File No. CT 98/2

THE COMPETITION TRIBUNAL

IN THE MATTER OF THE *COMPETITION ACT*, R.S. 1985, c.C-34, as amended, and the *Competition Tribunal Rules*, SOR/94-290, as amended (the "*Rules*");

AND IN THE MATTER OF an inquiry pursuant to subsection 10(1)(b) of the *Competition Act* relating to the proposed acquisition of ICG Propane Inc. by Superior Propane Inc.;

AND IN THE MATTER OF an Application by the Director for an order pursuant to s. 92 of the *Competition Act*.

B E T W E E N:

THE COMMISSIONER OF COMPETITION

Applicant

- and -

SUPERIOR PROPANE INC. et al.

Respondents

AFFIDAVIT OF DAVID RYAN AND ANDRÉ PLOURDE

William J. Miller
Department of Justice
Counsel to the Competition Commissioner
Place du Portage, Phase I
50 Victoria Street
Hull, Quebec
K1A 0C9

tel: (819) 997-3325
fax:(819) 953-9267

File No. CT 98/2

THE COMPETITION TRIBUNAL

IN THE MATTER OF THE *COMPETITION ACT*, R.S. 1985, c.C-34, as amended, and the *Competition Tribunal Rules*, SOR/94-290, as amended (the "*Rules*");

AND IN THE MATTER OF an inquiry pursuant to subsection 10(1)(b) of the *Competition Act* relating to the proposed acquisition of ICG Propane Inc. by Superior Propane Inc.;

AND IN THE MATTER OF an Application by the Director for an order pursuant to s. 92 of the *Competition Act*.

B E T W E E N:

THE COMMISSIONER OF COMPETITION

Applicant

- and -

SUPERIOR PROPANE INC. et al.

Respondents

AFFIDAVIT OF DAVID RYAN AND ANDRÉ PLOURDE

We, David Ryan and André Plourde, of the city of Edmonton in the Province of Alberta, JOINTLY AND SEVERALLY MAKE OATH AND SAY:

1. Attached hereto and marked as Exhibit "A" is a true copy of our evidence. The contents of Exhibit "A" and the findings and opinions expressed therein are true to the best of our knowledge, information and belief.
2. We were retained by counsel for the Commissioner of Competition to provide expert economic evidence in this matter.

3. Attached hereto and marked as Exhibit "B" and "C" are true copies of our curricula vita.

4. We make this affidavit pursuant to Rule 47(1) of the *Competition Tribunal Rules*.

Jointly and Severally
Sworn/Affirmed before me
at the city of EDMONTON in
the Province of ALBERTA , on
AUGUST 16, 1999

ANGELA E. WEAVER
Barrister & Solicitor

Commissioner for Taking Oaths, etc.
NOTARY PUBLIC

David Ryan
André Plourde

This is Exhibit "A" to the Affidavit of David Ryan and André Plourde
sworn before me at the city of Edmonton in the Province
of Alberta this 16 day of August, 1999

ANGELA E. WEAVER
Barrister & Solicitor

A Commissioner for Taking Affidavits, etc.

NOTARY PUBLIC

TABLE OF CONTENTS

Price Elasticities of Demand for Propane in Canada

1. SUMMARY OF CONCLUSIONS

(a) The principal objective of this report is to provide empirical evidence concerning the role, importance and substitutability of propane as an energy source in Canada. Since all these characteristics may differ according to the geographical region and the sector that is being considered, analysis is undertaken at as disaggregated a level as data availability allows. In the case of Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia, analysis is undertaken at the provincial level. As far as the remaining provinces are concerned (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and New Brunswick), data availability is such that analysis is undertaken at the regional level, namely the four Atlantic provinces as a whole.

(b) For each of these provinces/regions, three final-use sectors are examined, namely residential, industrial (including manufacturing, forestry, and construction), and commercial. In all cases, sectoral definitions are the standard ones used by Statistics Canada (as implemented in its publication entitled *Quarterly Report on Energy Supply-Demand in Canada* – catalogue no. 57-003, among others).

(c) The energy types considered in this analysis differ according to province/region and sector, since not all regions in Canada have access to the same energy types, and not all sectors can make use of all the energy types that are accessible. In general, the alternative energy types that are considered include electricity, natural gas, refined oil products (including diesel, fuel oil, motor gasoline, etc.), propane, and wood. In addition, as detailed later in this report, the modelling and estimation for each region/sector takes account of salient features of the market in that region/sector, such as, for example, the availability of natural gas.

(d) For the period 1982 to 1996 (the last year for which all of the relevant data series are available), we assembled annual data pertaining to the prices and quantities of the various energy types used in the residential, industrial, and commercial sectors of the provinces/regions of Canada.

(e) These data revealed that the shares of propane in the total quantity of energy consumed in each sector, and in the corresponding sectoral expenditures on energy, were relatively small in all provinces/regions. Indeed, in only a few cases (notably Alberta/residential), was the *maximum* average quantity or cost share of propane larger than the corresponding *minimum* share of all other energy types.

(f) Models of the inter-related demands for the various energy types were estimated for each sector in each province/region. The estimated parameters of these models were then used to calculate, for 1990 and 1996, own- and cross-price elasticities resulting from changes in propane prices.

(g) In general, the statistically significant own-price elasticities of the demand for propane were small, thus indicating that a change in propane prices induced a less-than-proportional variation in propane consumption, which suggests that propane demand was relatively inelastic in those years.

(h) Cross-price elasticities identified both substitution and complementarity relationships between propane and other energy types. In almost cases, however, the statistically significant elasticities were well below one (in absolute value). This suggests that there were limited substitution possibilities between propane and other energy types – a change in the price of propane generally induced proportionally much smaller changes in the demand for other energy types.

2. INTRODUCTION

(a) The principal objective of this report is to provide empirical evidence concerning the role, importance and substitutability of propane as an energy source in Canada. Since all these characteristics may differ according to the geographical region and the sector that is being considered, analysis is undertaken at as disaggregated a level as data availability allows. Specifically, as is explained in more detail later, since this analysis requires a time series of data on prices and quantities of propane and alternative energy types for each region/sector that is considered, the smallest region that can be analyzed is a province.

(b) While the level of analysis varies across regions as dictated by data availability, to the extent possible analysis is conducted here at the final-user level for each Canadian province. The four easternmost provinces are an exception. Indeed, many of the data series needed are only available for the Atlantic region (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and New Brunswick) as a whole. Consequently, these four provinces are treated, for the purposes of our analysis, as a single region. Overall, our analysis thus distinguishes seven regions (Atlantic region, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia). For each of these provinces/regions, three final-use sectors are examined, namely residential, industrial (including manufacturing, forestry, and construction), and commercial. In all cases, sectoral definitions are the standard ones used by Statistics Canada (as implemented in its publication entitled *Quarterly Report on Energy Supply-Demand in Canada* – catalogue no. 57-003, among others).

(c) A cursory view of the importance of propane is provided by simple statistical measures, such as the quantity share of propane in total sectoral energy use (in terajoules) and the cost (or expenditure) share of propane in the total cost of (or total expenditures on) energy (in dollars) for these different provinces/regions and sectors. However, this type of analysis does not indicate the extent to which different types of energy consumers can or are likely to change their consumption of propane in response to changes in the price of propane. Such price changes may result, for example, from any change in the structure of the industry that provides propane to these consumers. To examine the effects of changes in the price of propane on the demand for propane and other energy types, it is necessary to model the inter-related demands for these energy types and to estimate the parameters of such a model. Based on these parameter estimates, price elasticities of demand can be calculated, showing the proportional change in the demand for each energy type in response to a proportional change in its own price (*own-price* elasticity of demand) or in the price of a different energy type (*cross-price* elasticity of demand).

(d) A negative value for the *own-price* elasticity of demand for an energy type (such as propane) means that when the price of that energy type rises (falls), the quantity consumed of that energy type falls (rises), all else – such as the prices of other energy types – held constant. A positive *cross-price* elasticity of demand means that an increase (a fall) in the price of a given energy type will induce an increase (a fall) in the quantity of *another* type of energy consumed, again all else – such as the prices of all other energy types – held constant. Standard economic theory suggests that goods for which cross-price elasticities of demand are positive can be labeled "substitutes". For example, if all else held constant an increase in the price of propane leads to an increase in the quantity of natural gas consumed, then these two energy types can be thought of as substitutes, since one aspect of the response of consumers to the propane price increase is to substitute natural gas (for propane). A case where, all else held constant, increases (falls) in the price of a given energy type induce reductions (increases) in the quantity consumed of another type of energy would be characterized by a negative *cross-price* elasticity of demand, and the two energy types in question would be labeled "complements".

(e) Over at least the last decade, no publicly available study providing empirical evidence as to changes in Canadian energy consumption patterns resulting from changes in propane prices appears to have been undertaken. This situation prevails for Canada as a whole, for any Canadian province/region, and for any particular sector, such as residential, industrial, etc. The analysis here is designed to provide such empirical evidence, by estimating the parameters of models of the demand for various energy types (including propane), and then using these parameter estimates to calculate own- and cross-price elasticities of demand.

(f) The energy types considered in this analysis differ according to province/region and sector, since not all regions in Canada have access to the same energy types, and not all sectors can make use of all the energy types that are accessible. In general, the alternative energy types that are considered include electricity, natural gas, refined oil products (including diesel, fuel oil, motor gasoline, etc.), propane, and wood. In addition, as detailed later in this report, the modelling and estimation for each region/sector takes account of salient features of the market in that region/sector, such as, for example, the availability of natural gas.

(g) The remainder of this report is set out as follows. In the next section we describe the data that are used, and limitations that prevent a more detailed analysis. In section 4, we use these data to describe the role and importance of propane as an energy source in the various provinces/regions and sectors of Canada. In addition, this section includes a discussion of the alternative energy types that are considered in each region/sector. Section 5 contains details of the general model that is to be estimated for the different regions/sectors, along with an explanation of how the various elasticity measures are calculated based on the parameters of the model. A technical appendix complements the discussion in this section. Details of factors that are specific to a particular region/sector, and which are incorporated in the model for that region/sector, are also provided here. In section 6, the results of the estimation for each region/sector are presented and analyzed. The final section summarizes the findings.

3. DATA: SOURCES AND LIMITATIONS

3.1 General Remarks

(a) All of the data series discussed below were obtained for the time period extending from 1982 to 1996 (the last year for which all of the relevant data series were available). As noted earlier, seven provinces/regions (Atlantic region, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia) are considered in the analysis, and the relevant data series were assembled for each of them. Also, as noted earlier, provinces (and, in the case of Eastern Canada, the Atlantic region as a whole) are the smallest geographic area for which all of the required data series can be assembled. As far as the sectoral breakdown of the economy is concerned, here again data availability restricts the scope of our analysis to consider a disaggregation into residential, industrial, and commercial sectors (as noted in section 2 above, the definitions used follow those implemented by Statistics Canada in publications such as *Quarterly Report on Energy Supply-Demand in Canada*, among others).

(b) All of the quantity series discussed below represent measures of the energy content (for example, petajoules, gigajoules, etc.) of the various energy types. Note that in the case of the Atlantic region, the absence of natural gas distribution systems means that this energy type is not available for consumption in that region.

(c) Prices of the various energy types include the relevant taxes, and are measured in current dollars per unit of energy content (for example, dollars per gigajoule). With the exception of wood, conversion factors allowing us to go from current dollars per physical unit (for example, cents per litre of light fuel oil) to current dollars per unit of energy content were obtained from *Quarterly Report on Energy Supply-Demand in Canada* (Statistics Canada publication no. 57-003). In the case of wood, conversion factors were obtained from a 1985 publication by the federal department of Energy, Mines and Resources (now known as Natural Resources Canada) entitled: "The Ratepayer's Guide to Heating Systems".

(d) For purposes of estimating our models of inter-related demands for energy types, quantities of the refined oil products used in each sector (in each province/region) are added together to form a composite energy type called "oil products". The price of "oil products" is then represented by a weighted average of the relevant prices, where the weights used in aggregation are the quantities of the relevant individual refined products.

3.2 Residential Sector

(a) The following energy types are included in the analysis: electricity, natural gas, oil products (an aggregation of kerosene and light fuel oil), propane, and wood.

(a) For each province/region, time series on the *quantities* consumed of the first four energy types listed above were obtained from CANSIM (Canadian Socio-economic Information Management System), Statistics Canada's electronic database. In the case of wood, time series of the quantities consumed were obtained from Canada's National Energy Board.

(b) Data on the *prices* of electricity, natural gas, and light fuel oil consumed in the residential sector were obtained from Statistics Canada's CANSIM database, with additional information taken from various issues of *Electric Power in Canada* (a joint publication of the Canadian Electricity Association and Natural Resources Canada), and obtained directly (electronically or verbally) from a number of Canadian electric utilities. Propane prices were obtained from Natural Resources Canada. Wood prices were assembled by consulting the classified advertisements of daily newspapers for a number of Canadian cities. The resulting monthly wood price series were then transformed into annual series.

3.3 Industrial Sector

(a) The following energy types are included in the analysis: electricity, natural gas, oil products (diesel, heavy fuel oil, kerosene, and light fuel oil), and propane.

(b) Statistics Canada's CANSIM database is the source for all of the data series on the *quantities* of the various energy types consumed by this sector.

(c) The *price* data contained in CANSIM was again completed by additional information obtained from various issues of *Electric Power in Canada* and directly from a number of Canadian electric utilities. In addition, information on the prices of oil products (diesel, heavy fuel oil, and light fuel oil) and of propane was also obtained from Natural Resources Canada (especially from the Product Integrated Pricing System – PIPS, an electronic database).

3.4 Commercial Sector

(a) The analysis takes into consideration the following energy types: electricity, natural gas, oil products (diesel, heavy fuel oil, kerosene, light fuel oil, motor gasoline), and propane.

(b) As with the industrial sector, the source for all of the data series on the *quantities* of the various energy types consumed by this sector is Statistics Canada's CANSIM database.

(c) The *price* series were obtained from CANSIM, with added information from various issues of *Electric Power in Canada* and a number of Canadian electric utilities. Further, information on the prices of propane and of the oil products listed above was also obtained Natural Resources Canada (especially from PIPS).

3.5 Additional Data Used in the Analysis

(a) To take into consideration the fact that the availability to energy consumers of *natural gas* service has changed in the six westernmost provinces, we assembled time series on the proportion of the population living in areas with access to such service. We initially assembled the relevant information as part of Plourde and Ryan (1995).[1] The resulting

[1] André Plourde and David L. Ryan (1995) "Government Policy and Access to Natural Gas Service in Canada", *Canadian Public Policy*, vol. XXI, no. 3, pp. 304-316.

series have been updated using information contained in various issues of *Areas Served by Natural Gas* (a publication of the Canadian Gas Association) and the *Census of Canada* (published by Statistics Canada). A number of natural gas utilities (especially in British Columbia and Quebec) have also provided additional information on the extent of their distribution systems.

(b) Time series on *heating degree-days* for each province/region were taken from *Quarterly Report on Energy Supply-Demand in Canada* (Statistics Canada publication no. 57-003).

(c) *Population* series for each province/region were taken from Statistics Canada's CANSIM database. These were used in the residential sector in the calculation of per-capita expenditures on energy.

4. THE ROLE AND IMPORTANCE OF PROPANE: A COMPARATIVE ASSESSMENT

4.1 General Remarks

(a) Tables 4.1, 4.3, and 4.5 report, for each province/region, the share of each energy type in the total *quantity* of energy consumed in the residential, industrial, and commercial sectors respectively. In the discussion that follows, these will also be called "quantity shares".

(b) Shares, by energy types, of the total *cost* of (or expenditure on) energy consumed in each province/region are reproduced in Tables 4.2, 4.4, and 4.6 for the residential, industrial, and commercial sectors respectively. These will also be called "cost shares" in the discussion that follows.

4.2 Residential Sector (Tables 4.1 and 4.2)

(a) By the end of the sample period, residential energy consumption patterns in the *Atlantic* region are such that electricity has the largest quantity and cost shares of all energy types available for consumption. The increased penetration of electricity has come at the expense of all other energy types. For example, the 1996 quantity shares of all other energy types are lower than their sample period average values. Oil products, however, continue to play an important role in this sector, accounting for 40.0% of energy use by the end of the sample period. In 1996, wood still accounted for 16.5% of energy use (and 6.2% of energy costs). Between 1982 and 1996, propane met at most 2.0% of residential energy requirements in this region.

(b) Electricity is the primary fuel of choice in *Quebec*'s residential sector, with a quantity share of 53.0% and a cost share of 66.5%, on average, between 1982 and 1996. In the last year of the sample, these shares are either near (in the case of the quantity share) or at their maximum values for the sample period. The relative importance of oil products as a residential energy source has fallen over time. On average, wood has met 14.0% of Quebec's residential energy requirements, with a corresponding average cost share of

9.1%. Propane is a relatively small player in this sector: over the 15 years of our sample, its quantity share never exceeded 1.2% and its cost share peaked at 1.1%. In 1996, both measures of the relative importance of propane were either near (in the case of cost shares) or at their lowest recorded values since 1982.

(c) As far as *Ontario* is concerned, residential consumers of energy have made natural gas their main fuel of choice: its 1996 quantity share of 60.1% was the highest value since 1982, well above the sample average of 52.7%. However, price patterns are such that the average cost share of electricity has, on average, exceeded that of natural gas by 23.3 percentage points (54.0% vs. 30.7%) between 1982 and 1996. By the end of the sample period, oil products account for only 8.1% of the total quantity of energy consumed by Ontario's residential sector. Wood, a relatively smaller player here than in either Quebec or the Atlantic region, accounted for approximately 4.8% of energy use during our 15-year sample period. Propane's share of energy use peaked at 2.7%, as far as both quantity and cost are concerned. By 1996 propane's quantity share was 1.4% and its cost share 2.3%.

(d) In *Manitoba*, natural gas was again the main fuel of choice in the residential sector, with an average quantity share of 52.3%. However, prices were such that electricity's average quantity share of 35.7% translates into an average cost share of 56.6%. All other energy types are much smaller players in Manitoba's residential energy sector. Propane, for example, had an average quantity share of 1.3% (1996 value: 0.3%) and a corresponding cost share of 1.2% (1996 value: 0.5%) between 1982 and 1996.

(e) At 71.0%, natural gas had by far the largest average quantity share in *Saskatchewan*'s residential sector, with electricity recording an average share of 17.1% over the same period. Relative energy prices are again such that the cost share of electricity far exceeded its quantity share. Between 1982 and 1996, the average cost share of electricity was 43.0%, slightly higher than that of natural gas at 42.5%. The importance of oil products as a source of residential energy dropped during the sample period: their quantity share fell from its maximum value of 15.9% to 1.8% in 1996. On average, between 1982 and 1996, propane accounted for 2.2% (1996 value: 1.1%) of Saskatchewan residential energy use, with a corresponding average cost share of 2.7% (1996 value: 2.4%).

(f) The pattern of residential energy use found in *Alberta* is similar to Saskatchewan's. The quantity share of natural gas averaged 81.9%, while that of electricity was 13.4%, on average, between 1982 and 1996. Again, energy prices are such that the average cost share of electricity (at 38.1%) exceeded its average quantity share. Neither oil products nor wood ever accounted for more than 3.0% of total energy costs and 1.6% of total energy quantities consumed by Alberta's residential sector. During our sample period, the quantity share of propane peaked at 6.2% (and averaged 3.3%), while its cost share reached a maximum value of 7.7%, with an average of 4.4%. By 1996, however, the quantity share of propane had fallen to 1.0% with a corresponding cost share of 2.7%.

(g) In *British Columbia*, natural gas was again the primary energy type of choice in the residential sector, with an average quantity share of 48.3% over our sample period. However, electricity prices were higher than those of natural gas, with the result that the cost share of electricity averaged 60.3% compared to 26.3% for natural gas. The relative importance of oil products fell from a peak of 15.7% of the total quantity of energy consumed by the residential sector (and a cost share of 16.0%), to 1996 shares of 3.2% for both quantities and cost. Between 1982 and 1996, the average share of propane in the total quantity of energy consumed by this sector averaged 1.7%, with a corresponding average cost share of 1.6%.

(h) Overall, as far as the residential sector is concerned, natural gas recorded the highest average quantity share in every province to the west of Quebec. Indeed, in each of these provinces, natural gas's *minimum* quantity share exceeded electricity's *maximum* quantity share. The story is different as far as cost shares are concerned. Here, the high electricity prices (relative to those for natural gas) have meant that the average cost shares of electricity have exceeded those for natural gas in Ontario, Manitoba, Saskatchewan, and British Columbia. In Quebec, electricity recorded the highest average shares for both quantities and cost. Throughout the sample period, oil products and wood continued to play a more important role in meeting the energy requirements of residential consumers in Quebec and the Atlantic region. As far as propane is concerned, in every province/region with the exception of Alberta, its average quantity and cost shares were the lowest of all energy types considered. In Alberta, propane's average quantity share of 3.3% and average cost share of 4.4% exceeded those for oil products and wood.

4.3 Industrial Sector (Tables 4.3 and 4.4)

(a) Between 1982 and 1996, electricity and oil products were both important sources of energy for industrial users in the *Atlantic* region. In 1996, for example, the quantity shares of these two energy types were 49.5% and 48.6%, respectively. In terms of cost shares, that for electricity exceeded, on average, that for oil products because of the (relatively) high electricity prices. On average, propane met 1.3% of this region's energy requirements, thus accounting for 1.6% of its total energy costs. By 1996, propane accounted for 1.9% of sectoral energy use and 4.1% of energy costs.

(b) In *Quebec*, electricity had the highest average quantity and cost shares (56.2% and 71.1%, respectively) of energy types used in the industrial sector. This was followed by natural gas, at 26.0% and 15.3% respectively. Oil products played a smaller role, especially as the 1980s progressed. By the end of our sample period, oil products accounted for 12.5% of Quebec's industrial energy use and 8.4% of energy costs. The quantity share of propane averaged 0.7% and never exceeded 1.2%, while its average cost share was 1.0% and peaked at 1.7%.

(c) Natural gas recorded the highest average quantity share (59.1%) of energy types used in *Ontario*'s industrial sector between 1982 and 1996. During that time, the quantity share of electricity averaged 29.2%. However, relative energy prices were such that electricity recorded a higher average cost share (57.9%) than did natural gas (31.0%). As in Quebec, the role of oil products was reduced as the 1980s progressed, such that the quantity share of this energy type averaged 10.6% (and its cost share, 9.7%) over the sample period. The quantity share of propane reached a maximum value of 2.2% and averaged 1.1% between 1982 and 1996; corresponding values for propane's cost share were 2.4% and 1.4%, respectively.

(d) *Manitoba*'s industrial sector met its energy requirements primarily through the use of electricity, which recorded both the highest average quantity share (44.8%) and the highest average cost share (59.4%) of the energy types considered. During the sample period, the quantity share of natural gas always exceeded that for oil products, but the prices of these energy types were such that these differences were attenuated when average cost shares are considered (17.1% for oil products and 20.5% for natural gas). By the end of the period of analysis, propane use was almost at its sample minimum (1996 quantity share of 0.8%) and its cost share equaled 2.0%. Between 1982 and 1996, the highest shares recorded for propane were 4.0% and 5.8% for quantities and cost respectively.

(e) Natural gas was the primary fuel of choice in the industrial sector of *Saskatchewan*: its average quantity share was 63.7% during the sample period. However, the (relative) prices of electricity were such that this energy type recorded the highest average cost share, at 45.8%. By comparison, the average cost share of natural gas equaled 31.3%. The place of oil products in Saskatchewan's industrial energy use was similar to that found in Manitoba: an average quantity share of 13.9% and an average cost share of 19.6%. As far as propane is concerned, its average quantity share was 1.9% (compared to a peak value of 3.3%), while its average cost share equaled 3.3% (and reached its maximum at 6.6%).

(f) In *Alberta*, as in Saskatchewan, the primary fuel of choice of the industrial sector was natural gas. Indeed, its average quantity share was 68.5% and its *minimum* quantity share recorded between 1982 and 1996 exceeded the *maximum* quantity share of all other energy types considered. Nonetheless, the prices of the various energy types were such that the highest average cost share was recorded by electricity (at 52.3%). By comparison, the average cost share of natural gas stood at 27.8% (and peaked at 40.1%). During that period, oil products accounted on average for 8.0% of energy quantities and

16.5% of energy costs in Alberta's industrial sector. The quantity share of propane averaged 1.9% (and equaled 2.6% in 1996), while its average cost share was 3.5% (with a peak of 7.9% in 1996).

(g) For most of the period under consideration, electricity and natural gas accounted for similar shares of total energy quantities used by *British Columbia*'s industrial sector (average shares of 41.4% and 38.5%, respectively). By 1996, however, natural gas was outstripping electricity as an industrial energy source, with a quantity share of 47.1% (compared to 39.5% for electricity). Since electricity prices were higher than those for natural gas, the cost share of this energy type exceeded that for the latter, even by the end of the sample period (1996 cost shares of 66.4% for electricity and 14.1% for natural gas). Between 1982 and 1996, the quantity share of propane never rose above 2.1% (and stood at 0.6% in 1996), while its cost share peaked at 3.9% (compared to an average of 1.4% and a value of 1.8% in 1996).

(h) Between 1982 and 1996, natural gas was the primary energy type of choice in the industrial sector of Ontario, Saskatchewan, and Alberta. By the end of the sample period, this was also the case in British Columbia. In Quebec and Manitoba, electricity remains the industrial sector's primary energy type of choice. In the Atlantic region, electricity and oil products accounted for similar shares of industrial energy use, especially towards the end of the sample period. However, the prices of the various energy types were such that the highest cost share in every province/region was recorded by electricity. As far as propane is concerned, its *maximum* quantity and cost shares never exceeded the corresponding *minimum* shares of all other energy types considered in every province/region.

4.4 Commercial Sector (Tables 4.5 and 4.6)

(a) In the *Atlantic* region, both electricity and oil products were important sources of energy for commercial users, as was the case for that region's industrial sector. Over time, the relative importance of oil products fell, while that of electricity rose. Indeed, in 1996, the quantity share of electricity reached its peak value of 46.5% (against a 1982-1996 average of 38.8%) and the share of oil products in the total quantity of energy consumed by the commercial sector was 46.8%, its lowest value since 1982. In terms of total energy costs, the share of electricity exceeded that of oil products, by 54.1% to 42.7% on average (with even wider differences observed at the end of the sample period). In 1996, both the quantity share (6.7%) and the cost share (8.9%) of propane were at their peak values for the time period considered. On average during the sample period, propane was used to meet 4.0% of the energy requirements of this sector (with a corresponding average cost share of 3.2%).

(b) Electricity had the largest average quantity and cost shares of any energy type used in *Quebec*'s commercial sector – 44.5% and 56.2% respectively. The quantity share of oil products was lower at the end of the sample period than in 1982, while the reverse was true for the quantity share of natural gas. Overall, however, the average share of oil products still exceeded that for natural gas. The cost share of both of these energy types was, on average, much lower than that for electricity. On average during the sample period, propane accounted for 1.9% of the total quantity of energy used by the commercial sector and 1.8% of the corresponding cost. Note that the cost share was at its highest value in 1996 (3.4%).

(c) Natural gas was the primary fuel of choice in the commercial sector of *Ontario*: its average quantity share was 41.5% between 1982 and 1996. By comparison, the average quantity shares of electricity and oil products were 32.9% and 24.2%, respectively. However, price patterns for the various energy types were such that the average cost share of electricity (at 50.5%) exceeded that of the other two energy types. The average quantity share of propane was 1.4% between 1982 and 1996, while its corresponding cost share was 1.3%. Again, propane's cost share reached its peak in 1996 (3.6%).

(d) In *Manitoba*, natural gas was the primary fuel of choice in the commercial sector, with an average quantity share of 61.8% over the sample period. Electricity (average quantity share of 25.5%) and, to a lesser extent, oil products (average quantity share of 11.3%) also satisfied an important part of this sector's energy requirements. Again, between 1982 and 1996, the price of electricity was (relatively) high. As a result, the average cost share of this energy type (40.6%) exceeded that of both natural gas (38.2%) and oil products (19.0%), with these differences widening near the end of the sample period. Propane accounted for an average of 1.5% of total energy use, while its cost share averaged 2.2%. Again, the cost share of propane use in the commercial sector reached its peak value of 7.7% at the end of the sample period.

(e) Between 1982 and 1996, natural gas accounted for an average of 51.3% of all energy used by the commercial sector in *Saskatchewan*. The average quantity share of electricity was 30.2%, while that for oil products was 16.2%. Notable is the drop in the use of oil products, from a maximum quantity share of 35.0% to a minimum of 9.0% (and 9.5% in 1996). Nonetheless, energy price patterns were such that the highest average cost share was recorded by electricity (55.3%); by comparison that for natural gas equaled 20.8%. During the sample period, the quantity share of propane fluctuated between 1.6% and 2.9%, with an average value of 2.3%; its cost share never exceeded 3.5% (its value in 1996), and averaged 2.3%.

(f) The overall pattern of commercial energy use in *Alberta* was similar to that just described for Saskatchewan: the highest average quantity share was that of natural gas (58.2%), while electricity had, on average, the highest cost share (46.4%). Here again, the relative importance of oil products fell, but in a less pronounced manner than in Saskatchewan: by 1996, the average quantity share had dropped to 13.2% (from a peak value of 18.0%), while the cost share had fallen to 17.7% from its highest value of 33.7%. During the sample period, propane met as much as 10.1% of the energy requirements of Alberta's commercial sector, and accounted for as much as 14.2% of that sector's total spending on energy. On average, propane's quantity share equaled 3.9%, while its cost share was 5.2%.

(g) In *British Columbia*, electricity and natural gas were the two most important sources of energy for the commercial sector: the average quantity share for natural gas equaled 45.5% between 1982 and 1996, while that for electricity was 35.1%. The quantity share of oil products in 1996 (14.2%) was close to its sample average of 16.9%, as in Alberta. Again, the cost share of electricity exceeded that of the other energy types: on average, electricity accounted for 49.8% of the commercial sector's total energy spending, compared to averages of 24.8% and 22.5%, respectively, for natural gas and oil products. As far as propane is concerned, it accounted for 2.6% of energy use and 2.9% of energy spending by the sector between 1982 and 1996.

(h) Electricity and natural gas were the two most important sources of energy for commercial users in all provinces west of the Quebec-New Brunswick border. In the Atlantic region natural gas was not available for consumption, and oil products remained an important source of energy for the commercial sector. In the other provinces, the relative importance of oil products tended to fall, especially when energy price patterns are taken into account. As was the case with the industrial sector, in no province/region was the *maximum* share of propane (both quantity and cost) larger than the *minimum* share of any of the other energy types. It is notable, however, that both quantity and cost shares for propane were briefly above 10% for Alberta's commercial sector. Finally, for the commercial sector of every province/region, the cost share of propane was at its sample *maximum* in 1996.

4.5 The Role of Propane: An Overall Assessment

(a) Across all sectors and provinces/regions, the average share of propane in the total quantity of energy consumed varied from a minimum of 0.7% (Quebec, industrial) to a maximum of 3.9% (Alberta, commercial) over the course of our sample period. For all provinces/regions, with the exception of Manitoba, the highest average quantity share of propane occurred in the commercial sector, followed by the residential sector. On average, the share of propane in total energy use was lowest in the industrial sector. In Manitoba, the highest average quantity share for propane was found in the industrial sector, followed by those for commercial and residential uses. Only in Alberta, and then only in the residential sector, did the average share of propane use exceed that of any other energy type (specifically, oil products and wood). Further, only in Manitoba, Saskatchewan, and Alberta, and again only in the residential sector, did the *maximum* quantity share of propane exceed the *minimum* quantity share of any other energy type.

(b) As with quantities, Quebec and Alberta defined the bounds of propane's average cost share: for a low of 0.6% in Quebec's residential sector to 5.2% in Alberta/commercial. In contrast, the rankings of average cost shares across sectors were less uniform than was the case for the quantity shares, with the commercial sectors of four provinces/regions (Atlantic region, Quebec, Alberta, and British Columbia) providing the highest values. In Ontario, the average cost share of propane was highest in the residential sector, while it was at its largest value in the industrial sector of Manitoba and Saskatchewan. As with the quantity shares, only in Alberta's residential sector did the average cost share of propane exceed that of any other energy type (again, oil products and wood). This time, only in Ontario, Manitoba, Saskatchewan, and Alberta, and then only in the residential sector was the *maximum* cost share of propane larger than the *minimum* cost share of any other energy type.

Table 4.1 Share of Energy Type in Total *Quantity* of Energy Consumed, Residential Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane	Wood
Atlantic	*Average*	34.3		43.8	1.6	20.3
	Maximum	42.3		54.3	2.0	25.3
	Minimum	22.2	**	39.7	0.5	16.5
	1996 value	42.1		40.0	1.3	16.5
Quebec	*Average*	53.0	8.4	23.8	0.8	14.0
	Maximum	58.6	9.3	38.9	1.2	16.1
	Minimum	38.4	7.2	18.8	0.3	12.7
	1996 value	58.5	8.9	19.6	0.3	12.7
Ontario	*Average*	29.2	52.7	11.7	1.6	4.8
	Maximum	33.1	60.1	22.2	2.7	6.1
	Minimum	24.7	45.3	6.3	0.6	3.7
	1996 value	26.7	60.1	8.1	1.4	3.7
Manitoba	*Average*	35.7	52.3	4.5	1.3	6.3
	Maximum	39.5	54.7	11.6	3.3	8.0
	Minimum	28.1	48.1	1.5	0.3	5.6
	1996 value	37.1	54.7	2.0	0.3	5.9
Saskatchewan	*Average*	17.1	71.0	6.4	2.2	3.4
	Maximum	19.0	77.0	15.9	3.5	4.8
	Minimum	13.0	65.1	1.5	1.0	2.4
	1996 value	16.8	77.0	1.8	1.1	3.3
Alberta	*Average*	13.4	81.9	0.7	3.3	0.6
	Maximum	15.6	86.0	1.6	6.2	0.9
	Minimum	11.3	77.2	0.3	1.0	0.4
	1996 value	12.2	86.0	0.4	1.0	0.4
British Columbia	*Average*	34.9	48.3	7.9	1.7	7.1
	Maximum	37.8	54.7	15.7	2.8	9.8
	Minimum	31.5	42.9	3.1	0.8	4.3
	1996 value	36.6	54.7	3.2	0.8	4.7

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

Table 4.2 Share of Energy Type in Total *Cost* of Energy Consumed, Residential Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane	Wood
Atlantic	*Average*	56.4		32.0	1.3	10.2
	Maximum	68.5		48.5	1.8	13.9
	Minimum	37.2	**	23.6	0.4	6.2
	1996 value	66.6		25.3	1.8	6.2
Quebec	*Average*	66.5	5.4	18.4	0.6	9.1
	Maximum	75.3	6.6	35.9	1.1	11.4
	Minimum	46.8	4.3	11.0	0.3	7.5
	1996 value	75.3	5.1	11.8	0.4	7.5
Ontario	*Average*	54.0	30.7	10.8	1.5	2.9
	Maximum	64.9	37.2	23.2	2.7	4.4
	Minimum	37.3	25.9	5.0	0.4	2.1
	1996 value	59.9	28.7	6.9	2.3	2.3
Manitoba	*Average*	56.6	32.4	5.1	1.2	4.8
	Maximum	63.7	38.7	14.1	2.8	6.0
	Minimum	41.6	26.1	1.4	0.2	4.1
	1996 value	62.0	30.7	2.0	0.5	4.8
Saskatchewan	*Average*	43.0	42.5	8.1	2.7	3.7
	Maximum	49.8	45.3	22.3	4.4	4.9
	Minimum	27.6	39.3	1.7	1.3	2.5
	1996 value	49.4	42.6	2.1	2.4	3.5
Alberta	*Average*	38.1	55.6	1.2	4.4	0.7
	Maximum	46.7	60.4	3.0	7.7	1.0
	Minimum	30.7	49.6	0.5	1.4	0.5
	1996 value	40.6	55.3	0.7	2.7	0.6
British Columbia	*Average*	60.3	26.3	7.9	1.6	4.0
	Maximum	64.4	28.9	16.0	2.6	5.0
	Minimum	52.6	24.6	3.0	0.7	2.9
	1996 value	64.4	27.6	3.2	1.5	3.3

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

Table 4.3 Share of Energy Type in Total *Quantity* of Energy Consumed, Industrial Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane
Atlantic	*Average*	46.3	**	52.4	1.3
	Maximum	50.2		61.2	2.0
	Minimum	38.2		48.0	0.5
	1996 value	49.5		48.6	1.9
Quebec	*Average*	56.2	26.0	17.1	0.7
	Maximum	60.9	28.6	33.6	1.2
	Minimum	48.7	16.7	12.5	0.3
	1996 value	58.9	28.3	12.5	0.3
Ontario	*Average*	29.2	59.1	10.6	1.1
	Maximum	30.7	61.8	15.9	2.2
	Minimum	27.9	55.2	7.9	0.5
	1996 value	29.2	60.9	8.9	1.0
Manitoba	*Average*	44.8	38.2	14.7	2.3
	Maximum	57.7	47.4	20.1	4.0
	Minimum	33.5	26.0	11.9	0.7
	1996 value	54.2	32.8	12.2	0.8
Saskatchewan	*Average*	20.5	63.7	13.9	1.9
	Maximum	23.7	71.4	20.6	3.3
	Minimum	18.0	56.7	8.0	1.0
	1996 value	22.9	66.3	9.2	1.5
Alberta	*Average*	21.7	68.5	8.0	1.9
	Maximum	25.5	72.0	12.3	3.7
	Minimum	15.9	64.9	5.3	0.9
	1996 value	23.4	66.9	7.1	2.6
British Columbia	*Average*	41.4	38.5	19.3	0.9
	Maximum	45.9	47.1	27.6	2.1
	Minimum	37.6	33.6	12.4	0.5
	1996 value	39.5	47.1	12.8	0.6

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

Table 4.4 Share of Energy Type in Total *Cost* of Energy Consumed, Industrial Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane
Atlantic	*Average*	68.4		30.1	1.6
	Maximum	76.5		45.5	4.1
	Minimum	54.0	**	21.3	0.5
	1996 value	71.7		24.2	4.1
Quebec	*Average*	71.1	15.3	12.6	1.0
	Maximum	78.9	18.6	26.6	1.7
	Minimum	60.9	11.5	8.1	0.5
	1996 value	78.1	12.7	8.4	0.8
Ontario	*Average*	57.9	31.0	9.7	1.4
	Maximum	69.8	40.5	16.4	2.4
	Minimum	43.8	22.3	5.5	0.6
	1996 value	68.6	22.3	6.8	2.3
Manitoba	*Average*	59.4	20.5	17.1	3.0
	Maximum	73.6	33.9	27.5	5.8
	Minimum	39.1	10.5	11.5	1.0
	1996 value	72.3	12.8	12.9	2.0
Saskatchewan	*Average*	45.8	31.3	19.6	3.3
	Maximum	56.5	39.4	28.7	6.6
	Minimum	34.5	25.6	10.9	1.2
	1996 value	54.0	28.1	12.5	5.3
Alberta	*Average*	52.3	27.8	16.5	3.5
	Maximum	68.9	40.1	26.5	7.9
	Minimum	31.9	17.5	8.6	1.5
	1996 value	58.7	22.0	11.4	7.9
British Columbia	*Average*	60.9	15.4	22.3	1.4
	Maximum	69.5	20.4	31.7	3.9
	Minimum	47.3	11.5	15.8	0.5
	1996 value	66.4	14.1	17.7	1.8

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

Table 4.5 Share of Energy Type in Total *Quantity* of Energy Consumed, Commercial Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane
Atlantic	*Average*	38.8		57.2	4.0
	Maximum	46.5		71.6	6.7
	Minimum	25.6	**	46.8	2.7
	1996 value	46.5		46.8	6.7
Quebec	*Average*	44.5	25.4	28.3	1.9
	Maximum	48.6	31.2	45.3	3.4
	Minimum	39.1	13.7	21.8	1.3
	1996 value	43.6	31.2	23.2	2.0
Ontario	*Average*	32.9	41.5	24.2	1.4
	Maximum	36.3	47.8	29.0	2.4
	Minimum	25.6	37.6	20.5	0.6
	1996 value	35.3	40.1	22.2	2.4
Manitoba	*Average*	25.5	61.8	11.3	1.5
	Maximum	28.2	64.2	22.5	3.6
	Minimum	19.8	55.7	6.5	0.3
	1996 value	26.2	63.8	6.9	3.0
Saskatchewan	*Average*	30.2	51.3	16.2	2.3
	Maximum	39.5	56.2	35.0	2.9
	Minimum	17.2	45.1	9.0	1.6
	1996 value	33.7	54.9	9.5	2.0
Alberta	*Average*	24.6	58.2	13.3	3.9
	Maximum	28.6	63.8	18.0	10.1
	Minimum	17.2	52.4	11.7	1.6
	1996 value	27.5	52.4	13.2	6.9
British Columbia	*Average*	35.1	45.5	16.9	2.6
	Maximum	39.5	48.8	26.4	3.7
	Minimum	27.8	42.4	12.4	1.3
	1996 value	39.5	44.0	14.2	2.3

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

Table 4.6 Share of Energy Type in Total *Cost* of Energy Consumed, Commercial Sector (percent)‡

		Electricity	Natural Gas	Oil Products	Propane
Atlantic	*Average*	54.1		42.7	3.2
	Maximum	65.4		59.1	8.9
	Minimum	38.7	**	28.9	1.8
	1996 value	62.2		28.9	8.9
Quebec	*Average*	56.2	14.1	27.9	1.8
	Maximum	63.6	17.6	45.0	3.4
	Minimum	44.4	8.4	19.1	0.9
	1996 value	60.2	15.5	20.9	3.4
Ontario	*Average*	50.5	19.3	28.9	1.3
	Maximum	63.5	27.6	41.5	3.6
	Minimum	31.8	12.9	20.2	0.6
	1996 value	61.5	13.2	21.6	3.6
Manitoba	*Average*	40.6	38.2	19.0	2.2
	Maximum	50.4	45.3	35.3	7.7
	Minimum	23.3	31.6	10.3	0.4
	1996 value	47.3	33.7	11.2	7.7
Saskatchewan	*Average*	55.3	20.8	21.5	2.3
	Maximum	71.5	25.8	50.7	3.5
	Minimum	26.6	15.6	9.5	1.6
	1996 value	66.4	19.0	11.1	3.5
Alberta	*Average*	46.4	25.0	23.4	5.2
	Maximum	56.6	32.9	33.7	14.2
	Minimum	31.5	17.2	15.9	2.3
	1996 value	50.9	17.2	17.7	14.2
British Columbia	*Average*	49.8	24.8	22.5	2.9
	Maximum	57.6	28.0	35.6	4.8
	Minimum	36.4	20.2	14.8	1.6
	1996 value	57.4	20.2	17.6	4.8

‡ *Average*, *Maximum*, and *Minimum* refer to the annual values in the period 1982 to 1996. Percentages in each *Average* and *1996 value* row may not add to 100 due to rounding.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.

5. MODEL SPECIFICATIONS

5.1 General Remarks

(a) Three end-use sectors are considered: residential, industrial, and commercial. In the residential sector the end users are consumers, who are viewed as minimizing the expenditures necessary to attain a certain level of utility. In contrast, in the industrial and commercial sectors the end users of energy are firms or producers, who minimize the costs associated with producing a certain level of output. As a result, the expenditure functions for consumers depend on (unobserved) utility, while the cost equations for producers depend on the level of output. Hence, different specifications are typically used for these two types of functions. The following sub-sections contain details of the general form of the model used in the residential sector (consumers), and in the industrial and commercial sectors. Technical details are contained in the appendix.

5.2 Residential Sector

(a) Own-price and cross-price elasticities for different types of energy in the residential sector are obtained from a model of consumer demand for these various energy sources. Consumer expenditures on energy are treated as forming a separable sub-group, in that consumers allocate their total expenditure among energy and other goods in the first-stage of budgeting, and then allocate energy expenditures among the different energy types in the second stage of budgeting. With this two-stage budgeting procedure, expenditures on the different energy types (determined in the second stage) depend only on the prices of the different energy types and on total expenditure on energy (as well as on various conditioning variables discussed subsequently). In particular, the prices of other goods and consumer expenditures on non-energy goods are not relevant to the analysis.[2]

---

[2] See, for example, Angus Deaton and John Muellbauer (1980) *Economics and Consumer Behavior.* Cambridge: Cambridge University Press, pp. 127-137.

(b) Based on the assumption of cost-minimizing behaviour on the part of households, a system of energy expenditure share equations describing residential demand for the various energy sources is derived from the household's expenditure function. Here, the expenditure function that is used in the analysis yields the system of expenditure share equations known as the Almost Ideal Demand System (AIDS).[3] In view of the limited number of annual observations, to simplify the empirical analysis, the nonlinear price index (which depends on data and unknown parameters) that appears in these equations is replaced with a predetermined price index that depends only on data. The most common choice for this index, the Stone price index, is used here. The resulting system of expenditure share equations, known as the Linear Approximation to the Almost Ideal Demand System (LAIDS), has been frequently estimated in empirical consumer demand applications.[4]

(c) In energy demand analysis, it is common to make certain modifications to the above specification. First, it is often noted that complete consumer response to energy price changes (by substituting among different energy types) cannot occur instantaneously due to the need to change the type of capital equipment that is in place (such as the need to replace an oil furnace by a natural gas furnace before natural gas can be used in place of oil for space-heating purposes). As a result, only part of a consumer's desired response will occur in any period. To allow for the possibility of only partial adjustment by consumers in any period, the lagged (previous) value of the expenditure share for each energy type is included as an additional explanatory variable in the expenditure share equation for each energy type. As a result of the inclusion of this partial adjustment specification, consumer responses to energy price changes, and hence own-price and cross-price elasticities, may differ in the short run and in the long run.

(d) Another modification that is frequently made to the expenditure share equation formulation in the context of energy demand analysis is to extend the specification by

---

[3]Angus Deaton and John Muellbauer (1980) "An Almost Ideal Demand System", *American Economic Review*, vol. 70, no. 3, pp. 312-326.

[4] See, for example, Adolf Buse (1994) "Evaluating the Linearized Almost Ideal Demand System", *American Journal of Agricultural Economics*, vol. 76, no. 4, pp. 781-793.

including additional variables that may condition energy demands. Here, two additional variables are included. The first is a variable (ACCESS) that reflects the availability of natural gas, since no switch to this energy source can be made unless a distribution pipeline can be connected to the point of demand. The second is the number of heating degree-days (HDD), a weather-related variable that is designed to capture the changes in energy demands (especially for space-heating purposes) that are associated with colder weather.

5.3 Industrial and Commercial Sectors

(a) Own-price and cross-price elasticities for different types of energy in the industrial sector and in the commercial sector are obtained from a model of producer or firm demand for these various energy sources. As with the residential sector, energy is treated as forming a separable sub-group, in that producers allocate their total cost of producing a given level of output among energy and other inputs in the first-stage of budgeting, and then allocate energy expenditures among the different energy types in the second stage of budgeting. With this two-stage budgeting procedure in the producer context, expenditures on the different energy types (determined in the second stage) depend only on the prices of the different energy types (as well as on various conditioning variables discussed subsequently). In particular, the prices of other (non-energy) inputs are not relevant to the analysis. In addition, a necessary and sufficient condition for the validity of the two-stage budget allocation procedure for firms in the present context is that the equations describing the cost shares of each energy input do not depend on the level of output of the firm.[5]

(b) Based on the assumption of cost-minimizing behaviour on the part of firms, a system of energy expenditure share equations describing industrial or commercial demand for the various energy sources is derived from the firm's cost function for energy. Here, the transcendental logarithmic (translog) cost function is used in the analysis for both the

[5] See Melvyn Fuss (1977) "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", *Journal of Econometrics*, vol. 5, no.1, pp. 89-116.

industrial and commercial sectors.[6] The resulting system of expenditure share equations, known as the translog (input) cost share equations, has been estimated frequently in empirical studies of the demand by firms for inputs, including in the context of energy demand.[7]

(c) As in the residential sector, two modifications are made to the general translog cost share equation specification. First, to allow for the possibility of only partial adjustment by firms in any period, the lagged (previous) value of the expenditure share for each energy type is included as an additional explanatory variable in the cost share equation for each energy type. Thus, responses to energy price changes, and hence own-price and cross-price elasticities, may differ in the short run and in the long run. Second, energy demands are conditioned by including the variables ACCESS, which reflects the availability of natural gas, and HDD, the number of heating degree-days, which is designed to capture the effect of weather on energy demands.

---

[6]This functional form was introduced by L.R. Christensen, D.W. Jorgenson, and L.J. Lau (1971) "Conjugate Duality and the Transcendental Logarithmic Production Function", *Econometrica*, vol. 39, no. 4, pp. 255-256.

[7] See, for example, M. Fuss, R. Hyndman, and L. Waverman (1977) "Residential, Commercial, and Industrial Demand for Energy in Canada: Projections to 1985 with Three Alternative Models", pp. 151-179 in W.D. Nordhaus (ed.) *International Studies in the Demand for Energy*. Amsterdam: North-Holland; and Patricia Renou-Maissant (1999) "Interfuel Competition in the Industrial Sector of Seven OECD Countries", *Energy Policy*, vol. 27, no. 2, pp. 99-110.

6. ESTIMATION RESULTS

6.1 Econometric Considerations

(a) Additive stochastic error terms are appended to the share equations to allow for the likelihood that (even if the adjustment to the desired shares was instantaneous) observed shares and desired shares are not necessarily equal. These (unobserved) error terms on the different equations are likely to be correlated. Due to this feature and the cross-equation restrictions on the parameters (many parameters appear in more than one of the share equations), it is appropriate to estimate the system of share equations jointly. Since the actual shares sum to one, as do the estimated shares, the error terms on the system of cost share equations necessarily sum to zero, so that the system of equations is singular. This singularity is resolved in estimation by arbitrarily omitting one of the cost share equations, jointly estimating the remaining equations using a maximum likelihood procedure, and recovering estimates of the parameters of the omitted equation by using estimates of the other parameters in conjunction with the adding-up conditions. Provided estimation is by maximum likelihood, the results obtained will be invariant to the particular equation that is omitted.[8]

(b) For purposes of estimation, the prices of all energy types were normalized to equal one in 1991. In addition, in the residential sector, per capita expenditures on energy were also normalized to equal one in 1991.

(c) Due to the inclusion of lagged shares in the estimating equations, the actual data period used in the estimation is from 1983 to 1996, inclusive.

6.2 Elasticity Estimates

(a) Since the elasticities, both in the short run and in the long run, depend on data and the estimated parameters of the models, they differ for each year in the sample period (1983

[8] See A. Barten (1969) "Maximum Likelihood Estimation of a Complete System of Demand Equations", *European Economic Review*, vol. 1, no. 1, pp. 7-73.

to 1996). While the values of the elasticities from 1996 are the most recent, examination of the elasticity estimates for this year could be misleading, in that the values and significance of the elasticities may be changing throughout the sample period. To provide an indication of the variability involved, short-run and long-run elasticity estimates are provided for 1990 and 1996. All elasticity estimates are obtained using the estimated parameters from the models and the estimated cost or expenditure shares. The latter are obtained by substituting the estimated parameters and actual data into the cost or expenditure share equations for each energy type.

(b) The estimated elasticities are point estimates, and their value could frequently reflect variation (randomness) in the data rather than being indicative of the actual value of the elasticity. In order to provide some information on this aspect of the elasticity estimates, asymptotic standard errors are calculated for the elasticities, and a dagger (†) is used to denote those elasticities that are significantly different from zero at a 10% or higher level of significance. In the following discussion, attention is focussed on those elasticities that are significant.

6.3 Results

(a) Tables 6.1, 6.2, and 6.3 contain the estimated short-run and long-run elasticities of demand for various energy types in response to a change in the price of propane for each province/region in the residential, industrial, and commercial sectors, respectively. Thus, the values in these tables indicate the proportional change in the quantities consumed of the different energy types in response to a proportional change in the propane price. In general, positive cross-price elasticities indicate that two energy types are substitutes, since a rise in the price of one energy type induces an increase in the quantity consumed of the other. Conversely, negative cross-price elasticities indicate that two energy types are complements.

6.3.1 Residential Sector (Table 6.1)

(a) In the residential sector, significant own-price elasticities for propane are only found in Quebec in both years for which results are presented and in Manitoba in 1990. The estimated elasticities in Manitoba in 1996 have similar values to those in 1990, but they are no longer significant. In both these provinces these significant own-price elasticities are negative. However, those in Quebec are much larger than in Manitoba. In Quebec, the values of approximately –1.5 in 1990 and approximately –4 in 1996 indicate that propane demand is quite elastic, so that a proportional increase in the propane price will result in a more than proportional decrease in the quantity of propane demanded. In Manitoba the elasticities in 1990 are approximately -0.8, so that the proportional decrease in propane quantity is smaller than the proportional increase in the propane price.

(b) The cross-price elasticities are generally small in all provinces, with only approximately 5% of the values in Table 6.2 exceeding 0.4 in magnitude. The only relatively large cross-price elasticities are for oil products in Saskatchewan (approximately 0.5 in 1990 and 1.5 in 1996) and wood in British Columbia in 1996 (approximately –0.5). In both these cases the cross-price elasticities are significant, indicating that propane and oil products are substitutes in Saskatchewan, while wood and propane are complements in British Columbia.

(c) Significant cross-price elasticities between electricity and propane occur only in the Atlantic region and in Saskatchewan. In both these cases the elasticities are negative, so that electricity and propane are viewed as complements. However, these elasticities in the Atlantic region are considerably smaller than the corresponding elasticities in Saskatchewan, although even the latter do not exceed –0.15 in magnitude.

(d) Natural gas and propane are found to have significant cross-price elasticities in Quebec and in Alberta, and in both these cases these two energy types are complements. In Quebec these elasticities are approximately –0.3, while in Alberta they are approximately –0.06. Hence, even though the elasticities are significant, the extent of the response in natural gas demand to a change in the propane price is relatively small.

(e) In terms of the significant cross-price elasticities between propane and oil products, oil appears to be a substitute for propane in both the short run and the long run in Quebec and Saskatchewan, but a complement in British Columbia. The sizes of these cross-price elasticities are quite different in the three provinces – approximately 0.2 in Quebec, -0.4 in British Columbia, and 1.5 in Saskatchewan in 1996, although all these elasticities were smaller in 1990. Thus, apart from Saskatchewan in 1996, demand for oil products is relatively inelastic with respect to a change in the price of propane.

(f) Wood is a substitute for propane in the Atlantic region, but a complement in Manitoba and British Columbia. In all other provinces, these cross-price elasticities between wood and propane are insignificant. The largest of the significant cross-price elasticities for wood occur in Alberta, where the short-run value in 1996 is –0.519.

(g) In the Atlantic region, the only significant elasticities are the cross-price elasticities for electricity (negative) and for wood (positive). Thus, wood is a substitute while electricity is a complement for propane, although none of these cross-price elasticities exceed 0.4 in magnitude. The own-price elasticity of propane is insignificant in both years in both the short run and long run.

(h) Both natural gas and wood have significant cross-price elasticities in Quebec, with natural gas being a complement for propane and oil products a substitute. While all of these significant cross-price elasticities are also smaller than 0.4 in magnitude, the propane own-price elasticities in Quebec are very large, especially in 1996. The next largest own-price elasticities in this year are in Saskatchewan, and these have values that are approximately one-quarter the size of those in Quebec.

(i) None of the own-price or cross-price elasticities with respect to propane is significant in Ontario.

(j) In Manitoba, the only significant cross-price elasticities are with respect to wood, which is found to be a complement with propane. However, these elasticities are all less than -0.25 in magnitude, so that the effect of an increase in the price of propane on the demand for wood is relatively small. The own-price elasticities for propane in this province are significant in 1990, with values of approximately –0.8.

(k) Although the own-price elasticities of propane are not significant in Saskatchewan, significant cross-price elasticities are found for both electricity (a complement) and for oil products (a substitute). These cross-price elasticities for electricity in Saskatchewan are much larger than those found in any other province/region, although they are all less than –0.15 in magnitude. As noted previously, the cross-price elasticities for oil products in Saskatchewan are also very large relative to the values found in other provinces. In 1996 these elasticities exceed 1.4, indicating that a one percent increase in the price of propane will result in a greater than one percent increase in the quantity of oil products that is demanded.

(l) The only significant elasticities in Alberta are the cross-price elasticities for natural gas. However, these elasticities are very small (approximately –0.06), so that while natural gas and propane are found to be complements, the extent of this complementarity is extremely small.

(m) In British Columbia, both wood and oil products are found to be complements with propane. In 1996 both these cross-price elasticities are approximately –0.4, so that a one percent increase in the price of propane will result in a decrease in demand for wood and in demand for oil products of 0.4 percent. In common with the majority of the provinces, the own-price elasticity of propane in British Columbia's residential sector is not significant.

(n) To summarize, the elasticities of energy types with respect to the price of propane are relatively small in most provinces/regions, and are significant in approximately 33% of the cases presented. The only cross-price elasticities that are larger than one occur in

Saskatchewan for oil products. Almost all other cross-price elasticities are less than 0.4 in magnitude. Own-price elasticities for propane are only significant in Quebec and in Manitoba in 1990. In Quebec, these elasticities are very large, especially in 1996, indicating that demand for propane is very elastic in the residential sector. However, even in this province, the extent of substitution that occurs when the price of propane rises is relatively small. Overall, these results suggest that in the residential sector, especially outside Quebec, there is relatively little responsiveness in terms of consumption of alternative energy types when the price of propane changes

6.3.2 Industrial Sector (Table 6.2)

(a) Own-price elasticities of propane are only significant in Ontario, Alberta, and Quebec. In Alberta these elasticities are negative, and larger than one in magnitude, so that a one percent increase in the price of propane in Alberta will reduce propane consumption by approximately one percent. This price responsiveness appears to have decreased in the period 1990 to 1996. In Ontario the corresponding own-price elasticities are approximately -0.4, while in Quebec they are positive and larger than one in magnitude. At face value, this indicates that an increase in the price of propane in Quebec would increase usage of propane. In the Atlantic region and in British Columbia in 1996, and in Manitoba in 1990, these own-price elasticities are negative, but not significant.

(b) In general, the cross-price elasticities are small, with only 10% of the values in Table 6.2 having magnitudes that exceed 0.4. This indicates that an increase in the price of propane typically has only a small effect on the quantities consumed of the other energy types. The largest cross-price elasticities occur in Manitoba, where an increase in the price of propane will cause a reduction in consumption of natural gas, suggesting that these two energy types are complements.

(c) Focusing on the significant cross-price elasticities between propane and electricity, electricity appears to be a substitute for propane in both the short run and the long run in Ontario and Saskatchewan in 1990 and 1996, and also in Manitoba in 1990. In addition, the short-run elasticity is significant and positive in Quebec in 1996, while the long-run elasticity is significant and negative in Alberta in 1990. However, in all these cases the cross-price elasticities are very small, with the largest values (0.109 and 0.114) occurring in Saskatchewan. Thus, even though there is significant substitution between propane and electricity in these provinces at these times (or complementarity in Alberta in 1990), the magnitude of the substitution (complementarity) is quite small.

(d) In terms of the significant cross-price elasticities between propane and natural gas, natural gas appears to be a complement for propane in both the short run and the long run in Ontario, Manitoba, and Saskatchewan, but a substitute in Alberta. In Alberta these elasticities are approximately –0.1, so that a 1% increase in the price of propane will cause a 0.1% increase in the quantity of natural gas consumed. In Ontario the elasticities have a similar magnitude (but opposite sign), while they are much larger in Saskatchewan and particularly in Manitoba. However, even in Manitoba these elasticities are less than one, so that the proportional quantity response in natural gas demand is smaller than the proportional price change in propane.

(e) Propane appears to be a substitute for oil products in Manitoba, Alberta, and British Columbia, where the cross-price elasticities of oil products with propane are positive and significant. Again, these elasticities are relatively small, ranging from approximately 0.15 in British Columbia in 1990, to approximately 0.5 in Alberta in 1996. The corresponding elasticities in Quebec are negative and much larger in the long run than in the short run, indicating that propane and oil products are complements in this province.

(f) In the Atlantic region, none of the own-price or cross-price elasticities of propane are significant in either 1990 or 1996, in either the long run or the short run. Thus, increases in the price of propane do not appear to have significant effects on the quantities consumed of any energy type, including propane, in this region.

(g) In Quebec, an increase in the price of propane appears to induce an increase in consumption of propane and a reduction in consumption of oil products. In addition, the quantity of electricity consumed increases in the short run when the propane price rises. However, this effect is very small.

(h) An increase in the price of propane reduces propane consumption in Ontario, and tends to be associated with an increase in electricity consumption and a reduction in natural gas consumption. These effects tend to be very small, in that a one percent price increase in propane will induce less than a 0.2 percent change in the consumption of each of these other energy types.

(i) Electricity (in 1990) and oil products (in both years) are substitutes for propane in Manitoba, while natural gas is a complement. In addition, there is no significant change in propane consumption in response to an increase in its own price. Similar results hold in Saskatchewan, except that the cross-price elasticity of oil products with respect to propane is insignificant.

(j) Alberta has the largest negative response of propane consumption to a change in the price of propane. Here, both natural gas and oil products are substitutes, with oil products having much larger cross-price elasticities, although they are generally less than 0.5.

(k) In British Columbia, the only significant cross-price elasticity occurs for oil products. These are found to be substitutes for propane, although the size of the elasticity is only approximately 0.2. An increase in the price of propane has no significant effect on consumption of propane, electricity, or natural gas.

(l) In summary, the elasticities of energy types with respect to the price of propane are relatively small in most provinces/regions, and are significant in about 50% of the cases presented. None of the cross-price elasticities exceed one in magnitude, although the own-price elasticities of propane do exceed this value in Alberta and in Quebec. However, in Quebec these own-price elasticities have an unexpected positive sign. Overall, these results suggest that in the industrial sector, there is relatively little responsiveness in terms of consumption of alternative energy types when the price of propane changes.

6.3.3 Commercial Sector (Table 6.3)

(a) In all regions, and in both the short run and the long run (except for the Atlantic region in the long run), own price elasticities are negative and significant in 1996 in the commercial sector. Few of these own-price elasticities are significant in 1990, but most are still negative. Thus, in 1996, increases in the price of propane will cause a significant reduction in the quantity of propane consumed. However, despite the significance of this reduction in consumption, the size of the reduction is still relatively small. In Manitoba in 1996 these own-price elasticities have values close to 1.1, so that a one percent increase in the price of propane will result in a reduction in the quantity consumed of 1.1 percent. In all other regions in 1996, these own-price elasticities lie in the range –0.5 to –0.7. Thus demand for propane is generally inelastic (or not very responsive to own-price changes).

(b) Cross-price elasticities are generally small, with the largest value being 0.59, and only two values exceeding 0.33. Hence, an increase in the price of propane generally has only a small effect on the quantities consumed of other energy types. As with the industrial sector, the largest cross-price elasticities occur in Manitoba, where the quantities of oil products increase significantly when the propane price increases.

(c) In terms of cross-price elasticities of electricity with respect to the propane price, only the elasticities in Manitoba in 1990 and in British Columbia are significant. Both are small (less than 0.1), although they are positive in British Columbia, indicating that propane and electricity are substitutes, but negative in Manitoba, suggesting complements.

(d) Propane appears to be a substitute for natural gas in the commercial sector in Quebec and Alberta in both 1990 and 1996, and in Manitoba and Saskatchewan in 1996. In Quebec and Alberta in 1996 these elasticities are in the range 0.2 to 0.3, whereas their values of approximately 0.1 in Manitoba and Saskatchewan are much smaller. These cross-price elasticities of natural gas with respect to the propane price have similar significant (absolute) values (0.2 to 0.3) in Ontario, but here these elasticities are negative, indicating that natural gas and propane are complements.

(e) Propane appears to be a substitute for oil products in both Manitoba and Ontario, although the relevant cross-price elasticities are much larger in Manitoba than in Ontario. In all other provinces/regions, these cross-price elasticities of oil products with respect to the propane price are insignificant, except in British Columbia in 1990, where they are negative.

(f) In the Atlantic region, none of the cross-price elasticities are significant. In addition, the own-price elasticity of propane is only significant in the short run in 1996. Thus, as with the industrial sector, increases in the price of propane appear to have no significant effects on the quantities consumed of any energy type in this region.

(g) The own-price elasticities of propane are significant in Quebec in 1996, and have values close to –0.5. Thus a one percent increase in the propane price will result in a 0.5 percent decrease in propane consumption. This propane price increase will also lead to a significant increase in natural gas consumption.

(h) In Ontario the own-price elasticities of propane are significant in 1996, and have similar values to those for Quebec. In this province, all cross-price elasticities are significant in 1996. Thus, an increase in the propane price will result in increases in consumption of electricity and oil products, but decreases in consumption of natural gas. Here, the electricity cross-price elasticities are very small (0.02), while those for natural gas are the largest in absolute value (-0.2). In all these cases, the percentage change in consumption of these other energy types is very small, with a one percent change in the price of propane resulting in less than a 0.2 percent change in consumption of any other energy type.

(i) Natural gas and oil products are both substitutes for propane in Manitoba, with oil products having by far the largest cross-price elasticity. However, even these cross-price elasticities for oil products are less than 0.6. The own-price elasticities for propane in Manitoba are the largest for any province, and indicate that demand for propane in this province has close to a unitary elasticity.

(j) Both Saskatchewan and Alberta have a similar pattern of own-price and cross-price elasticities in 1996 to that observed in Quebec. Own-price elasticities lie in the range –0.6 to –0.7, while the only significant cross-price elasticities are for natural gas, which is a substitute for propane. While these cross-price elasticities for natural gas in Alberta are similar to those in Quebec (0.2 to 0.3), those in Saskatchewan are much smaller, at approximately 0.1. Thus, an increase in the price of propane has a significant, but relatively small, positive effect on the demand for natural gas.

(k) In British Columbia, the own-price elasticity for propane has a similar value to the other provinces/regions, but the only significant cross-price elasticity is for electricity. This cross-price elasticity is positive, indicating that electricity and propane are substitutes, but it is very small (approximately 0.07). An increase in the price of propane has no significant effect on the demand for either natural gas or oil products in 1996, although oil products are found to be a complement for propane in 1990.

(l) In summary, the own-price elasticities of propane in the commercial sector are generally negative and significant in 1996, although they are all less than one, except for Manitoba which has own-price elasticities that just exceed this value. Almost one-half of the cross-price elasticities in Table 6.3 are significant in 1996, indicating that an increase in the propane price does have significant effects on the demand for other energy types. However, the cross-price elasticities are all less than 0.6, and are mainly less than 0.3, so that the effect of propane price increases on the quantities consumed of these other energy types is relatively small.

6.3.4 Overview

(a) All in all, in about 35% of the cases considered, the own-price elasticity of propane is negative and significant, while it is positive and significant in fewer than 4% of the cases. In all other situations considered, no significant relationship between the quantity demanded of propane and its price can be detected in the data. This suggests that, in general, a change in the price of propane will lead to smaller-than-proportional reductions in propane consumption – propane demand is thus relatively inelastic.

(b) With a few exceptions, this result holds for both 1990 and 1996, for both short and long run, in all provinces/regions, and across the three end-use sectors considered. In the case of Quebec/industrial, own-price elasticities have an unexpected positive sign, suggesting that propane prices and consumption move in the same direction. In Quebec/residential, Alberta/industrial, and Manitoba/commercial, these elasticities vary between –1.1 and –4.6, indicating that the induced consumption changes are proportionally greater than the propane price changes that initiated them.

(c) As far as cross-price elasticities are concerned, statistically significant responses to propane price changes were identified in approximately 45% of the cases considered, with substitution relationships outnumbering complementarity by a factor of about two-to-one, especially in the industrial and commercial sectors. In the remaining cases, changes in propane prices did not give rise to statistically significant changes in consumption of the other energy types.

(d) As far as individual energy types are concerned, electricity and oil products tend to be substitutes for propane in the industrial and commercial sectors, while natural gas generally acts as a propane substitute in the commercial sector and as a complement in the industrial sector. In the residential sector, electricity, natural gas, and wood tend to emerge as complements to propane, while oil products are substitutes. Note, however, that there are exceptions to these generalizations: for example, natural gas in Alberta/industrial (a propane substitute) and in Ontario/commercial (a complement); oil products in Quebec/industrial and British Columbia/residential (complements); and wood in Atlantic/residential (a propane substitute).

(e) With the exception of oil products in Saskatchewan/residential and Quebec/industrial (and then only in 1996 for both), all cross-price elasticities reported in Tables 6.1, 6.2, and 6.3 are less than one in absolute value. Indeed, in only two additional cases (Manitoba/industrial, natural gas in 1996) do cross-price elasticities exceed 0.6 in absolute value. Changes in propane prices thus tend to induce proportionally smaller changes in consumption of other energy types.

(f) Waverman (1992, p.23)[9] suggests that: "...substantial substitution possibilities should only be considered at [cross-price elasticities] of 1.0 at a minimum." Otherwise, individual energy types should be treated as belonging to separate markets (Waverman 1992, p.25). In view of the predominant finding in this report of low cross-price elasticities between propane and other energy types, application of this rule-of-thumb would lead to the conclusion that propane and other energy types form separate markets in the provinces/regions of Canada.

[9] Leonard Waverman (1992) "Econometric Modelling of Energy Demand: When Are Substitutes Good Substitutes?", pp. 7-28 in David Hawdon (ed.) *Energy Demand: Evidence and Expectations*. London: Surrey University Press.

Table 6.1 Price Elasticities of Demand, Residential Sector *(variations in propane prices)*‡

		1990 Short-run	1990 Long-run	1996 Short-run	1996 Long-run
Atlantic	*Propane*	-0.118	-0.091	-0.001	0.040
	Electricity	-0.057†	-0.061†	-0.049†	-0.052†
	Natural Gas	**	**	**	**
	Wood	0.251†	0.270†	0.352†	0.380†
	Oil Products	-0.017	-0.018	-0.020	-0.021
Quebec	*Propane*	-1.568†	-1.546†	-4.485†	-3.805†
	Electricity	-0.015	-0.013	-0.012	-0.010
	Natural Gas	-0.279†	-0.245†	-0.324†	-0.281†
	Wood	0.066	0.057	0.078	0.066
	Oil Products	0.157†	0.137†	0.225†	0.196†
Ontario	*Propane*	-0.002	0.060	-0.280	-0.200
	Electricity	-0.022	-0.026	-0.023	-0.027
	Natural Gas	-0.034	-0.041	-0.027	-0.032
	Wood	-0.148	-0.182	-0.147	-0.172
	Oil Products	0.124	0.150	0.140	0.156
Manitoba	*Propane*	-0.777†	-0.859†	-0.568	-0.672
	Electricity	-0.008	-0.006	-0.007	-0.005
	Natural Gas	0.042	0.030	0.043	0.030
	Wood	-0.249†	-0.172†	-0.218†	-0.159†
	Oil Products	0.017	0.011	-0.029	-0.023
Saskatchewan	*Propane*	0.162	0.187	0.474	0.531
	Electricity	-0.141†	-0.150†	-0.125†	-0.133†
	Natural Gas	-0.015	-0.016	-0.016	-0.017
	Wood	-0.019	-0.021	0.014	0.015
	Oil Products	0.549†	0.582†	1.444†	1.511†
Alberta	*Propane*	-0.008	0.055	0.243	0.354
	Electricity	-0.010	-0.012	-0.014	-0.015
	Natural Gas	-0.063†	-0.071†	-0.062†	-0.069†
	Wood	0.125	0.143	0.149	0.172
	Oil Products	-0.019	-0.021	-0.043	-0.050
British Columbia	*Propane*	0.103	0.010	0.200	0.012
	Electricity	0.013	0.010	0.013	0.010
	Natural Gas	-0.001	-0.001	-0.004	-0.003
	Wood	-0.361†	-0.292†	-0.519†	-0.418†
	Oil Products	-0.196†	-0.152†	-0.437†	-0.360†

‡ Each entry shows the proportional change in the use of the energy type in that row due to a proportional change in the price of propane.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.
† Indicates that the elasticity is significantly different from zero at a 10% or better level of significance.

Table 6.2 Price Elasticities of Demand, Industrial Sector *(variations in propane prices)*‡

		1990 Short-run	1990 Long-run	1996 Short-run	1996 Long-run
Atlantic	*Propane*	0.124	0.171	-0.362	-0.343
	Electricity	-0.019	-0.021	-0.002	-0.004
	Natural Gas	**	**	**	**
	Oil Products	0.038	0.039	0.056	0.058
Quebec	*Propane*	0.956	2.220†	1.171†	2.626†
	Electricity	0.035†	0.077	0.032†	0.068
	Natural Gas	-0.103	-0.333	-0.143	-0.487
	Oil Products	-0.190†	-0.569†	-0.296†	-1.078†
Ontario	*Propane*	-0.400†	-0.533†	-0.307	-0.434†
	Electricity	0.065†	0.054†	0.056†	0.046†
	Natural Gas	-0.135†	-0.089†	-0.185†	-0.124†
	Oil Products	0.109	0.085	0.134	0.105
Manitoba	*Propane*	-0.120	-0.082	0.359	0.404
	Electricity	0.059†	0.059†	0.037	0.037
	Natural Gas	-0.609†	-0.713†	-0.793†	-0.905†
	Oil Products	0.270†	0.287†	0.331†	0.359†
Saskatchewan	*Propane*	0.141	0.177	0.141	0.198
	Electricity	0.109†	0.114†	0.105†	0.109†
	Natural Gas	-0.323†	-0.364†	-0.292†	-0.327†
	Oil Products	0.122	0.131	0.165	0.176
Alberta	*Propane*	-1.442†	-1.480†	-1.138†	-1.155†
	Electricity	-0.049	-0.057†	0.002	-0.005
	Natural Gas	0.101†	0.107†	0.157†	0.164†
	Oil Products	0.297†	0.319†	0.475†	0.502†
British Columbia	*Propane*	0.262	0.124	-0.476	-0.507
	Electricity	-0.022	-0.018	-0.002	0.001
	Natural Gas	-0.189	-0.166	-0.215	-0.184
	Oil Products	0.163†	0.147†	0.227†	0.207†

‡ Each entry shows the proportional change in the use of the energy type in that row due to a proportional change in the price of propane.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.
† Indicates that the elasticity is significantly different from zero at a 10% or better level of significance.

Table 6.3 Price Elasticities of Demand, Commercial Sector *(variations in propane prices)*‡

		1990 Short-run	1990 Long-run	1996 Short-run	1996 Long-run
Atlantic	*Propane*	-0.052	0.720	-0.475†	-0.077
	Electricity	-0.022	-0.166	0.027	-0.100
	Natural Gas	**	**	**	**
	Oil Products	0.034	-0.012	0.073	-0.002
Quebec	*Propane*	-0.036	0.404	-0.596†	-0.437†
	Electricity	-0.030	-0.055	-0.008	-0.034
	Natural Gas	0.199†	0.310†	0.207†	0.291†
	Oil Products	-0.042	-0.077	-0.028	-0.073
Ontario	*Propane*	-0.169	-0.061	-0.558†	-0.515†
	Electricity	0.006	0.003	0.025†	0.023†
	Natural Gas	-0.202†	-0.252†	-0.218†	-0.269†
	Oil Products	0.096†	0.111†	0.137†	0.155†
Manitoba	*Propane*	-2.172†	-2.289	-1.141†	-1.152†
	Electricity	-0.086†	-0.093†	-0.028	-0.034
	Natural Gas	0.031	0.032	0.086†	0.087†
	Oil Products	0.291†	0.309†	0.558†	0.589†
Saskatchewan	*Propane*	-0.568†	-0.644†	-0.645†	-0.700†
	Electricity	-0.031	-0.017	-0.019	-0.005
	Natural Gas	0.094	0.077	0.103†	0.088†
	Oil Products	0.095	0.078	0.138	0.114
Alberta	*Propane*	-0.283	-0.440	-0.652†	-0.722†
	Electricity	-0.086	-0.048	0.015	0.044
	Natural Gas	0.208†	0.160†	0.330†	0.272†
	Oil Products	-0.003	0.008	0.045	0.067
British Columbia	*Propane*	-0.362	-0.302	-0.625†	-0.601†
	Electricity	0.049†	0.051	0.067†	0.068†
	Natural Gas	0.070	0.073	0.096	0.100
	Oil Products	-0.136†	-0.149†	-0.187	-0.205

‡ Each entry shows the proportional change in the use of the energy type in that row due to a proportional change in the price of propane.
** The absence of natural gas distribution systems in the Atlantic region means that this energy type is not available for consumption in that region.
† Indicates that the elasticity is significantly different from zero at a 10% or better level of significance.

7. SUMMARY

(a) For the period 1982 to 1996, we assembled annual data pertaining to the prices and quantities of the various energy types used in the residential, industrial, and commercial sectors of the provinces/regions of Canada. Analysis could not be extended prior to or beyond this period due to lack of available data.

(b) These data revealed that the shares of propane in the total quantity of energy consumed in each sector, and in the corresponding sectoral expenditures on energy, were relatively small in all provinces/regions. Indeed, in only a few cases (notably Alberta/residential), was the *maximum* average quantity or cost share of propane larger than the corresponding *minimum* share of all other energy types.

(c) Models of the inter-related demands for the various energy types were estimated for each sector in each province/region. Although data limitations affect the choice of specifications for these models, as well as the results, the approaches employed here have been widely used in the energy demand literature. The estimated parameters of these models were then used to calculate, for 1990 and 1996, own- and cross-price elasticities resulting from changes in propane prices.

(d) In general, the statistically significant own-price elasticities of the demand for propane were small, thus indicating that a change in propane prices induced a less-than-proportional variation in propane consumption, which suggests that propane demand was relatively inelastic in those years.

(e) Cross-price elasticities identified both substitution and complementarity relationships between propane and other energy types. In almost cases, however, the statistically significant elasticities were well below one (in absolute value). This suggests that there were limited substitution possibilities between propane and other energy types – a change in the price of propane generally induced proportionally much smaller changes in the demand for other energy types. If a characterization proposed by Waverman (1992) is applied to the cases examined in this report, the predominant finding of low cross-price elasticities between propane and other energy types would lead to the conclusion that propane and other energy types form separate markets in the provinces/regions of Canada.

APPENDIX

This appendix contains technical details pertaining to the models specified in section 5.

A1. Residential Model

A1.1 System of Expenditure Share Equations

Analysis for the residential sector is based on the expenditure function (for energy) that yields the Almost Ideal Demand System (AIDS):[1]

$$\text{(A1.1.1)} \qquad \ln E = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln p_i \ln p_j + u\beta_0 \prod_{j=1}^{n} p_j^{\beta_j}$$

where $\beta_{ij} = \beta_{ji}$, $i, j = 1, \ldots, n$, and where:

n is the number of different types of energy sources,

p_i is the price of the ith alternative energy source (i = 1, …, n),

u is the household's level of utility,

E is per-capita expenditure on energy,

and α_0, β_0, α_i $(i = 1, \ldots, n)$, β_i $(i=1, \ldots, n)$ and β_{ij} $(i, j = 1, \ldots, n)$ are unknown parameters.

Expenditure (or budget) share equations for each energy type are derived from the expenditure function using Shephard's lemma,[2] whereby $s_i = p_i x_i / E$, the budget share of the ith alternative energy source, is obtained as $s_i = \partial \ln E / \partial \ln p_i$, (i = 1, …, n), where x_i is the quantity of the ith energy type. This yields the following set of budget share equations (the AIDS model):

$$\text{(A1.1.2)} \qquad s_i = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \beta_i \ln(E/P) \qquad\qquad i = 1, \ldots, n,$$

where P is a price index defined by:

$$\text{(A1.1.3)} \qquad \ln P = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln p_i \ln p_j \ .$$

---

[1] Angus Deaton and John Muellbauer (1980) "An Almost Ideal Demand System", *American Economic Review*, vol. 70, no. 3, pp. 312-326.

[2] See W.E. Diewert (1974) "Applications of Duality Theory", pp. 106-171 in M.D. Intriligator and D.A. Kendrick (eds.) *Frontiers of Quantitative Economics*, vol II. Amsterdam: North Holland.

To simplify the empirical analysis, the nonlinear price index in (A1.1.3) is replaced by the Stone price index, defined as:

(A1.1.4) $$\ln P^* = \sum_{k=1}^{n} s_k \ln p_k$$

This yields the Linear Approximation to the AIDS model (LAIDS), for which the set of budget share equations has the form:

(A1.1.5) $$s_i = \alpha_i^* + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \beta_i \ln(E/P^*) \qquad i = 1, \ldots, n,.$$

where ln P^* in (A1.1.4) can be calculated prior to estimation. Since the budget shares sum to one ($\sum_{i=1}^{n} s_i = 1$), there are various (adding-up) conditions (corresponding to the conditions required for the expenditure function (A1.1.1) to be linearly homogeneous in prices) that the parameters must satisfy:

(A1.1.6.1) $$\sum_{i=1}^{n} \alpha_i^* = 1,$$

(A1.1.6.2) $$\sum_{i=1}^{n} \beta_i = 1, \qquad \text{and}$$

(A1.1.6.3) $$\sum_{i=1}^{n} \beta_{ij} = 0 \quad (j = 1, \ldots, n) \text{ which, since } \beta_{ij} = \beta_{ji} \quad (i, j = 1, \ldots, n), \text{ implies that}$$

$$\sum_{j=1}^{n} \beta_{ij} = 0 \quad (i = 1, \ldots, n).$$

A partial adjustment mechanism is incorporated, so that in any period *t*, actual shares, s_{it}, only adjust partially from their value in the previous period, s_{it-1}, to their new desired level in period *t*, s_{it}^*. Thus,

(A1.1.7) $$s_{it} - s_{it-1} = \theta_i (s_{it}^* - s_{it-1}), \qquad 0 \le \theta_i \le 1.$$

Here θ_i is the adjustment parameter, which reflects the speed of adjustment towards the new desired share. If $\theta_i = 1$, $s_{it} = s_{it}^*$, so that adjustment is instantaneous. If $\theta_i = 0$, $s_{it} = s_{it-1}$, so that no adjustment occurs. If $0 < \theta_i < 1$, partial adjustment to the new desired level occurs in period *t*. To allow for this partial adjustment, and hence different short-run and long-run responses to a price change, equation (A1.1.5) is viewed as representing the desired share in period *t*, and is substituted in equation (A1.1.7). Rearranging this equation (and redefining the parameters to include the partial adjustment coefficient θ) yields the following budget share equations:

$$\text{(A1.1.8)} \qquad s_{it} = \alpha_i^* + \sum_{j=1}^{n} \beta_{ij} \ln p_{jt} + \beta_i \ln(E_t / P_t^*) + \lambda_i s_{it-1}, \qquad i = 1, \ldots, n,$$

where $\lambda_i = 1 - \theta_i$. In this formulation, each share adjusts partially to its own desired level, but is not directly affected by adjustments taking place in the other shares. Again the parameters must satisfy the adding-up conditions in (A1.1.6.1) to (A1.1.6.3), except that (A1.1.6.1) is now replaced by:

$$\text{(A1.1.6.1a)} \qquad \sum_{i=1}^{n} \alpha_i^* + \lambda = 1,$$

where:

$$\text{(A1.1.6.4)} \qquad \lambda_i = \lambda \quad (i = 1, \ldots, n).$$

Thus, due to the adding-up conditions, with this partial adjustment specification it is necessary that the rate of adjustment be the same for each energy source (the parameter λ_i must have the same value in each budget share equation).

A time trend, *t*, is incorporated in these budget share equations to allow for the possibility of technological change. In addition, the budget share formulation in (A1.1.8) is modified to allow for the inclusion of the variables *ACCESS* and *HDD*. These three modifications yield the following system of budget share equations:

$$\text{(A1.1.9)} \qquad s_{it} = \alpha_i^* + \sum_{j=1}^{n} \beta_{ij} \ln p_{jt} + \beta_i \ln(E_t / P_t^*) + \gamma_{it}\, t + c_i \ln HDD_t + d_i\, ACCESS_t + \lambda s_{it-1},$$

$$i = 1, \ldots, n,$$

where *ACCESS* is the proportion of the population who have access to natural gas,

HDD is the number of heating degree-days,

t is a time trend,

and γ_{it} $(i = 1, \ldots, n)$, c_i $(i = 1, \ldots, n)$ and d_i $(i = 1, \ldots, n)$ are additional unknown parameters, which must satisfy the following adding-up conditions:

$$\text{(A1.1.6.5)} \qquad \sum_{i=1}^{n} \gamma_{it} = 0 \ ,$$

(A1.1.6.6) $\sum_{i=1}^{n} c_i = 0$, and

(A1.1.6.7) $\sum_{i=1}^{n} d_i = 0$.

Thus, for the residential sector, the system of equations (A1.1.9) is estimated in conjunction with the parameter restrictions (A1.1.6.1a) and (A1.1.6.2) to (A1.1.6.7).

A1.2 Elasticities

For the LAIDS model, there are different possible elasticity expressions that can be used. Based on the most widely used expression,[3] the *short-run* own-price elasticities of demand, η_{ii}, and cross-price elasticities of demand, η_{ij}, are obtained as follows:

(A1.2.1) $\eta_{ij} = (\beta_{ii} - \beta_i s_i)/s_i - 1$

(A1.2.2) $\eta_{ij} = (\beta_{ij} - \beta_i s_j)/s_i$

Here η_{ii} shows the proportional change in demand for the ith energy source in response to a proportional change in its own price, while η_{ij} shows the proportional change in demand for this ith energy source in response to a 1% change in the price of the jth energy source.

Long-run elasticities are obtained by making use of the relationship that, in the long run, $s_{it} = s_{it-1}$. Using this relationship in (A1.1.9), we obtain the long-run share, s_{it}^{LR}, as:

(A1.2.3)
$$s_{it}^{LR} = (\alpha_i^* + \sum_{j=1}^{n} \beta_{ij} \ln p_{jt} + \beta_i \ln(E_t / P_t^*) + \gamma_{it}\, t + c_i \ln HDD_t + d_i\, ACCESS_t)/(1-\lambda) \qquad i = 1, \ldots, n.$$

Now, analogously to (A1.2.1) and (A1.2.2), long-run own-price elasticities of demand, η_{ii}^{LR}, and cross-price elasticities of demand, η_{ij}^{LR}, are obtained as follows:

(A1.2.4) $\eta_{ii}^{LR} = (\beta_{ii} - \beta_i s_i)/((1-\lambda)s_i^{LR}) - 1$

(A1.2.5) $\eta_{ij}^{LR} = (\beta_{ij} - \beta_i s_j)/((1-\lambda)s_i^{LR})$

---

[3] According to Adolf Buse (1994) "Evaluating the Linearized Almost Ideal Demand System", *American Journal of Agricultural Economics*, vol. 76, no. 4 pp. 781-793, this formulation of the price elasticity is also marginally preferred.

A2. Industrial and Commercial Models

A2.1 System of Cost Share Equations

Analysis for the industrial and commercial sectors is based on the homothetic translog cost function that allows for technical progress, and which has the form:

(A2.1.1) $$\ln C = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln p_i \ln p_j + \sum_{i=1}^{n} \gamma_{it}\, t \ln p_i + \alpha_y \ln y + \tfrac{1}{2}\gamma_{yy}(\ln y)^2 + \alpha_t t + \tfrac{1}{2}\gamma_{tt} t^2$$

where $\beta_{ij} = \beta_{ji}$, $i, j = 1, \ldots, n$, and where:

n is the number of different types of energy sources,

p_i is the price of the i[th] alternative energy source (i = 1, …, n),

y is the level of output,

C is the total cost of producing y,

t is a time trend,

and α_0, α_t, γ_{tt}, α_y, γ_{yy}, α_i $(i=1, \ldots, n)$, γ_{it} $(i=1, \ldots, n)$ and β_{ij} $(i, j = 1, \ldots, n)$ are unknown parameters.

Cost share equations for each energy type are derived from the cost function using Shephard's lemma,[4] whereby $s_i = p_i x_i / C$, the cost share of the i[th] alternative energy source, is obtained as $s_i = \partial \ln C / \partial \ln p_i$, (i = 1, …, n), where x_i is the quantity of the i[th] energy type. This yields the following set of cost share equations:

(A2.1.2) $$s_i = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \gamma_{it} t \qquad i = 1, \ldots, n.$$

Since the cost shares sum to one ($\sum_{i=1}^{n} s_i = 1$), there are various (adding-up) conditions (corresponding to the conditions required for the cost function (A2.1.1) to be linearly homogeneous in prices) that the parameters must satisfy:

(A2.1.3.1) $$\sum_{i=1}^{n} \alpha_i = 1,$$

[4] See W.E. Diewert (1974) "Applications of Duality Theory", pp. 106-171 in M.D. Intriligator and D.A. Kendrick (eds.) *Frontiers of Quantitative Economics*, vol II. Amsterdam: North Holland.

(A2.1.3.2) $\sum_{i=1}^{n} \gamma_{it} = 0$, and

(A2.1.3.3) $\sum_{i=1}^{n} \beta_{ij} = 0 \quad (j = 1, \ldots, n)$ which, since $\beta_{ij} = \beta_{ji} \ (i, j = 1, \ldots, n)$, implies that

$$\sum_{j=1}^{n} \beta_{ij} = 0 \quad (i = 1, \ldots, n).$$

A partial adjustment mechanism is incorporated, so that in any period *t*, actual shares, s_{it}, only adjust partially from their value in the previous period, s_{it-1}, to their new desired level in period *t*, s_{it}^*. Thus,

(A2.1.4) $$s_{it} - s_{it-1} = \theta_i (s_{it}^* - s_{it-1}), \qquad 0 \le \theta_i \le 1.$$

where θ_i has the same interpretation as in the residential sector. To allow for this partial adjustment, and hence different short-run and long-run responses to a price change, equation (A2.1.2) is viewed as representing the desired share in period *t*, and is substituted in equation (A2.1.4). Rearranging this equation (and redefining the parameters to include the partial adjustment coefficient θ) yields the following cost share equations:

(A2.1.5) $$s_{it} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \gamma_{it} t + \lambda_i s_{it-1} \qquad i = 1, \ldots, n,$$

where $\lambda_i = 1 - \theta_i$. In this formulation, each share adjusts partially to its own desired level, but is not directly affected by adjustments taking place in the other shares. Again the parameters must satisfy the adding-up conditions in (A2.1.3.1) to (A2.1.3.3), except that (A2.1.3.1) is now replaced by:

(A2.1.3.1a) $$\sum_{i=1}^{n} \alpha_i + \lambda = 1,$$

where:

(A2.1.3.4) $$\lambda_i = \lambda \quad (i = 1, \ldots, n).$$

Thus, due to the adding-up conditions, with this partial adjustment specification it is necessary that the rate of adjustment is the same for each energy source (the parameter λ_i must have the same value in each cost share equation).

Finally, the cost share formulation in (A2.1.5) is modified to allow for the inclusion of the variables *ACCESS* and *HDD*:

(A2.1.6) $$s_{it} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \gamma_{it}\, t + c_i \ln HDD_t + d_i\, ACCESS_t + \lambda\, s_{it-1} \qquad i = 1, \ldots, n,$$

where ACCESS is the proportion of the population who have access to natural gas,

HDD is the number of heating degree-days,

and c_i $(i = 1, \ldots, n)$ and d_i $(i = 1, \ldots, n)$ are additional unknown parameters that satisfy the following adding-up conditions:

(A2.1.3.5) $$\sum_{i=1}^{n} c_i = 0, \qquad \text{and}$$

(A2.1.3.6) $$\sum_{i=1}^{n} d_i = 0.$$

Thus, for the industrial and commercial sectors, the system of equations (A2.1.6) is estimated in conjunction with the parameter restrictions (A2.1.3.1a) and (A2.1.3.2) to (A2.1.3.6).

A2.2 Elasticities

For the translog cost share specification, *short-run* own-price elasticities of demand, η_{ii}, and cross-price elasticities of demand, η_{ij}, are obtained as follows:

(A2.2.1) $$\eta_{ii} = (\beta_{ii}/s_i) + s_i - 1$$

(A2.2.2) $$\eta_{ij} = (\beta_{ij}/s_i) + s_j$$

Here η_{ii} shows the proportional change in demand for the i^{th} energy source in response to a proportional change in its own price, while η_{ij} shows the proportional change in demand for this i^{th} energy source in response to a 1% change in the price of the j^{th} energy source.

Long-run elasticities are obtained by making use of the relationship that, in the long run, $s_{it} = s_{it-1}$. Using this relationship in (A2.1.6), we obtain the long-run share, s_{it}^{LR}, as:

(A2.2.3) $$s_{it}^{LR} = (\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln p_j + \gamma_{it}\, t + c_i \ln HDD_t + d_i\, ACCESS_t)/(1-\lambda), \quad i = 1, \ldots, n.$$

Now, analogously to (A2.2.1) and (A2.2.2), long-run own-price elasticities of demand, η_{ii}^{LR}, and cross-price elasticities of demand, η_{ij}^{LR}, are obtained as follows:

(A2.2.4) $$\eta_{ii}^{LR} = (\beta_{ii}/((1-\lambda)s_i^{LR})) + s_i^{LR} - 1$$

(A2.2.5) $$\eta_{ij}^{LR} = (\beta_{ij}/((1-\lambda)s_i^{LR})) + s_j^{LR}.$$