63.666*\text{T4}} + \underset{(9.18)}{68.474*\text{T6}} + \underset{(10.89)}{72.276*\text{T7}} \end{aligned}$$

$$R^2 = 0.881 \quad s = 8.821$$

The numbers in parentheses are the "t-values" of the regression coefficients.

About 88% of the variation in energy consumption, therefore, can be explained by size and type. As explained in the first section of this chapter, the predicted values of this regression can be considered as estimates of nondiscretionary energy consumption for a model of given size and type. The residuals, denoted by RENER, serve as estimates of discretionary consumption and replace ENER in subsequent analyses.

The end result of these changes is a regression of price against the retained explanatory variables and RENER. The estimated coefficients and other statistics are shown in Table 10.

Very little explanatory power was lost as a consequence of the changes made to the original formulation: the R^2 declined from 0.9834 to 0.9767, but the loss of 0.67% in the explanatory power of the model is negligible. The retained variables still explain about 98% of the variation in refrigerator prices.

The regression coefficients are estimates of the implicit prices of the corresponding product features. The coefficient of RENER indicates that consumers, other things being equal and on the average, pay \$1.24 for each kilowatt hour per month of energy consumption saved. In other words, if two refrigerators have the same features but the first consumes 10 kW•h/mon less than the second, it can be sold for \$12.40 more than the second. We shall return to this estimate in Chapter IV, after having an opportunity to examine the estimates obtained for all other appliances.

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1. This regression and others to be described in the following sections are based on the data used in this chapter. Although the results are generally similar to those outlined in Chapter II, differences in the data base cause differences in the estimates obtained.

Table 10

Refrigerators: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	8.060	0.12
TOTVOL	33.845	6.06
T2	19.457	0.40
T3	51.295	0.71
T4	78.825	2.01
T6	228.121	3.67
T7	323.110	5.53
RENER	-1.243	-0.79
MEAT	17.208	0.56
VEG	57.378	1.96
MEATTEMP	53.856	1.91
BUTTER	9.260	0.26
DOORSH	43.553	1.88
GLASS	103.210	2.97
ADJHALF	8.257	0.32
DOORIW	859.278	11.40
BLACK	225.120	2.82
TEXT	14.349	0.44
BR17	189.883	3.31
BR18	199.268	4.19
BR22	-134.774	-2.34
BR25	-1.980	-0.05
BR26	-131.867	-3.39
BR27	48.356	1.93
BR30	-71.809	-1.57
BR31	25.441	0.79
BR39	-22.286	-0.79
BR42	-26.832	-0.64
	R^2 = 0.9767	s = 66.374

The other regression coefficients in Table 10 indicate that consumers, again on the average and with other things remaining equal, pay about:

- $39 for each additional cubic foot of total volume;

- $19, $51, $79, $228 and $323 more for refrigerators of types 2, 3, 4, 6 and 7, respectively, than for a type 1 refrigerator. For example, if two refrigerators have the same features except that the first is of type 6 (two-door, side-by-side), while the second one is of type 7 (three-door, side-by-side), then the second sells for $95 (= $323 - $228) more than the first;

- $17 for an additional meat keeper, $57 for an additional vegetable crisper and $54 for the ability to control the temperature of a meat keeper;

- $9 for a butter conditioner, $43 for adjustable refrigerator shelving;

- $860 for through-the-door ice and water;

- $225 for a black panel, $14 for a textured door.

In relation to brand 4 which serves as the base, brands 17, 18, 27 and 31 appear to command a premium of about $190, $200, $48 and $25, respectively. The remaining brands (22, 25, 26, 30, 39 and 42) sell for about $135, $2, $132, $72, $23 and $27 less than brand 4, respectively.

These estimates are consistent with prior expectations with regard to their sign (negative for RENER, positive for all other variables), and appear to be consistent with respect to their magnitude.

As indicated by the "t-values" in Table 10, some variables (such as BR25, BUTTER, etc.) could be dropped without substantial loss of explanatory power. One of these, though, is RENER, suggesting that the implicit value of discretionary energy efficiency could be $0.

Freezers

The survey provided prices for a total of 103 freezer models, but only 60 of these models could be adequately described with the help of available product literature. The 60 observations on which this study is based represent 8 different brand names. Prices ranged from $278 to $595, with an average of about $428. Thirteen models were of the upright type with manual defrost and 47 were of the chest type, again with manual defrost; no upright frost-free models were observed. The sizes of the 60 models ranged from 5.2 to 23.2 cu. ft.; the average volume was about 14 cu. ft. The energy consumption varied between 43 kW•h/mon and 150 kW•h/mon, with an average of about 79 kW•h/mon.

The variables used to describe freezer features are shown in Table 11. The linear model with the greatest explanatory power utilizes all explanatory variables (FVOL to BR49) and explains about 92% of the variation in freezer prices.

Preliminary analysis suggested that it would be better to combine the individual operating features into one variable (TOTF), and to combine baskets, dividers, freezer and door shelves into another variable (TOTC) measuring a model's ability to organize food storage.

As explained in the first section of this chapter, a distinction must be made between discretionary and nondiscretionary energy consumption. Nondiscretionary consumption is the consumption that "goes with" a freezer of a given size, freezing capability and type, and is estimated by the predicted value of the following regression model:

$$\text{ENER} = \underset{(16.20)}{75.082} + \underset{(12.01)}{4.691}\ \text{FVOL} - \underset{(-7.87)}{3.601}\ \text{FCPTY} - \underset{(-8.77)}{30.595}\ \text{T3}$$

$$R^2 = 0.836 \qquad s = 10.462$$

The residuals of this regression (RENER) estimate the discretionary component of energy consumption and replace this variable in subsequent analyses.

The result of the changes mentioned above is a regression of PRICE against FVOL, FCPTY, T3, TOTF, TOTC and the brand dummy variables. The estimates of implicit prices of freezer features are shown with other statistics in Table 12.

About 6% of the total variation in prices explained by the "full" regression model (the difference between the R^2 of the full model and that of Table 12), is not explained when the individual features are combined into two variables, TOTC and TOTF. The coefficients of FVOL, FCPTY, T3, TOTF and TOTC are positive, indicating that consumers are willing to pay for greater size and freezing capability, for more features and shelving, and for upright over chest freezers. The coefficient of RENER is negative, as expected, and suggests that consumers do value energy efficient models.

In particular, it appears that consumers, on the average and other things being equal, pay approximately:

- $8 for each additional cubic foot of freezer volume;

- $0.50 for each kilogram per day improvement in freezing capability;

- $70 more for an upright freezer than for a chest freezer;

- $10 for each of interior light, power-on light, temperature safety light and safety lock;

Table 11

Freezers: Definition of Variables

PRICE	Average price ($), white model, delivery included
FVOL	Freezer volume (cubic feet)
FCPTY	Freezer capacity (kilograms per day)
ENER	Energy consumption (Energuide rating, kilowatt hours per month)
LIGHT	= 1 for interior light; = 0 otherwise
POWON	= 1 for power-on light; = 0 otherwise
TEMPSF	= 1 for temperature safety light; = 0 otherwise
LOCK	= 1 for safety lock and key; = 0 otherwise
BASKETS	Number of storage baskets, chest freezers
PARTNS	Number of partitions (dividers), chest freezers
FSHELVES	Number of freezer shelves, upright freezers
DSHELVES	Number of door shelves, upright freezers
TEXTFIN	= 1 if textured finish; = 0 otherwise
T1-T3	Dummy (0,1) variables for freezer type
BR17-BR49	Dummy (0,1) variables for brand name
TOTF	Number of features (= LIGHT + POWON + TEMPSF + LOCK)
TOTC	Number of containers (= BASKETS + PARTNS + FSHELVES + DSHELVES)

Table 12

Freezers: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	308.785	6.25
FVOL	8.014	5.11
FCPTY	0.483	0.25
T3	-70.166	-1.30
TOTF	9.750	1.44
TOTC	10.406	1.33
RENER	-0.164	-1.30
BR17	9.504	0.33
BR18	-73.223	-1.88
BR27	19.593	1.53
BR39	9.651	0.54
BR43	-66.186	-3.57
BR49	-0.807	-0.05
	$R^2 = 0.8625$	s = 35.251

- $10 for each container;

- $0.16 for each kilowatt hour per month saving in energy consumption.

Ranges

The study was limited to conventional free-standing ranges. Built-in ranges and cook tops, microwave ovens and other specialty products were not considered.

A total of 79 usable observations were obtained from the price survey and advertisements: 39 of these were self-cleaning, and 40 had conventional ovens. The large majority of the observed models (69 of 79) were 30" wide; the remainder were 24". All but one of the observed models had a conventional cook top; one model had a smooth top, but none had a modular one. Forty-five models had a regular clock, 32 had the digital variety and 2 had the solid state type. There was not much variation in oven capacity: the minimum oven space was 60.8 L, the maximum 87 L and the average about 78 L. The lowest priced model cost $380 and the highest $1 252, while the average price was about $670.

The features used in the study are listed in Table 13. About 94% of the variation in freezer prices is explained by these features. This is a high percentage and indicates that the principal features of ranges have been included in the list. Not all variables, however, are important in explaining the differences in price among the models. OUTR (the number of regular outlets), LIGHT (oven light) and VTSC (for variable temperature self-cleaning) were found to have inconsistent signs and to contribute very little to the explanatory power of the regression model.

In addition, energy consumption is highly correlated with oven space, oven width, type of oven and cook top:

$$\underset{(45.11)}{\mathrm{ENER} = 53.244} + \underset{(8.22)}{0.130\ \mathrm{OVSPAC}} + \underset{(5.56)}{2.248\ \mathrm{WIDTH}} - \underset{(-3.91)}{1.005\ \mathrm{TYPOV1}} + \underset{(5.10)}{5.510\ \mathrm{SMOOTHTP}}$$

$$R^2 = 0.725 \qquad s = 1.061$$

After dropping OUTR, LIGHT and VTSC, and replacing ENER by RENER, a regression of price against the remaining explanatory variables produces the estimates shown in Table 14.

The changes result in only a small loss of explanatory power: the R^2 decreases by about 1%, from 0.9414 to 0.9318. Thus the set of features enumerated in Table 14 accounts for nearly as much of the variation in prices as the larger original set of variables.

Table 13

Ranges: Definition of Variables

PRICE	Average price ($), white model, delivery included
WIDTH	= 1 for 30" width; 0 for 24" width
OVSPAC	Usable oven space (litres)
ENER	Energy consumption (kilowatt hours per month)
REG	= 1 for clock, regular; = 0 otherwise
DIG	= 1 for clock, digital; = 0 otherwise
OUTR	Number of regular appliance outlets
OUTT	Number of timed appliance outlets
PANEL	= 1 for glass cover for panel; = 0 otherwise
REG2	= 1 for conventional oven top; = 0 otherwise
SMOOTHTP	= 1 for "smooth top"; = 0 otherwise
LIGHT	= 1 for oven light; = 0 otherwise
MEAT	= 1 for meat probe; = 0 otherwise
ROTIS	= 1 for rotisserie; = 0 otherwise
VTSC	= 1 for variable temperature self-clean; = 0 otherwise
BLACKFRT	Black oven front panel (0 = none, 0.5 = half, 0.75 = three-quarter, 1 = full panel)
BLACKDRW	= 1 for black storage door panel; = 0 otherwise
TYPOV1-TYPOV2	Dummy variables for type of oven (TYPOV1 = 1 for self-cleaning and TYPOV2 = 1 for regular oven)
BR17-BR42	Dummy variables for brand names

From Table 14, it is estimated that, other things being the same, consumers pay on the average approximately:

- $183 more for a 30"-wide range than for a 24"-wide one;

- $138 more for a self-cleaning model than for a regular one;

- $262 more for a smooth top than for a conventional one;

- $3.80 for each kW•h/mon saving in energy consumption;

- $122 and $86 less for regular and digital clocks, respectively, than for a solid state clock;

- $11 for each additional timed outlet;

Table 14

Ranges: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	1216.592	3.32
OVSPAC	-9.429	-1.98
WIDTH	183.377	3.14
TYPOV1	138.505	7.94
SMOOTHTP	262.847	3.84
RENER	-3.836	-0.52
REG	-122.279	-2.73
DIG	-86.420	-1.92
OUTT	11.308	0.36
PANEL	33.065	1.49
MEAT	75.511	2.43
ROTIS	59.107	1.87
BLACKFRT	43.398	2.37
BLACKDRW	11.984	0.35
BR17	167.608	4.22
BR18	49.809	0.74
BR22	-174.765	-2.45
BR25	29.869	1.02
BR26	33.307	1.10
BR27	-94.627	-1.21
BR31	-95.684	-1.05
BR39	23.037	0.88
BR42	38.529	1.18

$R^2 = 0.9318$ $s = 55.022$

- $33 for the glass cover of the control panel;
- $75 for a meat probe;
- $59 for a rotisserie;
- $48 for a full front black panel;
- $12 for a black storage drawer panel.

The only apparently inconsistent estimate in Table 14 is the coefficient of OVSPAC. Casual inspection of models in showrooms, however, shows that, with depth and width held constant by custom and convention, oven capacity can be increased only by raising the range top or reducing the capacity of the storage drawer. A possible explanation for the negative coefficient of OVSPAC is that both design alterations are unattractive to consumers.

Clothes Washers

A list of the features used in the study can be found in Table 15. From the survey, advertisements, the Energuide directories and product literature we were able to collect complete information on 41 models of clothes washers. The observed models range in size from 68.8 L to 90 L of tub capacity, with an average capacity of 74.8 L. All were top loaders. Their energy consumption varied from 73 kW•h/mon to 160 kW•h/mon, and averaged about 112 kW•h/mon. The prices ranged from $471 to $950, but only 2 models had prices greater than $700; 5 models cost less than $500, and the remainder were evenly distributed in the $500 and $600 ranges. Twenty-nine models had a bleach dispenser, 18 had a fabric softener dispenser, and 7 were suds savers. Only 1 model -- the most expensive -- had solid state controls. Nineteen models had a self-cleaning filter.

About 98.9% of the variation in the price of clothes washers can be explained by the features listed in Table 15. In this formulation, dummy variables are used to capture the effects of different numbers of temperature selections. If these variables are replaced by the number of selections (NSEL), the accuracy declines slightly to 0.988.

As in all appliances previously examined, some of the explanatory variables contribute very little to the explanatory power of the regression model and may be dropped. Somewhat surprisingly, the number of wash/rinse temperature selections (NSEL or SEL2-SEL5) and water level selections (WLEV1-WLEV3) were not significant contributors. The extra rinse option could be combined with the number of cycles to form an adjusted number of cycles (TCYCL = NCYCL + ERINSE). This new variable appeared to perform better than the two variables it replaced.

Table 15

Clothes Washers: Definition of Variables

PRICE	Average price ($), white model, delivery included
CAPAC	Tub capacity (litres)
ENER	Energy consumption (kilowatt hours per month)
NUMCYC	Number of cycles
SPEED1-SPEED3	Dummy variables for number of speeds
BLEACH	= 1 for bleach dispenser; = 0 otherwise
SCFILT	= 1 for self-cleaning filter; = 0 otherwise
FABDISP	= 1 for fabric softener dispenser; = 0 otherwise
WLEV1-WLEV3	Dummy variables for water level settings
ERINSE	= 1 for extra rinse option; = 0 otherwise
SOLST	= 1 for solid state control panel; = 0 otherwise
C1-C3	Dummy variables for special cycles
SEL1-SEL5	Dummy variables for number of temperature selections
BR8-BR39	Dummy variables for brand names
TCYCL	= NUMCYC + ERINSE

Energy consumption is only weakly related to capacity and type. The regression of ENER against CAPAC and C3 can be summarized as follows:

$$\begin{array}{l} \text{ENER} = \underset{(0.52)}{21.754} + \underset{(2.19)}{1.226}\ \text{CAPAC} - \underset{(-1.38)}{10.602}\ \text{C3} \end{array}$$

$$R^2 = 0.166 \qquad s = 18.315$$

The predicted values and residuals of this regression are considered estimates of nondiscretionary and discretionary energy consumption, respectively. The residuals (RENER) replace the variable ENER.

After incorporating the above changes, the regression model was reestimated. The results are shown in Table 16. The changes resulted in a negligible loss in accuracy, as can be seen by comparing the R^2 of Table 16 (0.985) with that of the full model (0.989). Discretionary energy consumption is negatively related to price, as expected. Other things being equal, it is estimated that consumers will pay about $0.77 for each additional kilowatt hour per month of energy savings.

Table 16

Clothes Washers: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	-120.342	-0.83
CAPAC	7.904	4.55
C3	29.765	4.49
RENER	-0.771	-3.14
SPEED1	-58.846	-4.18
BLEACH	37.056	3.99
SCFILT	40.248	4.20
FABDISP	38.093	3.86
SOLST	295.792	17.01
TCYCL	6.808	1.71
BR8	-21.051	-1.31
BR18	6.373	0.46
BR22	-23.379	-1.96
BR25	85.349	3.88
BR26	-79.915	-4.09
BR27	80.670	4.24
BR30	-43.320	-2.22
BR31	-41.223	-3.83
BR39	22.791	1.96
	R^2 = 0.9846	s = 13.814

An examination of Table 16 also shows that consumers, other things being equal, pay approximately:

- $8 for an additional litre of tub capacity;
- $30 for a suds saver model;
- $59 more for models with two or more speeds than they pay for one-speed models;
- $37 for a bleach dispenser;
- $40 for a self-cleaning filter;
- $38 for a fabric softener dispenser;

- \$296 for a model with a solid state control panel;

- \$7 for each extra cycle.

Clothes Dryers

The 34 models used in the study came under ten different brand names. Their prices ranged from \$312 to \$700; the average price was \$403. Nineteen models were in the \$300 price range, 13 in the \$400 range and only 2 had prices greater than \$600.

Capacity varied from 132 L to 168 L, but the observations actually fell into three relatively homogeneous groups. One group of models had a capacity of 132 L, another 143 L, while the remainder had 167 L or 168 L of capacity.

Energy consumption ranged between 88 kW·h/mon and 111 kW·h/mon, with an average of 100 kW·h/mon. Eleven models allowed timed control only; of the automatic models, 19 controlled duration by means of a temperature sensor, while 4 had a moisture sensor. One model had a solid state control panel; it was the most expensive in our list. The number of cycles ranges from zero for timed models to four for some automatics. Seventeen models had an end-of-cycle signal, 19 had a lamp and 16 provided a drying rack.

The features identified for this study are described in Table 17. A regression of price against all explanatory variables indicates that the latter capture 98% of the variation in dryer prices.

There did not appear to be any difference in the consumers' evaluation of D2 (automatic dryers with temperature sensor) and D3 (automatic dryers with moisture sensor); the appropriate distinction appeared to be one between manual and automatic models. CYCLES and RACK contributed very little to the explanatory power of the model and were dropped.

The energy consumption of clothes dryers is not strongly related to capacity and type of control. The results of the regression of ENER against CAPAC and D1 (D2 and D3 now forming the base) can be summarized as follows:

$$\underset{}{\mathrm{ENER}} = \underset{(1.79)}{52.637} + \underset{(1.72)}{0.304}\ \mathrm{CAPAC} - \underset{(-3.36)}{9.211}\ \mathrm{D1}$$

$$R^2 = 0.323 \qquad s = 7.463$$

Table 17

Clothes Dryers: Definition of Variables

PRICE	Average price ($), white model, delivery included
CAPAC	Drum capacity (litres)
ENER	Energy consumption (kilowatt hours per month)
CYCLES	Number of automatic cycles
HEAT	Number of temperature selections
RACK	= 1 for drying rack; = 0 otherwise
LAMP	= 1 for dryer lamp; = 0 otherwise
EXCARE	= 1 for "extra care" option; = 0 otherwise
SIG	= 1 for end-of-cycle signal; = 0 otherwise
SOLST	= 1 for solid state panel; = 0 otherwise
D1-D3	Dummy variables for drying control
BR8-BR42	Dummy variables for brand names

Very little accuracy was lost as a consequence of dropping and modifying some explanatory variables. Table 18 shows the revised regression results.

The features listed in Table 18 explain approximately 98% of the variation in the prices of clothes dryers, almost the same percentage as the original set of features.

In particular, it can be noted that the coefficient of discretionary energy consumption is negative, as expected. It is estimated that consumers are willing to pay about $1.06 for each kW•h/mon of energy saved.

Other estimates shown in Table 18 indicate that consumers, other things being equal, pay approximately:

- $4.50 for each additional litre of drum capacity;

- $40 more for an automatic dryer than for a manual (timed) one;

- $5 for each additional temperature selection;

- $1.50 for a lamp;

- $10 for the "extra care" option;

- $24 for an end-of-cycle signal;

- $246 for a model with a solid state control panel.

Table 18

Clothes Dryers: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	-377.604	-0.17
CAPAC	4.544	0.34
D1	-40.457	-4.30
RENER	-1.062	-1.75
HEAT	5.159	1.04
LAMP	1.529	0.11
EXCARE	9.186	0.96
SIG	24.020	1.95
SOLST	246.146	12.59
BR8	-36.150	-2.03
BR17	188.116	0.57
BR18	8.320	0.72
BR25	-26.387	-1.86
BR30	-59.620	-5.22
BR31	-21.620	-1.89
BR39	-20.165	-2.03
BR42	355.819	0.75

$R^2 = 0.9786$ $s = 15.233$

Dishwashers

Through the survey of retail outlets and advertisements, prices were obtained for 43 dishwasher models for which product literature was also available. These models came under ten different brand names. Their price ranged from $431 to $973, with an average of about $597. Energy consumption varied from 85 kW•h/mon to 128 kW•h/mon, and averaged about 108 kW•h/mon. Twenty-three models were portable, with a hardwood top, and nearly all were convertible to built-in models.

The features shown in Table 19 account for 93.9% of the variation in dishwasher prices. However, hot water consumption (HWCON) should not be used in explaining the prices of dishwashers. Hot water consumption is not a consumer feature -- one does not buy a particular model because of it. (Hot water consumption together with the type of drying used does, of course, affect energy consumption. However, drying type was identical for all observed models.)

Table 19

Dishwashers: Definition of Variables

PRICE	Average price ($), white model, delivery included
HWCON	Hot water consumption (litres), normal cycle
ENER	Energy consumption (kilowatt hours per month)
PORT	= 1 if portable; = 0 otherwise
CYCLES	Number of special cycles
HTSWIT	= 1 for water heater switch; = 0 otherwise
FANDRY	= 1 for forced drying; = 0 otherwise
DISPOS	= 1 for soft food disposer; = 0 otherwise
SANI	= 1 for "sani" option; = 0 otherwise
BLACK	= 1 for a black front panel; = 0 otherwise
BR17-BR59	Dummy variables for brand names

In the case of all other appliances, it was argued that certain combinations of features (primarily related to size and type) implied a certain level of energy consumption. For dishwashers, however, we have no measure of size -- the type is the same for all observed models and the last determinant of energy consumption (hot water consumption) is not a feature in itself but rather an explanation of energy consumption. The remaining features do not affect energy consumption, at least in the manner in which the latter is measured by the Energuide program. All this suggests that in this case discretionary consumption equals total consumption.

Preliminary work indicated, somewhat surprisingly, that price was not significantly related to the number of cycles, or to the presence of fan-forced drying and black front panels. After dropping HWCON, CYCLES, FANDRY and BLACK, a regression of PRICE against all remaining explanatory variables produced the results summarized in Table 20.

Other things being equal, consumers appear to pay about $2.25 for each kilowatt hour per month of energy saved, and approximately:

- $18.50 more for a portable model than for a built-in one;

- $59 for a built-in water heater;

- $87 for a soft food disposer;

- $81 for a "sani" option.

The features listed in Table 20 account for 93.4% of the variation in dishwasher prices.

Table 20

Dishwashers: Regression Results

Variable	Estimated coefficient	"t-value"
INTERCEPT	630.761	5.47
ENER	-2.256	-2.30
PORT	18.507	1.32
HTSWIT	59.237	1.86
DISPOS	86.861	1.59
SANI	80.760	4.85
BR17	148.366	2.67
BR18	99.805	3.32
BR22	27.683	0.83
BR25	107.149	1.42
BR27	-45.178	-1.24
BR30	-24.567	-0.74
BR31	77.683	2.34
BR39	6.431	0.19
BR59	327.993	9.38
	R^2 = 0.9340	s = 42.831

Chapter IV

CONCLUSIONS

Two major conclusions can be drawn from this study:

1. Most domestic appliances on sale in Canada in 1982 use much less energy than their 1979 counterparts. Since the start of the Energuide program the energy ratings of most refrigerators, freezers, ranges, dishwashers and clothes washers have fallen considerably.

2. In 1982, energy efficiency commands a premium in the marketplace; however, that premium is generally small.

Reduction in Energy Used

As discussed in Chapter II of this report, energy efficiency has been improved in all the appliance groups studied. Table 21 summarizes the overall reduction in average electricity consumption in absolute and relative terms since the first Energuide year. For example, the average consumption of 1982 freezers was 16.2 kW•h/mon (or 16%) lower than that of 1980 freezers.

Table 21

Overall Average Reduction in Energy Consumption
(1982 vs. First Energuide Year)

Appliance	First year	Average reduction (kW•h/mon)	Average reduction (%)	Source
Refrigerators	1979	26.8	19	Table 4
Freezers	1980	16.2	16	Table 5
Ranges	1981	0.4	1	Table 6
Dishwashers	1981	2.8	2	Table 7
Clothes washers	1981	0.6	0	Table 8

More detailed estimates of energy savings are influenced by three factors: the base year against which comparisons are made; the particular models compared; and the type of appliance considered.

The *base year* clearly affects estimated savings. Strictly speaking, our analysis can only cover the period for which an appliance has been listed in the Energuide Directory (1979-82 for refrigerators; 1980-82 for freezers; 1981-82 for clothes washers, dishwashers and ranges. We can extend our results by using earlier estimates of energy usage provided by other authors (Lane 1981 and Drapkin 1981). Estimated energy savings, then, depend crucially on the accuracy of those earlier estimates (by definition, from non-Energuide sources) and their comparability with the appliance types and sizes used here. In every case, the increases in energy efficiency measured from the earlier bases are much greater than those estimated solely from the Energuide Directory.

The *particular models* compared can drastically change estimates of energy savings. The variation in energy consumption across apparently similar models (i.e., models with the same features as listed in the Energuide Directory) is generally lower in 1982 than it was at the start of the Energuide program. The least efficient designs tend not to be represented in 1982 models. This in itself is important for energy conservation. The narrower range of energy consumption offered ensures that even consumers who have no interest in conservation, and who may be completely unaware of the Energuide program, are unable to select very wasteful models.

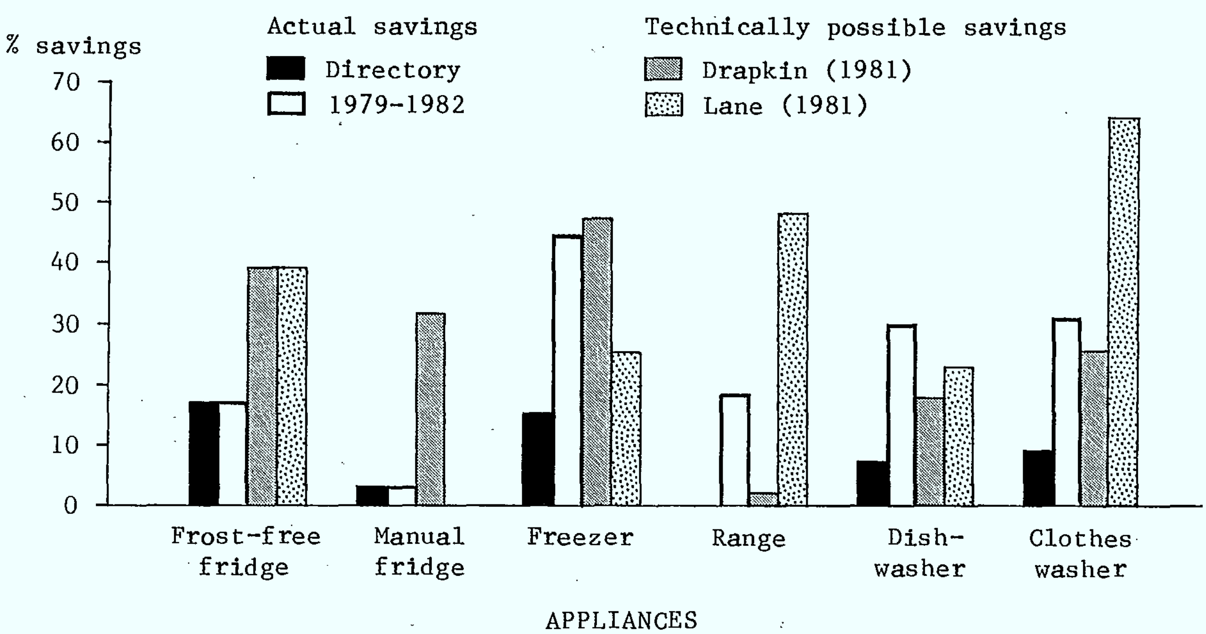
However, in almost every appliance group, low-energy-consuming models were available at the outset of the Energuide program. The difference between the most efficient model when Energuide was first applied to that appliance and the most efficient model in 1982 tends to be fairly small. This difference is less than 1% for dishwashers and clothes washers; about 2% for ranges; 5%-9% for freezers, depending on their type and size; and 10%-15% for refrigerators. It appears that the Energuide program has led manufacturers to produce many models similar to their most efficient ones, rather than breaking through to radically different designs. It is interesting that although low-energy-consuming models existed right from the start of the Energuide program, there were few of them. If consumers had recognized and valued energy efficiency, efficient models would have sold well and competition between manufacturers should have led to more efficient models being produced. Apparently the market did not work in this way until Energuide was started. Perhaps consumers had no way of recognizing energy efficiency; perhaps they did not value this feature until after Energuide was introduced; or perhaps the market was not competitive. Here, as in all the comparisons presented, we cannot isolate the role of Energuide in the trends observed. Since 1979 many things have changed: energy prices have risen, awareness of conservation has grown, energy conservation advertising has increased, etc. The effect of Energuide cannot be separately distinguished. We observe concomitant variation, not causality.

The *type of appliance* considered is important, particularly for refrigerators. Energy savings vary so much over the different types of refrigerators that it makes more sense to calculate average savings for each type.

Given the reservations discussed above, Figure 1 summarizes our findings on appliance trends for selected types of appliances. The types and sizes used have been chosen to be comparable with earlier research.

Figure 1

Energy Savings: Actual and Potential



In Figure 1, frost-free fridge represents a two-door top freezer automatic defrost refrigerator of 14.5-15.4 cu. ft.; manual fridge represents a single-door manual defrost refrigerator of 9.5-12.4 cu. ft.; freezer represents a chest freezer manual defrost of under 14 cu. ft.; range represents a 30"-wide range with a self-cleaning oven and a regular top; dishwasher and clothes washer are averaged over all models.

The first two bars in Figure 1 show our estimates of the average energy savings actually achieved by each appliance. The first bar (Directory) measures savings over the period for which that appliance has been covered by the Energuide Directory. Apart from two-door top freezer frost-free refrigerators (which, on average, reduced consumption by 17%, or 27 kW•h/mon) and freezers (which, on average, reduced consumption by 15%, or 10 kW•h/mon), the changes in energy usage are more modest (virtually no change for ranges; 11% or 13 kW•h/mon for dishwashers; and 10% or 10 kW•h/mon for clothes washers).

The second bar measures savings since 1979, using estimates of 1979 consumption provided by Drapkin and Lane (where these estimates differed, their average was used). Results here are much more impressive. Since 1979, freezers have reduced their average energy consumption by 49% (or 53 kW•h/mon); dishwashers by 25%-40% (or 35 kW•h/mon-71 kW•h/mon, depending on whose base estimate is used); clothes washers by 24%-38% (or 33 kW•h/mon-61 kW•h/mon); and ranges by 18% (or 14 kW•h/mon). It seems that most efficiency gains were made before the Energuide program was actually extended to the appliance. Presumably manufacturers, alerted by the program's initiation in 1979, anticipated program extensions.

An alternative explanation, which cannot be rejected at this stage, is that non-Energuide factors influenced manufacturers: that trends in prices, energy conservation awareness, etc., stimulated increases in efficiency irrespective of the Energuide program. This latter hypothesis can be tested by comparing Canadian appliance trends with those in countries where there are no programs of the Energuide type. Such a comparison is beyond the scope of this research project, but further research in this area could provide valuable evidence of Energuide's effects.

Given that appliance efficiency has increased since 1979, have efficiency gains matched expectations? The second two bars in Figure 1 show the energy savings estimated as technically possible by Drapkin and Lane, respectively. The Drapkin estimates reflect design changes which could be introduced within three years of 1979; that is, Drapkin expected that these savings *could* have been made by 1982 (see Table 1 in Chapter I of this report). The Lane estimates reflect design changes which were considered to be technically possible under existing market conditions and could be introduced within five years (see Table 2). The base date for Lane's estimates is 1978/79, except for ranges, where the base is 1980. Consequently, Lane's figures relate to savings which *could* be made by 1983/84, or for ranges by 1985.

The largest gap between actual and potential savings occurs for the single-door manual defrost refrigerator, size 9.5-12.5 cu. ft. We estimate only a 3% (1.7 kW•h/mon) improvement in the average energy rating for this appliance from 1979 to 1982. Lane suggests that a 30% (18 kW•h/mon) improvement is techically possible by 1984. Given the slow progress made so far, it seems unlikely that this level of savings will be achieved.

This shortfall is worth further investigation. Single-door manual defrost refrigerators represented 17.8% of the Canadian market in 1981; the 9.5-12.4 cu. ft. size range was the most popular, taking 10.9% of the total market (CAMA 1982). This type of refrigerator is at the low-price end of the market. Efficiency gains here would presumably be of particular benefit to lower-income groups. At present it appears that these refrigerators are falling behind other types and are not realizing their technical potential, with unfortunate distributional consequences.

Two-door top freezer automatic defrost refrigerators (frost-free fridge in Figure 1) are also not realizing estimated technically possible energy savings. Lane and Drapkin both estimate 39% gains as possible (i.e., a saving of 64 kW•h/mon for Lane, and 52 kW•h/mon for Drapkin; Drapkin's estimate is from a smaller base). We estimate that the average energy rating for 14.5-15.4 cu. ft. units has fallen by only 17% (27 kW•h/mon). In fact, results are very sensitive to the size category chosen. Drapkin's data refer to a 16 cu. ft. box; in the 15.5-17.5 cu. ft. range (the most popular on the market, CAMA 1982) we estimate a 24% gain in average efficiency (a saving of 39 kW•h/mon). Actual savings are lower than technically possible, but not much lower.

Clothes washers have improved their energy ratings more than Lane estimated as technically possible by 1983/84. Failure to introduce front-loading (drum-type) machines prevents Drapkin's estimates from being obtained.

For freezers and dishwashers, efficiency gains also exceed expectations. Ranges have made small gains, but exceed the efficiency expected by Lane for 1985. In fact, neither the Lane nor the Drapkin estimates of technical possibilities are strictly comparable to our results. Both authors expected improvements in efficiency to come from the use of forced air convection in ovens. This feature is currently excluded from the Energuide ratings; therefore, any gains from convector fans are not reflected in our estimates of actual energy savings. Forced air convection should be evaluated under the Energuide program. If this feature can save energy, the current ratings system may be favouring inefficient ranges.

Valuation of Energy Efficiency

The analysis in Chapter III was based on the premise that an appliance can be described as a collection of features and that consumers, in purchasing appliances, act as if they pay the sum of implicit market values of product features, one of which is energy efficiency.

The number and exact description of these features varies from one appliance type to another. Neither, however, is given a priori; some judgement is necessary in drawing the line between important and unimportant features, and in their description.

In judging the adequacy of our approach, we used essentially two criteria: one was the expected sign of the estimated values of product features (positive for utility-increasing features, negative otherwise); the second criterion was the proportion of the variation of observed prices explained by the regression.

In reviewing the estimates given in Chapter III, it will be noted that all the estimates satisfied the first criterion, and that in all cases the proportion of explained variation was high (98% for refrigerators, 86% for freezers, 93% for ranges, 98% clothes washers and dryers, and 93% for dishwashers).

The numerous estimates of the implicit prices of product features need not be repeated here. Three considerations should be borne in mind in interpreting them. First, all estimates are sample estimates and subject to the variability of all such estimates. In this respect, there is a difference between the results of Chapters II and III, because those of Chapter II are based on entire populations and not on samples. Second, there is still a tendency for certain product features to "go together" (multicollinearity), which may cause some uncertainty in the accuracy of value estimates of individual features. One type of relationship — that between energy consumption and Energuide features — was especially treated, but others may still be present. Third, the estimates of the implicit values of product features utilized in the study may have absorbed the effects of other features deemed as being of secondary importance. For example, the estimated premiums and penalties of the brand names reflect the net effect of such diverse features as marketing image, technical reliability and warranty differences.

Of special interest are the estimates of the implicit price of energy efficiency for each appliance. These are the regression coefficients of RENER and ENER presented earlier in Chapter III, which are reproduced in Table 22.

Table 22

Implicit Value of Energy Efficiency by Appliance Type

Appliance	Coefficient	"t-value"	Source
Refrigerators	-1.24	-0.79	Table 10
Freezers	-0.16	-1.30	Table 12
Ranges	-3.84	-0.52	Table 14
Clothes washers	-0.77	-3.14	Table 16
Clothes dryers	-1.06	-1.75	Table 18
Dishwashers	-2.26	-2.30	Table 20

The coefficients show how much consumers appear to pay on the average for each kilowatt hour per month of electricity consumption saved, other features remaining equal. For example, if clothes washer A has the same features as B but consumes 20 kW•h/mon less than B, then A can command a premium of 20 x 0.77, or $15.40.

All the coefficients of Table 22 are negative, indicating that consumers consider energy efficiency a valuable feature. Their values vary from one type of appliance to another, but are generally small. The largest is that of ranges ($3.84 per kw•h/mon), while the smallest is that of freezers ($0.16 per kW•h/mon). These are, of course, static measurements of the implicit value of energy efficiency and reflect the conditions observed in June 1982. Since this type of study was conducted for the first time, it is not possible to tell whether or not there has been an improvement in energy conservation awareness over time.

For each type of appliance, the hypothesis could be tested that the true implicit value of energy efficiency is $0, or, to put it differently, that consumers attach no value to energy efficiency. The test depends on the risks of error that one is willing to assume. At a conventional 10% level of significance, the hypothesis that consumers place no value on energy efficiency would be rejected in the case of clothes washers, dishwashers and clothes dryers, but cannot be rejected in the case of ranges, refrigerators and freezers. Stated more simply and roughly, we cannot dismiss the possibility that, in buying ranges, refrigerators and freezers, buyers attach no importance to energy efficiency, even though they appear to do so, as evidenced by the negative signs of the energy coefficients in Table 22.

We can only speculate as to why there might be a difference in attitudes towards energy efficiency by buyers of different appliances. Refrigerators, freezers and ranges are the appliances that have been longest under the Energuide program. The 1979 Energuide Directory included only refrigerators; the 1980 directory listed refrigerators and freezers; ranges, clothes washers and dishwashers first appeared in the 1981 directories; clothes dryers have not as yet appeared in any published directory.[1] It is possible -- although admittedly speculative -- that the narrowing of the range of energy consumption brought about by the older Energuide programs has weakened somewhat the importance of energy efficiency as a factor in purchasing decisions.

In any event, it is useful to compare the estimates shown in Table 22 with a "rational" consumer's valuation of energy efficiency. Table 23 shows the present value of 1 kW•h of electricity saved monthly over 15 years under a reasonable range of discount rates and

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1. Clothes dryers first appear in the published 1982 directory. -- Ed.

electricity prices. Fifteen years was chosen as the average expected lifetime of an appliance (Lane 1981, p. 47). The discount rates are indicative of current interest rates for ordinary savings accounts. The price range is for 1 kW•h of electricity (current Ontario price appears to be between 4 and 5 cents per kilowatt hour). The present value is the discounted value of an annuity of $12P -- where P is the price of 1 kW•h in dollars -- receivable at the end of every year for 15 years at the indicated discount rate.

For example, the present value of the annual dollar savings resulting from a 1 kW•h/mon saving in electricity consumption over 15 years is $4.09, when the price of 1 kW•h is $0.05 and the discount rate is 12%. A rational consumer should be indifferent between two appliance models -- identical in all respects except for energy consumption -- one consuming 1 kW•h/mon less, but priced $4.09 more than the other. To this consumer, therefore, the value of 1 kW•h/mon of energy efficiency should be $4.09, assuming that future electricity prices are expected to remain constant.

Table 23

Present Value of 1 kW•h/mon of Electricity Savings over 15 Years

	Price of 1 kW•h of electricity			
Discount Rate (%)	$0.04 ($)	$0.05 ($)	$0.06 ($)	$0.07 ($)
10	3.65	4.57	5.48	6.39
12	3.27	4.09	4.90	5.72
15	2.81	3.51	4.21	4.91

It can be noted that most of the estimates of the implicit value of energy efficiency listed in Table 22 are lower than the values in Table 23. This would suggest that consumers' implied discount rates are considerably higher than 15%; in other words, consumers appear to value present receipts and outlays much more than rational economic calculus and present economic conditions justify. This, in turn, indicates that energy conservation programs such as Energuide have not yet exhausted the potential to persuade consumers that electricity saved is money earned.

Summary

Overall, the results of this study appear encouraging. The average electricity consumption of appliances has declined and, in certain cases, the decline has been substantial, far exceeding expectations. Consumers appear to value energy efficiency, but there is room for improvement in their awareness of the value of energy conservation. Although the entire credit cannot be claimed exclusively by the Energuide program, in the appliance field it is reasonable to attribute to the program a substantial proportion.

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