Exhibit No.:	______________
Issues:	Rate Design-Income/ Consumption Correlation
Witness:	Thompson
Type of Exhibit:	Rebuttal Testimony
Sponsoring Party:	Missouri Gas Energy
Case No.:	GR-2006-0422
Date Testimony Prepared:	November 21, 2006

MISSOURI PUBLIC SERVICE COMMISSION

MISSOURI GAS ENERGY

CASE NO.

GR-2006-0422

REBUTTAL TESTIMONY OF

PHILIP B. THOMPSON

Mt. Pleasant, Michigan

November 21, 2006

REBUTTAL TESTIMONY OF PHILIP B. THOMPSON

CASE NO. GR-2006-0422

November 2006

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. Philip B. Thompson, RT Associates, 1777 Rose Marie Lane, Mt. Pleasant, Michigan, 48858.

Q. ON WHOSE BEHALF ARE YOU APPEARING IN THIS PROCEEDING?

A. I have been retained by Missouri Gas Energy (MGE).

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL AND EMPLOYMENT BACKGROUND.

A. I have a B.A. in Economics from Kent State University and a Ph.D. in Economics from the University of Arizona. From 1982-1984 I was an instructor at Texas A&M University. From 1984-1986 I was a Public Utility Economist with the Missouri Office of the Public Counsel, and from 1986-1994 served as Public Counsel's Chief Economist. From 1994-2000 I was an Assistant Professor of Economics at the University of Missouri-Rolla, and since August 2000 I have been a faculty member in the Economics Department at Central Michigan University. Earlier this year I was promoted to the rank of Temporary Associate Professor.

Throughout my career I have made presentations at many conferences and published papers in peer-reviewed journals and in other publications, mostly on topics related to utility and energy economics, including the influence of household income on residential natural gas consumption. My vita is attached to this testimony as Schedule PBT-1.

Q. HAVE YOU EVER TESTIFIED BEFORE THIS COMMISSION?

A. Yes. I filed written testimony in numerous cases while employed by the Office of the Public Counsel, and in other cases while working as a consultant. In many of these cases I also appeared for cross-examination at a hearing.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. I will present the results of a study I performed in an effort to ascertain the relationship between residential gas consumers' income levels and their usage of natural gas in MGE's service territory. This is in response to the direct testimony of Public Counsel witness Meisenheimer insofar as she appears to recommend (on page 5 of that testimony) that the Commission look first to increasing volumetric charges, as opposed to fixed monthly charges, for the residential customer class to recover the revenue increase in this case.

Q. WHY IS THE INCOME-CONSUMPTION RELATIONSHIP FOR NATURAL GAS CONSUMERS IMPORTANT?

A. Residential natural gas rate structures have typically consisted of a monthly fixed charge, known as the customer charge, and a rate applied to each volumetric unit of consumption, also sometimes called the commodity or energy charge. In some rate structures the fixed charge includes a charge for the first units of usage each month, in which case the volumetric charge is not levied on that usage. Purchased gas costs are always collected through a volumetric rate, while the LDC's non-gas or margin costs are collected through a combination of the fixed charge and the volumetric rate.

When rate design for the residential class is contemplated, a decision must be made concerning how to apportion the total margin revenue to be collected between the fixed and volumetric charges. As the proportion of the margin revenue target that is collected through the volumetric charge increases, bills for customers with above-average usage rise and those for below-average users fall.

In deciding how to apportion a class revenue increase between the rate components, this Commission has traditionally used cost-of-serve studies as a starting point, but has considered other factors in its final rate determinations. These factors include "*consumption characteristics (effect on low income customers)*, economic factors, current rate structures, value of service, *rate affordability*, customer service quality, historical rates, the concept of gradualism to avoid or minimize potentially disruptive rate shifts or rate shock, and the magnitude of the required increases or the overall rate impact of the increase in the revenue requirement." (*Re: Missouri Gas*

Energy, Report and Order, GR-96-285, issued February 1, 2001, Missouri Public Service Commission, pp. 40-41, emphasis added, footnotes deleted.)

In order to consider the impact of a particular fixed/volumetric charge apportionment on low income customers, we must first have information about the income-consumption relationship. For example, if low income consumers use less than the average amount of gas (within the residential class), a larger fixed charge will increase the burden of such customers relative to other customers. On the other hand, if low income customers use *above*-average quantities, bills for such customers would be reduced by collecting a greater portion of the margin revenue target through the fixed charge and a smaller portion from the volumetric charge.

The Commission has in two relatively recent cases considered both possibilities. In Case No. GR-2000-512 the Commission approved a Stipulation and Agreement settling the case, which included an increase in AmerenUE's monthly fixed charge for residential customers from $8 to $9. But three Commissioners expressed concern that an increase in the customer charge is regressive, meaning that it results in larger bill increases for low income customers.

The Commission has also recognized the alternative possibility in its Report and Order in Case No. GR-96-285 (February 1, 2001, p. 41, footnote 12), stating that "frequently lower income customers use more gas for heating because the homes they heat are often older and more poorly insulated, thereby causing those people who can least afford it, to consume more gas to achieve the same degree of heating as newer, better insulated homes." Finally, advocacy agencies for low income customers often argue that such customers are below-average users who would be harmed disproportionately by a revenue increase apportionment weighted heavily toward the fixed charge.

Which view is correct? Both arguments have theoretically sound underpinnings. The question therefore becomes an empirical one: What is the income-consumption relationship?

Q. YOU SEEM TO BE SUGGESTING THAT THERE ARE TWO POSSIBILITIES: CONSUMPTION IS LOW AT LOW INCOME LEVELS AND INCREASES WITH INCOME, OR THAT USAGE STARTS HIGH AT LOW INCOMES AND DECLINES WITH INCOME. IS THAT CORRECT?

A. Those are two possibilities, but there is a third. In a sense, both sides of the argument may be correct. That is, usage may be high at low income levels and fall as income increases, but then reaches a minimum and begins to climb again after a certain income level. If we imagine a graph with income on the horizontal axis and monthly usage per customer on the vertical, the relationship I have just described would have "U"-shape; see Schedule PBT-2 for examples. I believe, based on an econometric study of residential natural gas consumption determinants, that the relationship between income and consumption in MGE's service territory is of this "U"-shaped type.

There is, of course, one other possibility—that there is no connection between income and natural gas usage. In my opinion, this possibility is easily ruled out for both theoretical and empirical reasons.

Q. HOW MIGHT THE "COMBINATION" RELATIONSHIP YOU REFER TO BE EXPLAINED?

A. Simply as a combination of the two most likely explanations for the individual relationships. At the lowest income levels, families live in homes that are inefficient in their gas use. Their homes are older, not well insulated, and lacking energy-efficient doors and windows. Their furnaces may be older and not well maintained, especially if the home is rented.

As incomes rise above the very lowest levels, families obtain the wherewithal to improve the thermal integrity of their residences and the efficiency of their furnaces, and usage declines. But at some income level usage begin to rise once again as the household gas bill becomes a smaller factor in the family budget and as more gas appliances (e.g., swimming pool heaters) are added. In addition, households with higher incomes tend to occupy larger homes.

Q. PLEASE DESCRIBE THE CONTENTS OF SCHEDULE PBT-2.

A. Schedule PBT-2 contains a report to MGE that I authored to present and explain the results of my econometric study. It includes a general overview section and a technical section. The remainder of this testimony will provide the highlights of the study results, but a more complete description of the results appears in the report.

Q. PLEASE PROVIDE A BASIC DESCRIPTION OF THE STUDY YOU CONDUCTED.

A. The study begins with a simple visual presentation in Figures 1 and 2 of Schedule PBT-2 of the income-usage data for MGE's customers. This very basic presentation indicates that the average low-income customer uses an average or above-average amount of natural gas.

The more detailed portion of the study explains the way in which average monthly usage in MGE's residential customer class varies across geographic units and over time. The geographic units employed are zip codes. The time periods are the entire two-year period under examination (October 1998 through September 2000), referred to as "annual" models, and each individual month during that period, the "monthly" models. (Note: A "model" is simply a single regression equation containing a specific set of explanatory variables.)

The annual models take average monthly usage in a zip code over the entire two-year period as the *dependent* variable, or the variable whose behavior we wish to explain. Various combinations of *independent* or *explanatory* variables are used to determine the causes of variations in usage across zip codes and the contribution of each explanatory variable. These included weather, income, housing characteristics (e.g., age), and household characteristics (e.g., employment history). Data for a total of 181 zip codes in MGE's service territory were used.

The monthly models have average monthly usage *for each month in the period* as the dependent variable. Thus, instead of only 181 observations (one for each zip code), there are 4,344 (24 for each zip code). A very similar set of explanatory variables is examined, with the addition of a price variable.

Q. WHERE DID YOU GET THE DATA YOU USED?

A. The raw data and the variables derived from it are described in Schedule PBT-2. Data provided by MGE consisted of customer usage and the number of bills by zip code for each of the months (October 1998 through September 2000) in the study period, along with data on the weather and on the Company's prices over the period. Data on population and housing variables were taken from the 2000 U.S. Census. Questions in the 2000 Census ask about the respondent's demographic, economic, and housing characteristics in 1999, which is in the middle of the two-year period covered by my study.

Q. PLEASE SUMMARIZE THE RESULTS.

A. I will first present the results of some simple calculations indicating that low income customers use above-average amounts of natural gas. The sum of total usage over the period over all 181 zip codes divided by the total number of bills, also summed across months and zip codes, yields an average usage per bill of 72.01 Ccf (hundred cubic feet). The same calculation performed using only the 23 zip codes with the lowest average household income (covering approximately one-tenth of the total number of bills, or the lowest income decile) yields an average usage per bill of 86.69 Ccf, 20% higher than the overall average.

Regression analysis allows us to more closely examine whether it is income or other factors that drive these differences in consumption, and whether the income-consumption relationship is "U"-shaped. As I suggested earlier, the results of my econometric study strongly suggest that the income-consumption relationship in MGE's service territory does indeed have a "U"-shape, so that average monthly consumption at first declines as income rises, then turns upward with further increases in income. There is no evidence that consumption increases steadily from lowest incomes to highest incomes. Schedule PBT-2 contains detailed support for these conclusions.

For the annual models presented in Schedule PBT-2, depending on which model is examined, the bottom of the "U" occurs at annual income levels ranging from $45,650 to $73,945 (1999 dollars). In addition, the low-income section of the "U" crosses the average usage level at incomes ranging from $32,203 to $47,005 when the estimated relationship is evaluated at the means of the other explanatory variables. This means that consumers with incomes below these levels consume above-average amounts of gas.

For the monthly models, the bottom of the "U" occurs at annual income levels ranging from $58,857 to $66,108 (1999 dollars). The low-income section of the "U" crosses the average usage level at incomes ranging from $35,624 to $42,656, again when the estimated relationship is evaluated at the means of the other explanatory variables.

Q. YOU STATED EARLIER THAT YOU EXAMINED OTHER VARIABLES IN ADDITION TO INCOME AS DETERMINANTS OF RESIDENTIAL USAGE. PLEASE EXPLAIN THE RESULTS OF YOUR STUDY IN THIS REGARD.

A. Most of these other variables contributed to gas usage in the anticipated direction. Colder weather, measured as an increase in Heating Degree-Days (HDD), increases usage. An increase in the median age of homes in a zip code increases average usage in that area, all else equal, as does an increase in the size of a home (measured as the average number of rooms).

A variable measuring the unemployment rate for each zip code also has a positive effect on gas usage. That is, the higher the unemployment rate in a zip code, the higher the gas consumption. A possible interpretation of this result is that not working is associated with a greater proportion of the time in which at least one family member is at home, which is likely to result in higher average thermostat settings. That is, many consumers turn down the thermostat during the day if nobody is home, but not if someone is home.

A variable measuring the proportion of homes that are owner-occupied is positively related to usage in some model specifications and has no impact on usage in other models. The reason for this result is unclear since it is the opposite of what one would expect, but it may be due to the fact that the home ownership percentage is highly correlated (correlation coefficient = .71) with home size as measured by the median number of rooms.

Some interesting results with respect to price variables were obtained: a positive relationship between price and usage. At first this would appear to run counter to the so-called law of demand, which holds that, all else equal, higher prices cause lower consumption. But a possible explanation for this result may be simply that higher prices tend to coincide with colder weather, which is the case for this dataset, and colder weather causes higher consumption. Consumers generally are unaware of the price of natural gas at the time of consumption, at least in the same sense that they are aware of the price of a gallon of gasoline or milk. In any event this result does not affect the overall performance of the models with respect to the other variables; a model that does not include a price performs very much like those that do with respect to the other explanatory variables.

In some model specifications I included the lagged (i.e., previous period's) value of the dependent variable CCF as an independent variable. Its estimated coefficient was positive, meaning that consumption in a given month was higher if preceded by a high usage month than if preceded by a low usage month.

Q. DO THE RESULTS OF YOUR STUDY INDICATE THAT INCREASING THE FIXED MONTHLY CHARGE FOR MGE WOULD HAVE A REGRESSIVE IMPACT ON LOW INCOME CUSTOMERS?

A. No. In fact, the results of my study indicate that, because low income customers in MGE's service territory consume higher than average volumes, increasing the *volumetric* charge would be much more likely to have a regressive impact on low income consumers.

Q. PLEASE STATE YOUR OVERALL CONCLUSIONS.

A. In my opinion, there is no evidence that increases in the monthly customer charge (proportionally larger than increases in the volumetric charge) are regressive. The results of my study indicate that the income-consumption relationship for residential natural gas usage in MGE's service territory is mildly "U"-shaped: above-average at the lowest income levels, declining through middle incomes, and then rising again to above the average at higher income levels. This result can be seen from a simple visual inspection of the data as well as from more detailed statistical analyses.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the Matter of Missouri Gas Energy's Tariff Sheets Designed to Increase Rates for Gas Service in the Company's Missouri Service Area.	))))	Case No. GR-2006-0422

AFFIDAVIT OF PHILIP B. THOMPSON

STATE OF Michigan)
) ss.
COUNTY OF Isabella)

Philip B. Thompson, of lawful age, on his oath states: that he has participated in the preparation of the foregoing Rebuttal Testimony in question and answer form, to be presented in the above case; that the answers in the foregoing Rebuttal Testimony were given by him; that he has knowledge of the matters set forth in such answers; and that such matters are true and correct to the best of his knowledge and belief.

Philip B. Thompson

PHILIP B. THOMPSON

Subscribed and sworn to before me this 17 day of November 2006.

[signature]

Notary Public

My Commission Expires: 12-12-2007

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EDUCATION

Ph.D., Economics, University of Arizona, May, 1988.
Dissertation: *The Spatial and Temporal Distribution of Risks Associated with Low-Level Radioactive Waste Disposal* (Advisor: David E. Pingry)

B.A., Economics, Magna Cum Laude, Kent State University, June, 1976

EMPLOYMENT EXPERIENCE

August 2006 to present	Temporary Associate Professor of Economics, Central Michigan University
August 2000 to July 2006	Temporary Assistant Professor of Economics, Central Michigan University
August 1998 to August 2000	Assistant Professor of Economics, University of Missouri-Rolla
August 1994 to May 1998	Visiting Assistant Professor of Economics, University of Missouri-Rolla
August 1994 to present	Principal, RT Associates, consulting on Public Utility, Regulatory, and Antitrust Economics
May 1986 to August 1994	Chief Public Utility Economist, Office of the Public Counsel, State of Missouri.
May 1984 to May 1986.	Public Utility Economist, Office of the Public Counsel, State of Missouri
August 1982 to May 1984	Visiting Instructor, Department of Economics, Texas A&M University, teaching Principles and Money & Banking.

NATIONAL OFFICES:

Member, Gas Technology Institute Advisory Council, 1993 - 2001, and GRI Advisory Council Science and Technology Committee, 1999 - 2001.

National Association of State Utility Consumer Advocates, Chair, Economics and Finance Committee, 1990 - 1994.

PUBLICATIONS

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Bailey, Christopher, Gregory Falls, Paul Natke, and Philip Thompson, 2006. "Measuring the Economic Impact of a Regional Public University: The Case of Central Michigan University." Under review at *Mid-American Journal of Business.*

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CONFERENCE PARTICIPATION

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Thompson, Philip B., presenter, and Gary Tan, "Price Asymmetry in the Midwest Retail Gasoline Market Revisited," Midwest Economic Association International 69th Annual Meeting, Milwaukee, WI, March, 2005.

Thompson, Philip B., presenter, "New Faculty Mentoring: Getting a Good Start," Western Economic Association International 75th Annual Conference, Vancouver, BC, July, 2000.

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Thompson, Philip B., presenter, "Low-Level Radioactive Waste Disposal: Cost-Risk Tradeoffs," Western Economic Association International 73rd Annual Conference, Lake Tahoe, July, 1998.

CONFERENCE PARTICIPATION (continued)

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Respondent, Gas Research Institute Energy Seminar, *Electric Utility Restructuring and its Impact on the Gas Industry*, Asheville, North Carolina, August, 1995.

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OTHER SCHOLARLY AND PROFESSIONAL ACTIVITIES

ARTICLE REVIEWING/REFEREEING

Article Review for the Journal of Economic Education, 2005

Article Review for Energy Economics, 2005

PRESENTATIONS

Thompson, Philip B., presenter, "An Economic Analysis of U.S. Policy for Low-Level Radioactive Waste Management," UMR College of Arts and Sciences Humanities-Social Sciences Lecture Series, April, 1999.

TESTIMONY

Missouri General Assembly, Joint Interim Committee on Telecommunications and Energy Sources, testimony on behalf of the University of Missouri containing comments on the Public Service Commission Task Force Report on Retail Electric Competition, September, 1998.

Missouri Public Service Commission: Written testimony in over sixty docketed cases before the MPSC between 1984 and 1996, and in 2001, and oral cross examination on that testimony in approximately half of those cases.

Missouri Senate, Commerce and Consumer Protection Committee, testimony regarding changes in Missouri law relating to telecommunications, March 1992.

DISSERTATION AND THESIS COMMITTEES

Hilton, Cory, candidate for M.A. in Economics, Central Michigan University, Thesis Committee. His as yet untitled thesis concerns aspects of electricity deregulation. 2006.

Tan, Gary Peng-Liang, M.A. in Economics, Central Michigan University, Plan B paper, "Price Asymmetry in the Midwest Retail Gasoline Market Revisited," 2002-2003

Mank, Del, Ph. D. in Engineering Management, Donald Myers, Committee Chair. *Links Between R&D Activity and Stockholder Value in High-Tech Industries*, 1998 - 2000.

Lu, Chaoyuan, Ph. D. in Engineering Management, Colin O. Benjamin, Committee Chair. *Managing Risk and Uncertainty on Research and Development Projects*. 1995 - 1996 .

Almasqué-Cain, Judith, M.S. in Electrical Engineering, E. Keith Stanek, Committee Chair. *Developing a Compliance Plan for a Coal-Fired Utility Under "The 1990 Clean Air Act"*, 1994 - 1995.

SCHOLARLY AWARDS

Honorable Mention (second place), Conference prize competition, Eighth National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference, National Regulatory Research Institute, The Ohio State University, Columbus, Ohio, 1992.

SERVICE ACTIVITIES

Member, Energy Optimization Committee, Central Michigan University

Member, Economic Impact Group, Central Michigan University

Panel Member, Speak Up Speak Out Series, Panel on Election 2004 Environmental Issues, Central Michigan University, Sept. 2004

Discussant, numerous occasions at a variety of professional meetings, 1995-present

Department Representative, various College of Arts and Sciences committees, University of Missouri-Rolla, 1995 - 2000 .

Advisor for Undergraduate Economics Majors, University of Missouri-Rolla, 1995 - 2000.

Member, University Advisory Board, University of Missouri and Network Resources, Inc., Richard L. Wallace, Project Director and Vice President for Academic Affairs, *Study of Missouri's Telecommunications Infrastructure Development*, 1994.

PROFESSIONAL SOCIETY MEMBERSHIPS

American Economics Association
Industrial Organization Society
International Association for Energy Economics
Midwest Economics Association
Missouri Valley Economic Association
Western Economic Association International

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The Relationship Between Household Income and Natural Gas Consumption in Missouri Gas Energy's Service Territory: A Report to MGE

Philip B. Thompson, Ph.D., Principal, RTAssociates, Mt. Pleasant, MI

I. Introduction

An important consideration in deciding how to apportion a given residential margin revenue requirement between the fixed monthly customer charge and the volumetric rate is how the apportionment will affect customers at various income levels. Collecting more revenue through the volumetric rate and less through the customer charge leads to higher bills for above-average users and lower bills for those whose usage is below the average. The impact on customers in different income groups therefore depends on the relationship between household income and natural gas consumption.

There are four distinct theoretical possibilities regarding this relationship. The first is that there is no significant connection between usage levels and income; this is essentially the null hypothesis for the study. The second is that natural gas usage is positively related to income: as household income rises, so does gas consumption, as households add more gas-using appliances such as gas hearths and swimming pool heaters. A third possibility is that consumption may increase as income decreases below a certain level because of the tendency for lower income families to live in older homes that are less well insulated and that have less efficient heating equipment. In addition, families at the low end of the income spectrum are more likely to live in rental housing, which yields fewer incentives for efficiency. Landlords are less likely to invest in energy efficiency measures such as efficient furnaces and windows and doors because they typically do not pay tenants' utility bills. Renters are less likely than homeowners to invest in such measures because their tenure in a given housing unit tends to be shorter than the payback period for those investments. Furthermore, low-income homeowners may find it difficult to afford the up-front costs associated with efficiency investments and would be unable to find lenders willing to help.

The final possibility is a combination of the second and third. At lower income levels consumption decreases as income rises because households' ability to pay for efficiency retrofits and to afford newer, better-insulated housing rises. Then at some income level usage reaches a minimum and begins to increase as more appliances are added and as families come to afford higher levels of comfort. This possible outcome is depicted graphically as a "U"-shaped curve, with income on the horizontal axis and usage per month on the vertical. As will be discussed in greater detail below, this study finds a high likelihood that the income-consumption relationship for Missouri Gas Energy's (MGE's) service territory is of this type.

The purpose of this report is to present the results of a study I performed to investigate the income-consumption relationship in MGE's service territory. In the next section I provide a general overview of the results, and the third section consists of a discussion of the more technical aspects of the study. The report ends with a summary and conclusions.

II. General Overview of Models and Results

This study is based on data from two sources. MGE provided me with monthly total usage figures and bill numbers for its residential customers in each zip code it serves, for the entire 24-month (October 1998 through September 2000) period of the study. In the most detailed analysis performed for this study (which I call the monthly analysis) I used this data as given, in its monthly form: I divided total usage in each zip code in each month by the corresponding number of bills to obtain the average usage per bill, which I call CCF. (Variable names as used in the regression analysis appear in all capital letters throughout this report.) There are therefore 4,344 observations (181 zip codes X 24 months) in the monthly dataset. MGE also gave me weather and price data that I used to calculate appropriate weather and price variables for each of the zip code-months. My other data source, from which I obtained demographic, economic, and housing data, is the 2000 U.S. Census. I used the statistical method known as regression analysis in this portion of the study to determine the most important factors affecting the quantity of natural gas consumed.

Before addressing the results of the monthly analysis, I will first present two more basic analyses that are based on a single usage number for each zip code: the overall monthly average use for the 24 month period. The first of these is very simple, consisting of a graphical presentation of the income-usage relationship. The second, which I will call the annual analysis, is a regression study similar to the monthly analysis, but instead of using each month's usage as the so-called dependent variable for each zip code, I use the overall monthly average use for the 24 month period.

Figures 1 and 2 on the next page present the basic data visually. Figure 1 is a scatter plot of the income-consumption relationship, with each triangle corresponding to a zip code. It shows that there doesn't seem to be a clear relationship between income and monthly usage. Although there are many low-income zip codes with below average usage (the average is about 70 Ccf/month), there are many at above that level, with some low-income zip codes having much higher than average usage levels. With a little imagination one might glimpse a U-shaped line running through the data points, but there is nothing conclusive in this simple visual examination of the data.

The same data is used in Figure 2, but there it is grouped by income decile. In order to calculate the coordinates of these ten points, I grouped the zip codes into ten income-based strata so that approximately the same number of bills was in each group. I then calculated the average usage per month within each decile; these are the points in the graph, connected by a line leading from lowest income to highest. In this presentation of the data the U-shaped relationship is a bit more obvious. Significantly, the highest average consumption of over 87 ccf/month occurs in the lowest income decile, which has an average income of $33,314.

Figure 1: Household Income and Average Monthly Natural Gas Usage 1998-2000; Overall Average = 72.01 ccf

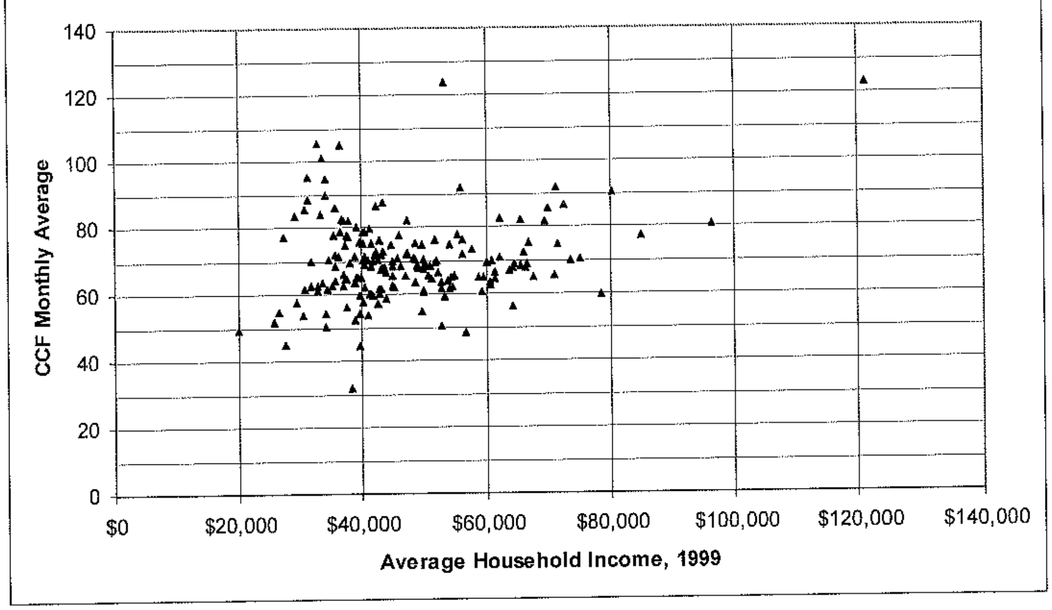
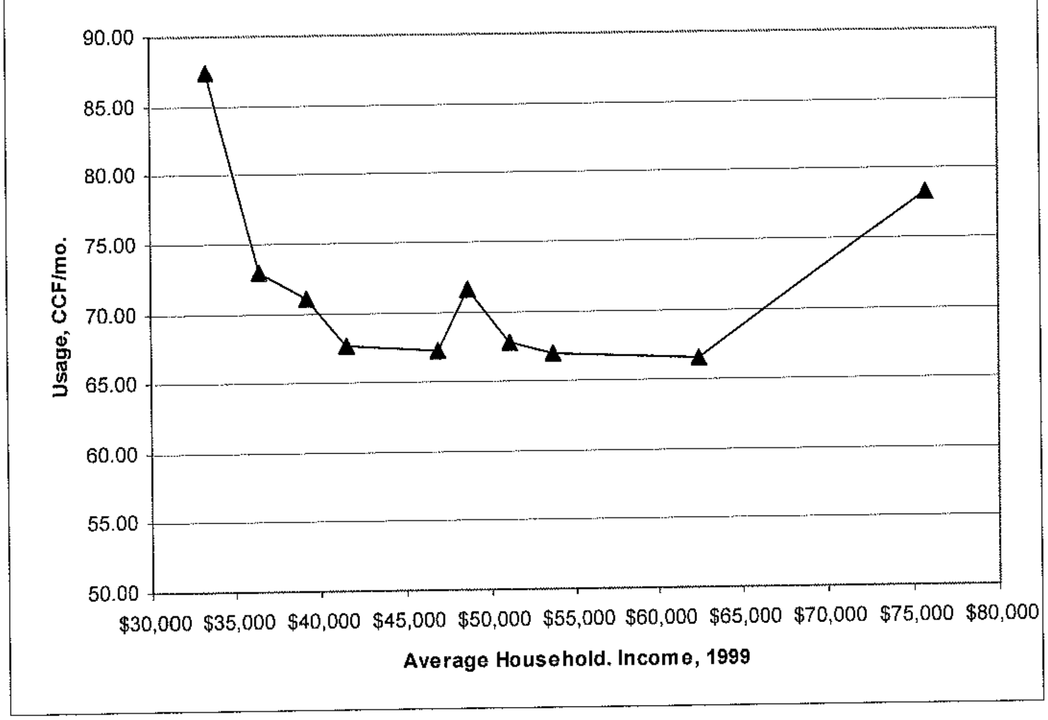


Figure 2: Household Income by Decile and Average Monthly Natural Gas Usage 1998-2000; Overall Average = 72.01 ccf



Based on these visual examinations alone one could reasonably conclude that MGE's low income customers use above-average amounts of gas, but it is nevertheless of interest to ask what may be behind these results. Are there other factors associated with income that are the real determinants of gas usage? If so, what are these? The answers are not only of interest for their rate design implications, but for broader public policy goals such as energy efficiency and helping low-income users pay their heating bills. The best way to examine the roles of potential household natural gas usage determinants is through a well-established statistical technique known as regression analysis. In this approach the goal is to find what the contribution is of each potential determinant (the "independent" variables) of natural gas usage (the "dependent" variable).

The independent variables discussed below in connection with either the annual or monthly model groups were selected initially because of their theoretical roles as determinants of residential gas consumption. Several other variables were used in some trial models but are not discussed because they turned out not to be significant determinants of gas usage, or because some other, similar variable performs just a bit better in the models. For example, the number of persons per household was used instead of the average number of rooms as representing the "size" of a home, and while the former did help explain gas usage, it did not do so as well as the latter. Similarly, the proportion of homes built before a particular year was used in place of median home age, but the latter appeared to work a little better. The proportion of homes occupied by the owner did not seem to explain gas usage in the models as well as theory would predict (a discussion of the results appears below). These similarities in performance between two related variables (e.g., the age of homes versus the proportion of homes older than some preselected limit) are largely due to similar patterns of variation (in the statistical sense) across zip codes. The remaining discussions are largely confined to those model specifications that performed better, but in many cases the improvement in model performance offered by a particular independent variable was modest.

Returning to the annual model, the independent variable HDD, or heating degree-days, is derived in a manner slightly similar to CCF. That is, monthly HDD are calculated for each month and zip code, using a bill-cycle weighting process described in the technical section below, and then are summed across months to get the total HDD over the period. It is reasonable to expect the regression coefficient on HDD to be positive—colder weather (higher HDD) leads to increased gas consumption.

Other independent variables used in the annual models are taken from or calculated using 2000 U.S. Census of Population data. The variable AGEMED is the median age of housing units in a zip code, and is calculated by subtracting the census data's "Median Year Built" from 1999. Median age of housing is used as a proxy variable for the energy efficiency of homes (degree of insulation, quality of windows, efficiency of heating equipment, etc.). Theory predicts that the regression coefficient on AGEMED will be positive—that older homes consume more gas, all else equal. The independent variable RMSMED is the median number of rooms in a zip code's housing units and is a proxy for home size. The coefficient on this variable is also expected to be positive, because heating larger homes requires more gas.

Another factor that would tend to affect gas usage is whether someone is at home during normal working hours. Many homes are kept at lower temperatures when nobody is home for several hours. The variable UNEMP is the unemployment rate for persons aged 16 and over and is a proxy for the proportion of households in which someone is at home during the day. The regression coefficient on this variable is expected to be positive since it is unlikely that the thermostat in such a home would be lowered during the day.

Two income variables were used. One is mean (average) household income for a zip code (AY) and the other is median household income (MY), which is the "middle" income value for the zip code: 50% of households have higher incomes than the median. These two variables have substantially different values for most zip codes; on average, the mean income is 21.4% higher than the median, and in only two of the 181 zip codes is the median larger (by only 0.5% and 0.3%). This means that the income distribution is skewed, so that a few high income earners in each zip code have a large impact on the average. The argument for using the mean income is that it picks up the impact of a few large income earners on the average consumption of natural gas. On the other hand, the median is a better indicator of "central tendency," since very large incomes have no more impact than slightly large incomes. To illustrate this, imagine a student who has scored 2/100 on 9 quizzes and 82/100 on the tenth. The average score is 10, but since the student scores 2/100 nine times out of ten, we would probably conclude that 2/100 is the most likely score. Both income variables were used (but not in the same regression) and in most of the results, including the ones given in Tables 1 and 2 below, they performed about the same.

To test for the existence of a "U"-shaped income-consumption relationship, the square of the income variable, denoted AY2 or MY2, is also included. If the relationship is in fact "U"-shaped, adding the square of income will improve the performance of a model, measured by its R^2 coefficient. In addition, the coefficient on the income variable will be negative and statistically significant, and the coefficient on its squared value will be positive and statistically significant.

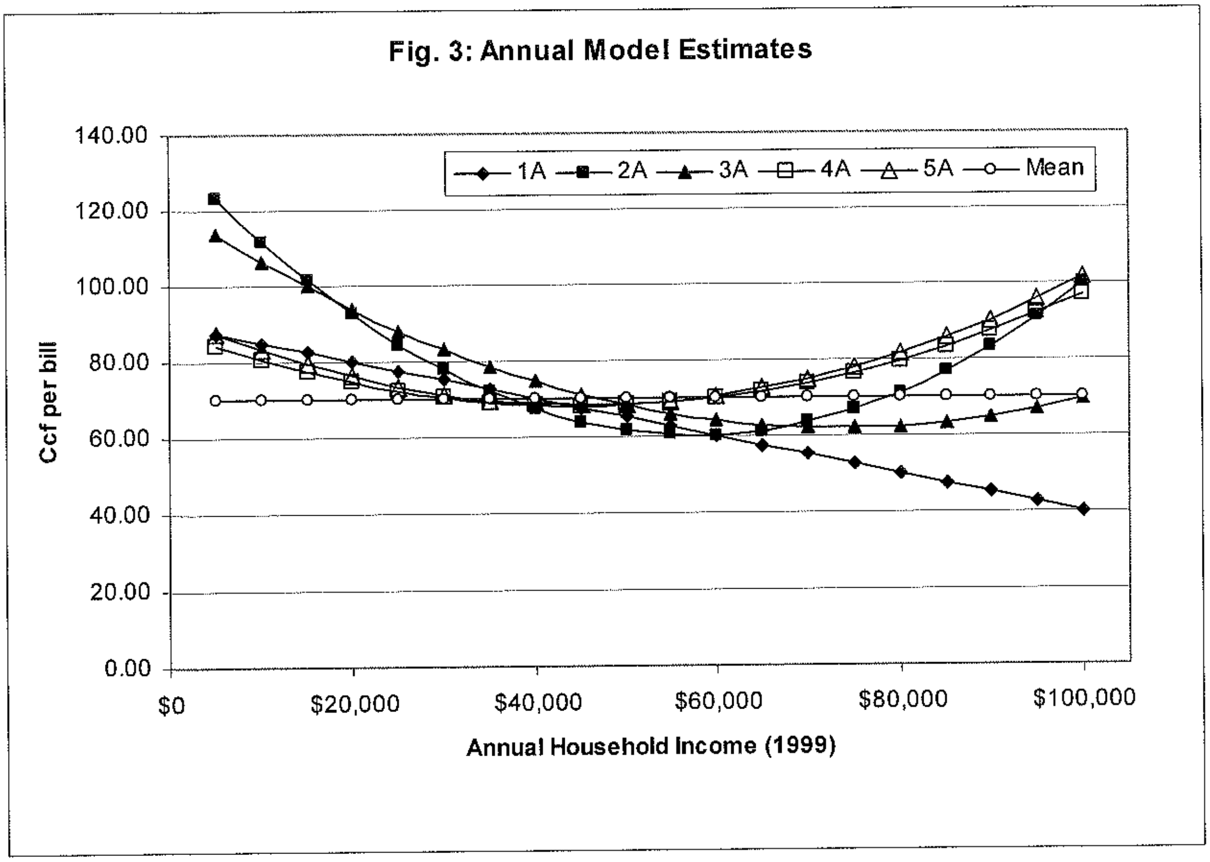
Estimation of the annual models employs a technique known as weighted ordinary least squares. The results of the models that generally perform the best are presented in Table 1. In each model the dependent variable is CCF. Each model is designated with a number along with the letter A to signify the annual set of models. (More complete information about each model, including t-statistics, is presented in the technical section of this report.) If a cell in the table is blank, the corresponding independent variable was not used in that model. A graph of the income-consumption relationships derived from Table 1 appears in Figure 3.

Model 1A is presented to show what happens when no squared income term is included. Although in my opinion the correct specification includes the squared income variable, which is not in Model 1A, it is interesting to note that median income (MY) has a negative and statistically significant influence on consumption in Model 1A (see Section III below for t-statistics). This means that if the income-consumption relationship is linear rather than U-shaped, low income customers use more gas than high income users. The addition of the squared income variable MY2 in equations 2A, 4A, and 5A improves the fit of the regression to the data. This can be seen from the slight improvement in the R^2 statistic, which measures how well the model fits the data; R^2 must lie between 0 and 1, and a higher value indicates a better fit. In addition and more importantly, both income variables are statistically significant. The conclusion from these annual models is therefore that the income-consumption relationship is indeed U-shaped. This conclusion in turn implies that a larger customer charge would result in lower bills for customers at the lowest income levels than they would receive if the *volumetric* rate were made larger. Table 1 also includes two lines that show 1) the household income level (1999 dollars) at which monthly usage is at a minimum, and 2) the income level at which usage equals the average, and below which usage is above average.

TABLE 1: Regression Results from Annual Models

Dependent variable = CCF (mean = 69.83)	Coefficients on Variables in Model No.:				
Variable Names	1A	2A	3A	4A	5A
HDD	0.002037	0.004647	0.003041	0.002126	0.002677
AGEMED	0.735	0.379	0.538	0.548	0.556
RMSMED	20.046	15.361	13.953	12.529	9.628
MY	-0.0005	-0.0026		-0.000892	-0.001052
MY2		2.25×10^{-8}		9.77×10^{-9}	1.14×10^{-8}
AY			-0.001612		
AY2			1.09×10^{-8}		
UNEMP				1.3652	1.4277
PCTOWNOC					0.1704
CONSTANT	-61.38	-0.625	1.765	-23.01	-20.54
R^2	.990	.994	.991	.995	.995
Income level at bottom of "U"	N.A.	$57,867	$73,945	$45,650	$46,140
Income level below which usage exceeds the average	N.A.	$37,135	$47,005	$32,203	$34,613

The coefficients listed in Table 1 are interpreted as follows, using model 4A as an example. The coefficient on AGEMED is 0.548, which implies that a 10-year increase in the age of a housing unit increases gas consumption by approximately 5.5 Ccf per month, about 8% of the average consumption level of 69.83 Ccf per month. Similarly, we see that the coefficient on RMSMED equals roughly 12.53, which means that a house with one more room will use an additional 12.53 Ccf per month, on average, all else held constant. The impacts of other variables can be similarly calculated. See Table 3 in Section III below for a list of the mean values for all variables to get an idea of how large each variable is, and therefore what can be thought of as a reasonable change in its size.



The estimation of the monthly models is carried out using a technique known as panel data analysis, which accounts for variations across both zip codes and months. There are a total of 4,344 (24 months x 181 zip codes) observations. The dependent variable CCF varies both across zip codes and months. HDD varies across months, and because different zip codes are on different (combinations of) bill cycles and are in different geographic regions (3 in total), HDD also varies to some extent across zip codes. The same can be said about the price variable PRICE (current month's non-gas margin plus gas cost). Data taken from the U.S. Census (all variables except for CCF, HDD, and the price variables) vary across zip codes but not across months. That is, a given zip code is assigned the same income (or AGEMED, RMSMED, etc.) value for each of the 24 months in the study period. Table 2 below presents the results of five monthly models. Figure 4 on page PBT-2-9 graphically depicts the estimated income-consumption relationships for these models.

There are several explanatory variables used in the annual models that are also used in the monthly models: HDD, AGEMED, RMSMED, and UNEMP. The variation in consumption within a zip code across months is considerably greater than the variation across zip codes either within a given month, or, with reference to the annual models discussed above, across zip codes for the entire study period. The vast majority of the *monthly* variation in usage is driven by HDD. Indeed, a trial model including only HDD as an explanatory variable performed very well, and adding the other independent variables increased the performance of the models only marginally.

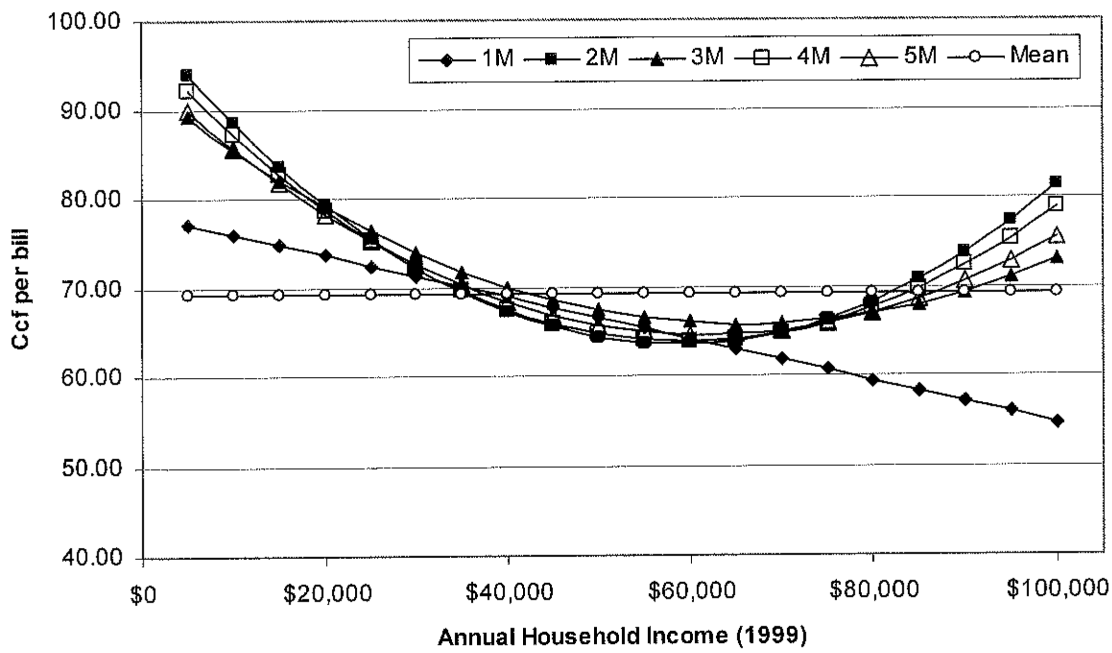
TABLE 2: Regression Results from Monthly Models

Dependent variable = CCF (mean = 69.17)	Coefficients on Variables in Model No.:				
Variable Names	1M	2M	3M	4M	5M
HDD	0.146	0.1465	0.1464	0.1465	0.1245
CCF(-1)					0.3266
AGEMED	0.447	0.3892	0.412	0.3735	0.2173
RMSMED	13.477	13.175	11.319	13.607	9.745
MY	-0.0002	-0.0012		-0.0011	-0.0010
MY2		1.05×10^{-8}		9.42×10^{-9}	7.73×10^{-9}
AY			-0.0008		
AY2			6.72×10^{-9}		
UNEMP				0.2779	0.1444
CONSTANT	-61.47	-36.65	-33.76	-42.32	-34.08
R^2	0.6522	0.6531	0.6526	0.6532	0.7224
Income level at bottom of "U"	N.A.	$58,857	$66,108	$59,873	$62,160
Income level below which usage exceeds the average	N.A.	$35,624	$42,656	$35,925	$37,701

This does not mean that the other variables are not important determinants of gas usage. Regression analysis allows us to answer the question, "What is the impact of a particular variable, assuming all of the other variables are held constant?" By including HDD in the regression equation, we effectively examine the impacts of the other variables after extracting the impact of weather. Even though variations in these other factors do not cause as much variation in usage per customer as weather over the study period, regression analysis allows us to isolate the separate impacts of the other variables in terms of usage variations across zip codes. Put another way, weather is the most important determinant of month-to-month variations in usage, while the other variables are important in explaining usage variations across zip codes.

As was the case in the annual models, the coefficients on weather (HDD), housing age (AGEMED), housing size (RMSMED), and unemployment (UNEMP) all have the expected signs and are statistically significant. In addition, both the income variables are statistically significant and each has the sign that yields a "U"-shaped income-consumption relationship: negative for MY (AY in Model 3M) and positive for MY2 (AY2 in Model 3M). And as was the case for the annual models, the equation that omits the squared income variable (1M) indicates that a hypothesized linear income-consumption relationship (if correct) is downward-sloping—low-income customers use more gas than high income consumers.

Fig. 4: Monthly Model Estimates



Results of models including the price variable PRICE, which are not presented here, are at first somewhat puzzling. In all of the models I examined that included PRICE, the price variable had a positive and statistically significant coefficient. While this is somewhat troubling from the standpoint of pure microeconomic theory–the price variable should have a negative coefficient, to comport with the theory that higher prices reduce consumption—the rather unique case of utility pricing in which consumers are rarely aware of the marginal price of an additional unit of consumption helps explain it. Indeed, while consumers should reasonably be expected to be are aware that they use more gas in cold weather, they generally cannot determine *how much* more until they receive a bill, by which time they are already halfway into the next billing month. In addition, increases in price (which more frequently result from gas cost increases rather than margin rate increases) tend to occur during colder weather periods, which is in fat the case for this dataset.

What conclusions can be reached from the annual and monthly models? First, that the income-consumption relationship in MGE's service territory is very likely "U"-shaped, and that larger fixed customer charges are *not* regressive. Second, as would be expected, older, larger homes use more gas than newer, smaller ones. Third, the presence of non-working adults in a household tends to increase gas consumption. While it can be argued that the models of household natural gas consumption examined in this study do not allow us to precisely state the extent to which usage increases at low income levels, I have seen no evidence whatsoever to indicate that low-income customers as a group use a lower than average quantity of natural gas.

III. Technical Details: Variable Calculations and Regression Techniques

This section describes the data used and provides additional discussion of the regression analyses. An initial issue was determining the zip codes to include in the analysis. MGE provided me with a list of 226 zip codes. Forty-five of these could be eliminated because either 1) usage in the zip was either 0 in all 24 months or fewer than 24 months of data were available; or 2) they do not appear in the 2000 census. The eliminated zip codes accounted for less than 2% of MGE volume sales over the study period. After eliminating these 45, there were 181 zip codes remaining.

Table 3 lists the names of variables used in the study, their respective mean values, and a brief definition of each. Some are discussed at greater length following the table. Note that all variables with monthly values that vary by month (CCF, HDD, PRICE) cover the period October 1998 through September 2000. If two numbers appear under "Mean," the first is for the annual models, and the second is for the monthly models. See Tables 1 and 2 to determine which variables were used in each model.

Table 3: Variable Means and Definitions

Name	Mean	Description
CCF	69.83/69.17	Usage per bill, MGE residential class
HDD	8389.5/349.56	Bill-cycle weighted heating degree-days, 65° basis
AGEMED	31.011	Median age of housing in zip, 1999
RMAVG	5.56	Mean number of rooms per housing unit
PRICE	0.48784	MGE's residential non-gas margin plus volumetric gas rate
MY	39,389	1999 median household income
MY2	1.71×10^9	MY x MY
AY	47,183	1999 mean household income
AY2	2.42×10^9	AY x AY
UNEMP	5.08	Unemployment rate, percent
PCTOWNOC	74.14	Percentage of housing units that are owner-occupied

Values for CCF were computed from data provided by MGE on total volumes recorded by month and zip code and the corresponding number of bills. For annual data, the mean shown is the 24 month total of usage divided by the 24 month total bills. For monthly data, that same calculation is carried out using individual CCFs for each month, and the mean is the sum of these monthly figures divided by 4,344, the number of observations. The difference between the two values is explained by the variation in the number of bills across months in a given zip code.

Values for HDD were calculated in a standard way. First, HDD for each month, billing cycle, and weather region in MGE's service territory were calculated. This yielded 1,512 HDD values (24 months x 21 billing cycles x 3 weather stations–Kansas City, Joplin, and St. Joseph). This calculation involved summing the daily HDD figures across the days in a month/billing cycle/weather region. Then, if a given zip code had only one bill cycle, the simple sum was used. But if a zip code had multiple billing cycles, the monthly HDD figure for that zip code is a weighted sum of the bill cycle HDD, with the weights equal to the proportion of total monthly volumes for a zip code recorded for each bill cycle.

AGEMED was calculated from the Census data, equal to 1999 minus the median year built as recorded in the census data. RMSMED was taken directly from the census data.

The price variables were calculated in a manner similar to HDD and were based on the prices (residential non-gas margin plus volumetric gas price) in effect for MGE on each day of the study period. PLAG1 is simply PRICE lagged one month.

The remaining variables were calculated as described in Table 3.

The regressions were done using E-Views version 5.0. The annual regressions used the software's ordinary least squares weighted regression option, with the weights being the number of bills in each zip code. The monthly regressions were done using the random effects panel data specification.

The regression results and some calculations based thereon are presented below in Table 4 (annual models) and Table 5 (monthly models). The additional calculations include usage at various income levels based on a particular model and on the overall means of all other variables; these are the numbers that appear graphically in Figures 3 and 4 above. For those models including the squared income term, the value of income at the minimum of the "U" is also shown, along with the income level below which predicted usage is above average.

Table 4: Annual Model Results (t-statistics in italics below coefficients)

Variable name	1A	2A	3A	4A	5A
	Model No. and Estimated Coefficients (t-statistic in italics)				
HDD	0.002037 *2.21*	0.004647 *6.34*	0.003041 *3.35*	0.002126 *2.66*	0.002677 *3.33*
AGEMED	0.735073 *13.20*	0.378578 *7.26*	0.537519 *8.06*	0.548467 *9.80*	0.556374 *10.15*
RMSMED	20.04573 *12.00*	15.36074 *11.59*	13.95276 *8.84*	12.5293 *9.58*	9.627645 *5.95*
MY	-0.0005 *-6.00*	-0.0026 *-13.51*		-0.000892 *-2.61*	-0.001052 *-3.10*
MY2		2.25E-08 *11.55*		9.77E-09 *3.48*	1.14E-08 *4.07*
AY			-0.001612 *-7.61*		
AY2			1.09E-08 *6.95*		
UNEMP				1.3652 *5.85*	1.4277 *6.22*
PCTOWNOC					0.1704 *2.93*
CONSTANT	-61.37712 *-6.17*	-0.624673 *-0.07*	1.764664 *0.16*	-23.0128 *-2.49*	-20.53606 *-2.26*
ADJ. WTD. RSQ.	0.989556	0.99404	0.990556	0.994991	0.9952
F	111.561	183.0926	102.6354	187.2284	168.6933
Income at minimum CCF		$57,867	$73,945	$45,650	$46,140
Income where predicted usage equals average		$37,135	$47,005	$32,203	$34,613

Table 4, Continued

Predicted usage by income level, evaluated at the means of other variables

Model Number	1A	2A	3A	4A	5A
$5,000	87.47	123.04	113.73	84.21	87.61
$10,000	84.98	111.71	106.49	80.48	83.21
$15,000	82.49	101.50	99.79	77.24	79.37
$20,000	80.00	92.42	93.64	74.49	76.11
$25,000	77.51	84.46	88.03	72.23	73.41
$30,000	75.02	77.63	82.97	70.46	71.29
$35,000	72.53	71.92	78.45	69.17	69.73
$40,000	70.04	67.34	74.48	68.38	68.75
$45,000	67.55	63.88	71.05	68.07	68.33
$50,000	65.06	61.55	68.17	68.25	68.49
$55,000	62.57	60.34	65.83	68.92	69.21
$60,000	60.08	60.26	64.04	70.08	70.51
$65,000	57.59	61.30	62.79	71.72	72.37
$70,000	55.10	63.47	62.09	73.86	74.81
$75,000	52.61	66.76	61.93	76.48	77.81
$80,000	50.12	71.18	62.32	79.59	81.39
$85,000	47.63	76.72	63.25	83.19	85.53
$90,000	45.14	83.39	64.73	87.28	90.25
$95,000	42.65	91.18	66.75	91.86	95.53
$100,000	40.16	100.10	69.32	96.92	101.39

Table 5: Monthly Model Results (t-statistics in italics below coefficients)

Variable name	Model Numbers and regression coefficients (t-statistics in parentheses) 1M	2M	3M	4M	5M
HDD	0.146 *89.24*	0.1465 *89.38*	0.1464 *89.28*	0.1465 *89.30*	0.124486 *70.64*
CCF(-1)					0.326629 *35.03*
AGEMED	0.447 *7.69*	0.3892 *6.57*	0.412 *6.93*	0.3735 *6.32*	0.217301 *11.01*
RMSMED	13.4770 *8.18*	13.1750 *8.12*	11.3190 *7.67*	13.6070 *8.41*	9.7447 *18.24*
MY	-0.0002 *-2.61*	-0.0012 *-4.40*		-0.0011 *-3.98*	-0.0010 *-10.46*
MY2		1.05E-08 *3.75*		9.42E-09 *3.33*	7.73E-09 *8.45*
AY			-0.0008 *-3.66*		
AY2			6.27E-09 *3.51*		
UNEMP				0.2779 *1.72*	0.1444 *2.78*
CONSTANT	-61.468 *-8.02*	-36.653 *-3.66*	-33.759 *-3.42*	-42.319 *-4.06*	-34.08478 *-9.84*
ADJ. WTD. RSQ.	0.6522	0.6531	0.6526	0.6532	0.722485
F	2037.471	1636.528	1632.697	1364.146	1548.91
Income at minimum CCF	N.A.	$58,857	$66,108	$59,873	$62,160
Income where predicted usage equals average	N.A.	$35,624	$42,656	$35,925	$37,701

Table 5,
continued
Predicted usage by income level, evaluated at the means of other variables

Model Number	1M	2M	3M	4M	5M
$5,000	77.17	93.96	89.14	92.13	89.80
$10,000	75.99	88.57	85.46	87.20	85.58
$15,000	74.80	83.70	82.10	82.74	81.74
$20,000	73.62	79.36	79.05	78.74	78.29
$25,000	72.43	75.54	76.32	75.22	75.22
$30,000	71.25	72.25	73.90	72.17	72.54
$35,000	70.06	69.48	71.79	69.60	70.25
$40,000	68.88	67.24	70.00	67.49	68.34
$45,000	67.69	65.52	68.52	65.85	66.82
$50,000	66.51	64.33	67.35	64.69	65.69
$55,000	65.32	63.66	66.50	63.99	64.94
$60,000	64.14	63.52	65.96	63.77	64.58
$65,000	62.95	63.90	65.73	64.02	64.61
$70,000	61.77	64.81	65.82	64.73	65.02
$75,000	60.58	66.24	66.22	65.92	65.82
$80,000	59.40	68.20	66.93	67.58	67.01
$85,000	58.21	70.68	67.96	69.72	68.58
$90,000	57.03	73.69	69.30	72.32	70.54
$95,000	55.84	77.22	70.96	75.39	72.88
$100,000	54.66	81.28	72.92	78.94	75.61

IV. Summary and Conclusions

This study has used two approaches (weighted cross section and random-effects panel data) to investigate the relationship between usage and a number of independent explanatory variables. Regression coefficients with few exceptions are statistically significant and of the correct (i.e., predicted or expected) sign. Most important, there is no evidence that usage and household income are positively related through all levels of income. Rather, the relationship between usage and income has a "U"-shape. At lower income levels, usage increases as income falls, and at the lowest income levels is greater than the overall average usage. The relationship becomes positive at higher income levels—beyond some income level, usage increases with income. The implication for ratemaking is that larger proportional increases in the fixed monthly customer charge are not regressive. That is, increases in the customer charge do not harm low income users as a group. In fact, effecting a residential rate increase by disproportionately increasing the volumetric charge would likely have a greater harmful impact on such customers.