RESEARCH REPORT

UNDERSTANDING MULTI-RESIDENTIAL ENERGY AND WATER END-USE LOAD PROFILES

EXTERNAL RESEARCH PROGRAM

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Understanding Multi-Residential Energy and Water End-Use Load Profiles

Submitted to

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Abstract

Detailed (hourly) gas/electricity/water consumption in 34 multi-residential buildings over a two-year period are examined. A new model is presented and used to characterize for each building its temperature response, the effective thermal capacity and heating/cooling system overhead during the heating or cooling season. More than two fold differences in the energy per unit area or water used per apartment unit among the buildings are observed. A study of seasonal and daily variability suggests that at least a part of these differences in the building energy efficiency can be attributed to poor or complete lack of energy management in many of the buildings.

The data also suggests that in-suite electric heating is 2.5 times more efficient than central gas heating system in multi-residential buildings. The same appears true of in-suite air conditioning, when compared to centralized cooling systems.

Key Words

Energy Consumption, Water Consumption, Load Profiles, Multi-Unit Residential Buildings

Executive Summary

Energy used in residential buildings is a major energy use in Canada (21% of all energy) and presumably in most areas in the Northern hemisphere. A substantial fraction of this energy (24%) is used in multi-residential buildings. However, very little attention has been given to examining the patterns of energy and water consumption, let alone how they can be improved. This report suggests that significant savings and improvements in the efficiency of multi-residential systems are achievable, and this could go long way toward reducing energy usage and fulfilling Canadian Kyoto obligations.

Watershed Technologies Inc. and OZZ Energy Solutions Inc. have been monitoring energy and water usage in multi-residential buildings in Toronto area since 1996. The present analysis looks at detailed (hourly) gas and electricity loads in 34 buildings and water consumption in 21 buildings over a two-year period from May 2001 to April 2003. An earlier report by OZZ documented the different physical features of these buildings and presented an overall summary and a preliminary analysis of gas, electricity and water consumption data along with daily and seasonal summaries[1]. A more detailed analysis is offered in the present report.

A new model is developed which describes the building's energy consumption for cooling and heating more effectively than the traditional degree-day model. The new model quantifies not only the changes in energy load per unit change in temperature but also its effective thermal capacity, the heating system overhead and system response to other weather factors, namely wind, relative humidity and solar access.

A new term has been defined called the "overhead". This is the energy consumed to keep the system operating when no instantaneous heat is required. It represents consumption that is independent of efficiency; a fixed amount of energy that is wasted independent of how much energy is required to satisfy the building load. At this time, the physical basis for this "overhead" is not understood. In gas-heated buildings the overhead is substantial although quite variable from building to building. In the electrically heated buildings we monitored there is no apparent overhead. In addition to the overhead, it appears that gas-heated buildings require over twice the energy to provide space heating when compared to electrically heated buildings. Although it is difficult to substantiate, our analysis suggests that the centrally cooled buildings also have a system overhead lacking in buildings cooled by individual in-suite window units.

We also observe large differences in performance (energy per m^2) among buildings. The least 'efficient' building can consume more than three times the energy overall or more than two and half times the energy per unit change in temperature than the most 'efficient' building over a heating season. The inefficient buildings tend also exhibit large day-to-day or season-to-season variability measured either from common trend or from

[1] "Energy and Water Consumption Load Profiles in Multi-Residential Buildings," Ozz Energy Solutions. Prepared for Housing Technology Group, Policy and Research Division, Canada Mortgage and Housing Corporation, June 2004.

model-predicted values. This large uncontrolled variability suggests a failure in or total lack of the energy management in many of these buildings.

We believe that the availability of an improved model, based on these data, may lead to a better understanding of the factors influencing building performance, and to significant improvements in building management and efficiency.

Résumé

L’énergie consommée dans les bâtiments résidentiels représente une part importante (21 %) de l’énergie consommée à l’échelle du Canada et, sans doute, dans la plupart des régions de l’hémisphère Nord. Un pourcentage considérable de cette énergie (24 %) est employé dans les collectifs d’habitation. Cependant, peu d’attention a été accordée à l’examen des schémas de consommation de l’énergie et de l’eau, et encore moins à la réduction de cette consommation. Selon le présent rapport, il est possible d’effectuer des économies et des améliorations importantes pour accroître l’efficacité des installations mécaniques dans les collectifs d’habitation, ce qui permettrait de réduire de beaucoup la consommation d’énergie et de pouvoir espérer respecter les obligations du Canada relativement à l’accord de Kyoto.

Depuis 1996, Watershed Technologies Inc. et OZZ Energy Solutions Inc. surveillent la consommation d’énergie et d’eau dans des immeubles d’habitation de la région de Toronto. L’analyse dont il est ici question porte sur les charges électriques et gazières précises (mesurées à chaque heure) dans 34 bâtiments, et sur la consommation d’eau dans 21 bâtiments sur une période de deux ans, soit de mai 2001 à avril 2003. Un rapport produit antérieurement par OZZ documente les différentes caractéristiques physiques de ces bâtiments. Il présente un relevé général et une analyse préliminaire des données relatives à la consommation de gaz, d’électricité et d’eau, ainsi que des relevés quotidiens et saisonniers.[1] Une analyse plus détaillée figure dans le présent rapport.

Un nouveau modèle a été élaboré. Ce nouveau modèle est plus efficace que le modèle traditionnel de degré-jour pour décrire la consommation énergétique d’un bâtiment pour la climatisation et le chauffage. En plus de quantifier les changements de charges énergétiques requis par unité de changement de température, il mesure la capacité thermique effective, la charge énergétique générale de l’installation de chauffage et la façon dont l’installation réagit à d’autres facteurs climatiques, notamment le vent, l’humidité relative et l’exposition au soleil.

Un nouveau terme a été défini. Il s’agit de la « charge énergétique générale », qui correspond à l’énergie consommée pour maintenir le fonctionnement de l’installation mécanique quand aucune chaleur instantanée n’est requise. Cette charge représente la consommation indépendamment de l’efficacité, c’est-à-dire la quantité fixe d’énergie gaspillée peu importe la quantité d’énergie requise pour répondre aux besoins du bâtiment. À l’heure actuelle, le fondement physique de cette « charge énergétique générale » n’est pas établi. La charge énergétique générale des bâtiments chauffés au gaz est énorme et elle varie d’un bâtiment à un autre. Parmi les bâtiments chauffés à l’électricité que nous avons évalués, aucune charge énergétique générale n’a été enregistrée. En plus, il semblerait que le chauffage au gaz nécessite plus de deux fois la quantité d’énergie que requiert le chauffage à l’électricité. Bien qu’il soit difficile d’étayer nos constatations, notre analyse indique que si un bâtiment possède un

[1] *Energy and Water Consumption Load Profiles in Multi-Residential Buildings*, Ozz Energy Solutions. Rédigé pour le Groupe de la technologie résidentielle, Division des politiques et de la recherche, Société canadienne d’hypothèques et de logement, juin 2004.

climatiseur central, une charge énergétique générale est enregistrée, alors que cette charge générale est absente dans les bâtiments dotés de climatiseurs d’air individuels.

Nous observons aussi de grandes différences de rendement (énergie par m^2) parmi les bâtiments. Les bâtiments les moins « efficaces » peuvent consommer plus de trois fois l’énergie de l’ensemble du bâtiment ou plus de deux fois et demie l’énergie par unité de changement de température comparativement aux bâtiments les plus « efficaces », pendant une saison de chauffage. De plus, les bâtiments inefficaces ont tendance à afficher une grande variabilité quotidienne ou saisonnière, selon des valeurs tendancielles ou des prédictions obtenues par modélisation. Cette grande variabilité désordonnée semble indiquer un échec, voire un manque total de la gestion de l’énergie dans ces bâtiments.

Nous croyons que la disponibilité d’un modèle amélioré, fondé sur ces données, pourrait entraîner une meilleure compréhension des facteurs qui influencent le rendement d’un bâtiment et favoriser de grandes améliorations au chapitre de la gestion et de l’efficacité du bâtiment.

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Introduction.

Energy use in existing multi-residential buildings seems to have rarely been examined, even though collectively such use must represent a substantial energy drain on Canadian energy reserves. An earlier report by OZZ Energy solutions Inc. looked at the energy and water consumption in 34 multi-residential buildings monitored by Watershed Technologies and OZZ Energy Solutions Inc. over a two year period from May 1st, 2001 to April 30th, 2003[2].

The report by OZZ documented the different physical features of the 34 buildings and presented an overall summary and a preliminary analysis of gas, electricity and water consumption data along with daily and seasonal summaries. A more detailed analysis is offered in the present report.

The daily dependence of the gas and electricity consumption for heating or cooling on current and past temperatures (degree days) and three other climate variables (relative humidity, wind, and solar access) is examined using traditional regression or linear models.

A new non-linear model of energy consumption for heating or cooling is developed. It duplicates the observed load based on the current and past temperatures and weather variables to the same degree of accuracy as the regression models. In addition the new model characterizes the building-heating system in terms of energy required to maintain set level for one degree change in outside temperature, the effective or apparent thermal capacity and the system overhead. The system overhead is the cost to have the heating or cooling system running when there is no instantaneous demand for heat. Unlike the system efficiency, which is determined by the ratio of energy delivered to energy supplied, the overhead is a fixed energy loss that is independent of the amount of energy delivered.

We characterize the daily variability in energy/water consumption data. This is measured either as deviations from model predicted values or as deviations from common pattern corrected for each building's average performance. We also looked at the differences between years or heating seasons. All measures of deviations appear to be correlated with the building's efficiency, measured as mean daily consumption per unit area.

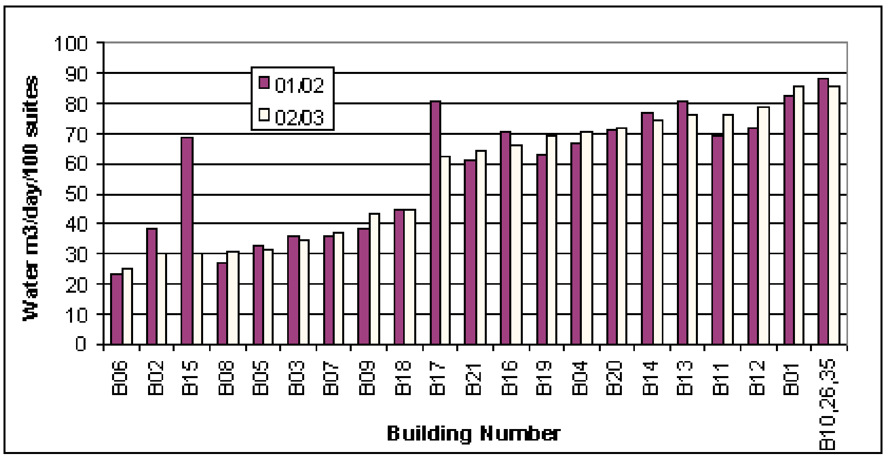
This relationship between variability and performance may provide a good yardstick to identify opportunities for controls improvements, based on monitoring data.

[2] See footnote 1 in the Executive Summary

1.0 Water Consumption

The amount of water consumed per apartment or per unit varies substantially between buildings. This is shown in Figure 1 for two consecutive years from May to April. Note that we have used the number of apartment units rather than unit area used in dealing with energy consumption. There seems to be more variation in the water consumption per unit area than per number of units. Also there is no correlation between the water consumed per unit and the average unit floor area. The source data are given in Table W1 in the Appendix.

Figure 1: Water Consumption, m^3 per day per 100 apartment units.
Note: The solid bars are from May 1st, 01 to April 30th, 02 and shaded bars from May 1st, 02 to April 30th, 03.



There are two buildings, B15 and B17, which used substantially more water in the first year than in the second. This may be due to a water retrofit program, or to repairs. We also note that there is large variation between the buildings, which can probably be traced to the occupancy, the demography, and the efficiency of the water equipment, including leakage factors.

To examine the leakage we determined the ratio of the maximum to minimum usage in a day for sample period for each building. The sample period chosen was a week in March, 2003 (from 7th to 13th). The minimum water consumption typically occurred from 4 to 5 am and the maximum late morning or early evening. The ratio of maximum to minimum ranged from low of 3.9 to high 18.4. The values are listed in Table W1 in appendix W. The values toward the lower end of this spectrum may come from buildings where there is considerable leakage although without more detailed monitoring program it is difficult to say where the dividing line is. The building B15 that had very high water consumption in the first year (2001/02) had many weeks when the ratio was less than 2.

From experience monitoring many multi-residential buildings, a minimum to average ratio of 0.2 (20%) seems to be a good benchmark target for water leakage.

2.0 Natural Gas Consumption

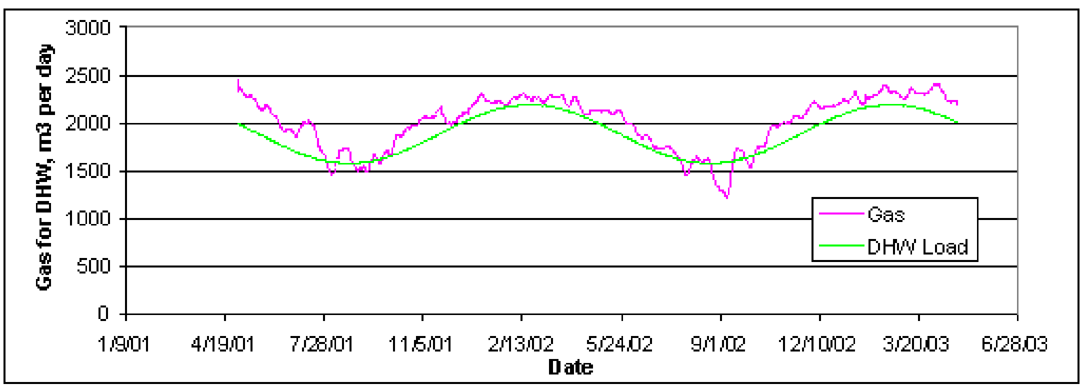
2.1 Domestic Hot Water.

All the buildings in our data set use gas for domestic hot water heating. In all but three of the buildings it is also used for space heating. Other uses, not necessarily common to all buildings, include heating of the corridor air, use in the common laundry facility to run the dryers, heating of the parking garage, heating of the swimming pool, and cooking. Typically none of these end uses are metered separately. Commonly there is only one meter for a building, and sometimes one gas meter serves two or three adjacent buildings.

The two major uses of gas are space heating and heating domestic water. Because during the summer months gas is used only for domestic hot water (DHW), we can establish a base line for DHW load in each building[3]. By making use of the known fluctuations in the groundwater temperature with season we can extend this gas demand for DHW to the rest of the year. We were able to verify this estimated load curve for DHW for three electrically heated buildings in our data set that used gas only for the DHW. These are shown in Figure 2 below. In our earlier analysis we established that none of the other end uses except for the DHW are large enough for us to be able to estimate and separate them from the space heating.

Figure 2: Total Observed and Estimated Gas Consumption for Domestic Hot Water (DHW) in Three Electrically Heated Buildings Combined

Note: 'Gas' is the observed and 'DHW load' is the estimated consumption, expressed as m3 per day.



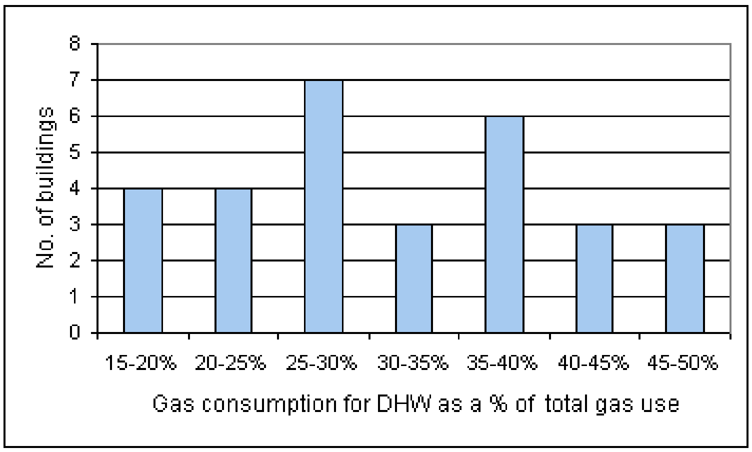
While there is a general agreement between the observed and estimated gas consumption there is nevertheless good deal of daily variation in the gas used for domestic hot water. A daily coefficient of variation of 8% is observed for the three buildings combined. For individual buildings the coefficient of variation could be 14%[4]. This alone can explain a

[3] "Energy and Water Consumption Load Profiles in Multi-Residential Buildings," op. cit.
[4] This follows from simple laws of statistics governing the relationship between the variability and sample size.

part of the large variability observed in the total gas consumption and in the portion estimated for space heating in gas-heated buildings.

Apart from day-to-day variation in the amount of gas used for DHW there is also considerable variation in the gas consumption for DHW from one building to the next. The domestic hot water consumes anywhere from about 16% to 49% of the total gas used in a building[5]. This amount of variation is astonishing, and it would be of interest to know the reasons for it. No doubt an efficient/inefficient gas heating system in some buildings appliance efficiency, and building occupancy are some of the contributing factors. The graph below provides a frequency distribution of the DHW use as a fraction of total energy, across our data set.

Figure 2A: Domestic Hot Water Natural Gas Consumption as a Percentage of Total Gas Use



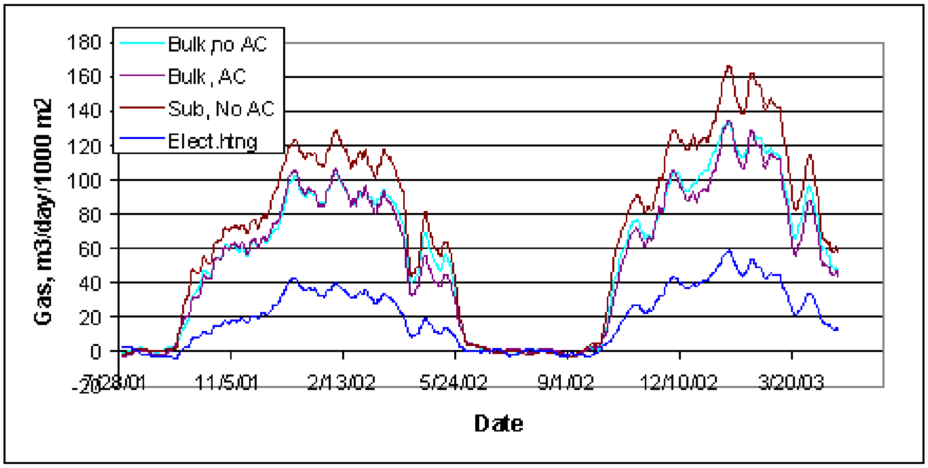
[5] Table 2, op. cit.

2.2 Space heating.

The seasonal pattern of gas and electricity consumption for space heating is shown in Figure 3. For convenience, the buildings have been grouped by mode of electrical metering and whether or not they have a centralized cooling system. For comparison we have included in our graph the average of three electrically heated buildings.

Figure 3: Seasonal Energy Consumption for Space Heating

Note: Gas is in m^3 per day per $1000m^2$, for purpose of comparison the electricity load has also been converted gas equivalent. Data are 13-day running averages



Notes: Bulk, no AC, bulk--metered buildings without central air; Bulk, AC, bulk-metered with central cooling; Sub, No AC, sub-metered buildings without central cooling; Elect. heating, electrically hated buildings, also no central cooling. Electric load (kWh) has been converted to gas equivalent by multiplying by 96/1000.

As a group, the heating costs for sub-metered buildings seem to be somewhat higher than the rest of the buildings. The eight buildings comprising this group are older buildings generally with fewer stories than the rest.

We can see that the gas consumption is very dependant on temperature. The correlation coefficients of the gas consumption, averaged for all buildings, against the temperature by seasons are tabulated in the Table 1 below.

Table 1: Correlations between Average Daily Gas Consumption and Temperature by Seasons

Season		Total Gas	Total less DHW
Fall 01	1/9/01 to 14/10/01	-0.768	-0.774
Winter 01/02	15/10/01 to 15/4/02	-0.971	-0.971
Spring 02	16/04/02 to 31/5/02	-0.950	-0.950
Summer 02	1/6/02 to 31/8/02	-0.660	-0.696
Fall 02	1/9/02 to 14/10/02	-0.795	-0.789
Winter 02/03	15/10/02 to 15/4/03	-0.971	-0.975

There is a clear, and what appears to be a linear relationship between the gas consumption and temperature during both winter seasons, 01/02 and 02/03. The significant, negative correlations in the fall, spring and summer appear to be due to the temperatures that are less than 18^{o}C. This is more clearly seen in Appendix "G", Figure G1. In what follows, we have generally defined the two heating seasons to be from 05/10/01 to 28/05/02 (Season 1) and from 05/10/02 to 30/04/03 (Season 2). The latter season is somewhat shorter because of the data was cut off at the end of April in 2003.

2.3 Linear Models of Gas Consumption

Three different models were assessed to characterize energy use for space heating/cooling as a function of climate variables. Model 1L is the standard model, using an intercept, and degree days only. Model 2L also includes the "lagged degree days", i.e. the degree days from the previous three days, and Model 3L also includes other weather variables (wind, humidity, and solar opacity, which is a term used at weather stations to indicate cloud cover). The resulting linear regression equations are:

Model 1L $\quad \text{Gas} \sim \mathit{Intrcpt}_1 + \mathit{Slpe}_1 * \text{DgrD}$

Model 2L $\quad \text{Gas} \sim \mathit{Intrcpt}_2 + \mathit{Slpe}_2 * \text{DgrD} + \mathit{Lag1} * \text{LagD1} + \mathit{LaG2} * \text{LagD2} + \mathit{LaG3} * \text{LagD3}$

Model 3L $\quad \text{Gas} \sim \mathit{Intrcpt}_3 + \mathit{Slpe}_3 * \text{DgrD} + \mathit{Lag1} * \text{LagD1} + \mathit{LaG2} * \text{LagD2} + \mathit{LagG3} * \text{LagD3} + \mathit{H} * \text{Hmdty} + \mathit{W} * \text{Wnd} + \mathit{O} * \text{OpD}.$

where DgrD (degree days) = 18^{o}C-temperature, and LagD1, LagD2, and LagD3 are the degree days 1, 2 or 3 days before. Hmdty, Wnd and OpD stand for the measured relative humidity, wind speed and daytime opacity. In carrying out the calculations we have standardized the measured Hmdty, Wnd and OpD to the zero mean in order to remove their effect on the intercept. The italicized terms are the regression coefficients. These same equations could also be used to characterize the energy demand for cooling during the summer months.

All three models have been fitted to daily gas consumption for each building that had an adequate number of observations. Initially we fitted the Model 1, 2L and 3L separately for first and second heating season. We then tested the different models separately for each season. The results are shown in Table G1, in Appendix “G”. A separate table is provided for each season. The results are also summarized in Table 2 below. In Appendix “G”, Table G1, we list the correlations coefficients for each building for each model, as well as the Model 1 parameter values, the number of observations and the F-values that test the significance of Model 2L over Model 1L and Model 3L over Model 2L. The summary text Table 2 below lists the average values over all 23 buildings; these are the bottom lines in Table G1. Only those buildings were included that had more than 140 observations in both heating seasons.

Table 2: Model 1L Regression Coefficients and Tests of Model 2L versus Model 1L and Model 3L versus Model 2L;

(Note: values are averages for 23 buildings with data for both seasons. Season 1: 05/10/01 to 28/05/02, 238 days; Season 2: 05/10/02 to 30/04/02, 208 days)

								No.significant	
	No.Obs.	Mean	Intrcpt	Slope	r^2	R_2^2	R_3^2	F2/1	F3/2
Ssn1	229	75.11	15.56	4.32	0.862	0.899	0.909	22	20
Ssn2	206	94.00	14.53	4.38	0.896	0.919	0.935	23	23

Note: Mean is the mean daily consumption during the heating season for 23 buildings. r^2, R_2^2 and R_3^2 are squared correlations for Model 1L, 2L and 3L. No. significant: these are all out of 23, e.g. entry such as 22 in Column F2/1 means that in 22 cases out of 23 Model 2L was significantly better than Model 1L.

We observe that Model 2L is almost always an improvement over Model 1L; this means that not only is the daily temperature important but also temperature over the previous three days. Similarly, Model 3L is statistically significantly better than Model 2L. This means that at least one of the climate variables has a significant influence on the gas consumption. However, practically speaking, the difference between Models 2L and 3L is not very large.

Table G2 (Ssn 1) and Table G2 (Ssn 2) show the fitting of Model 2L to our data. The two heating seasons have been kept separate. All the buildings that have a substantial number of observations (more than 140) are included in the calculations. Three buildings (not in Table G1) had an adequate number of observations in the second heating season but not in the first. These were included in the calculations. The text Table 3 below gives the summary (average) for all the parameters for both seasons

Table 3: Model 2L Regression Coefficients and Significance Tests of Lag1, Lag2 and Lag3 Regression Coefficients

(Note: values are averages for 23 buildings in Season 1 and for 27 buildings in Season 2)

								Significance level		
	Mean	R_2^2	Intrcp	Slope	Lag1	Lag2	Lag3	Lag1	Lag2	Lag3
Ssn 1	73.53	0.90	9.61	3.35	0.70	0.27	0.43	22/23	20/23	21/23
Ssn 2	92.57	0.92	9.95	3.32	0.67	0.24	0.31	26/27	19/27	18/27

Note: Mean is the mean daily consumption during the heating season, 23 buildings in Ssn1, 27 in Ssn2. Significance level refers to the number significant (out of 23 or 27) at least at 5% level.

All three lag terms (Lag1, Lag2, Lag3) appear to be significant for almost all buildings. However, it is somewhat baffling why Lag3 coefficient is on the average larger than Lag2 term; why would temperature three days ago have more influence than the one two days before?

For Model 3L the results are given in Table G3 and in the text Table 4 below. Although not shown, the regression coefficients for lag terms continue to be significant. The significance of the climate variables seems to be somewhat different for the two seasons. In general they are more important in Season 2 than in Season 1. Wind is the most important climate variable both seasons. Humidity is more important than opacity in Season 1 and vice versa in Season 2.

Table 4: Model 3L RegressionCoefficients and Significance Tests of Humidity, Wind and Daytime Opacity Regression Coefficients

Note: values are averages for 23 buildings in Season 1 and for 27 buildings inSeason 2

										Significance level		
	R_3^2	Intrcpt	Slope	Lag1	Lag2	Lag3	Hmdty	Wind	OpD	H	W	O
Ssn1	0.95	11.69	3.31	0.84	0.30	0.40	10.39	0.26	0.18	11/23	16/23	6/23
Ssn2	0.93	9.73	3.17	0.75	0.29	0.34	-2.3	0.43	0.53	7/27	26/27	14/27

Notes: Significance level: 11/23 denotes that 11 out of 23 cases H (Humidity) is significant, 26/27 denotes that W (Wind) is significant in 26 out of 27 cases, etc

"Mean" in Table 2 is the mean daily gas consumption; it is essentially the average daily gas used for heating (m^3 per day per $1000m^2$) averaged over 23 buildings that have data common to both seasons. The average gas consumption in 2002/03 is about 25% higher than in the previous year, primarily on the account of lower temperatures in the 02/03 season as compared to 01/02.

The fact that the mean consumption varies from year to year should not have an effect on the regression coefficients. After all, the variable driving the increase (i.e. temperature) along with its lag effects have been included in the models. However, there are significant differences in the regression coefficients between the two seasons. For Model 1L 15 buildings out of 23 have significant differences between the two seasons. In case of Models 2L and 3L the number of cases when the two relationships are different is even higher: 19 and 22 buildings respectively out of 23. Some of the differences are not large but nevertheless they are statistically significant[6].

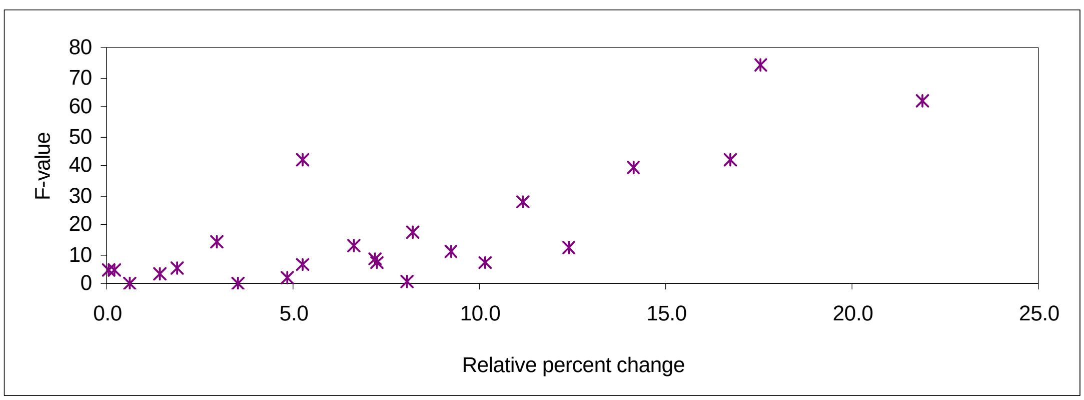
Table G4, Appendix "G", lists the results of the significance tests and along with the changes in the mean abundance. In Table G4 we also show the percent change in the mean consumption from Season 1 to Season 2. The increase varies considerably. At the lower end Building B29 consumes only 9% more gas in the 02/03 season than in the previous year, at the upper end Building B05 burns 48% more gas in the second year.

[6] It may well be that the calculated seasonal differences in Model 2 and Model 3 are caused by changes in the groundwater temperature and hence changes in DHW gas consumption. As it is, we have used the same groundwater temperatures both seasons.

It is a puzzle why, for any give building, the gas consumption is differently related to temperature and other climatic variables from one season to the next. If we were looking at the temperature alone as in Model 2L, we could expect that the differences were due to different wind/humidity/opacity conditions. Quite the opposite is true: when the wind/humidity/opacity are included the differences between the seasons are even more pronounced. Adding additional terms such as degree days squared does not change the picture. In some cases, these differences in building performance may be an indication of retrofits or improvements, but in many cases, the range of performance from one season to the next may simply reflect a randomness in the manner that the heating systems are managed or controlled.

The values of the F-test (tabulated in Table G4) are one measure how different the two seasons actually are. Another measure is the percent change in the mean consumption. The correlation between the two is rather weak ranging from 0.187 to 0.356 (Table G4). However, if we correlate the F-values and the relative percent change, i.e. relative to the mean ignoring whether the change is up or down, the correlations increase substantially. They now range from 0.62 to 0.79. In Figure 4 below we have plotted the F-value (Model 1L) against the relative percent change. This clearly shows a relationship between the variables.

Figure 4: F- value Measuring the Change in the Regression Residuals between Seasons vs. Relative Percent Change in the Mean Gas Consumption from Heating Season 1 to Season 2.



Note: The relative percent change is calculated as the absolute value of [mean2/mean1-Average(mean2/mean1)] where mean1 and mean2 are means for a building for Season 1, 2 and Average() is the average over all buildings. The absolute values are then converted to percentages.

When the building efficiency, (expressed as average daily heating consumption per $1000m^2$), changes from one season to the next and when the relationship of the building gas consumption to the temperature and to the other climate variables also changes, this suggests a problem in the energy management of the building. The change could be caused by a change in the boiler efficiency, an unbalanced heat delivery system, improper tracking of the demand for the heat by the control system, and a host of others. All we can say that this problem appears to be quite common. Perhaps one third of the buildings have rather poor energy management.

It is difficult to say how much energy can be saved by good energy management. However, it is not uncommon to see a building's energy consumption to change 10 to 15% from one season to the next relative to its position among all other buildings, all other variables such as weather being equal. This percentage would also be the minimum potential improvement for these buildings.

Predicting the Consumption. Since the relationship of the gas consumption to temperature and other climate variables changes from one season to the next, it should not be possible to predict the daily gas consumption based on the historical data using our regression models even though we know the climate variables. What happens if we try to do it anyway?

If we predict the average daily consumption in Season 2, given the daily weather pattern, based on the data from Season 1, we will underestimate the daily consumption in Season 2 on the average of 3.3%. However, at the individual building level the average bias ranges anywhere from –15.3% to 24.4%. Predicting Season 1 daily consumption based on Season 2 consumption and climate data results on an average bias of 1.3% while the estimated consumption by individual buildings ranges from about –13.6% to 14.6%. The details are shown in Table G5. At those magnitudes of bias there is not much hope of being able collect data from one year to predict the building efficiency in future years. Without better controls or feedback monitoring, a building can be somewhat efficient one year and rather inefficient the next, or vice versa. This may point to "randomness" in the manner in which the buildings are being managed, rather than to specific physical characteristics.

2.4 Non-linear Models of Gas Consumption

When the linear Models were fitted we got more or less consistently higher coefficient values for Lag3 term than for Lag2. It does not make sense that the temperature three days before would have greater impact on the gas than the temperature two days before. According to the Newton's Law of Cooling the effect of the past temperatures should decrease exponentially in time. Hence, we replaced the above linear Models 2L and 3L by models that incorporate the exponential Law of Cooling. The various degree-day coefficients in the linear models (for the different lagged days) have been replaced by a single coefficient which decreases exponentially with time. The new non-linear models are as follows:

Model 2 $\quad \text{Gas} \sim Intrcpt_2 + Slpe_2 * [\text{DgrD} + lagC * \text{LagD1} + lagC^2 * \text{LagD2} + lagC^3 * \text{LagD3}]$

Model 3 $\quad \text{Gas} \sim Intrcpt_2 + Slpe_2 * [\text{DgrD} + lagC * \text{LagD1} + lagC^2 * \text{LagD2} + lagC^3 * \text{LagD3}] + H * \text{Hmdty} + W * \text{Wnd} + O * \text{OpD}$.

Table 5 below compares the respective fits (R^2's) for the linear and non-linear models. By and large, the R^2's are very much the same for the linear and non-linear models, differing mostly in the third decimal place. The reason that the linear model R^2's are slightly higher is because they have two extra parameters.

Table 5: Comparisons of Linear and Non-linear Models
Values are the averages for 23 buildings

	Linear Models		Non-linear Models		F-test 3/2	Significance level
	R_2^2	R_3^2	R_2^2	R_3^2		
Ssn1	0.899	0.909	0.891	0.902	11.31	21out of 23
Ssn2	0.919	0.935	0.917	0.933	19.05	23 out of 23

Detailed comparisons of linear Model 3L and non-linear Model 3 are given in Table G6 (Appendix "G") for second heating season. While the parameterization is somewhat different, if we compare the total temperature effect, captured by what we call the composite slope (defined in Table G6, see also next page), the two models give much the same parameter values and not just the same R^2's. Generally, any situation true for linear models appears also to be true for non-linear models.

In Table 5 we also compare the two non-linear models with each other. The column labelled 'F-test 3/2' shows the average of F-values when Model 3 is tested against Model 2. The next and the last column shows the number of cases where the test is significant.

Tables G7 and G8 give the results for fitting non-linear Models 2 and 3 to our gas consumption data sets. The results are summarized in the text Table 6 below. The first line for a given season gives the Model 2 parameters, the second line the Model 3 parameters.

Table 6: Comparisons of Non-Linear Models 2 and 3.
Note: Values are the averages for 23 buildings for Ssn 1 and 26 buildings, Ssn 2.

	Model	R^2	Intrcpt	Slope	lagC	Hmdty	Wind	OpD	No. Significant out of 23 (Ssn1) or 26 (Ssn2)		
SSn1	2	0.89	10.36	3.21	0.33				Hmdty	Wind	OpD
Ssn1	3	0.90	12.39	3.18	0.37	12.40	0.29	0.12	10	15	2
Ssn2	2	0.92	9.41	3.35	0.27						
Ssn2	3	0.93	10.36	3.08	0.33	-1.33	0.44	0.48	2	22	12

Notes: "No. Significant out of 23" column refers to number of times Hmdity (Humidity), Wind, or OpD (day time opacity) are significant

Model 3 appears to be an improvement over the Model 2 mostly because wind and at times humidity and opacity have a significant impact on the heating costs.

We can improve the non-linear model's R^2 by including higher lags such as degree-days lagged four and five days. For some buildings these extra terms are in fact significant. However, it seems futile to pursue better fits in this direction in the face of large season-to-season fluctuations perhaps due to changes in the building's energy management.

2.5 Understanding the Patterns of Gas consumption

It has been observed that the slope of the gas consumption-temperature relationship is related to the building insulation[7]. Here we have gone one step further and calculated not only the slope effect but also the lag effects. We may think of the slope as being related to the building insulation and the lag, the thermal capacity of the building. These are rather general terms and their relationship to actual insulation and thermal mass has not been assessed, since we don't have any information on insulation, thermal mass, or air filtration.

It appears that we can characterize a building's gas consumption and its response to temperature by the three primary parameters of Model 2 or 3, namely:

Intercept (m^3 per $1000m^2$ day per day)	Consumption at $18C^o$. If positive this is an estimate of the heating overhead (a fixed consumption independent of the load).
Slope (m^3 per $1000m^2$ day per day/C^o)	Rate at which gas consumption increases with the temperature. Presumably related to the building envelope, air infiltration, ventilation, and boiler efficiency
LagC (dimensionless)	Relates how well the building retains heat, and presumably to the thermal mass of the building.

To further understand these relationships, the slope and lagC are combined into a new term that we call the "Composite Slope". In addition we can measure the variability from the predicted consumption based on Model 2 or 3 fit This variability is calculated as a square root of residual mean square, dubbed here as StDev.

The Intercept is a measure of the heating system overhead, although it can also depend on the indoor set temperature or temperature reference point as well as the internal and external gains in the building. If the building temperature is set too high the building is overheated and the estimated intercept becomes more a measure of overheating rather than the heating system overhead. In any case, we observe that our calculated intercept is correlated with the total mean consumption ($r = 0.817$ for Ssn 1, $r = 0.531$ for Ssn 2).

The total effect of the temperature is perhaps best characterized by the composite slope. For our different models it is obtained from

Composite slope = Slope	Mode1 1
Composite slope = Slope + Lag1 + Lag2 + Lag3	Model 2L, 3L
Composite slope = $Slope*(1+lagC+lagC^2+lagC^3)$	Model 2, 3

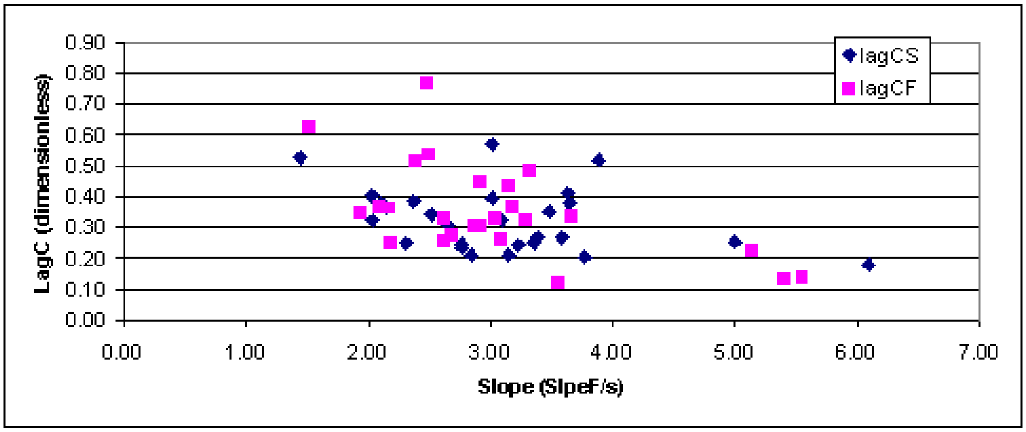
[7] Data set collected by UK Building Research Station by Mr. Derek Whiteside. It is published in: Hand, D. J.,Daly, F, McConway, K., Lunn, D. and Ostrowsky, E. eds. (1994) A Handbook of Small Data Sets. London: Chapman & Hall [139,272]

Note that Model 2L, 3L and Model 2, 3 refer to the linear and non-linear models respectively. (Model 1 and 1L are identical, since there are no terms from lagged days.) The composite slope tends to be much the same irrespective whether we use linear or non-linear versions of Model 2 or 3. Even the slope calculated using Model 1 is still in the same neighborhood. Comparisons of the composite slopes for linear (Model 1) and non-linear Model 3 are shown in Table G9.

We can show graphically the inter-relationship between some of the above parameters and the mean daily consumption. Figure 5 plots the lag effect against slope for the first and second heating season. The relationship between the two variables is not very clear.

Figure 5: Lag Effect (LaC) vs. Slope

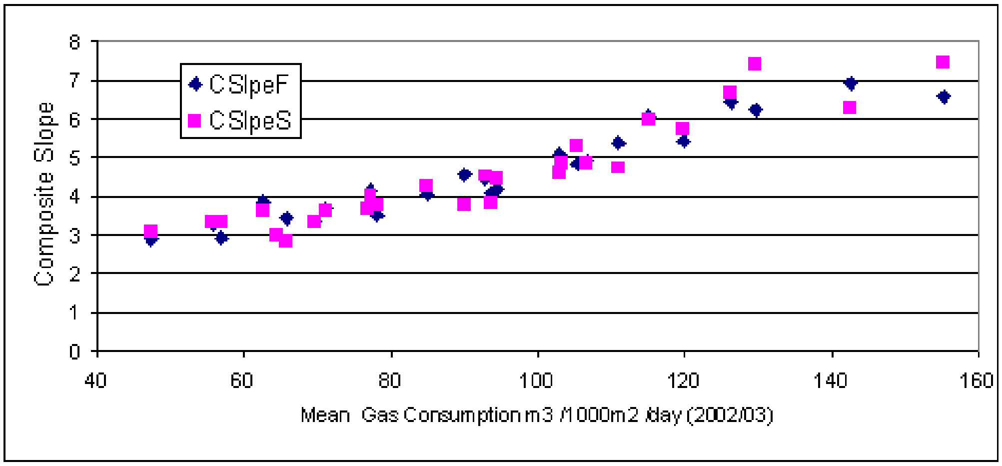
Note: The suffix F or S stands for the first (F) or second (S) heating season. The slope has dimensions m^3 per $1000m^2$ day per day/C^o; LagC is dimensionless.



We do notice, however, that the building with the smallest slope (and the lowest consumption of gas in m^3 per 1000 m^2) has one of the highest lag effects. Also two of the buildings with highest slopes (and the highest consumption) have low LagC values suggesting very poor heat retention properties (either low mass, or high relative consumption from other factors).

In Figure 6 we show the composite slope graphed against the mean gas consumption. The composite slopes for both seasons (CSlpeF, CSlpeS) have been plotted against the gas consumption (x-axis) during the second heating season. By identifying the pairs of points that represent each building in the 2 seasons, we can thus see graphically the differences in the composite slopes in the same building between the two seasons.

Figure 6: Plot of Composite Slope (CSlpeF, first season, CSlpeS, second season) vs. Mean Gas Consumption during the first/second heating season; Model 3 parameter values.



Note: Mean and CSlpeF/S have dimensions m^3 per $1000m^2$ per day.

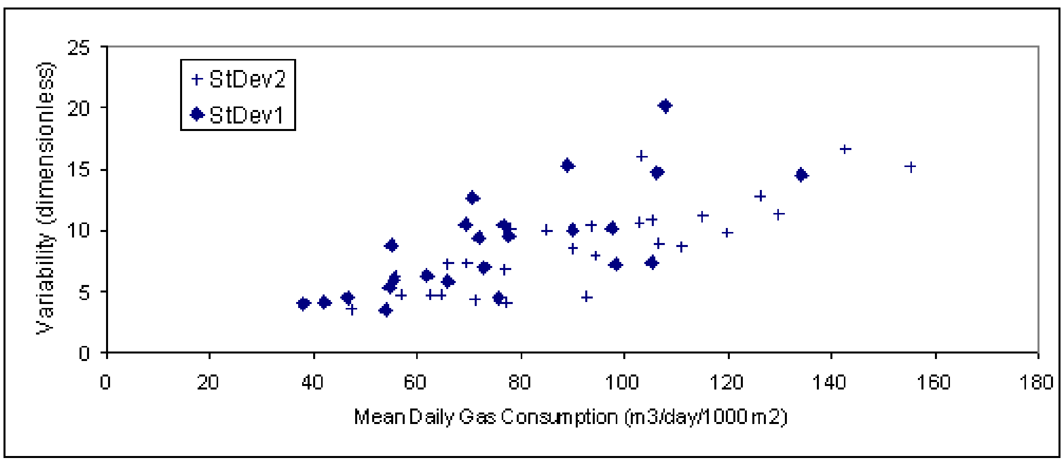
The correlations between the composite slope and the mean consumption during the heating season is quite high; for the first season we get r = 0.929 and for the second r = 0.939. The composite slope along with the heating overhead can be used to summarize the building heating consumption while the lag term (lagC) defines its response pattern in time.

Variability

We can use these models both to predict gas consumption and to assess the variability or predictability of a given building on a daily basis.

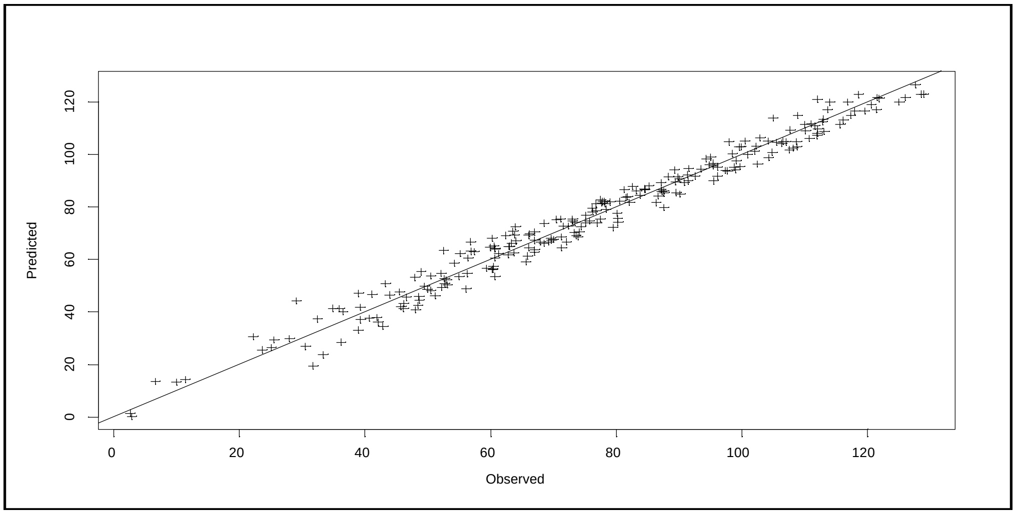
We find that the variability is also closely correlated with the mean gas consumption per unit area. In the two figures below we show the variability plotted against the mean gas consumption.

Figure 7: Variability (StDev) vs. Mean Daily Gas Consumption
Note: First Heating season (StDev1); r = 0.72; the second heating season (StDev2), r = 0.82



The variability is a measure of deviations between the observed and predicted values, or in statistical terminology it is the square root of mean residual sums of squares. It does not make much difference whether we use Model 2 or model 3 residuals. They are much the same. The correlation coefficient is somewhat better for the second season than for the first. In any case, as the consumption goes up so does the variability. Graphically, if we plot the predicted value against the observed as in Figure 8 StDev is a measure of the width of the band around the diagonal that contains most of the points.

Figure 8: Predicted versus Observed Daily Gas Consumption for the Average of all the buildings, First heating season, R^2=0.975, StDev=4.5



2.6 Summary: Natural Gas Consumption.

We have used two different kinds of models to analyze the gas usage in relationship to weather data during the two heating seasons. If all the weather parameters are taken into account, including average temperature on the 3 previous days, there is not much difference between the two sets of models in terms of statistical goodness of fit. However, the second set of models, termed here as “non-linear” appear to have an advantage in that they have fewer parameters, and their parameter values may suggest physical interpretation.

The main parameters of the non-linear models are the intercept or “overhead”, the “composite slope” and the lag term. The overhead relates a constant level of energy expended to keep the system operating, regardless of the demand for heat. The composite slope is related to the building insulation and the boiler efficiency. The lower the insulation value of the building, or the boiler efficiency, the higher the slope. The slope would also affected by heat delivery losses, air infiltration rates and other temperature related heat losses. The lag term reflects the extent to which the building retains the heat and may reflect the thermal mass of the building, or its relative importance in determining gas consumption.

As we would expect, the intercept or the apparent heating overhead is positively correlated with the mean gas consumption (r = 0.82, 0.53). What we call overhead appears as constant losses in the heat delivery system. This has been evaluated further in an in a section below, titled “other studies”.

The total effect of the temperature on gas consumption is best characterized by what we call the composite slope, which is a combination of the slope and lag terms. The composite slope along with the overhead are a measure of the building’s energy efficiency, in terms of the gas consumption for space heating per 1000 m^2 of building area.

Poor insulation, high infiltration and inefficient heat delivery may account for the observed inefficiencies among the buildings. However, the variations in the model parameters from one season to the next, as well as the high within-season variability that we see in the more “inefficient” buildings, suggest an inadequate heating control, in response to changes in temperature. It is highly probable that substantial energy savings could be realized simply by better energy management of the existing systems

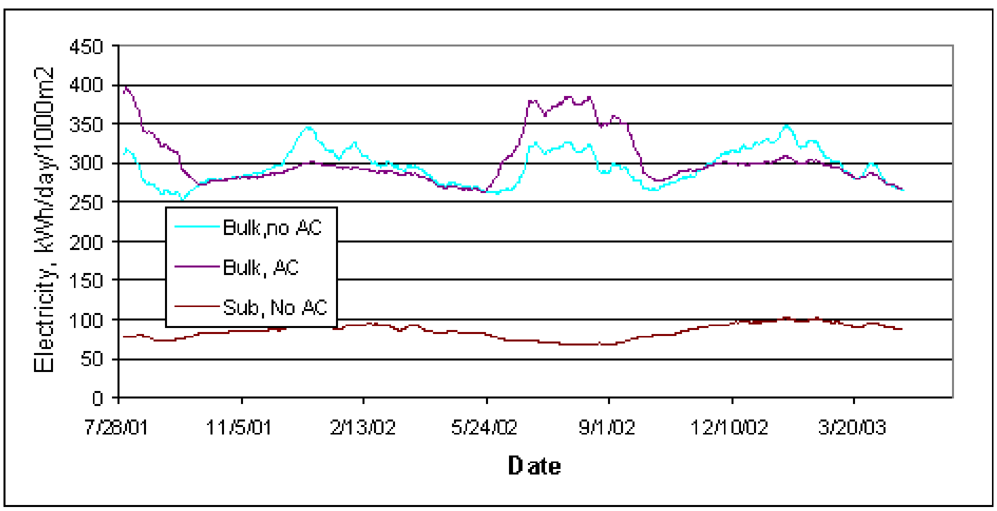
3.0 Electricity Consumption

We have classified the gas-heated buildings into three major groups depending on the mode of electric metering and whether the building is centrally air conditioned or not. In addition there are three buildings in our data set that are electrically heated.

Sub metered buildings are those that have individual electric meters for each suite, and the cost of electricity for domestic use is borne by the tenants. In bulk-metered buildings all electrical usage goes through one meter and the cost is borne by the building operator. Based on the comparison of electric loads in sub-metered versus bulk-metered buildings we estimated that up to 75% of the total use of electricity in multi-residential buildings is for in-suite use. This may be an overestimate since the sub-metered buildings in our data set are older buildings, have fewer numbers of stories and may in general use less electricity for common services.

Below we show the average electric consumption from Aug. 1st, 2001 to April 30th, 2003 in gas-heated buildings for bulk-metered buildings with and without central cooling and for sub metered buildings (without central cooling). The plots are 13-day running averages; the averaging was necessitated by large day-to-day variations even though the data are by building groups.

Figure 9: 13 day Running Average of Average Electric Load by groups of buildings (kWh per 1000m² per day) from July 28th, 01 to April 30th, 03



Notes: Bulk, no AC, bulk-metered buildings without central air; Bulk, AC, bulk-metered with central cooling; Sub, No AC, sub-metered buildings without central cooling.

The curve for sub-metered buildings shows some seasonal variation with some decrease in the load during the summer months. This may be a reflection of different outside lighting loads due to differing day lengths, and mechanical operation of the space heating system. All bulk-metered buildings show a substantial load increase during the summer/fall months, presumably due to air conditioning. The increase is more pronounced in buildings with central cooling. Both groups of bulk metered buildings also show a load increase in the winter. There is no apparent correlation between the consumption of electricity and gas, when compared across the building sample.

The electric load is correlated with the temperature during a number of the seasons. Table 7 below gives the correlations by building groups. Each correlation is between the temperature and total daily average electric load for a group of buildings.

Table 7: Correlations between the Temperature and Electric Load.

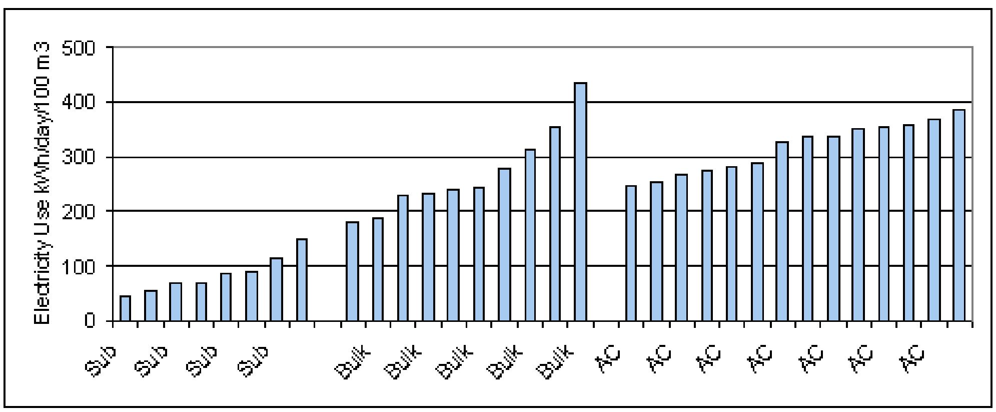
Group/Season	F 01	W 01/02	Sp 02	Sm02	F 02	W 02/03
Bulk, no AC	-0.054	-0.661	-0.517	0.870	0.763	-0.661
Bulk, AC	0.679	-0.571	-0.135	0.915	0.820	-0.625
Sub, no AC	-0.628	-0.642	-0.770	-0.353	-0.657	-0.594
Bulk, Electr Htng	-0.684	-0.936	-0.909	0.310	-0.481	-0.941

Notes: Seasons are defined as follows: Fall (F); 01/09 to 14/10, Winter (W):15/10 to 15/04; Spring (Sp): 16/04 to31/05; Summer (Sm): 01/06 to 31/08

It is obvious that in the electrically heated buildings the electric load is temperature driven. This explains high negative correlations in the fall, winter and spring seasons in the last row of Table7. In the bulk metered buildings the positive correlations in the summer and fall season are due to electrically powered air conditioners. Other correlations are rather difficult to explain.

There is good deal of variation among the buildings in the total electric load per unit area as shown in Figure 10 both within and between groups. The first group of buildings in the graph is the sub-metered buildings. Their load figures do not include any in-suite use or air conditioning. The other two groups are bulk-metered buildings, without central cooling and with central cooling. In these, the depicted load figures include all electric usage in the building. None of the buildings shown in is electrically heated.

Figure 10: The Average Annual Electricity Load (kWh per day per 1000m^2) for one year period (May, 02 to April, 03).



Note: The First group of buildings (Sub) are the sub-metered buildings, the second (Bulk) are the bulk-metered buildings without central cooling, and the third group (AC) are the bulk-metered buildings with central cooling.

The total load per unit area varies over three fold in the sub-metered buildings, over two fold in the bulk-metered buildings without the central cooling and about 60% in the bulk-metered buildings with central cooling. We don't know the reason for these large variations.

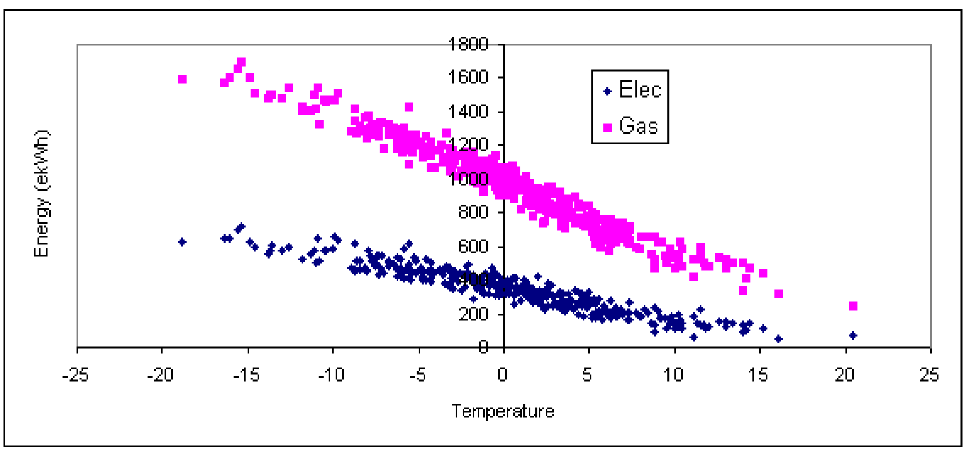
Daily variability was calculated as the deviation from the common daily average (all buildings in a group) adjusted to the each building's overall mean. Thus calculated, the variability follows a rather interesting pattern. The coefficient of variation was largest among the sub-metered buildings, averaging about 13%. This may be due to the smaller absolute value of the electrical use in this group, since any variations in energy used by the central systems would create a larger percentage change. For both bulk metered building groups, the coefficient of variation averaged only about 7%. Incidentally, the coefficient of variation was smallest among the electrically heated buildings, namely about 3%.

3.1 Electrically Heated Buildings

Three of the buildings in our data set are electrically heated by in-suite radiant ceilings. All of the three buildings are bulk metered so that the tenants do not pay for the heat directly. Thus, they do not have any particular incentive to save the heating costs. We have analyzed the data using the same models as for the gas-heated buildings. In Figure 11 below we compare the two modes of heating by plotting the daily consumption, in ekWh, against the temperature. Daily gas consumption is the average daily consumption for space heating for 23 buildings, for electricity it is the average for three buildings. From total gas readings we have subtracted the estimated use for DHW, from electrical loads we have subtracted the average summer usage to exclude the domestic and other uses of electricity in the building. It appears that there is no air conditioning taking place during the summer in the electrically heated buildings (Figure 3).

Figure 11: Energy Consumption in Gas and Electrically Heated Buildings

Note: Gas and electricity are for space heating only. All energy units are in ekWh per 1000m^2 per day.



Note that in both cases, the space heating energy shown is over and above internal gains. In the case of gas, the DHW use has been taken out, and in the case of electricity, the base load has been removed. From Figure 11 we note that the gas consumption and the gas-temperature slope are considerably larger than the electrical consumption or the slope (about 2.5 times). Although we have not shown the regression line it is nevertheless evident that the spread of points is also much larger for the gas than for the electricity even though the gas represents an average daily consumption for 23 buildings and electricity of only 3 buildings. While the two data sets are for two different sets of buildings we believe that these comparisons are qualitatively valid generalizations.

The results of fitting Models 2 and 3 are shown in Table E1, Appendix “E”. For purpose of comparison have included the results of the gas-heated buildings. A more detail analysis of the electrical data shows small but significant difference between the seasons and between buildings.

The results of fitting Model 3 (Table E1) to the gas and electrical data are shown in the text Table 8 below (Model 2 data are available in Table E1).

Table 8: Comparison of Electrically and Gas-heated Buildings

Notes:. Model 3 parameter values and significance tests of humidity, wind and daytime opacity. Values are based on averages for 3 electrically and 23 gas-heated buildings for Season 1 and Season 2. Combined (Cmbnd) line is based on both Season 1 and 2 data. Energy units are ekWh per 1000m^2 per day

									Signif. level		
Electr.	R_3^2	Mean	Intrc	Slpe	lagC	Hmdty	Wind	Opacity			
Ssn 1	0.96	589	317	11.58	0.45	83.4	2.01	1.27	**	**	**
Ssn 2	0.97	694	306	12.98	0.41	-10.5	2.94	4.16		**	**
Cmbnd	0.97	638	310	12.35	0.42	48.7	2.44	2.35	**	**	**
Gas											
Ssn 1	0.98	784	146	31.68	0.33	134.3	2.68	1.25	**	**	
Ssn 2	0.98	982	104	32.73	0.33	-8.6	4.50	4.82		**	**
Cmbnd	0.98	875	134	32.22	0.32	35.3	3.38	3.59	**	**	**

In the table above, the intercept for electrically heated buildings represents all the other uses of electricity (corridor and garage lighting, domestic use, elevators, etc) while the intercept for the gas-heated buildings represents the gas space heating overhead since the other uses (domestic hot water) have already been subtracted. Average daily consumption, averaged over both seasons of heating is 322 kWh per 1000m^2 for electrically heated buildings and 875 ekWh for gas-heated buildings (Table E1, Model 3); this is more than two and half fold difference.

This difference may be real and not different just because a different set of buildings are involved. If we convert and mean daily electric load (= Mean – Intercept) to gas equivalents (by dividing the figures in Table 8 by 10.4 (~1000/96)) and compare the results with all the gas-heated buildings we note that the consumption is by far smaller than the consumption for the lowest use gas-heated building in our data set.

The composite slope represents the energy cost of increasing the building’s internal temperature by one degree Celsius. The composite slopes for electrical and gas-heated buildings are 20.8 and 47.1 (calculated using data in Table 8, 'Cmbnd' line) suggesting that the gas space heating requires about 2.3 times more energy than the electric heating; this is excluding the overhead consumption that seems to be common with the gas heating.

The range of composite slopes for gas-heated buildings, calculated from Table G9 in ekWh equivalents (by multiplying the values by 1000/96), varies from about 30 to 77. The composite slope for electric heating is well below this range. Thus, even the most efficient gas-heated building requires about 45% more energy than the electrically heated buildings in our sample.

3.2 Space Cooling

Many of the multi-residential buildings are centrally cooled. Typically these are bulk metered with the building owner assuming the cost. Many of the older buildings that are bulk metered but don't have central cooling appear nevertheless to have window units in the individual apartments. The cost is again assumed by the building operator. None of the sub-metered buildings in our data set are centrally cooled and if they have individual window air conditioners we have no data on the electric loads generated by them, since this would be part of the load paid by the tenants, and not part of our database.

The correlations between the temperature and electric load are lower for bulk-metered buildings with no central cooling in the fall than for the buildings that are centrally cooled, Table 7. Summer correlations are much the same. We believe that this is because the central cooling is generally extended for longer periods of time than the tenant controlled window units.

To estimate the energy cost of cooling and to characterize the electric load we have fitted our two non-linear models to summer month's data (June, July, and August). The cooling season for centrally cooled buildings extends somewhat further.

Table 9 below summarizes the results for Model 3 parameters and the energy consumption for cooling for 15 bulk metered centrally cooled buildings and for 7 bulk metered buildings without central cooling. From high correlations between the temperature and electric load (Table 7) during the summer months we infer that the latter group of buildings must have window air conditioners.

Table 9: Dependence of Electric Load for Cooling on Temperature and other Climate Variables.
Model 3 parameters. The kWh is expressed as kWh per 1000m^2 per day for June-August period.

	R_3^2	kWh/day	Slope	lagC	Hmdty	Wind	OpD
Bulk, AC	0.85	45.37	6.21	0.47	9/15	2/15	10/15
Bulk, no AC	0.87	33.98	4.45	0.50	1/7	1/7	4/7

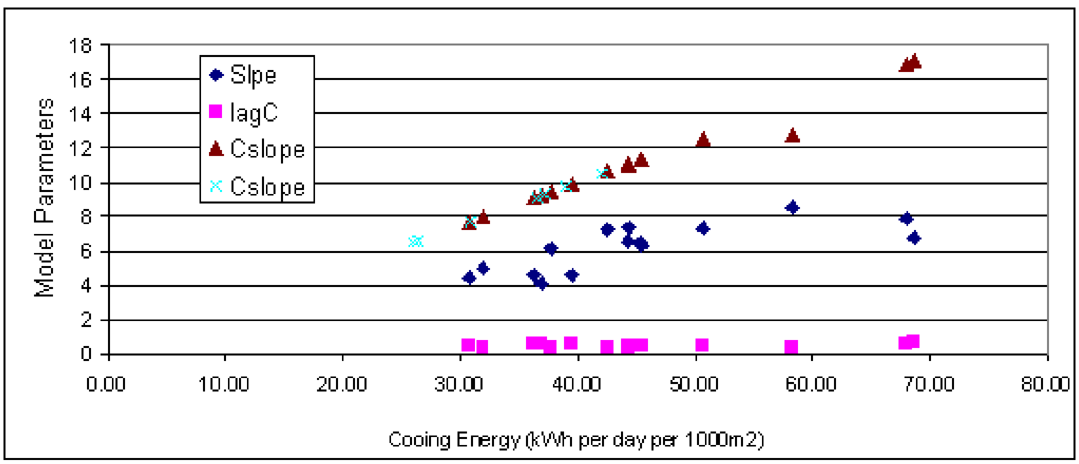
Notes: Entries in columns Hmdty (Humidity), Wind, and OpD (day time opacity) denote the number of times the climate variable is significant, e.g. '9/15'in the Hmdty column means that humidity is significant in 9 cases out of 15.

Our model (Model 3) appears to explain the electric load imposed by cooling rather well (R_3^2 = 0.85, 0.87). During these three summer months the electric load in all the bulk-metered buildings seems to have much the same relationship to the temperature and to other climate variables irrespective whether the building is centrally cooled or not. The overall energy consumption (kWh per 1000m^2 per day) is somewhat higher in centrally cooled buildings. In addition, the consumption seems to extend over a longer period of time.

The parameter values and cooling consumption for individual buildings are given in Table E2 for Model 2 and Table E3 for Model 3. There is not much difference between the two models as far as the intercept, slope and lag parameters are concerned although Model 3 is significantly better, in statistical sense, than Model 2. This is mostly because both the humidity and opacity have significant effect on the energy cost. We also note that the building with the highest cooling energy use is B32aux (Table E2). This is a centralized cooling unit for three buildings, B30, B31 and B32. Since the costs are expressed on per 1000m^2 basis, we would have expected this largest unit to be the most economical rather than the most uneconomical one, because of economies of scale.

In Figure 12 we have plotted the composite slope, slope and lagC parameters against the mean cooling energy use. As expected the relationship between the composite slope and consumption is linear. The average composite slope for non-centrally cooled buildings is 8.35 and 11.2 for centrally cooled buildings. The difference in the consumption may be because not all non-centrally cooled buildings have window air conditioners, because of a lack of delivery-related losses, or because the temperature reference points are different.

Figure 12: Mean Cooling Energy Use (June-Aug) vs. Composite Slope (CSlope), slope (Slpe) and lag parameter (lagC) for centrally cooled buildings as well as the composite slope (CSlope2) for bulk–metered buildings without central cooling.



In Table 10 (below) we compare the energy consumption and parameters for cooling and heating using electricity. These are the averages for 15 centrally cooled buildings and for 3 electrically heated buildings.

Table 10: Comparison of Energy Consumption (kWh per day per 1000m^2) and other Parameters between Summer Cooling and Winter Heating.
Note: For cooling the values are for 15 buildings with central cooling, Summer 02; for heating the values refer to the combined season 1 and season 2 results (Table 8).

	R_3^2	kWh/day	Slope	lagC	CSlope
Cooling	0.85	45.4	6.21	0.47	11.18
Heating	0.95	328.5	12.35	0.42	20.80

The table gives us comparative energy use associated with electric heating and cooling. The components listed in the above Table represent the consumption per day over the temperature range experienced, and are not really comparable. The composite slopes (Cslopes), however, are in fact consumption per unit increase or decrease of temperature and the ratio between the Cslopes is thus the comparative consumption. The heating seems to use twice as much energy as the cooling, implying an effective COP of about 2.0 for centrally cooled buildings.

3.3 Summary: Electricity Consumption

As with the gas, we encounter substantial variability in electric load per unit area between buildings as well as day-to-day variation within buildings measured either as deviations from common pattern or from model predicted values. Because the electric metering does not separate domestic use from communal service or resistive load from inductive load it is difficult to pinpoint or to explain the source of variability or the potential opportunities for energy saving.

Temperature driven loads, namely electric heating and air conditioning are well explained (R^2 =0.97 for heating, R^2 = 0.85, 0.87 for air conditioning) by a common model that characterizes each building's response to temperature. The model parameters are the composite slope, which is the building's energy demand for one degree change in temperature, and a lag term that relates to the manifest or apparent 'thermal mass' of the building.

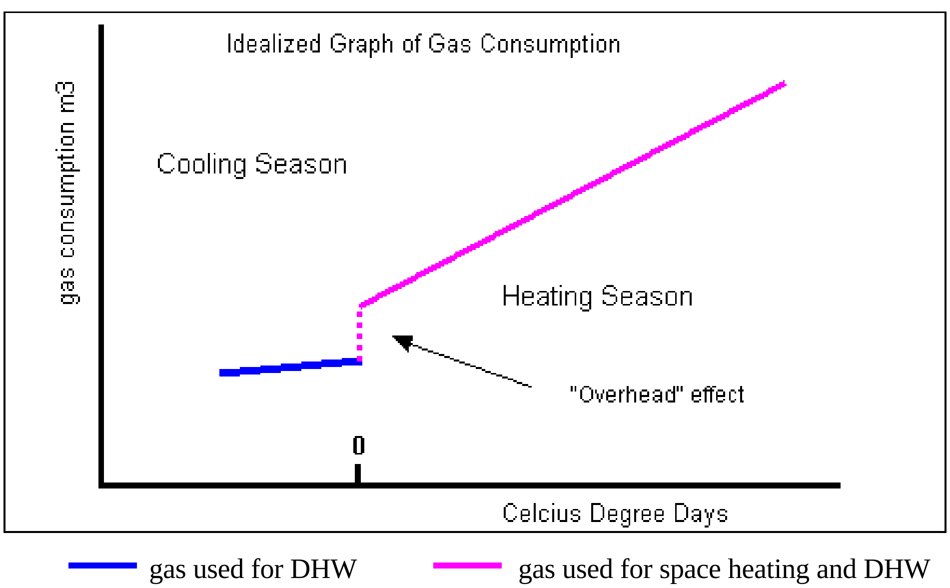
The number of buildings heated with electricity in our database is only three and they may well be over-heated, since the tenants control the heating of their units but do not bear the costs. Nevertheless, the energy consumption for electric heating is much smaller than even the most efficient gas-heated building. The average gas-heated building requires about two and half times the energy needed by electrically heated buildings for space heating.

4.0 Other Studies

A review of other gas and electrically heated buildings outside the current data set reveals an interesting aspect of the "overhead". This review included 9 electrically heated buildings and 12 gas-heated buildings, and the results are provided in Appendix "O". The performance in terms of energy consumption was plotted against degree-days, using a 14 day window, where each point represents the consumption and degree day summary for the previous 14 day period. It was found that the gas-heated buildings had a high balance temperature, averaging 21 ^{0}C, whereas the electrically heated buildings had a lower balance temperature, in the range of 18 ^{0}C. The balance temperature is the temperature below which the buildings require heat, projected by a simple regression line (model 1L). Typical plots of electric and gas-heated buildings are provided in Appendix "O". These demonstrate the "overhead" characteristic of the gas heating systems, when compared to electric. In the fall season, the two systems types both appear to come on at about the same time, and at the same ambient conditions. However, it can be seen that just after startup, there is a significant non-linear jump in consumption for the gas heating systems that is not present in the electric heated buildings. This reflects in part the start-up cost and in part "overhead" of simply keeping the centralized gas systems running. This may be a reflection of the typical 2-pipe radiator or fan coil system that maintains a loop temperature irrespective of the demand at the suite level.

This overhead, shown graphically in Figure 13, represents a significant waste on the part of central gas heating systems in delivering the heat from the boiler to the suites. Furthermore, this phenomenon is not a weather dependent variable, such as losses to the outside, or losses from infiltration. Rather it is a fixed quantity or overhead that must be consumed just to keep the system operating. An idealized graph showing the heating performance of gas heated buildings is provided below. Detailed graph samples are provided in appendix O. Note these graphs are based on the type one linear model (model 1L).

Figure 13: Graphical Representation of "Overhead" Associated with Natural Gas Use



Conclusions

Gas, electric and water consumption per unit area vary two to three fold among the 34 buildings surveyed. The data also provides evidence that buildings with high energy and water consumption are in fact poorly managed and that better energy control systems could result in substantial savings.

Electric in-suite heating, lacking both the energy overhead and delivery losses, seems to consume less than half as much energy than gas space heating. Also, centralized cooling appears to be less efficient than in-suite window air conditioners.

A new non-linear model is created to describe energy consumption for space conditioning in multi-residential buildings. In this model, the energy for heating and cooling is predicted based on three building parameters, called the “overhead”, “lag C”, and the “composite slope”. The “overhead” represents fixed system losses that are independent of the load, “lag C” represents the effects of the 3 previous days, and the composite slope represents temperature response. These parameters can be used as a measure of the building’s energy performance and can be calculated for any building that has been monitored on daily basis for its energy consumption over a heating or cooling season.

Besides characterizing the heating/cooling system’s overhead, effective insulation and thermal mass, the new model is a significant improvement over the basic degree-day model. It achieves on the average a 35% to 40% reduction in unexplained variability (in terms of residual sums of squares). This offers a much improved tool in predicting daily energy consumption, and identifying building management problems in multi-residential buildings.

The relationship between the model parameters, and individual system components such as boiler efficiency, heat delivery costs, air infiltration, remains to be determined by detailed monitoring that would cover the major energy systems and building controls.

Appendix “E”
Electrical Data

Table E1

Comparison of the gas and electric heating and their dependance on the climate variables. The energy units are ekWh per day per $1000m^2$.

Model 2

	r^2	R_2^2	R_3^2	Mean	$Intrcpt_2$	$Slpe_2$	lagC	Significance levels $Intrcpt_2$	$TmpSlpe_2$	lagC
Ssn 1	0.89	0.94	0.96	589.0	306.7	12.52	0.41	**	**	**
Ssn2	0.90	0.94	0.97	693.7	307.5	13.87	0.36	**	**	**
Cmbnd	0.91	0.95	0.97	637.9	303.1	13.28	0.39	**	**	**
Gas										
Ssn 1	0.94	0.97	0.98	782.4	131.9	33.33	0.31	**	**	**
Ssn2	0.95	0.97	0.98	981.5	104.7	34.51	0.29	**	**	**
Cmbnd	0.95	0.97	0.98	875.2	125.9	33.77	0.30	**	**	**

	Ssn1	**Ssn2**	**Cmbnd**		
Cost of heating (electric) =	**282.3**	**386.250**	**334.73**	**% increase from Ssn 1 to Ssn 2**	**37%**
Cost of heating (gas) =	**782.4**	**981.490**	**875.24**		**25%**

Model 3

	R_3^2	$*Intrcpt_3$	$*Slpe_3$	*lagC	Hmdty	Wnd	OpD	Significance levels Hmdty	Wnd	OpD
Ssn 1	0.96	317.1	11.50	0.446	83.41	2.01	1.27	**	**	
Ssn2	0.97	306.2	12.98	0.410	-10.46	2.94	4.16		**	**
Cmbnd	0.97	310.7	12.35	0.426	48.70	2.44	2.35	**	**	**
Gas										
Ssn 1	0.98	146.2	31.68	0.329	134.34	2.68	1.25	**	**	
Ssn2	0.98	103.9	32.73	0.332	-8.62	4.50	4.82		**	**
Cmbnd	0.98	133.6	32.22	0.324	35.28	3.38	3.59		**	**

	Ssn1	**Ssn2**	**Cmbnd**		
Cost of heating (electric) =	**271.9**	**387.5**	**327.2**	**% increase from Ssn 1 to Ssn 2**	**42%**
Cost of heating (gas) =	**782.4**	**981.5**	**875.2**		**25%**

Composite slope (Cmbn, electric heating)	**20.80**
Composite slope (Cmbn, gas heating)	**47.14**

F-test for difference between sesons (electric) =	**9.41**	**df=6,434**
F-test for difference between sesons (Gas) =	**8.92**	**df=6,434**

Table E2

Electric load for cooling as a function of Climate variables. Cooling season from June 1 to August 30th, 2002.Electricity measures as kWh per $1000m^2$.

Bulk metered buildings with central cooling

Model 2

	r^2	R_2^2	R_3^2	Mean	$Intrcpt_2$	$TmpSlpe_2$	lagC	t-values* $Intrcpt_2$	$TmpSlpe_2$	lagC
B04	0.63	0.69	0.80	285.90	257.39	4.38	0.4	**	**	**
B09	0.65	0.75	0.76	459.66	420.37	4.52	0.6	**	**	**
B10	0.72	0.83	0.87	372.29	337.52	4.25	0.56	**	**	**
B12	0.66	0.7	0.77	309.84	279.50	5.11	0.33	**	**	**
B13	0.85	0.92	0.94	400.34	362.89	5.92	0.38	**	**	**
B14	0.76	0.8	0.87	415.34	367.44	7.85	0.35	**	**	**
B15	0.63	0.78	0.87	322.17	287.34	3.78	0.64	**	**	**
B17	0.86	0.91	0.94	433.37	391.95	7.01	0.33	**	**	**
B18	0.67	0.76	0.77	344.67	279.20	7.96	0.56	**	**	**
B19	0.75	0.79	0.85	419.22	376.44	6.77	0.38	**	**	**
B24	0.72	0.82	0.86	310.71	267.66	5.89	0.48	**	**	**
B26	0.73	0.81	0.87	384.16	341.74	5.92	0.47	**	**	**
B27	0.83	0.87	0.93	321.87	279.87	7.11	0.33	**	**	**
B29	0.72	0.78	0.79	381.29	324.54	8.35	0.43	**	**	**
B32aux	0.66	0.81	0.85	306.20	240.16	7.02	0.65	**	**	**
Avrge* **	**0.72**	**0.80**	**0.85**	**364.47**	**320.93**	**6.12**	**0.46**			

Avrage cost of cooling per day per $1000m^2$ **43.53**

Bulk metered buildings without central cooling.

	r^2	R_2^2	R_3^2	Mean	$Intrcpt_2$	$TmpSlpe_2$	lagC	t-values* $Intrcpt_2$	$TmpSlpe_2$	lagC
B01	0.74	0.81	0.86	228.48	203.26	3.81	0.41	**	**	**
B11	0.66	0.76	0.83	288.43	253.14	4.46	0.54	**	**	**
B22	0.76	0.87	0.90	277.54	241.60	4.47	0.55	**	**	**
B25	0.75	0.87	0.89	446.20	408.55	4.50	0.57	**	**	**
B28	0.63	0.70	0.79	246.62	221.98	3.56	0.44	**	**	**
B33	0.76	0.87	0.90	257.35	227.21	3.89	0.52	**	**	**
B35	0.72	0.88	0.89	375.75	334.89	4.21	0.67	**	**	**
Avrge* **	**0.72**	**0.82**	**0.87**	**302.91**	**270.09**	**4.13**	**0.53**			

Avrage cost of cooling per day per $1000m^2$ **32.82**

*** significant at 5% level**
**** significant at 1% level.**

Note that the average cost of cooling (presumably by window units) is almost as high as that provided by central cooling unit.

Model 2 Electr ~ $Intrcpt_2$+$Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.
Model 3 Electr ~ $Intrcpt_3$+$Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+ H*Hmdty+W*Wnd+O*OpD; DgrD=18C° - Temp
R_3^2 refers to squared multiple correlation for Model 3.
R_2^2 refers to squared multiple correlation for Model 2.

ElecClmteCoolngNls.xls

Table E3

Electric load for cooling as a function of Climate variables. Cooling season from June 1 to August 30th, 2002.Electricity measures as kWh per 1000m^2.

Bulk metered buildings with central cooling

Model 3

	R_3^2	****Cost	*$Slpe_3$	*lagC	Hmdty	Wnd	OpD	Significance levels Hmdty	Wnd	OpD	
B04	0.804	30.72	4.44	0.44	129.02	-0.52	-2.08	**		**	7.631
B09	0.756	39.5	4.59	0.59	11.68	0.12	0.13				9.839
B10	0.868	36.31	4.57	0.54	19.98	0.12	1.63			*	9.09
B12	0.767	31.95	4.96	0.39	106.27	-0.73	-2.47	**		**	7.943
B13	0.937	37.75	6.11	0.36	69.24	0.38	-1.12	**		*	9.387
B14	0.869	50.66	7.32	0.44	137.12	-1.62	-3.71	**	**	**	12.58
B15	0.874	36.91	4.12	0.62	85.38	0.36	0.59	**			9.24
B17	0.941	42.47	7.23	0.33	94.57	0.12	-1.31	**		*	10.66
B18	0.768	67.97	7.87	0.59	41.51	-1.03	0				16.87
B19	0.849	45.35	6.48	0.45	125.76	-1.11	-2.71	**	**	**	11.3
B24	0.864	45.41	6.33	0.47	40.24	0.08	1.99			*	11.36
B26	0.865	44.26	6.52	0.43	26.72	0.52	2.54			**	11.05
B27	0.932	44.36	7.36	0.34	108.24	-0.32	-0.77	**			11
B29	0.785	58.28	8.53	0.34	12.58	-0.24	1.22				12.75
B32aux	0.850	68.65	6.73	0.7	147.04	-1.31	-3.9	**	*	**	17.05
Avrge* **	**0.85**	**45.37**	**6.21**	**0.47**	**77.02**	**-0.35**	**-0.66**	**9/15**	**2/15**	**10/15**	11.12

******Cost of cooling** **45.37**
per day per 1000m^2 **(difference between the mean and the intercept at 18C^o)**

Bulk metered buildings with no central cooling

Model 3

	R_3^2	****Cost	**$Slpe_3$	**lagC	Hmdty	Wnd	OpD	Significance levels Hmdty	Wnd	OpD	
B01	0.86	26.38	4.17	0.38	24.29	0.30	1.31			*	6.575
B11	0.83	36.49	5.05	0.47	1.35	0.80	3.01		*	**	9.109
B22	0.90	37.12	4.76	0.53	25.65	0.23	1.16				9.268
B25	0.89	38.96	4.59	0.58	40.17	-0.17	0.11	*			9.725
B28	0.79	26.01	4.08	0.39	1.07	0.49	2.68			**	6.491
B33	0.90	30.87	4.17	0.49	12.65	0.35	1.21			*	7.699
B35	0.89	42.02	4.33	0.67	33.64	-0.04	0.36				10.49
Avrge* **	**0.87**	**33.98**	**4.45**	**0.50**	**19.83**	**0.28**	**1.40**	**1/7**	**1/7**	**4/7**	8.354

******Cost of cooling** **33.98**
per day per 1000m^2 **(difference between the mean and the intercept at 18C^o)**

*** Signicant at 5% level**
**** Signicant at 1% level**
***** Avrge is the average the corresponding parameter values of all the buildings**

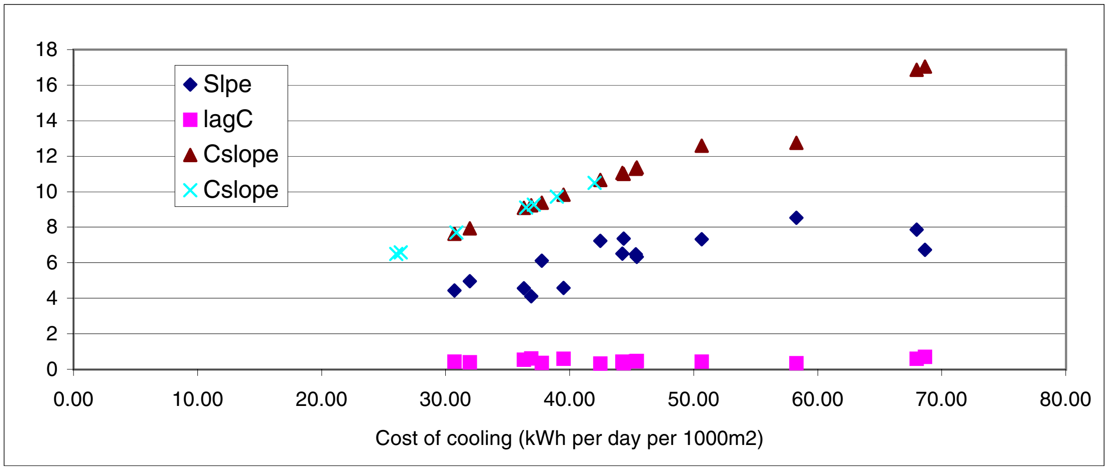
Model 2 **Electr ~** **$Intrcpt_2$+$Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]**
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3 **Electr ~** **$Intrcpt_3$+$Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+**
H*Hmdty+W*Wnd+O*OpD; DgrD=18C^o - Temp

R_3^2 refers to squared multiple correlation for Model 3.
R_2^2 refers to squared multiple correlation for Model 2.

ElecClmteCoolngNls.xls

Composite slopes and lag parameters plotted against the cost of cooling



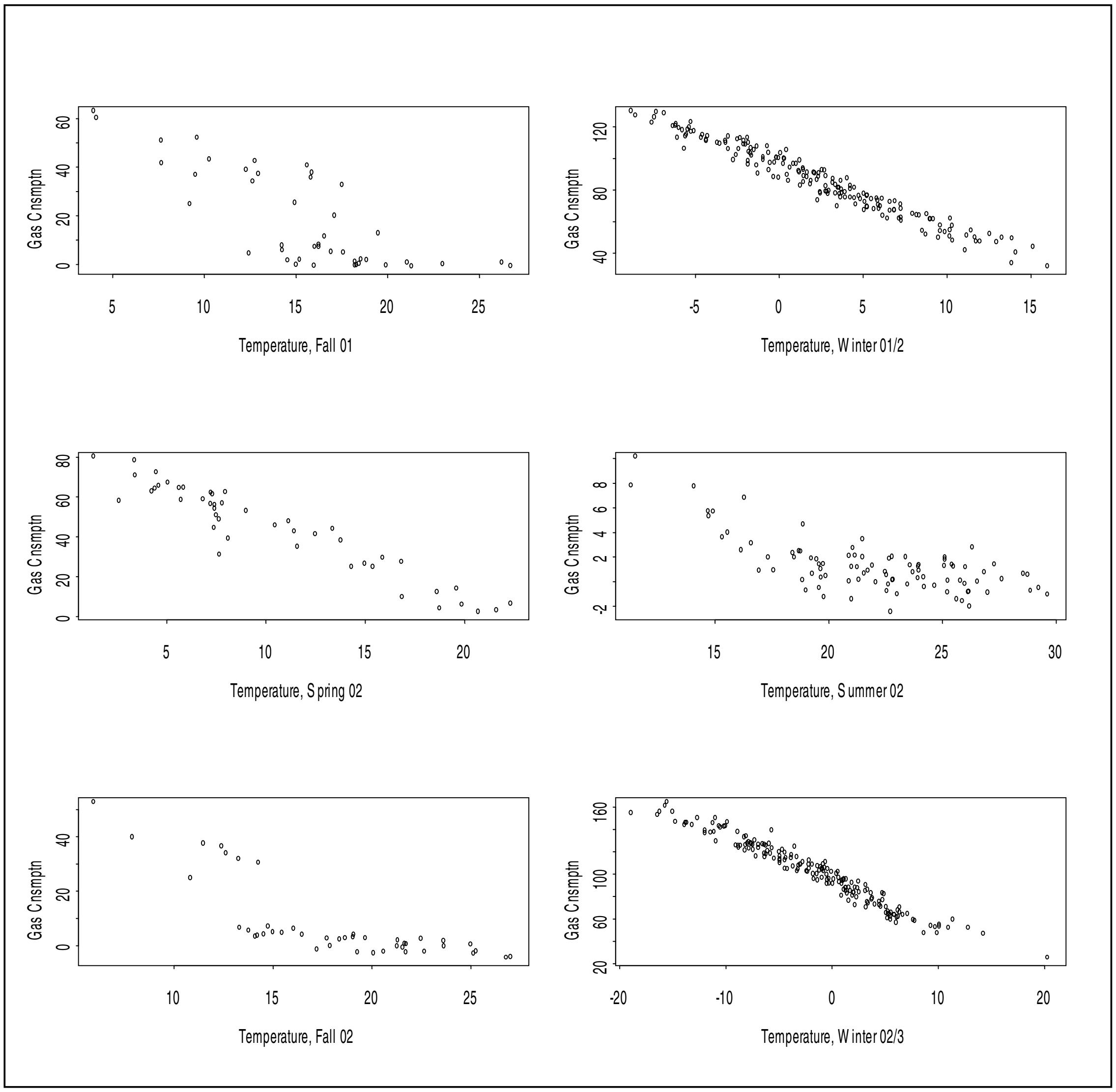
Plots are the plots of the Model 3 parameters (Slope, lagC and composite slope [Cslope] for centrally cooled buildings (Summer, 02). CSlope2 is the composite slope for bulk metered buildings without central cooling.

Model 3		Buildings with central cooling			
	R_3^2	Cost	Slpe	lagC	Cslope
B04	0.804	30.72	4.44	0.44	7.63
B09	0.756	39.50	4.59	0.59	9.84
B10	0.868	36.31	4.57	0.54	9.09
B12	0.767	31.95	4.96	0.39	7.94
B13	0.937	37.75	6.11	0.36	9.39
B14	0.869	50.66	7.32	0.44	12.58
B15	0.874	36.91	4.12	0.62	9.24
B17	0.941	42.47	7.23	0.33	10.66
B18	0.768	67.97	7.87	0.59	16.87
B19	0.849	45.35	6.48	0.45	11.30
B24	0.864	45.41	6.33	0.47	11.36
B26	0.865	44.26	6.52	0.43	11.05
B27	0.932	44.36	7.36	0.34	11.00
B29	0.785	58.28	8.53	0.34	12.75
B32aux	0.850	68.65	6.73	0.7	17.05
		Buildings without central cooling.			
					Cslope
B01	0.86	26.38	4.17	0.38	6.57
B11	0.83	36.49	5.05	0.47	9.11
B22	0.90	37.12	4.76	0.53	9.27
B25	0.89	38.96	4.59	0.58	9.73
B28	0.79	26.01	4.08	0.39	6.49
B33	0.90	30.87	4.17	0.49	7.70
B35	0.89	42.02	4.33	0.67	10.49

Appendix "G"

Gas Data

Figure G1 Average gas consumption over all buildings plotted against the temperature by . seasons. The gas data are the estimated daily consumption minus DHW (m^3 per $1000m^2$) for all gas heated buildings.



Note the following definitions: Fall: 9/1 to 10/14; Winter (heating season): 10/15 to 4/15
Spring: 4/16 to 5/31; Summer: 6/1 to 8/31

Correlations between the temperature and daily average gas consumption.

	Total -DHW	Total
Fall, 01	-0.774	-0.768
Winter, 01/02	-0.976	-0.971
Spring 02	-0.950	-0.950
Summer 02	-0.696	-0.660
Fall 02	-0.789	-0.795
Winter, 02/03	-0.975	-0.971

Table G1 (Ssn 1)

Relationship of the daily gas consumption (m^3) to degree days (Model 1).
Correlations coefficients for Model 1, 2L, 3L and tests of Model 2L vrs 1 (F2/1) and 3L vrs 2L (F3/2)
Daily gas consumption (m^3) is estimated to include only the space heating (per 1000m^3)

The first heating season (05/10/01 to 05/28/02).

		Model 1		Model 1	Model 2	Model 3			
Bldng	Mean	Intrcpt	DgrD	r^2	R_2^2	R_3^2	No.Obs	F2/1	F3/2
B01	54.64	13.80	2.98	0.751	0.846	0.849	237	47.26	*1.95
B02	70.42	14.46	4.09	0.761	0.822	0.829	236	26.64	*2.81
B03	77.66	12.62	4.66	0.854	0.904	0.911	231	39.23	6.29
B04	54.12	-0.27	3.61	0.915	0.943	0.951	174	27.08	8.71
B05	71.30	9.02	4.57	0.882	0.911	0.917	237	25.31	5.49
B06	104.46	34.71	5.12	0.911	0.946	0.952	238	49.87	9.93
B07	88.16	28.15	4.41	0.724	0.787	0.793	237	22.88	*2.37
B08	65.31	11.73	3.89	0.926	0.948	0.955	210	30.36	10.09
B10	89.17	20.00	5.09	0.852	0.893	0.921	233	28.90	26.82
B11	107.14	27.62	5.84	0.677	0.806	0.817	238	51.24	4.71
B12	37.57	-3.18	2.80	0.923	0.940	0.951	197	17.90	15.11
B13	46.29	8.19	2.80	0.907	0.938	0.947	238	38.15	13.44
B15	96.74	12.12	6.21	0.931	0.935	0.941	238	4.54	7.34
B18	97.64	11.28	6.34	0.956	0.960	0.970	238	9.00	23.51
B19	41.66	-0.16	3.07	0.917	0.949	0.962	238	49.05	24.79
B23.34	133.11	46.84	6.33	0.858	0.877	0.890	238	12.35	9.28
B24	72.00	11.92	4.04	0.907	0.928	0.942	184	17.47	14.42
B26	76.08	18.72	4.22	0.847	0.849	0.878	234	*0.91	17.95
B27	55.06	11.99	3.16	0.889	0.922	0.927	238	32.68	5.93
B28.33	68.79	23.99	3.30	0.784	0.809	0.811	236	10.26	*0.88
B29	105.38	31.08	5.46	0.780	0.853	0.862	238	38.95	4.70
B30	53.46	6.01	3.48	0.953	0.975	0.977	238	69.11	6.17
B31	61.38	7.31	3.97	0.917	0.937	0.944	238	24.75	9.75
Avrge	**75.11**	**15.56**	**4.32**	**0.862**	**0.899**	**0.909**	**229**	**29.26**	**9.76**

Model 1 **Gas ~** **Intrcpt+Slpe*DgrD**

Model 2L **Gas ~** **$Intrcpt_2$+$Slpe_2$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3**
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3L **Gas ~** **$Intrcpt_3$+$Slpe_3$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+**
H*Hmdty+W*Wnd+O*OpD.

Gas m^3 per day per 1000 m^2

Degree days (DgrD) = 18^o-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

F2/1 and F3/2 refer to F-values to test Model 2 vrs Model 1 or Model 3 vrs 2
F2/1 is based on the average on 3 and 224 degrees of freedom, F3/2 on 3 and 221 df.
Values marked with * are not significant, all other are significant at 1% level.

Table G1 (Ssn 2)

Relationship of the daily gas consumption (m^3) to degree days (Model 1).
Correlations coefficients for Model 1, 2L, 3L and tests of Model 2L vrs 1 (F2/1) and 3L vrs 2L (F3/2)
Daily gas consumption (m^3) is estimated to include only the space heating (per $1000m^3$)

The second heating season (05/10/02 to 04/30/03).

		Model 1		**Model 1**	**Model 2**	**Model 3**			
Bldng	Mean	Intrcpt	DgrD	r^2	R_2^2	R_3^2	No.Obs	F2/1	F3/2
B01	65.91	20.74	2.49	0.813	0.861	0.884	208	23.14	13.73
B02	89.96	24.20	3.62	0.885	0.910	0.922	208	19.11	9.91
B03	102.88	21.90	4.43	0.891	0.906	0.914	206	10.82	6.41
B04	62.61	-0.76	3.49	0.945	0.953	0.970	208	11.82	38.74
B05	105.35	14.90	4.99	0.902	0.930	0.933	207	26.70	3.63
B06	119.80	22.38	5.37	0.906	0.941	0.950	208	40.67	11.44
B07	106.68	21.50	4.69	0.921	0.938	0.944	208	18.33	7.42
B08	93.65	27.18	3.66	0.852	0.871	0.883	208	9.76	7.07
B10	110.94	26.57	4.65	0.900	0.906	0.946	208	4.07	49.05
B11	142.54	40.95	5.60	0.807	0.872	0.882	208	34.54	5.75
B12	47.35	-5.42	2.99	0.950	0.962	0.977	189	19.51	40.91
B13	56.88	0.89	3.08	0.910	0.942	0.963	208	37.05	38.07
B15	129.67	-2.96	7.20	0.941	0.946	0.962	202	5.49	27.58
B18	126.32	9.77	6.42	0.916	0.927	0.937	208	10.97	10.54
B19	55.79	-1.76	3.17	0.886	0.914	0.940	208	21.73	28.67
B23.34	155.19	31.44	6.82	0.870	0.927	0.931	208	52.40	4.71
B24	94.42	15.69	4.34	0.916	0.925	0.948	208	7.69	30.58
B26	85.01	10.13	4.13	0.885	0.892	0.914	208	4.51	17.12
B27	69.62	12.70	3.14	0.867	0.887	0.919	208	12.04	26.52
B28.33	78.06	14.11	3.58	0.827	0.858	0.886	197	13.91	15.24
B29	114.99	14.33	5.55	0.890	0.933	0.939	208	43.15	6.19
B30	71.16	8.29	3.46	0.955	0.966	0.975	208	21.66	24.58
B31	77.27	7.46	3.85	0.967	0.976	0.981	208	26.94	19.58
Avrge	**94.00**	**14.53**	**4.38**	**0.896**	**0.919**	**0.935**	**206**	**20.70**	**19.28**

Model 1	**Gas ~**	**Intrcpt+Slpe*DgrD**
Model 2L	**Gas ~**	**$Intrcpt_2$+$Slpe_2$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3**
		where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.
Model 3L	**Gas ~**	**$Intrcpt_3$+$Slpe_3$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+ H*Hmdty+W*Wnd+O*OpD.**

Gas m^3 per day per 1000 m^2

Degree days (DgrD) = 18^o-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

F2/1 and F3/2 refer to F-values to test Model 2 vrs Model 1 or Model 3 vrs 2

F2/1 is based on the average on 3 and 201 degrees of freedom, F3/2 on 3 and 198 df.

All the F-values listed are significant at 1% level.

Table G2, Ssn 1

Relationship of the daily gas consumption (m^3 per $1000m^2$) to changes in climate.
Daily gas consumption is estimated to include only the space heating.

The first heating season (05/10/01 to 05/28/02).

Model 2L	**Linear model**									t-values*		
	r^2	R_2^2	R_3^2	Mean	*$Intrcpt_2$	*$Slpe_2$	Lag1	Lag2	Lag3	Lag1	Lag2	Lag3
Avrge	0.94	0.97	0.98	75.72	11.95	3.32	0.69	0.27	0.36	**	*	**
B01	0.74	0.84	0.84	55.06	5.91	1.86	0.64	0.23	0.84	**	*	**
B02	0.76	0.82	0.83	70.72	5.94	2.86	0.66	0.35	0.84	*	*	**
B03	0.85	0.90	0.91	77.66	3.25	3.55	0.58	0.36	0.83	*	*	**
B04	0.92	0.95	0.95	54.69	-7.57	2.91	0.55	0.21	0.40	**	*	**
B05	0.88	0.91	0.91	71.90	2.39	3.72	0.46	0.20	0.68	*	*	**
B06	0.91	0.94	0.95	105.34	29.73	3.72	1.25	0.31	0.21	**	*	*
B07	0.71	0.78	0.78	88.91	19.43	3.03	0.55	0.83	0.65	*	*	*
B08	0.92	0.95	0.95	65.92	6.65	3.16	0.51	0.23	0.36	**	*	**
B10	0.85	0.89	0.92	90.01	12.83	3.72	0.93	0.47	0.50	**	*	*
B11	0.67	0.80	0.81	107.86	7.26	3.35	1.21	0.51	2.25	*	*	**
B12	0.92	0.94	0.95	37.95	-7.52	2.39	0.33	0.10	0.26	**	*	**
B13	0.90	0.94	0.94	46.68	4.52	2.15	0.52	0.04	0.35	**		**
B15	0.93	0.93	0.94	97.57	10.45	5.75	0.46	0.34	-0.22	*	*	*
B18	0.96	0.96	0.97	98.38	9.14	5.77	0.91	-0.15	-0.04	**	*	
B19	0.92	0.95	0.96	42.02	-4.80	2.41	0.50	0.17	0.33	**	*	**
B23.34	0.85	0.87	0.89	134.16	43.09	4.97	1.39	0.26	0.00	**	*	
B24	0.90	0.92	0.94	72.81	6.32	3.44	0.22	0.24	0.51	*	*	**
B26	0.84	0.84	0.87	76.62	16.97	4.15	-0.09	0.10	0.19			*
B27	0.88	0.92	0.92	5.52	7.67	2.44	0.48	0.22	0.34	**	*	**
B28.33	0.77	0.80	0.80	69.35	22.37	2.52	0.80	0.38	-0.27	**	*	*
B29	0.77	0.85	0.85	106.32	21.68	3.21	1.89	0.69	0.35	**	*	*
B30	0.95	0.97	0.98	53.91	2.36	2.77	0.72	0.03	0.24	**		**
B31	0.92	0.94	0.94	61.87	3.02	3.22	0.70	0.13	0.23	**	*	*
Avrge* **	**0.86**	**0.90**	**0.91**	**73.53**	**9.61**	**3.35**	**0.70**	**0.27**	**0.43**			

Avrage cost of (m^3) heating per day per $1000m^2$ **73.53** **Overhead** **9.61**

***$Intrcpt_2$, *$Slpe_2$ are all significant at 1%.**

*** Signicant at 5% level**

**** Signicant at 1% level**

***** Avrge is the average the corresponding parameter values of all the buildings**

Model 2L Gas ~ $Intrcpt_2$+$Slpe_2$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3L Gas ~ $Intrcpt_3$+$Slpe_3$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+ H*Hmdty+W*Wnd+O*OpD.

Gas m^3 per day per 1000 m^2 **Hmdty, Wnd and OpD standardized to 0 mean**

Degree days (DgrD) = 18°-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

Table G2, Ssn 2

Relationship of the daily gas consumption (m^3) to changes in climate.
Daily gas consumption is estimated to include only the space heating (per $1000m^3$)

The second heating season (05/10/02 to 04/30/03).

Model 2L	**Linear model**									t-values*		
	r^2	R_2^2	R_3^2	Mean	*$Intrcpt_2$	*$Slpe_2$	Lag1	Lag2	Lag3	Lag1	Lag2	Lag3
Avrge	0.95	0.97	0.98	92.77	10.14	3.32	0.68	0.24	0.32	**	*	**
B01	0.81	0.86	0.88	65.91	16.24	1.63	0.48	0.21	0.42	**	*	**
B02	0.89	0.91	0.92	89.96	19.55	2.79	0.39	0.23	0.48	*	*	**
B03	0.89	0.91	0.91	102.88	17.27	3.73	0.20	0.50	0.25	*	*	*
B04	0.95	0.95	0.97	62.61	-2.57	2.98	0.52	0.09	0.01	**		
B05	0.90	0.93	0.93	105.35	8.27	3.81	0.50	0.32	0.73	*	*	**
B06	0.91	0.94	0.95	119.80	15.04	3.70	1.32	0.17	0.59	**	*	**
B07	0.92	0.94	0.94	106.68	17.02	3.75	0.62	0.32	0.25	**	*	*
B08	0.85	0.87	0.88	93.65	23.31	2.85	0.55	0.21	0.27	*	*	*
B09	0.92	0.93	0.94	76.89	10.07	2.88	0.57	-0.01	0.24	**		*
B10	0.90	0.91	0.95	110.94	24.53	4.06	0.62	0.05	0.04	*		
B11	0.81	0.87	0.88	142.54	29.05	3.32	1.29	0.47	1.18	**	*	**
B12	0.95	0.96	0.98	47.35	-7.49	2.45	0.40	0.18	0.09	**	*	*
B13	0.91	0.94	0.96	56.88	-2.86	2.18	0.76	0.20	0.15	**	*	*
B15	0.94	0.95	0.96	129.67	-6.81	6.58	0.27	0.47	0.09	*	*	
B17	0.90	0.92	0.95	64.49	6.77	2.20	0.73	0.00	-0.08	**		
B18	0.92	0.93	0.94	126.32	5.80	5.25	1.23	0.09	0.08	**		
B19	0.89	0.91	0.94	55.79	-5.42	2.30	0.71	0.22	0.15	**	*	*
B23.34	0.87	0.93	0.93	155.19	18.28	4.39	1.25	0.56	1.36	**	*	**
B24	0.92	0.93	0.95	94.42	12.79	3.69	0.48	0.15	0.18	*		*
B25.35	0.79	0.82	0.84	103.30	15.20	3.45	0.32	0.38	0.71	*	*	*
B26	0.89	0.89	0.91	85.01	7.30	3.67	0.11	0.28	0.22		*	*
B27	0.87	0.89	0.92	69.62	9.62	2.40	0.61	0.21	0.09	**	*	
B28.33	0.83	0.86	0.89	78.06	9.29	2.55	0.65	0.43	0.23	*	*	*
B29	0.89	0.93	0.94	114.99	6.93	3.63	1.75	0.39	0.19	**	*	*
B30	0.96	0.97	0.98	71.16	6.30	2.87	0.64	0.02	0.05	**		
B31	0.97	0.98	0.98	77.27	5.33	3.26	0.57	0.16	-0.02	**	*	
Avrge* **	**0.89**	**0.92**	**0.93**	**92.57**	**9.95**	**3.32**	**0.67**	**0.24**	**0.31**			

Avrage cost of (m^3) heating per day per $1000m^2$ **92.57** **Overhead** **9.95**

***$Intrcpt_2$, *$Slpe_2$ are all significant at 1%.**

*** Signicant at 5% level**

**** Signicant at 1% level**

***** Avrge is the average the corresponding parameter values of all the buildings**

Model 2L Gas ~ $Intrcpt_2+Slpe_2*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3$

where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3L Gas ~ $Intrcpt_3+Slpe_3*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+H*Hmdty+W*Wnd+O*OpD$.

Gas m^3 per day per 1000 m^2 **Hmdty, Wnd and OpD standardized to 0 mean**

Degree days (DgrD) = 18°-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

Table G3, Ssn 1

Relationship of the daily gas consumption (m^3 per $1000m^2$) to changes in climate.
Daily gas consumption is estimated to include only the space heating.

The first heating season (05/10/01 to 05/28/02).

Model 3L		**Linear model**								Significance levels		
	R_3^2	$*Intrcpt_3$	$*Slpe_3$	*Lag1	Lag2	Lag3	Hmdty	Wnd	OpD	Hmdty	Wnd	OpD
Avrge	0.98	13.37	3.15	0.78	0.28	0.32	10.85	0.23	0.17	**	**	
B01	0.84	6.60	1.78	0.69	0.23	0.82	2.73	0.13	0.26			
B02	0.83	6.54	2.74	0.75	0.34	0.85	-8.56	0.23	0.54			
B03	0.91	4.92	3.29	0.75	0.37	0.79	5.43	0.39	-0.03		**	
B04	0.95	-5.26	2.73	0.64	0.23	0.31	17.98	0.20	-0.03	**	**	
B05	0.91	3.69	3.56	0.56	0.21	0.64	4.51	0.25	0.43		**	
B06	0.95	30.67	3.64	1.29	0.32	0.19	0.35	0.16	0.78		*	**
B07	0.78	19.88	2.96	0.59	0.82	0.66	-10.06	0.17	0.84			*
B08	0.95	8.04	2.99	0.62	0.21	0.33	2.02	0.29	0.23		**	
B10	0.92	16.03	3.21	1.28	0.47	0.44	7.41	0.76	0.63		**	*
B11	0.81	9.90	3.23	1.22	0.57	2.12	41.85	0.08	0.27	**		
B12	0.95	-5.48	2.24	0.40	0.11	0.19	17.89	0.19	-0.07	**	**	
B13	0.94	5.96	1.97	0.63	0.06	0.30	14.13	0.23	-0.16	**	**	
B15	0.94	12.25	5.44	0.66	0.35	-0.25	5.54	0.45	0.00		**	
B18	0.97	10.72	5.44	1.15	-0.16	-0.05	-6.84	0.54	0.26		**	
B19	0.96	-3.22	2.17	0.65	0.18	0.29	9.29	0.33	-0.07	**	**	
B23.34	0.89	44.05	5.11	1.23	0.30	-0.08	24.91	-0.25	0.91	*		*
B24	0.94	7.83	3.15	0.40	0.29	0.45	3.35	0.47	0.12		**	
B26	0.87	20.52	3.59	0.26	0.12	0.11	26.86	0.74	-0.75	**	**	**
B27	0.92	8.89	2.28	0.57	0.23	0.30	10.18	0.21	-0.06	*	**	
B28.33	0.80	21.97	2.58	0.75	0.37	-0.26	-8.33	-0.06	0.47			
B29	0.85	23.49	3.15	1.88	0.74	0.25	37.60	-0.01	-0.27	**		
B30	0.98	3.02	2.67	0.78	0.04	0.22	3.90	0.14	-0.04		**	
B31	0.94	4.43	3.12	0.74	0.17	0.16	25.90	0.07	-0.38	**		*
Avrge* **	**0.95**	**11.69**	**3.31**	**0.84**	**0.30**	**0.40**	**10.39**	**0.26**	**0.18**			

Avrage cost of heating per day per $1000m^2$ **73.53** **Overhead** **11.69**

$*Intrcpt_3$, $*Slpe_3$ and *Lag1 are all significant at 1% level (except Lag1 for B7 and B26) which is signif. at 5% level)

*** Signicant at 5% level**

**** Signicant at 1% level** ****Lag2 is signif. at 5% (or better) 3 and Lag3 15 times out of 24.**

***** Avrge is the average the corresponding parameter values of all the buildings**

****** F3/2 F-value for test between Model 2 and Model 3; if >2.65 signif. at 5%, if >3.18 signif. At 1% level.**

Model 2L Gas ~ $Intrcpt_2+Slpe_2$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3L Gas ~ $Intrcpt_3+Slpe_3$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+ H*Hmdty+W*Wnd+O*OpD.

Gas m^3 per day per 1000 m^2 **Hmdty, Wnd and OpD standardized to 0 mean**

Degree days (DgrD) = 18^o-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

Table G3, Ssn 2

Relationship of the daily gas consumption (m^3) to changes in climate.
Daily gas consumption is estimated to include only the space heating (per $1000m^3$)

The second heating season (05/10/02 to 04/30/03).

Model 3L — **Linear model** — Significance levels

	R_3^2	*$Intrcpt_3$	*$Slpe_3$	*Lag1	**Lag2	**Lag3	Hmdty	Wnd	OpD	Hmdty	Wnd	OpD
Avrge	0.98	9.98	3.17	0.75	0.28	0.36	-1.82	0.41	0.53		**	**
B01	0.88	14.45	1.61	0.47	0.31	0.45	-18.30	0.17	1.01	**	*	**
B02	0.92	20.48	2.65	0.48	0.19	0.51	11.44	0.38	0.19		**	
B03	0.91	17.26	3.59	0.27	0.55	0.28	-0.70	0.39	0.39		**	
B04	0.97	-2.62	2.84	0.59	0.12	0.05	0.15	0.40	0.54		**	**
B05	0.93	7.63	3.74	0.53	0.37	0.76	-6.33	0.22	0.55		*	
B06	0.95	14.95	3.63	1.37	0.15	0.64	4.36	0.29	0.86		**	**
B07	0.94	17.71	3.65	0.69	0.28	0.28	10.07	0.31	0.31		**	
B08	0.88	24.05	2.70	0.65	0.19	0.30	9.08	0.40	0.27		**	
B09	0.94	10.04	2.75	0.64	0.03	0.27	-1.25	0.34	0.33		**	
B10	0.95	25.07	3.75	0.79	0.07	0.12	7.40	0.86	0.93		**	**
B11	0.88	27.94	3.30	1.30	0.49	1.24	-4.98	0.24	1.35			**
B12	0.98	-7.06	2.35	0.45	0.21	0.07	5.06	0.30	0.45		**	**
B13	0.96	-2.98	2.01	0.85	0.26	0.19	-2.92	0.44	0.41		**	**
B15	0.96	-9.05	6.29	0.34	0.77	0.13	-30.65	0.78	0.91	**	**	**
B17	0.95	4.93	1.97	0.83	0.16	-0.02	-8.94	0.49	0.22	*	**	
B18	0.94	5.64	4.96	1.37	0.22	0.11	-8.91	0.67	0.20		**	
B19	0.94	-4.37	2.08	0.84	0.21	0.19	10.61	0.54	0.14	*	**	
B23.34	0.93	18.51	4.28	1.32	0.53	1.41	6.42	0.35	0.67		*	
B24	0.95	12.77	3.41	0.63	0.24	0.22	-4.67	0.69	0.40		**	
B25.35	0.84	13.60	3.37	0.35	0.47	0.76	-14.11	0.36	1.34		*	**
B26	0.91	6.81	3.38	0.24	0.46	0.23	-15.87	0.61	-0.05	*	**	
B27	0.92	8.92	2.19	0.70	0.33	0.13	-11.10	0.54	0.60		**	**
B28.33	0.89	10.50	2.44	0.72	0.33	0.31	16.35	0.45	0.71	*	**	*
B29	0.94	7.12	3.47	1.84	0.42	0.22	0.99	0.42	0.33		**	
B30	0.98	5.79	2.75	0.69	0.10	0.07	-8.07	0.30	0.33	*	**	**
B31	0.98	4.96	3.16	0.61	0.21	0.00	-5.09	0.25	0.34		**	**
Avrge* **	**0.93**	**9.73**	**3.17**	**0.75**	**0.29**	**0.34**	**-2.30**	**0.43**	**0.53**			

Avrage cost of heating per day per $1000m^2$ 92.57 Overhead 9.73

***$Intrcpt_3$, *$Slpe_3$ and *Lag1 are all significant at 1% level (except Lag1 for B3, B15, B26 and B25.35)**

*** Signicant at 5% level**

**** Signicant at 1% level** ****Lag2 is signif. at 5% (or better) 6 and Lag3 10 times out of 27.**

***** Avrge is the average the corresponding parameter values of all the buildings**

****** F3/2 F-value for test between Model 2 and Model 3; if >2.65 signif. at 5%, if >3.18 signif. At 1% level.**

Model 2L Gas ~ $Intrcpt_2$+$Slpe_2$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3L Gas ~ $Intrcpt_3$+$Slpe_3$*DgrD+Lag1*LagD1+Lag2*LagD2+Lag3*LagD3+ H*Hmdty+W*Wnd+O*OpD.

Gas m^3 per day per 1000 m^2 **Hmdty, Wnd and OpD standardized to 0 mean**

Degree days (DgrD) = 18^o-temperature

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2L.

R_3^2 refers to squared multiple correlation for Model 3L.

Table G4

Test for the differences between the two heating seasons.
F values are shown for Model 1, 2 and 3.

	Change in avrge cost		Percent	F-test for difference between seasons			Significance		
Bldng	Difference*	Rel. % **	Change	Model 1	Model 2	Model 3	at 5% level		
B01	7.6	5.2	20.6	6.72	9.99	6.37	s	s	s
B02	0.7	1.9	27.8	5.47	5.23	3.19	s	s	s
B03	6.3	6.6	32.5	12.70	6.69	4.09	s	s	s
B04	10.4	10.2	15.7	6.95	8.64	8.89	s	s	s
B05	15.2	21.9	47.8	61.67	23.19	14.97	s	s	s
B06	3.6	11.2	14.7	27.89	25.57	17.42	s	s	s
B07	0.4	4.8	21.0	2.14	4.55	2.93	ns	s	s
B08	9.4	17.5	43.4	73.95	30.25	18.37	s	s	s
B10	2.9	1.4	24.4	3.22	7.00	5.12	ns	s	s
B11	16.5	7.2	33.0	8.55	4.91	3.54	s	s	s
B12	9.1	0.2	26.0	4.35	1.35	4.15	ns	ns	s
B13	8.3	3.0	22.9	14.40	12.98	16.39	s	s	s
B15	14.0	8.2	34.0	17.34	7.41	10.04	s	s	s
B18	9.8	3.5	29.4	0.14	1.48	1.50	ns	ns	ns
B19	4.8	8.1	33.9	0.50	1.24	2.85	ns	ns	s
B23.34	3.2	9.3	16.6	11.21	16.00	13.08	s	s	s
B24	3.5	5.3	31.1	42.11	17.10	16.32	s	s	s
B26	10.0	14.1	11.7	39.59	18.22	15.39	s	s	s
B27	4.3	0.6	26.4	0.09	1.02	4.33	ns	ns	s
B28.33	9.6	12.4	13.5	12.09	8.23	8.21	s	s	s
B29	9.3	16.7	9.1	41.85	34.26	25.13	s	s	s
B30	1.2	7.3	33.1	6.94	3.70	5.64	s	s	s
B31	3.0	0.0	25.9	4.60	6.37	10.68	ns	s	s
Avrge			25.8				15***	19***	22***
Corrltns between the diff. and F =				**0.356**	**0.203**	**0.187**			
Corrltns btwn the relative (%) change and F =				**0.791**	**0.756**	**0.622**			

Difference* **This is calculated as abs(Mean1-Mean2-(Averege(Mean1-Mean2))**
where 'Mean1' is the mean gas consumption for season 1 and 'Average is
the average over all buildings, and similarly for Mean2.

Rel. % ** **This is calculated as abs(Mean2/Mean1 - Avrge(Mean1/Mean2))**

15*** **In 15 times out of 23 the two seasons are statistically different when Model 1 is used.**
19*** **In 19 times out of 23 the two seasons are statistically different when Model 2 is used.**
22*** **In 22 times out of 23 the two seasons are statistically different when Model 3 is used.**

Note: **Relatively high correlations between relative procent change (either up or down from the mean change) and F-values suggests that greiter the relative change greater the differences between the model parameters from one season to the next.**

F-values for Model 1 have about 2 and 400 degrees of freedom,
For Model 3 about 5 and 400 df and Model 3 about 8 and 400df.

Table G5.
Summary of predicting gas consumption in individual buildings on the basis Model 3 relationship between climate variables and gas consumption in previous (later) season.

Model 3	Heating season 01/02			Predict Season 1 from Season 2 data.		
				Relative	Absolute	Relative
	Mean	r^2	R_3^2	Mean	relMean	St.Dev
B01	62.11	0.733	0.829	-5.5%	9.1%	0.109
B02	78.83	0.745	0.792	0.1%	7.4%	0.137
B03	85.91	0.863	0.915	1.4%	9.0%	0.110
B04	64.98	0.658	0.978	-6.7%	9.1%	0.178
B05	81.74	0.885	0.906	12.3%	13.6%	0.107
B06	114.77	0.878	0.934	-6.5%	7.9%	0.089
B07	96.85	0.657	0.713	-2.7%	6.7%	0.094
B08	73.64	0.971	0.957	14.6%	15.4%	0.185
B10	99.53	0.858	0.927	-2.5%	6.7%	0.088
B11	125.95	0.710	0.850	1.7%	7.7%	0.118
B12	44.06	0.790	0.966	0.7%	7.3%	0.184
B13	52.39	0.911	0.954	-6.1%	9.5%	0.106
B15	108.94	0.916	0.931	2.8%	10.0%	0.194
B18	107.59	0.964	0.980	-4.8%	13.8%	0.797
B19	48.15	0.913	0.967	-1.1%	10.0%	0.154
B23.34	147.64	0.833	0.856	-3.5%	8.8%	0.111
B24	82.46	0.688	0.958	9.4%	11.4%	0.095
B26	84.05	0.843	0.868	-11.5%	13.4%	0.120
B27	62.37	0.892	0.934	-1.7%	8.0%	0.118
B28.33	75.47	0.747	0.778	-3.3%	10.0%	0.137
B29	118.99	0.702	0.775	-13.6%	14.1%	0.115
B30	60.51	0.947	0.974	2.0%	5.5%	0.086
B31	70.50	0.945	0.962	-4.3%	6.0%	0.087
Average				**-1.3%**	**9.6%**	**0.153**

Model 3	Heating Season 02/03			Predict Season 2 from Season 1 data.		
				Relative	Absolute	Relative
	Mean	r^2	R_3^2	Mean	relMean	St.Dev
B01	70.23	0.769	0.844	3.8%	11.6%	0.132
B02	95.75	0.881	0.917	-2.3%	13.5%	0.191
B03	108.37	0.869	0.901	-3.1%	8.6%	0.108
B04	67.95	0.936	0.967	5.7%	7.0%	0.062
B05	112.64	0.888	0.926	-8.3%	10.7%	0.096
B06	128.84	0.895	0.941	9.0%	9.8%	0.077
B07	114.34	0.910	0.930	2.6%	9.8%	0.152
B08	99.60	0.828	0.860	-15.3%	15.4%	0.087
B10	117.90	0.886	0.950	1.5%	8.1%	0.114
B11	153.32	0.832	0.892	-4.2%	9.7%	0.113
B12	52.35	0.942	0.975	-0.3%	6.9%	0.104
B13	61.69	0.894	0.953	14.6%	15.8%	0.286
B15	139.12	0.922	0.952	10.9%	16.9%	0.518
B18	135.78	0.908	0.929	-1.4%	5.3%	0.074
B19	60.93	0.865	0.924	4.2%	8.6%	0.177
B23.34	166.99	0.856	0.919	9.3%	12.5%	0.130
B24	100.69	0.907	0.946	-8.3%	8.6%	0.052
B26	90.61	0.876	0.913	19.3%	20.5%	0.238
B27	74.38	0.848	0.909	3.9%	8.7%	0.111
B28.33	85.08	0.797	0.862	6.8%	13.9%	0.177
B29	123.79	0.860	0.916	24.4%	26.3%	0.243
B30	76.41	0.948	0.969	-2.9%	5.7%	0.098
B31	82.97	0.961	0.977	6.4%	7.5%	0.081
Average				**3.3%**	**11.4%**	**0.149**

Mean1 as funcntion of mean2

0.833434	0.611449
0.045106	4.751736
0.942055	6.581006
341.4096	21
14786.33	909.5024

Mean 1	P Mean 1	
62.11	59.14604	5.0%
78.83	80.41278	-2.0%
85.91	90.92906	-5.5%
64.98	57.23997	13.5%
81.74	94.49199	-13.5%
114.77	107.9886	6.3%
96.85	95.90883	1.0%
73.64	83.62234	-11.9%
99.53	98.87252	0.7%
125.95	128.3894	-1.9%
44.06	44.23923	-0.4%
52.39	52.02851	0.7%
108.94	116.5588	-6.5%
107.59	113.7718	-5.4%
48.15	51.3951	-6.3%
147.64	139.7858	5.6%
82.46	84.52828	-2.4%
84.05	76.12643	10.4%
62.37	62.60479	-0.4%
75.47	71.5192	5.5%
118.99	103.7856	14.7%
60.51	64.2975	-5.9%
70.50	69.76232	1.1%

Mean2 as function of mean1

1.130328	5.153114
0.061174	5.420512
0.942055	7.664061
341.4096	21
20053.66	1233.494

Mean 2	P mean 2	
70.2	75.4	-6.8%
95.8	94.3	1.6%
108.4	102.3	6.0%
67.9	78.6	-13.6%
112.6	97.5	15.5%
128.8	134.9	-4.5%
114.3	114.6	-0.2%
99.6	88.4	12.7%
117.9	117.7	0.2%
153.3	147.5	3.9%
52.3	55.0	-4.7%
61.7	64.4	-4.2%
139.1	128.3	8.4%
135.8	126.8	7.1%
60.9	59.6	2.3%
167.0	172.0	-2.9%
100.7	98.4	2.4%
90.6	100.2	-9.5%
74.4	75.7	-1.7%
85.1	90.5	-5.9%
123.8	139.7	-11.4%
76.4	73.6	3.9%
83.0	84.8	-2.2%

Table G6

Comparison of linear and non linear models. Slopes and composite slopes are m^3 per $1000m^2$ per C^o.

The second heating season (05/10/02 to 04/30/03).

Model 3	**Linear model**				**Non -linear model**				
	R_3^2	*Intrcpt$_3$	*Slpe$_3$	CmpsteSlpe	R_3^2	*Intrcpt$_3$	*Slpe$_3$	*lagC	CmpsteSlpe
Avrge	0.98	9.98	3.17	4.57	0.98	10.74	3.09	0.33	4.52
B01	0.88	14.45	1.61	2.84	0.88	15.04	1.44	0.53	2.81
B02	0.92	20.48	2.65	3.83	0.92	21.63	2.52	0.34	3.77
B03	0.91	17.26	3.59	4.68	0.91	18.82	3.39	0.27	4.60
B04	0.97	-2.62	2.84	3.60	0.97	-2.56	2.84	0.21	3.59
B05	0.93	7.63	3.74	5.40	0.93	9.50	3.48	0.35	5.29
B06	0.95	14.95	3.63	5.78	0.95	15.53	3.64	0.38	5.75
B07	0.94	17.71	3.65	4.91	0.94	18.53	3.58	0.27	4.86
B08	0.88	24.05	2.70	3.84	0.88	24.66	2.65	0.31	3.80
B09	0.94	10.04	2.75	3.69	0.94	10.50	2.76	0.25	3.66
B10	0.95	25.07	3.75	4.73	0.95	25.18	3.77	0.20	4.73
B11	0.88	27.94	3.30	6.32	0.88	29.07	3.01	0.57	6.26
B12	0.98	-7.06	2.35	3.08	0.98	-6.77	2.31	0.25	3.07
B13	0.96	-2.98	2.01	3.30	0.96	-2.95	2.03	0.40	3.30
B15	0.96	-9.05	6.29	7.53	0.96	-6.98	6.09	0.18	7.42
B17	0.95	4.93	1.97	2.94	0.95	4.16	2.04	0.32	2.98
B18	0.94	5.64	4.96	6.65	0.94	5.49	5.00	0.25	6.66
B19	0.94	-4.37	2.08	3.32	0.94	-4.34	2.10	0.38	3.32
B23.34	0.93	18.51	4.28	7.54	0.93	20.24	3.88	0.52	7.45
B24	0.95	12.77	3.41	4.50	0.95	13.46	3.35	0.25	4.46
B25.35	0.84	13.60	3.37	4.95	0.83	15.52	3.01	0.39	4.84
B26	0.91	6.81	3.38	4.31	0.91	8.17	3.22	0.24	4.23
B27	0.92	8.92	2.19	3.35	0.92	9.08	2.15	0.37	3.34
B28.33	0.89	10.50	2.44	3.79	0.89	10.97	2.37	0.39	3.76
B29	0.94	7.12	3.47	5.95	0.94	6.60	3.63	0.41	5.98
B30	0.98	5.79	2.75	3.60	0.98	5.76	2.77	0.24	3.60
B31	0.98	4.96	3.16	3.99	0.98	5.03	3.14	0.21	3.98
Avrge* **	**0.93**	**9.73**	**3.17**	**4.55**	**0.93**	**10.36**	**3.08**	**0.33**	**4.52**

Avrge **Coefficients represent values fitted to the average gas consumption.**

*** **Avrge is the average the corresponding parameter values of all the buildings**

Note: Differences between linear and non linear model are minor, R^2's and CmpsteSlope's (Composite slope) are almost the same.

Linear model: **CmpsteSlpe = Slpe + Lag1 + Lag2 + Lag3**

Non-linear model: **CmpsteSlpe = Slpe*(1 + lagC+lagC^2 + lagC^3)**

Table G7, Ssn 1.

Relationship of the daily gas consumption (m^3 per $1000m^2$) to changes in climate.
Daily gas consumption is estimated to include only the space heating.

The first heating season (05/10/01 to 05/28/02).

Model 2		**Non -linear model**						t-values*		
	r^2	R_2^2	R_3^2	Mean	$Intrcpt_2$	$Slpe_2$	lagC	$Intrcpt_2$	$Slpe_2$	lagC
Avrge	0.94	0.97	0.97	75.72	12.81	-3.19	0.31	**	**	**
B01	0.74	0.83	0.83	55.06	6.90	-1.60	0.60	**	**	**
B02	0.76	0.81	0.82	70.72	7.29	-2.53	0.48	**	**	**
B03	0.85	0.89	0.90	77.66	4.88	-3.19	0.40		**	**
B04	0.92	0.94	0.95	54.69	-6.40	-2.78	0.31	**	**	**
B05	0.88	0.90	0.91	71.90	4.21	-3.49	0.30		**	**
B06	0.91	0.94	0.95	105.34	29.84	-3.73	0.33	**	**	**
B07	0.71	0.77	0.78	88.91	20.49	-2.59	0.52	**	**	**
B08	0.92	0.94	0.95	65.92	7.68	-3.03	0.28	**	**	**
B10	0.85	0.89	0.92	90.01	13.73	-3.53	0.38	**	**	**
B11	0.67	0.79	0.80	107.86	9.37	-2.61	0.75		**	**
B12	0.92	0.94	0.95	37.95	-6.55	-2.33	0.23	**	**	**
B13	0.90	0.93	0.94	46.68	5.22	-2.10	0.31	**	**	**
B15	0.93	0.93	0.94	97.57	10.13	-5.69	0.10	**	**	**
B18	0.96	0.96	0.97	98.38	8.43	-5.84	0.11	**	**	**
B19	0.92	0.95	0.96	42.02	-4.04	-2.30	0.32	**	**	**
B23.34	0.85	0.87	0.88	134.16	42.72	-5.02	0.25	**	**	**
B24	0.90	0.91	0.93	72.81	8.48	-3.25	0.24	**	**	**
B26	0.84	0.84	0.87	76.62	18.11	-4.14	0.03	**	**	
B27	0.88	0.91	0.92	55.52	8.46	-2.32	0.33	**	**	**
B28.33	0.77	0.80	0.80	69.35	21.57	-2.56	0.27	**	**	**
B29	0.77	0.85	0.85	106.32	21.41	-3.35	0.49	**	**	**
B30	0.95	0.97	0.98	53.91	2.75	-2.77	0.26	**	**	**
B31	0.92	0.94	0.94	61.87	3.52	-3.18	0.25	*	**	**
Avrge* **	**0.86**	**0.89**	**0.90**	**75.71**	**10.36**	**-3.21**	**0.33**			

Avrage cost of (m^3) heating per day per $1000m^2$ **75.71** **Overhead** **10.36**

*** significant at 5% level**
**** significant at 1% level.**

Model 1 Gas ~ Intrcpt+Slpe*DgrD

Model 2 Gas ~ $Intrcpt_2$+$Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3 Gas ~ $Intrcpt_3$+$Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+ Hmdty*H+Wnd*W+OpD*O.

Gas m^3 per day per 1000 m^2 Degree days (DgrD) = 18^o-temperature

H, W, and O are observed humidity, wind and opacity, standardized to zero mean.

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2.

R_3^2 refers to squared multiple correlation for Model 3.

Table G7, Ssn 2.

Relationship of the daily gas consumption (m^3) to changes in climate.

Daily gas consumption is estimated to include only the space heating (per $1000m^3$)

The second heating season (05/10/02 to 04/30/03).

Model 2		**Non -linear model**						t-values*		
	r^2	R_2^2	R_3^2	Mean	$Intrcpt_2$	$Slpe_2$	lagC	$Intrcpt_2$	$Slpe_2$	lagC
Avrge	0.95	0.97	0.98	92.77	10.81	3.26	0.28	**	**	**
B01	0.81	0.86	0.88	65.91	16.74	1.52	0.47	**	**	**
B02	0.89	0.90	0.92	89.96	20.63	2.66	0.31	**	**	**
B03	0.89	0.90	0.91	102.88	18.54	3.57	0.23	**	**	**
B04	0.95	0.95	0.97	62.61	-2.58	2.98	0.17		**	**
B05	0.90	0.92	0.93	105.35	9.87	3.60	0.33	**	**	**
B06	0.91	0.94	0.95	119.80	15.62	3.71	0.37	**	**	**
B07	0.92	0.94	0.94	106.68	17.73	3.67	0.25	**	**	**
B08	0.85	0.87	0.88	93.65	23.90	2.79	0.28	**	**	**
B09	0.92	0.93	0.94	76.89	10.50	2.91	0.21	**	**	**
B10	0.90	0.91	0.95	110.94	24.55	4.07	0.15	**	**	**
B11	0.81	0.87	0.88	142.54	30.08	3.07	0.55	**	**	**
B12	0.95	0.96	0.98	47.35	-7.20	2.41	0.23	**	**	**
B13	0.91	0.94	0.96	56.88	-2.78	2.19	0.35		**	**
B15	0.94	0.94	0.96	129.67	-5.55	6.50	0.12		**	**
B17	0.90	0.92	0.95	64.49	5.89	2.26	0.22	**	**	**
B18	0.92	0.93	0.94	126.32	5.64	5.30	0.21		**	**
B19	0.89	0.91	0.94	55.79	-5.28	2.29	0.33	**	**	**
B23.34	0.87	0.92	0.93	155.19	19.87	4.00	0.50	**	**	**
B24	0.92	0.92	0.95	94.42	13.36	3.67	0.18	**	**	**
B25.35	0.79	0.81	0.83	103.30	16.82	3.19	0.34	**	**	**
B26	0.89	0.89	0.91	85.01	8.45	3.62	0.14	**	**	*
B27	0.87	0.89	0.92	69.62	9.76	2.38	0.28	**	**	**
B28.33	0.83	0.86	0.89	78.06	9.66	2.46	0.37	**	**	**
B29	0.89	0.93	0.94	114.99	6.61	3.76	0.39	*	**	**
B30	0.96	0.97	0.98	71.16	6.22	2.90	0.19	**	**	**
B31	0.97	0.98	0.98	77.27	5.30	3.24	0.18	**	**	**
Avrge* **	**0.90**	**0.92**	**0.93**	**93.39**	**9.41**	**3.35**	**0.27**			
Avrage cost of (m^3) heating per day per $1000m^2$				**93.39**	**Overhead**		**9.41**			

*** significant at 5% level**

**** significant at 1% level.**

Model 1 Gas ~ Intrcpt+Slpe*DgrD

Model 2 Gas ~ $Intrcpt_2$+$Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3 Gas ~ $Intrcpt_3$+$Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+
Hmdty*H+Wnd*W+OpD*O.

Gas m^3 per day per 1000 m^2 Degree days (DgrD) = 18^o-temperature

H, W, and O are observed humidity, wind and opacity, standardized to zero mean.

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2.

R_3^2 refers to squared multiple correlation for Model 3.

Table G8, Ssn 1.

Relationship of the daily gas consumption (m^3 per $1000m^2$) to changes in climate.
Daily gas consumption is estimated to include only the space heating.

The first heating season (05/10/01 to 05/28/02).

Model 3		**Non -linear model**						Significance levels			
	R_3^2	*$Intrcpt_3$	*$Slpe_3$	*lagC	Hmdty	Wnd	OpD	Hmdty	Wnd	OpD	****F3/2
Avrge	0.97	14.15	3.04	0.33	12.69	0.25	0.12	**	**		19.35
B01	0.83	7.84	1.51	0.63	6.75	0.20	0.16				2.86
B02	0.82	8.15	2.39	0.51	-3.78	0.31	0.43				3.39
B03	0.90	6.66	2.92	0.45	10.81	0.47	-0.16		**		8.84
B04	0.95	-4.26	2.62	0.33	20.63	0.23	-0.10	**	**		12.00
B05	0.91	5.61	3.29	0.33	8.90	0.32	0.33		**		6.67
B06	0.95	30.69	3.67	0.33	0.43	0.16	0.78			**	10.36
B07	0.78	21.26	2.49	0.54	-5.86	0.25	0.72				2.64
B08	0.95	9.03	2.87	0.30	4.31	0.32	0.18		**		11.36
B10	0.92	16.50	3.14	0.43	8.70	0.78	0.60		**		28.26
B11	0.80	12.66	2.48	0.76	51.42	0.26	0.02	**			5.74
B12	0.95	-4.72	2.18	0.25	19.24	0.21	-0.10	**	**		19.05
B13	0.94	6.52	1.94	0.35	15.50	0.25	-0.18	**	**		15.32
B15	0.94	11.63	5.41	0.13	4.30	0.44	0.02		**		7.02
B18	0.97	9.77	5.55	0.14	-8.18	0.52	0.29		**		23.07
B19	0.96	-2.64	2.09	0.37	10.74	0.36	-0.10	**	**		29.34
B23.34	0.88	43.54	5.14	0.22	23.91	-0.26	0.93				9.43
B24	0.93	9.71	2.91	0.31	7.71	0.52	-0.02		**		15.98
B26	0.87	21.18	3.55	0.12	27.85	0.76	-0.77	**	**	*	18.49
B27	0.92	9.60	2.17	0.36	11.95	0.24	-0.10	*	**		7.31
B28.33	0.80	21.11	2.62	0.26	-10.10	-0.08	0.51				1.13
B29	0.85	22.92	3.32	0.48	35.95	-0.05	-0.22	**			4.55
B30	0.98	3.35	2.68	0.28	4.67	0.15	-0.05		**		6.74
B31	0.94	4.77	3.09	0.26	26.64	0.08	-0.40	**			10.66
Avrge* **	**0.94**	**12.39**	**3.18**	**0.37**	**12.40**	**0.29**	**0.12**				

Avrage cost of heating per day per $1000m^2$ **93.39** **Overhead** **12.39**

***$Intrcpt_3$, *$TmpSlpe_3$ and *lagC are all significant at 1% level (except lagC for B26 which is signif. at 5% level)**

*** Signicant at 5% level**

**** Signicant at 1% level**

***** Avrge is the average the corresponding parameter values of all the buildings**

****** F3/2 F-value for test between Model 2 and Model 3; if >2.65 signif. at 5%, if >3.18 signif. At 1% level.**

Model 1 Gas ~ Intrcpt+Slpe*DgrD

Model 2 Gas ~ $Intrcpt_2$+$Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3 Gas ~ $Intrcpt_3$+$Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+
Hmdty*H+Wnd*W+OpD*O.

Gas m^3 per day per 1000 m^2 **Degree days (DgrD) = 18^o-temperature**

H, W, and O are observed humidity, wind and opacity, standardized to zero mean.

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2.

R_3^2 refers to squared multiple correlation for Model 3.

Table G8, Ssn 2.

Relationship of the daily gas consumption (m^3 per $1000m^2$) to changes in climate.
Daily gas consumption is estimated to include only the space heating.

The second heating season (05/10/02 to 04/30/03).

Model 3 — **Non -linear model** — Significance levels

	R_3^2	*$Intrcpt_3$	*$Slpe_3$	*lagC	Hmdty	Wnd	OpD	Hmdty	Wnd	OpD	****F3/2
Avrge	0.98	10.74	3.09	0.33	-0.59	0.43	0.48		**	**	44.71
B01	0.88	15.04	1.44	0.53	-17.65	0.19	0.95	*		**	13.15
B02	0.92	21.63	2.52	0.34	13.43	0.40	0.11		**		9.79
B03	0.91	18.82	3.39	0.27	3.49	0.41	0.26		**		6.13
B04	0.97	-2.56	2.84	0.21	0.21	0.40	0.54		**	**	39.08
B05	0.93	9.50	3.48	0.35	-3.25	0.25	0.41				3.17
B06	0.95	15.53	3.64	0.38	3.83	0.30	0.83		*	*	10.87
B07	0.94	18.53	3.58	0.27	11.71	0.32	0.25		**	**	7.49
B08	0.88	24.66	2.65	0.31	9.95	0.41	0.23		**		7.15
B09	0.94	10.50	2.76	0.25	-0.98	0.34	0.31		**		11.25
B10	0.95	25.18	3.77	0.20	7.25	0.86	0.93		**	**	49.35
B11	0.88	29.07	3.01	0.57	-5.14	0.29	1.26			*	5.40
B12	0.98	-6.77	2.31	0.25	5.83	0.30	0.43		**	**	41.21
B13	0.96	-2.95	2.03	0.40	-3.16	0.44	0.41		**	**	38.40
B15	0.96	-6.98	6.09	0.18	-24.34	0.79	0.76	*	**		24.11
B17	0.95	4.16	2.04	0.32	-10.48	0.48	0.27		**		35.40
B18	0.94	5.49	5.00	0.25	-9.61	0.67	0.21		**		10.68
B19	0.94	-4.34	2.10	0.38	10.27	0.54	0.14		**		28.89
B23.34	0.93	20.24	3.88	0.52	7.35	0.42	0.53		*		4.53
B24	0.95	13.46	3.35	0.25	-3.24	0.70	0.36		**		30.08
B25.35	0.83	15.52	3.01	0.39	-10.59	0.41	1.18			*	6.30
B26	0.91	8.17	3.22	0.24	-12.19	0.63	-0.15		**		15.92
B27	0.92	9.08	2.15	0.37	-10.65	0.55	0.59		**	*	26.72
B28.33	0.89	10.97	2.37	0.39	17.04	0.45	0.68		**		15.22
B29	0.94	6.60	3.63	0.41	-0.75	0.40	0.38		**		6.04
B30	0.98	5.76	2.77	0.24	-8.33	0.30	0.33		**	*	25.00
B31	0.98	5.03	3.14	0.21	-4.68	0.25	0.33		**	*	19.65
Avrge*	**0.93**	**10.36**	**3.08**	**0.33**	**-1.33**	**0.44**	**0.48**				

Avrage cost of heating per day per $1000m^2$ — 75.71 — Overhead — 10.36

***$Intrcpt_3$, *$TmpSlpe_3$ and *lagC are all significant at 1% level (except $Intrcpt_3$ for B04, B13-18 and B29 signif. at 5% level)**

*** Signicant at 5% level**

**** Signicant at 1% level**

***** Avrge is the average the corresponding parameter values of all the buildings**

****** F3/2 F-value for test between Model 2 and Model 3; if >2.65 signif. at 5%, if >3.18 signif. At 1% level.**

Model 1 Gas ~ Intrcpt+Slpe*DgrD

Model 2 Gas ~ $Intrcpt_2+Slpe_2$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]
where LagD1,LagD2, and LagD3 are the degree days 1, 2 or 3 days before.

Model 3 Gas ~ $Intrcpt_3+Slpe_3$*[DgrD+lagC*LagD1+lagC^2*LagD2+lagC^3*LagD3]+
Hmdty*H+Wnd*W+OpD*O.

Gas m^3 per day per 1000 m^2 Degree days (DgrD) = 18^o-temperature

H, W, and O are observed humidity, wind and opacity, standardized to zero mean.

r^2 refers to squared correlation coefficient between gas cnsmptn and temperature (Model 1)

R_2^2 refers to squared multiple correlation for Model 2.

R_3^2 refers to squared multiple correlation for Model 3.

Table G9

Comparison of consumption-temperature slope (DgD)
and the composite slope CSlpeF, CSlpeS)

		Season 1			Season 2	
		CSlpeF	DgrD	Mean	CSlpeS	DgrD
B01	55.06	3.42	2.98	65.91	2.81	2.49
B02	70.72	4.56	4.09	89.96	3.77	3.62
B03	77.66	5.07	4.66	102.88	4.60	4.43
B04	54.69	3.85	3.61	62.61	3.59	3.49
B05	71.90	4.82	4.57	105.35	5.29	4.99
B06	105.34	5.43	5.12	119.80	5.75	5.37
B07	88.91	4.92	4.41	106.68	4.86	4.69
B08	65.92	4.08	3.89	93.65	3.80	3.66
B09						
B10	90.01	5.36	5.09	110.94	4.73	4.65
B11	107.86	6.92	5.84	142.54	6.26	5.60
B12	37.95	2.88	2.80	47.35	3.07	2.99
B13	46.68	2.92	2.80	56.88	3.30	3.08
B15	97.57	6.25	6.21	129.67	7.42	7.20
B17						
B18	98.38	6.44	6.34	126.32	6.66	6.42
B19	42.02	3.25	3.07	55.79	3.32	3.17
B23.34	134.16	6.59	6.33	155.19	7.45	6.82
B24	72.81	4.16	4.04	94.42	4.46	4.34
B25.35				85.01	4.84	4.13
B26	76.62	4.04	4.22	85.01	4.23	4.13
B27	55.52	3.34	3.16	69.62	3.34	3.14
B28.33	69.35	3.51	3.30	78.06	3.76	3.58
B29	106.32	6.06	5.46	114.99	5.98	5.55
B30	53.91	3.68	3.48	71.16	3.60	3.46
B31	61.87	4.15	3.97	77.27	3.98	3.85
Avrge*	**75.71**	**4.60**	**4.32**	**97.70**	**4.82**	**4.56**

Corrolation between mean and Composite slope/temperature

	CSlpeF	DgD	CSlpeS	DgD
r =	**0.931**	**0.925**	**0.931**	**0.921**

r^2 between mean and other variables, first season.

	Mean	R32	Intrcpt3	Slpe3	lagC	CSlpeF
r^2 =	**1**	**0.09**	**0.67**	**0.50**	**0.00**	**0.87**

r^2 between mean and other variables, second season.

	Mean	R32	Intrcpt3	TmpSlpe3	lagC	CSlpeS
r^2 =	**1**	**0.07**	**0.28**	**0.55**	**0.06**	**0.88**

Appendix “W”

Water Data

Table W1.

Amount of water used, m^3 per day per 100 units from 01/05/01 to 30/04/02 and from 01/05/02 to 30/04/03.

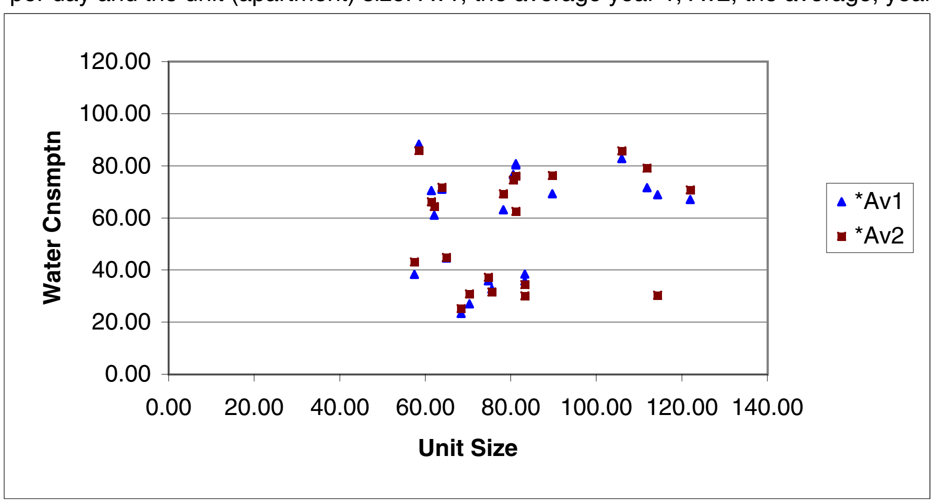
	Unit size	m^3 per day per 100 units		
Bldng#	m^2	01/02	02/03	max/min*
B01	105.95	82.76	85.78	5.51
B02	83.28	38.48	30.13	6.17
B03	83.28	35.80	34.39	10.21
B04	121.98	67.09	70.79	6.16
B05	75.57	32.67	31.59	14.29
B06	68.37	23.33	25.17	4.36
B07	74.75	35.91	37.22	10.88
B08	70.35	27.04	30.80	8.39
B09	57.49	38.36	43.13	5.71
B10,26,35	58.51	88.26	85.83	4.54
B11	89.68	69.33	76.27	7.19
B12	111.87	71.60	79.05	6.67
B13	81.16	80.39	76.08	4.82
B14	80.56	76.68	74.60	4.81
B15	114.30	68.93	30.37	3.92
B16	61.41	70.46	66.19	6.77
B17	81.16	80.81	62.48	18.35
B18	64.96	44.64	44.83	4.83
B19	78.27	63.11	69.27	5.06
B20	63.88	70.95	71.71	18.00
B21	62.08	61.06	64.30	7.71

max/min* **This is the ratio for one week only, March 7th to 13th, 2003 based on hourly records.**

Additional data not in the report

Total water	Bldng#	SpceHtng	Pool	#Units	FlrArea	Bldng#	Unit size	*Av1	*Av2
	B01	G	No	246	26063.38	B09	57.49	38.36	43.13
	B02	G	No	157	13074.2	B10,26,35	58.51	88.26	85.83
	B03	G	No	157	13074.2	B16	61.41	70.46	66.19
	B05	G	No	173	13074.2	B21	62.08	61.06	64.30
	B06	G	No	69	4717.243	B20	63.88	70.95	71.71
	B07	G	No	235	17565.7	B18	64.96	44.64	44.83
	B08	G	No	235	16532.42	B06	68.37	23.33	25.17
	B10,26,35	G	No	787	46047	B08	70.35	27.04	30.80
	B15	G	No	150	17144.97	B07	74.75	35.91	37.22
	B16	E	No	357	21922	B05	75.57	32.67	31.59
	B20	E	No	227	14501.74	B19	78.27	63.11	69.27
	B21	E	No	267	16575.24	B14	80.56	76.68	74.60
	B04	G	OutSh	196	23908.12	B13	81.16	80.39	76.08
	B09	G	In	473	27194.97	B17	81.16	80.81	62.48
	B11	G	Out	93	8340.404	B02	83.28	38.48	30.13
	B12	G	OutSh	217	24276.02	B03	83.28	35.80	34.39
	B13	G	InSh	287	23291.59	B11	89.68	69.33	76.27
	B14	G	InSh	273	21993.63	B01	105.95	82.76	85.78
	B17	G	InSh	287	23291.59	B12	111.87	71.60	79.05
	B18	G	OutH	186	12082.82	B15	114.30	68.93	30.37
	B19	G	InSh	281	21993.63	B04	121.98	67.09	70.79

Graph showing the relationship between the average water consumed per 100 units per day and the unit (apartment) size. Av1, the average year 1, Av2, the average, year 2.



Units: Water consumption m^3 per day per 100 units

Units size m^2

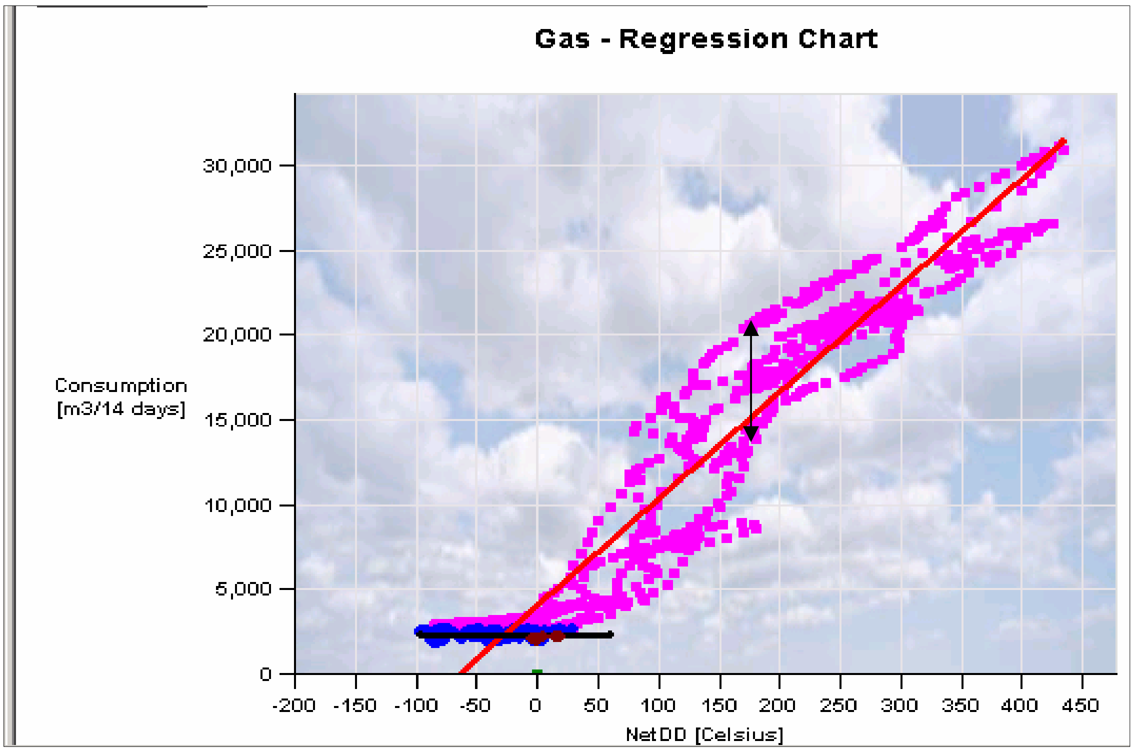
*Av1= Average Water Consumption from May1, 2001 - April 30, 2002

*Av2= Average Water Consumption from May1, 2002 - April 30, 2003

Appendix “O”
Other Studies

In these charts, the gas consumption (m3) for a 14 day period is plotted against the cummulative degree days for the same period (model 1). As degree days increase the gas consumption increases as well.

This site shows a wide variation in gas management (see range)



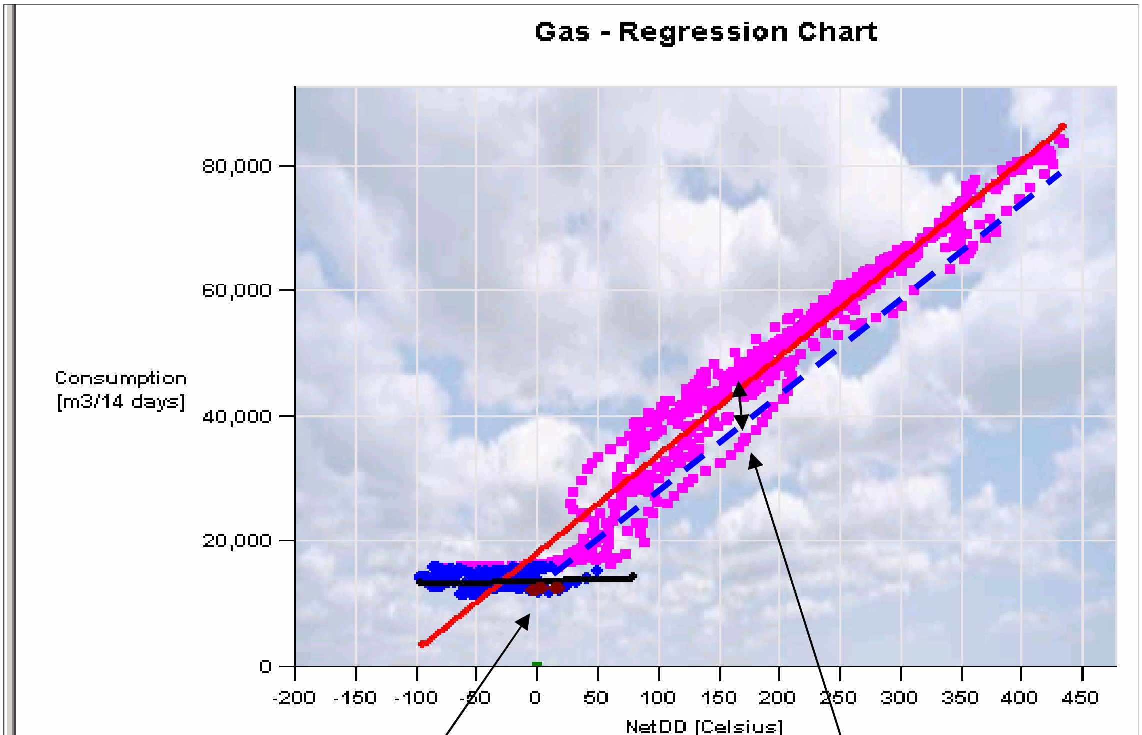
This range of 5,000 m3/14 days implies a potential saving from better management of over 50,000 m3 of gas during a heating season. This represents 25% of the gas use for space heating at this site.

Legend

- heating season data points
- Water heating data points (DHW)
- Data over the most recent week

Gas Continued. Appendix "O"

This graph has less spread in gas consumption during the season. However it clearly demostrates the "overhead" factor, where the heating system comes on, at about 18 C, but requires extra gas to operate.



heating system comes on
at balance temperature of 17 C

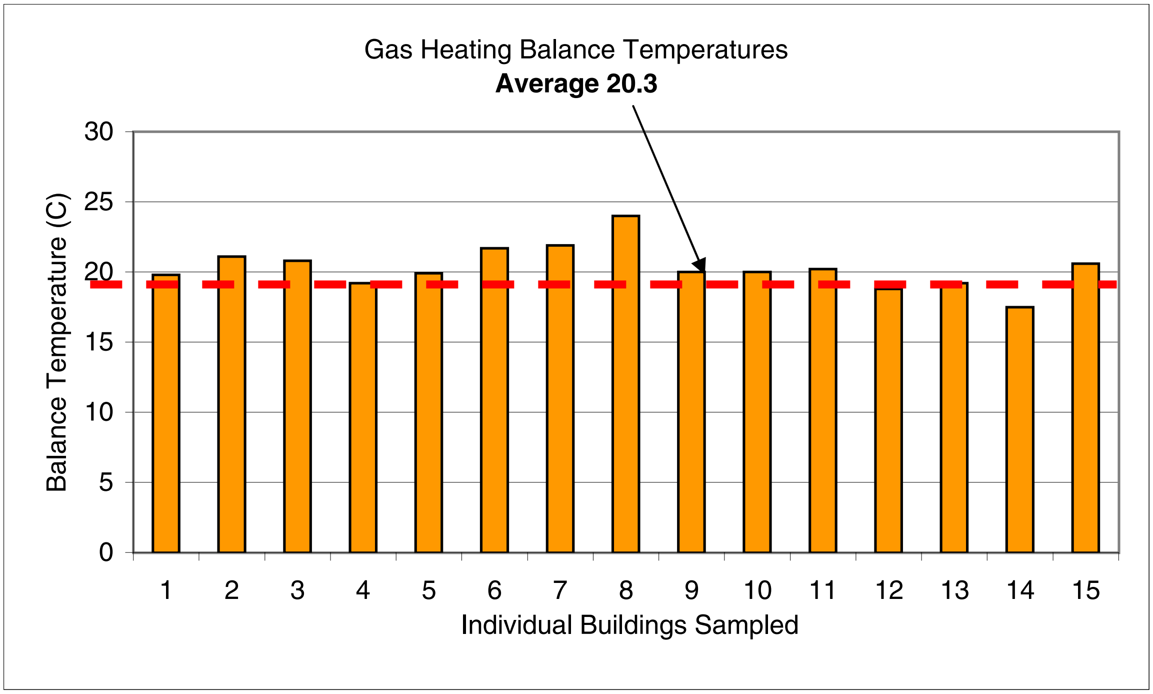
Gas overhead factor: approximately 5000 m3 in 14 days, or 50,000 m3 over the heating season, a cost of about $20,000 per year

Legend

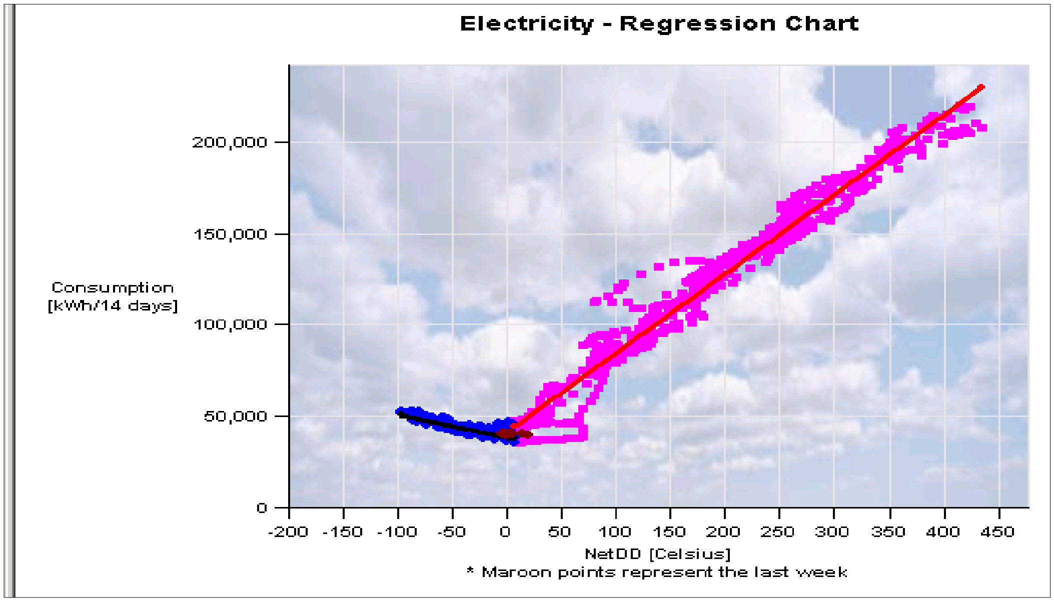
- heating season data points
- Water heating data points (DHW)
- Data over the most recent week

Appendix "O"

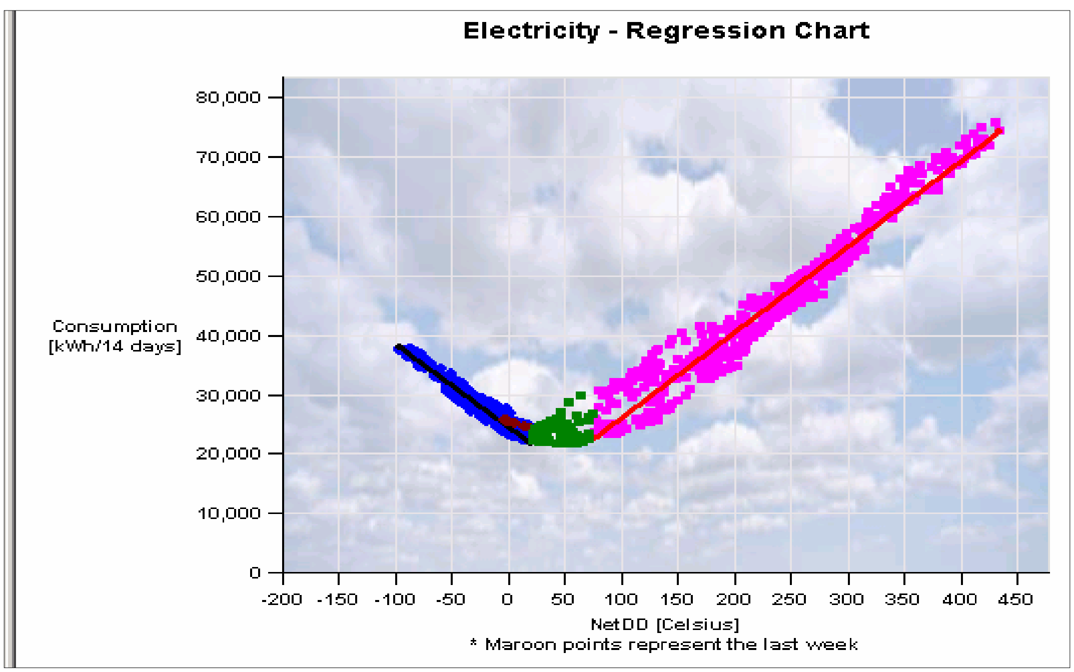
Sample of Balance Temperatures for 15 Gas Heated Buildings


Gas Heating Balance Temperatures
Average 20.3
30
25
20
15
10
5
0
Balance Temperature (C)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Individual Buildings Sampled

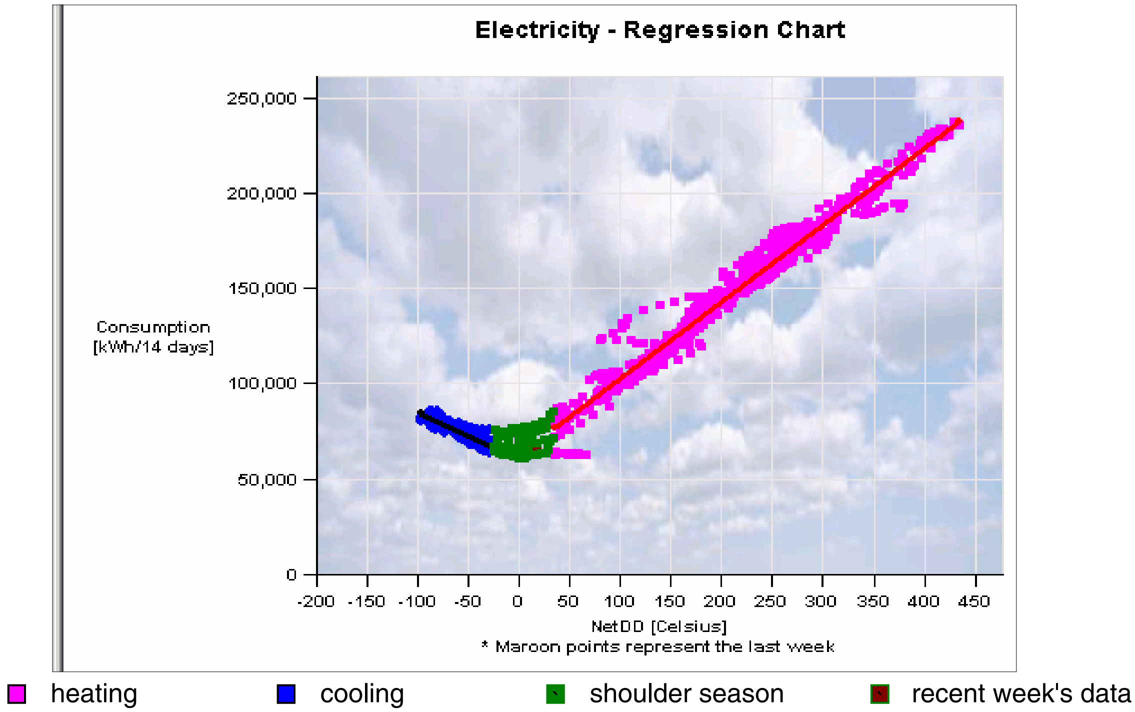
These graphs demonstrate typical electric heating response to temperature. Note that there is no "overhead" effect, and the scatter is reduced as compared to gas.



heating cooling shoulder season recent week's data



heating cooling shoulder season recent week's data



Sample of Balance Temperatures for 20 Electrically Heated Buildings