Final Report on HUD52667 Spreadsheet Update

GARD Analytics February 12, 2007

The U.S. Department of Housing and Urban Development (HUD) operates the Housing Choice Vouchers program, also called Section 8. The Housing and Community Development Act of 1974 authorized the Section 8 program which has been modified several times including by the Quality Housing and Work Responsibility Act of 1998 which resulted in the current Housing Choice Vouchers program. As part of the Housing Choice Vouchers program, the participant is reimbursed for a share of the total housing cost. The total housing cost includes not only rent, but also an allowance for utilities such as electricity, natural gas and other fuels. The local public housing authorities must routinely update the allowances for utility costs. To make this easier, HUD provided a standard form called HUD-52667 and guidance in the instructions for that form. The guidance included the amount of energy consumed by heating, water heating, lighting and refrigeration, cooking, etc. These individual energy consumptions are also called end-uses. The allowances are often portrayed in a tabular format with values in dollars per month for each end use by the number of bedrooms. The tables are then reproduced for each type of housing, such as single family detached, townhouse, or apartment. This is also the format used in the HUD 52667 form.

The history of the guidance provided in the instructions for HUD 52667 dated originally back to the era of the original Housing and Community Development Act of 1974. This was soon after the beginning of the energy crisis in the 1970's. Housing from this era had few conservation features that people now take for granted, such as sufficient wall and roof insulation, double-paned "thermal" windows, and efficient furnaces and water heaters. The guidance provided for determining the utility allowances had not been significantly updated since that time yet the common use of more energy conserving building practices, due in part to the energy crisis, had reduced the amount of energy used for heating, cooking and water heating in a typical residence. This resulted in the utility allowances being larger than necessary to cover the energy costs for the residents. Of course, housing stock has also changed between the 1970's and now, specifically the floor area of newer homes has increased.

In 2002 and 2003, GARD Analytics worked with HUD to create a spreadsheet version of HUD Form 52667 primarily using data from the U.S. Department of Energy's Residential Energy Consumption Survey (RECS) from 1997. The approach used the RECS data that serves as the basis of the report "A Look at Residential Energy Consumption in 1997" published by the U.S. Department of Energy - Energy Information Administration. Multiple linear regression was used with the RECS data to derive correlations for most of the end-uses shown on the 52667 form. For heating energy consumption, for example, the relationship developed was based on heating degree-days and number of bedrooms. Correlations were developed for each of the building types.

Since that time, the spreadsheet has been updated and enhanced several times. The latest round of enhancements includes revising the method by which heat pump efficiencies are computed based on climate, updating the heating energy use calculation to reflect the complex issues with climate, and compare the results of the spreadsheet with actual data.

1. Revise Heat Pump Efficiency Adjustment

1.1 Overview

A new formula was added to the HUD 52667 spreadsheet that adjusted the electricity used for heating based on climate when a heat pump was specified. Prior to this update, the HSPF (heating seasonal performance factor) was used as a direct adjustment factor for the heat pump energy consumption calculation. The HSPF measure is based on combining efficiencies under different conditions, but it does not provide a heating seasonal efficiency for all climates. Since heat pumps are a refrigeration-based system, they lose capacity and efficiency at lower temperatures. Because of loss of capacity at low temperatures in northern climates, the heat pump supplemental heat, which is electric resistance, is used extensively at lower outside air temperatures. This makes the actual seasonal efficiency lower in colder northern climates and higher in warmer climates.

1.2 Simulation Results

Recently, the Florida Solar Energy Center (FSEC) examined this exact issue of the influence of climate on heat pump efficiency. A paper titled "Climatic Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air-Source Heat Pumps" was published in 2004 by ASHRAE and was written by Philip Fairey, Danny Parker, Bruce Wilcox and Matthew Lombardi. All but Wilcox are researchers at FSEC. The paper is available from ASHRAE or at:

http://www.fsec.ucf.edu/bldg/pubs/hspf/

The paper describes the use of the DOE-2 building energy simulation program to examine the issue of how heating energy performance changes in different climates for heat pumps. FSEC is considered one of the premier research institutions on heat pump models used in building energy simulation programs. They used DOE-2 simulations with a heat pump model that includes modifications based on their experience in real world field studies and laboratory research. The paper examined heat pump heating performance in:

- Miami
- Houston
- Ft Worth
- Phoenix
- Los Angeles
- Atlanta
- Las Vegas
- St. Louis
- New York City
- Seattle
- Fresno
- Detroit
- Minneapolis
- Denver
- San Francisco.

The paper showed that the HSPF should be modified by a factor based on heating design temperature and the nominal HSPF. A subset of the paper's results was used to find the performance for heat pumps nominally rated at 6.8 HSPF. The decrease in performance is shown in the Degradation column on Table 1.

Table 1 – Heating Degradation

City	Degradation (%)	Typical Low Temp (F)	Calculated (%)	Diff (%)
Altanta, GA	4.2%	29.3	3.8%	0.4%
Denver, CO	25.3%	16.1	20.7%	4.6%
Detroit, MI	21.9%	13.5	24.0%	-2.1%
Fort Worth, TX	-2.4%	33.9	-2.1%	-0.3%
Fresno, CA	-3.7%	40	-9.9%	6.1%
Houston, TX	0.5%	40.8	-10.9%	11.4%
Las Vegas, NV	-10.1%	41	-11.1%	1.0%
Los Angeles, CA	-35.9%	52.7	-26.1%	-9.8%
Miami, FL	-34.7%	59.2	-34.4%	-0.4%
Minneapolis, MN	36.0%	0.3	40.8%	-4.8%
New York, NY	11.4%	20.9	14.5%	-3.1%
Phoenix AZ	-18.0%	48.5	-20.7%	2.7%
San Francisco, CA	-24.8%	45	-16.2%	-8.5%
Seattle, WA	-2.4%	34.8	-3.2%	0.9%
St. Louis, MO	23.2%	15.6	21.3%	1.9%

In the paper, a strong correlation was found between the ASHRAE 99% design heating temperature for the location and the amount of performance degradation. The form of the model from the paper was:

$$\%deg = a + b * Temp + c * Temp^2 + d * HSPF$$

The data included results for different types of heat pumps with different nominal HSPF values. The correlation for HSPF values of less than 8.5 had an R-square value of 0.965. The closer the R-square value to 1.0 the better the model fits the data. For the 52667 spreadsheet, only a single value of HSPF was going to be needed so the portion of the model based on HSPF was not included. Instead the values for an HSPF of 6.8 were used since they were closest to 6.7, the default value in the spreadsheet. The HSPF of 6.7 is based on the 2rw+di report examining the median efficiency of heat pumps shipped throughout the U.S. from 1982 to 1990.

1.3 Update the Climate Data

ASHRAE publishes the 99% heating design day temperatures for many cities but unfortunately, they do not include all of the locations present in the zipCodeToDegreeDay.xls spreadsheet used to provide the location specific climate data for the 52667 spreadsheet. Instead the "U.S. Monthly Climate Normals – CLIM81" product from the National Oceanic and Atmospheric Administration was used which is the same source of data used for the degree day data already present in the zipCodeToDegreeDay.xls spreadsheet. Several different types of data were examined from the Climate Normals files and compared to see which showed the strongest correlation.

Table 2 – Models Using Data from U.S. Monthly Climate Normals

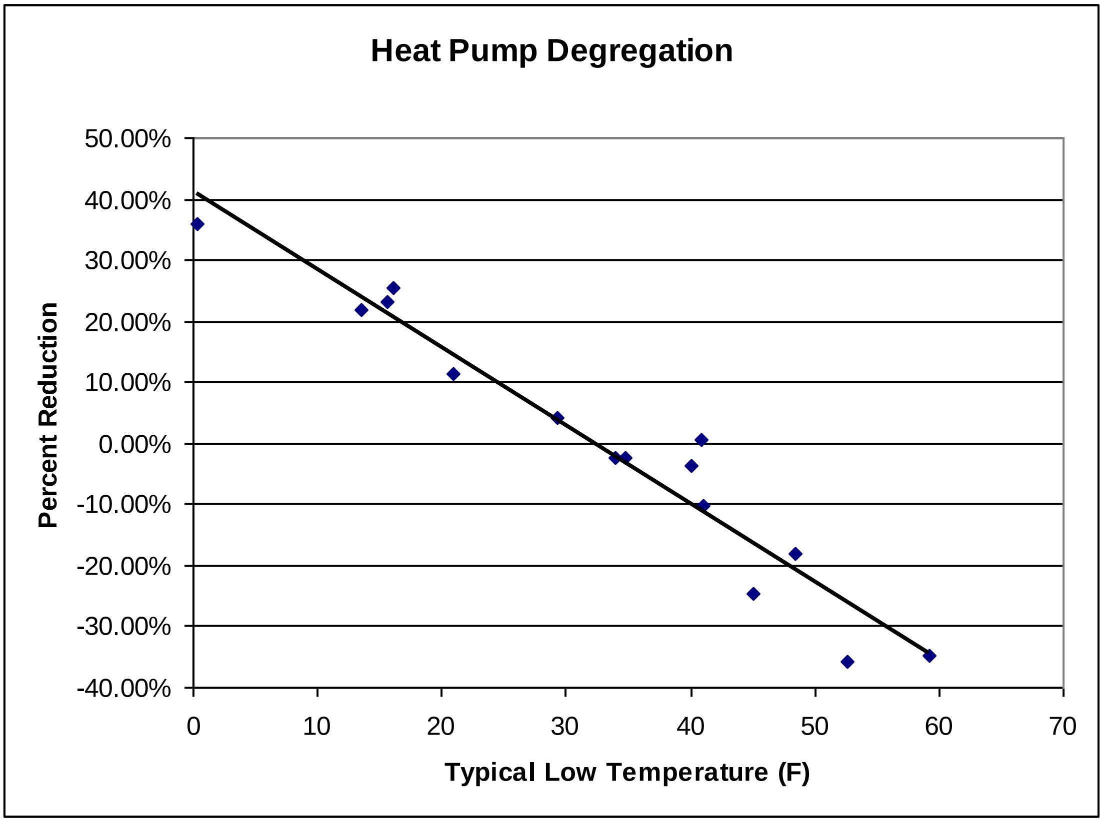
Measure	R-square
HDD	0.74
Lowest Monthly Temperature	0.91
Lowest Mean Temperature Monthly – linear	0.94
Lowest Mean Temperature Monthly – quadratic	0.95

While the quadratic form using the Lowest Mean Temperature Monthly was slightly better than the linear form, the linear form was chosen since the increase in the models fit did not justify the added complexity of a quadratic model. The form of the model was then:

%deg = a + b * Temp

where Temp was the value from the U.S. Monthly Climate Normals. The HUD52667Model spreadsheet uses the term "Typical Low Temperature" instead of Lowest Mean Temperature Monthly since it is a simpler description.

Figure 1 – Model for Heat Pump Heating Degradation



The coefficients are shown below:

%deg = 0.412069 - 0.012766 * Temp

This model was used in the 52667 spreadsheet to adjust the performance for heat pumps in different climates. The results of using this model compared to the actual data is shown in Table 1. The zipCodeToDegreeDay.xls spreadsheet was updated to include the temperature data from U.S. Monthly Climate Normals and labeled as Typical Low Temperature. The new spreadsheet is called zipCodeToDegreeDay-Ver02.xls.

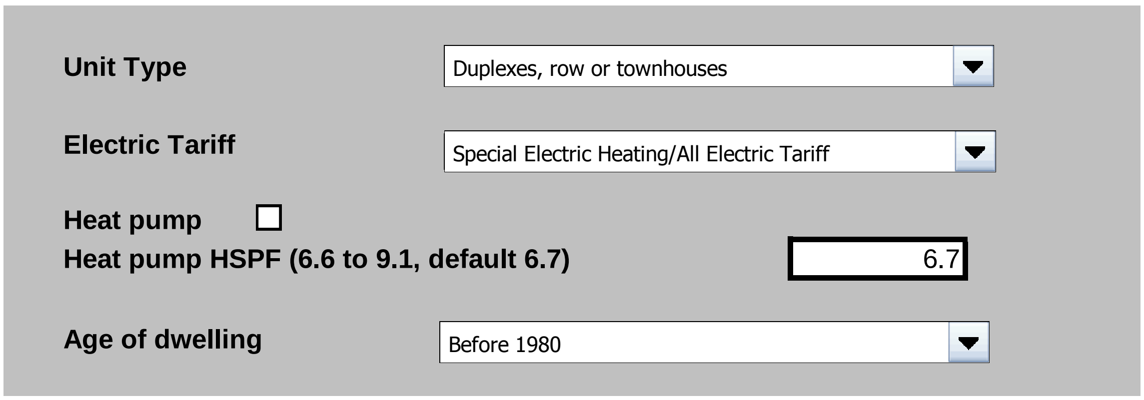
1.4 Updating the Spreadsheet

Prior to including the new heat pump degradation model in the spreadsheet, the age of dwelling and heat pump portions of the spreadsheet model were updated (HUD52667Model-Ver07.xls) to be more consistent with the rest of the spreadsheet organization. The original spreadsheet received from HUD (HUD_Utilitymodel_R.xls) included formulas in the "Derived Consumption Equation Section" which was intended to include only constants derived by analysis. These formulas were eliminated and replaced with constants. The adjustments represented by the replaced formulas were included in the "Coefficient Adjustments" section.

The updated spreadsheet was tested against the original spreadsheet received from HUD (HUD_Utilitymodel_R.xls) to ensure that the calculations were consistent. For the Atlanta (Hartfield) location, 24 combinations of age of dwelling, heat pump or no heat pump, and unit type were compared and no differences were found. The unit types tested were detached, townhouse, apartment, and manufactured. The age of units tested included before 1980, 1980 to 1996, and 1996 or newer. No differences were found in these comparisons.

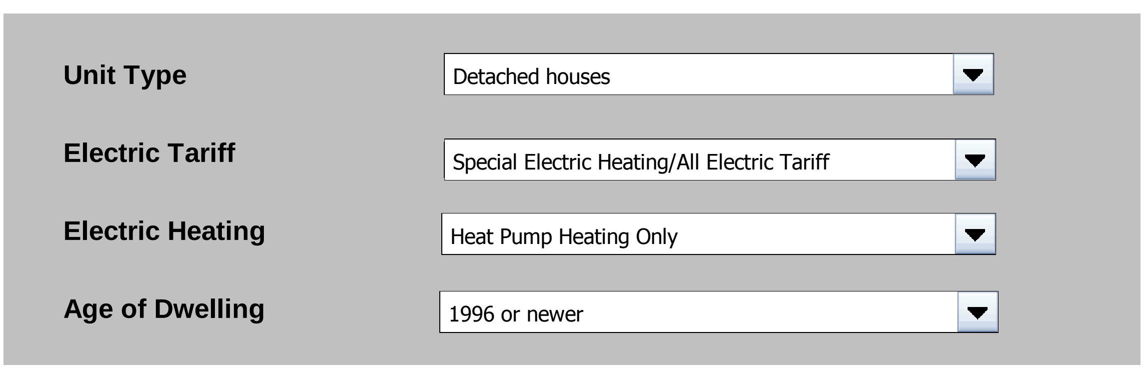
As part of this initial structural update of the spreadsheet, the input fields for each 52667 tab in the spreadsheet were revised. The original version showed the heat pump HSPF as an entry field and a checkbox for the use of a heat pump. The age of dwelling choices did not include all years. This version is shown in the Figure 2 below.

Figure 2 – Original User Controls for HUD_Utilitymodel_R.xls



One problem with these controls is the entry for the heat pump HSPF. The value is intended to represent the average efficiency for heat pumps. It may be unrealistic for any public housing authority to know the average heat pump heating efficiency for their jurisdiction without a detailed survey. So the input was removed and put into the calculation section of the spreadsheet. An advanced user could still change the value but the typical user no longer needs to worry about supplying this value. In addition, an option was added in the age of dwellings to "Mixed Ages" and the heat pump option was changed to electric heating options for either heat pumps or mixed heat pumps and electric resistance heating. These two new options represent no adjustment so multipliers of 1.0 were used. When heat pumps are used, the adjustment described in Sections 1.1 and 1.2 is used. For ages of the dwelling other than "Mixed Ages," adjustment multipliers of 1.43 were used for before 1980, 1.0 was used for 1980 to 1996, and 0.78 was used for 1996 or newer. These adjustment multipliers are applied to heating and cooling energy use and represent changes in insulation, glazing, and building sealing that occurred since the oil embargo. The revised input structure is shown in Figure 3.

Figure 3 – Updated Users Controls for HUD52667Model-Ver07.xls



Next, the heat pump climate adjustment correlation was included in the spreadsheet (HUD52667Model-Ver08.xls). The new section on heat pump was expanded to include the calculation of the heating degradation and the total heat pump efficiency as shown in Figure 4.

Figure 4 – Heat Pump Adjustment Calculations with Degradation

Heat Pump Adjustment		
Heat pump HSPF (6.6 to 9.1, default 6.7)	Btu/W	6.7
Typical Low Temp	deg F	59.2
Coefficients for Model of Heat Pump Degradation		
Constant		0.412069
Coefficients for Typical Low Temp		-0.012766
Calculated Degradation		-0.34370732
Adjusted Heat Pump HSPF with Degradation	Btu/W	9.002839013
Mixed Electric Resistance and Heat Pump Heating		1
Heat Pump Heating Only		0.37899156
Selected (in use)		0.37899156

In addition, a small correction was made to the spreadsheet model related to the air conditioning energy consumption. A previous update included coefficients for air conditioning energy consumption that could result in negative energy consumption for some single-family homes with zero bedrooms (not a very likely combination). Since negative energy consumption is not possible, the function was modified so the value could not be smaller than zero.

1.5 Testing the Added Heat Pump Degradation Formula

The testing was repeated, this time with two different climates to check how the degradation of heat pump performance was working. The original spreadsheet (HUD_Utilitymodel_R.xls) was linked to one of the 52667 tabs in the revised spreadsheet so that the differences were reported. The sections compared were the annual portion of the Annual and Monthly Consumptions section for both the original and updated spreadsheet. An example of the values reported for the section compared is shown in Figure 5.

Figure 5 – Section Compared

Annual and Monthly Consumptions

Electric Use	Units	Studio Annual	1 Bedrm Annual	2 Bedrm Annual	3 Bedrm Annual	4 Bedrm Annual	5 Bedrm Annual
Other Electric	kWh	2642	3871	5099	6777	8006	9234
Other Electric + Cooking	kWh	3298	4780	6262	8195	9677	11159
Other Electric + Cooking + Water Heating	kWh	4382	6470	8557	11094	13182	15269
Other Electric + Cooking + Water Heating + Heating	kWh	4411	6510	8610	11159	13259	15358
Other Electric + Cooking + Water Heating + Heating + Air Conditioning	kWh	5014	8655	12295	16386	20027	23667
Natural Gas Use							
Cooking	Therms	45	62	79	97	114	131
Cooking + Water Heating	Therms	112	167	222	277	332	386
Cooking + Water Heating + Space Heating	Therms	118	176	235	293	351	409
Liquified Petroleum Gas Use							
Cooking	lbs	206	286	366	446	526	606
Cooking + Water Heating	lbs	517	770	1024	1277	1530	1784
Cooking + Water Heating + Space Heating	lbs	545	814	1082	1351	1620	1888
Fuel Oil Use							
Water Heating	gal	53	82	112	141	171	200
Water Heating + Space Heating	gal	58	89	121	152	184	215
Water	Cubic Feet	5775	8342	10908	13475	16042	18608
Sewer	Cubic Feet	5775	8342	10908	13475	16042	18608

The values of this section were compared for two climates, four unit types, three building ages, and with and without heat pumps. For each of these 24 cases, 90 different numbers were compared. The results of the testing showed no differences for all values except for those that included electric heating. The two climates chosen were Detroit, Michigan (Detroit Metro area) and Miami, Florida (Miami International Airport). The expected degradation for Detroit was 24% and that was the same change found during testing. The Miami degradation was -34% (actually an increase in performance) and that also was the same change found during testing.

2. Apply New Heating Degree-Day Algorithm

2.1 Overview

The formulas used for computing the heating energy consumption were replaced in the HUD 52667 spreadsheet. The formulas for natural gas, electricity and fuel oil heating consumption used in the original and updated spreadsheet were based on heating degree-days (HDD) and number of bedrooms. Each category of housing had a separate formula for heating energy consumption. Similar to cooling energy, the formula was in the form of:

heating consumption = c1 x HDD + c2 x BED x HDD

where c1 and c2 were constants derived by multiple linear regression of the appropriate subset of RECS data and BED is the number of bedrooms. During an earlier update, it was noticed that the heating energy consumption did not increase linearly with heating degree-days but increased less at higher heating degree-day values. This may be caused in part by the increased use of energy conserving measures in residential building design in colder climates due to both common practice and energy code requirements.

Several different models were fitted to the data looking for a model with the best fit possible and a combination of the best models was chosen. The new model and coefficients based on RECS data were incorporated into the spreadsheet and tested.

2.2 Choosing the Model

The spreadsheet named heatingRegressionRevised.xls contains the derivation, selection and testing of the new heating energy formulas found in the HUD 52667 spreadsheet.

The Energy Information Administration of the U.S. Department of Energy performs a survey every few year titled Residential Energy Consumption Survey (RECS). The detailed results of the survey from 2001 are available on the website:

http://www.eia.doe.gov/

Or more specifically at:

http://www.eia.doe.gov/emeu/recs/recs2001/publicuse2001.html

Three of the files were used and certain fields were extracted from each:

File 1 – Section A: Housing Unit Characteristics

HDD65- Heating Degree-Days to base 65, 1-04 TO 12-04

TYPEHUQ - Type of Home: as report by Respondent (Mobile Home, Single-Family detached, Single-Family Attached, Apartment in Building containing 2-4 units, Apartment in Building Containing 5 or more units)

BEDROOMS - Number of bedrooms

File 4 – Section D: Space heating

FUELHEAT - Main fuel used for heating home

File 11 – Energy Consumption

BTUELSPH - Electric Space Heat Use (Estimated)

BTUNGSPH- Natural Gas Space Heat Use (Estimated)

BTUFOSPH - Fuel Oil Space Heat Use (Estimated)

The existing HUD 52667 spreadsheet included formulas for heating energy consumption in form of

$$E = c1 \times HDD + c2 \times BED \times HDD$$

where E is the heating energy consumption, HDD is heating degree days, BED is the number of bedrooms and c1 and c2 were coefficients based on linear regression of the RECS data, see Table 3. This original model is referred to as M0.

Table 3 – Existing Coefficients for Heating Energy Consumption

Utility or Service	Housing	Units	C1 Coeff for HDD	C2 Coeff for HDD*BED
Heating with Natural Gas	Mobile	kBtu/yr	8.3980	0.4488
Heating with Natural Gas	SF Det	kBtu/yr	5.2061	2.8699
Heating with Natural Gas	SF Att	kBtu/yr	5.4043	2.4475
Heating with Natural Gas	Apt 2-4	kBtu/yr	5.8488	3.1626
Heating with Natural Gas	Apt 5+	kBtu/yr	3.7176	0.5954
Heating with Electricity	Mobile	kBtu/yr	3.8723	0.1746
Heating with Electricity	SF Det	kBtu/yr	2.2044	0.9426

Heating with Electricity	SF Att	kBtu/yr	1.6030	0.8226
Heating with Electricity	Apt 2-4	kBtu/yr	1.6186	0.5653
Heating with Electricity	Apt 5+	kBtu/yr	1.1652	0.6768
Heating with Fuel Oil	Mobile	kBtu/yr	8.4437	0.0000
Heating with Fuel Oil	SF Det	kBtu/yr	5.6093	2.4951
Heating with Fuel Oil	SF Att	kBtu/yr	3.2605	3.3847
Heating with Fuel Oil	Apt 2-4	kBtu/yr	5.3947	3.8621
Heating with Fuel Oil	Apt 5+	kBtu/yr	2.8670	1.5561

To capture the shape of the data better, six different alternative models were tried and called M1 to M6:

M1: E = c1 x HDD + c2 x BED x HDD + c3 x HDD^2 + c4

M2: E = c1 x HDD + c2 x BED x HDD + c3 x BED x HDD^2 + c4

M3: E = c1 x HDD + c2 x BED x HDD + c3 x BED^2 x HDD^2 + c4

M4: E = c1 x HDD + c2 x BED x HDD + c3 (two steps using 4000 HDD breakpoint)

M5: E = c1 x HDD + c2 x BED x HDD + c3 x LOG(HDD) + c4

M6: E = c1 x HDD + c2 x BED x HDD + c3

Since heating with electricity and natural gas are the primary methods of heating homes in the U.S., those energy sources were used from the RECS data to choose from these six models. The original model, M0 is also shown for reference. The following table shows the R-Square values for each model. The R-Square reflects how well the regression equation fits the data with zero indicating a very poor fit and one being a perfect fit. All regressions were performed using Microsoft Excel 2003 using the Analysis Toolpak regression function.

Table 4 – R-Square Values for the Models

Heating Source	Building	M0	M1	M2	M3	M4	M5	M6
Natural Gas	Mobile	0.454	0.480	0.480	0.490	0.318	0.474	0.468
Natural Gas	SF Det	0.373	0.405	0.403	0.397	0.253	0.407	0.397
Natural Gas	SF Att	0.243	0.384	0.367	0.304	0.261	0.370	0.285
Natural Gas	Apt 2-4	0.345	0.377	0.367	0.348	0.288	0.366	0.348
Natural Gas	Apt 5+	0.329	0.335	0.331	0.345	0.154	0.331	0.329
Electricity	Mobile	0.617	0.625	0.627	0.631	0.337	0.623	0.622
Electricity	SF Det	0.588	0.595	0.595	0.592	0.389	0.592	0.592
Electricity	SF Att	0.386	0.483	0.467	0.431	0.313	0.434	0.413
Electricity	Apt 2-4	0.418	0.506	0.500	0.539	0.325	0.463	0.448
Electricity	Apt 5+	0.434	0.482	0.487	0.470	0.332	0.468	0.460

Many of the new models offered better R-square values compared to the original (M0) model but the improvements are relatively small. This indicates that much of the variation in the energy consumption cannot be explained by only heating degree day and number of bedrooms. Other variables from the RECS database that were not included may have a significant affect along with the random variation one would expect with any survey.

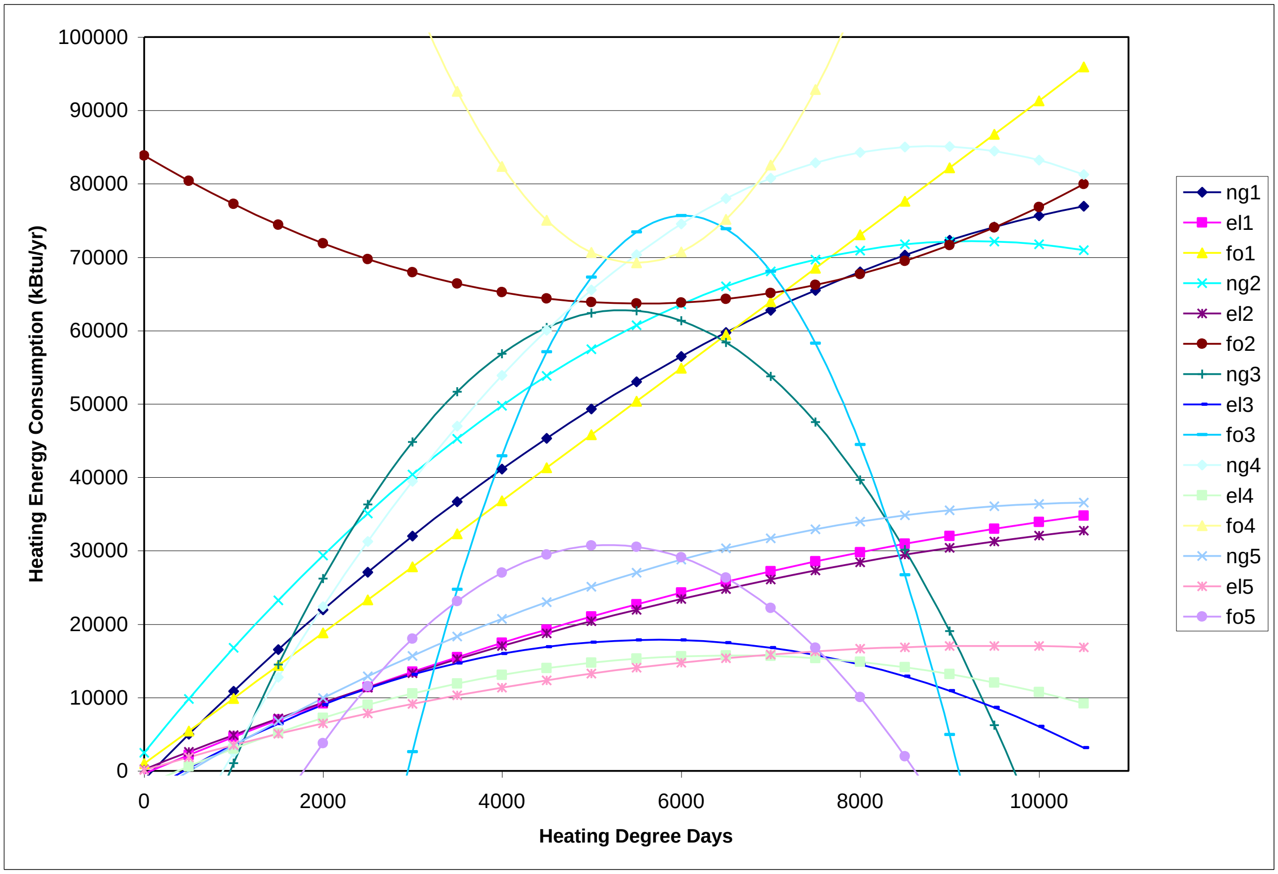
For M4, the average value of the R-square for two regressions was used since that model consisted of linear models above and below 4000 HDD. The M4 model did not predict the heating energy well even though it was the original form of the model suggested by looking at the data. The reason is that by dividing the data into two groups, above and below 4000 HDD, the data for each regression was "rounder" than the combined data set.

The M1 model had the most R-square values that were either the highest or second highest. After that M2, M3, and M5 were selected less often, in that order.

The next step was to examine the actual formulas graphically. The following figure shows an example of the M1 model for each of the fifteen combinations of type of home and energy source used for heating. While most climates in the United States are under 10,000 HDD, annually, Alaska ranges from 10,000 HDD in the more populated areas to almost 20,000 in Barrow on the Artic Ocean. According to the 2001 Residential Energy Consumption Survey by the U.S. Department of Energy, approximately 10% of the residential energy use for the United States is for home located above 7000 annual HDD.

The specific curves are not as important as the fact that some of the resulting models are not shaped in a sensible way. From an engineering perspective, as the number of heating degree days increase the heating energy consumption should also increase though not always at the same rate. Some of the formulas resulted in curves that decreased at either low values or at higher values of heating degree days. This test was repeated for 0, 1, 2, 3, and 4 bedrooms. If the resulting formula did not make engineering sense for all of these cases, it was eliminated. Unfortunately, for the M1 model, this eliminated 10 of the 15 combinations. M2, M5 and M6 were also tested with only M6 having reasonable, although linear, formulas for almost all cases.

Figure 6 – Model M1 Formulas for 2 Bedrooms



Given that no single model had good formulas for each of the fifteen combinations of type of home and energy source used for heating, a combination approach was used instead. If the M1 model had a good form it was used. If M1 did not have a good form but M2 did, it was used instead. Finally, if neither M1 nor M2 had a good form, M6 was used instead. In two cases, this was still not sufficient. For the case of fuel oil in single-family detached homes and for the case of fuel oil in apartment buildings with five or more units, the natural gas formula was used instead. These cases did not have as many data records and perhaps cannot be characterized well by heating degree-days and number of bedroom, no matter how they are combined. The following table shows the model chosen for each case:

Table 5 – Model Chosen

Utility or Service	Housing type	Model Chosen
Heating with Natural Gas	Mobile	M1
Heating with Electricity	Mobile	M1
Heating with Fuel Oil	Mobile	M1
Heating with Natural Gas	SF Det	M2
Heating with Electricity	SF Det	M1
Heating with Fuel Oil	SF Det	M2 (Natural Gas)
Heating with Natural Gas	SF Att	M6
Heating with Electricity	SF Att	M6
Heating with Fuel Oil	SF Att	M6
Heating with Natural Gas	Apt 2-4	M2
Heating with Electricity	Apt 2-4	M6
Heating with Fuel Oil	Apt 2-4	M6
Heating with Natural Gas	Apt 5+	M1
Heating with Electricity	Apt 5+	M6
Heating with Fuel Oil	Apt 5+	M1 (Natural Gas)

The actual coefficients used are shown in the following table:

Table 6 – Coefficients for Heating Energy Consumption

Heating Service	Housing	Constant	Coeff for HDD	Coeff for HDD*Bedrooms	Coeff for HDD squared	Coeff for Bedrooms * HDD^2
Gas	Mobile	-1144.7255	11.75380	0.373003	-0.000481998	0.000000000
Gas	SF Det	5564.4850	3.87028	4.074306	0.000000000	-0.000193070
Gas	SF Att	20276.4148	1.55103	2.477753	0.000000000	0.000000000
Gas	Apt 2-4	-9535.5193	7.47292	5.667555	0.000000000	-0.000406474
Gas	Apt 5+	-3706.9764	6.36576	0.575422	-0.000350855	0.000000000
Electricity	Mobile	-360.3958	4.91118	0.106173	-0.000169548	0.000000000
Electricity	SF Det	160.5446	3.05608	0.925467	-0.000171961	0.000000000
Electricity	SF Att	3429.3215	0.95110	0.787405	0.000000000	0.000000000
Electricity	Apt 2-4	2344.2830	1.14258	0.551677	0.000000000	0.000000000
Electricity	Apt 5+	2071.9133	0.74502	0.676854	0.000000000	0.000000000
Fuel Oil	Mobile	960.7713	11.06409	-1.077004	0.000012628	0.000000000
Fuel Oil	SF Det	5564.4850	3.87028	4.074306	0.000000000	-0.000193070
Fuel Oil	SF Att	2106.0179	2.97520	3.353263	0.000000000	0.000000000
Fuel Oil	Apt 2-4	27473.5657	1.15573	3.726906	0.000000000	0.000000000
Fuel Oil	Apt 5+	-3706.9764	6.36576	0.575422	-0.000350855	0.000000000

These values were placed into the HUD52667 spreadsheet and the heating equation formulas were modified to use the new coefficients in the calculation section titled “Consumption Table (kBtu per year)” located at K208 in the HUD 52667 spreadsheet model on the 52667 tabs.

2.3 Testing the Revised Formulas

To confirm that the formulas and coefficients were properly included in the HUD 52667 spreadsheet, two separate calculations were performed and compared. The heating energy use estimated using the HUD 52667 spreadsheet with the revised formulas was compared with the value from the existing formula. The percent difference using the HUD 52667 spreadsheet was compared with a separate calculation using the heatingRegressionRevised.xls spreadsheet. Zero, two and four bedroom values were compared for each type of housing, for each heating energy source, and for each of the cities shown in the following table.

Table 7 – Cities Tested

City	HDD
MIAMI INTL AP	149
HOUSTON BUSH INTL AP	1525
ATLANTA HARTSFIELD AP	2827
ST LOUIS INTL AP	4758
DENVER INTL AP (DATA FROM DNR)	6128
MINNEAPOLIS INTL AP	7876

These percent differences were compared side by side and an error in one of the formulas was discovered and corrected. The entire procedure was repeated and this time no error was found.

As part of this testing process, graphs of the heating energy consumption estimate as a function of heating degree days were developed. These graphs are the best way to illustrate the change of this revision. Note that the original formulas all resulted in zero heating energy consumption at zero heating degree days but the new formulas do not. This often results in a consumption increase at low heating degree day locations and a decrease at higher heating degree day locations. The following pages show these graphs.

Figure 7 – Natural Gas Heating Energy Consumption Changes for Mobile Homes

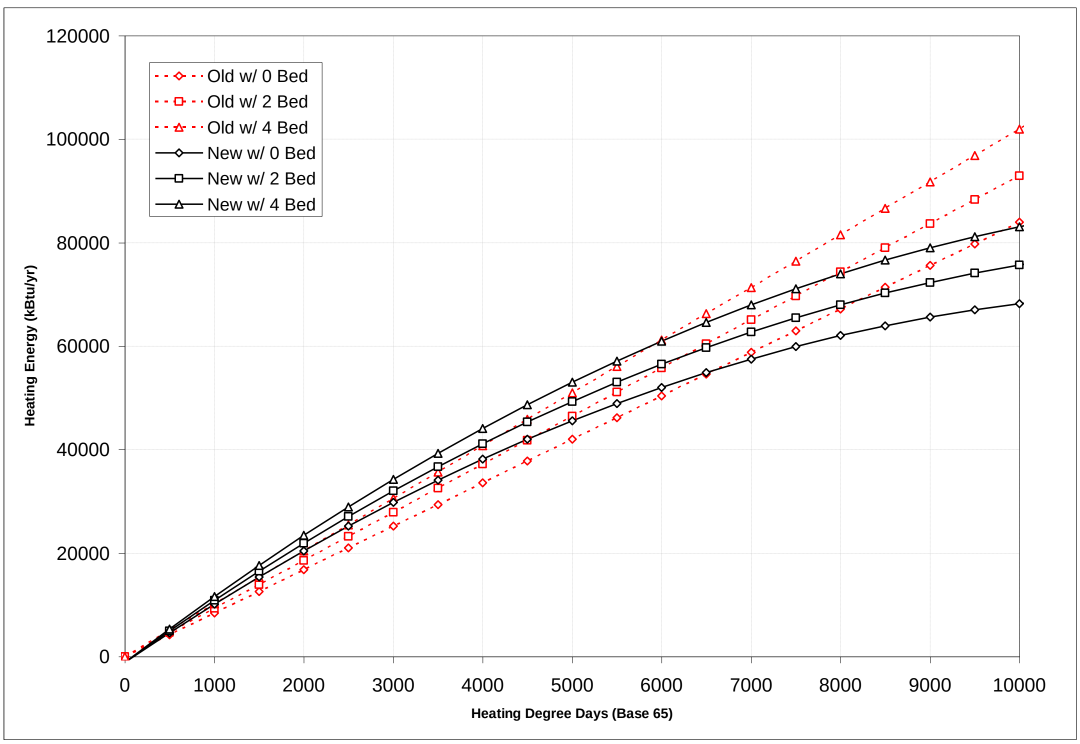


Figure 8 – Natural Gas Heating Energy Consumption Changes for Single-Family Detached

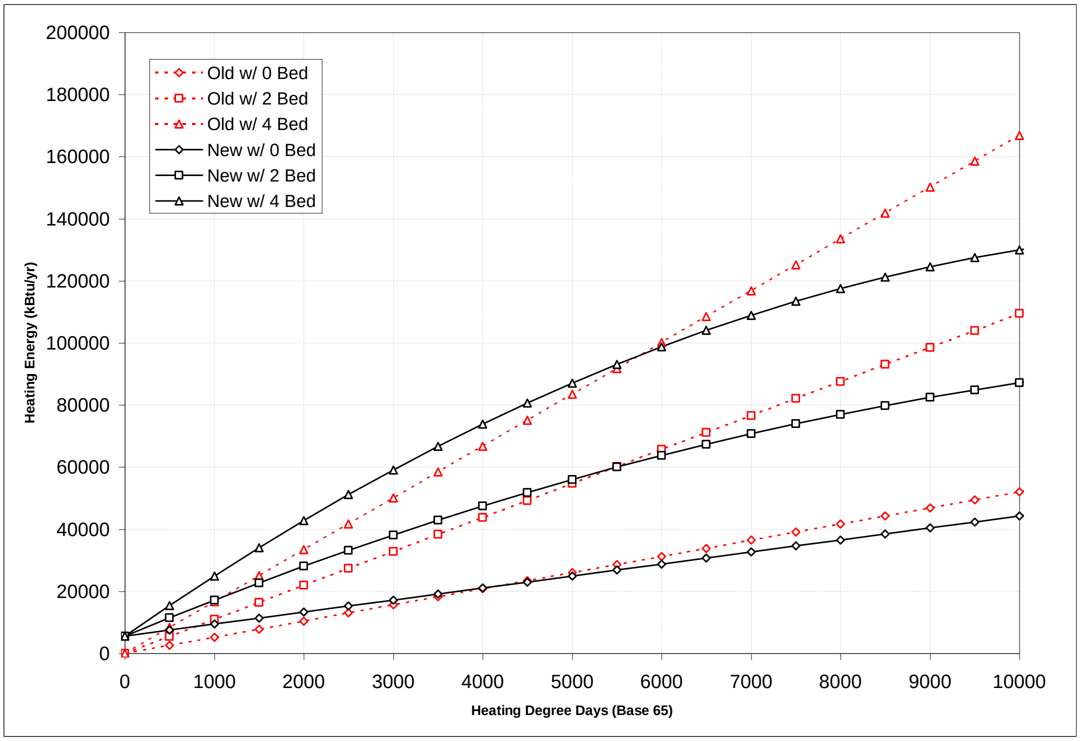


Figure 9 – Natural Gas Heating Energy Consumption Changes for Single-Family Attached

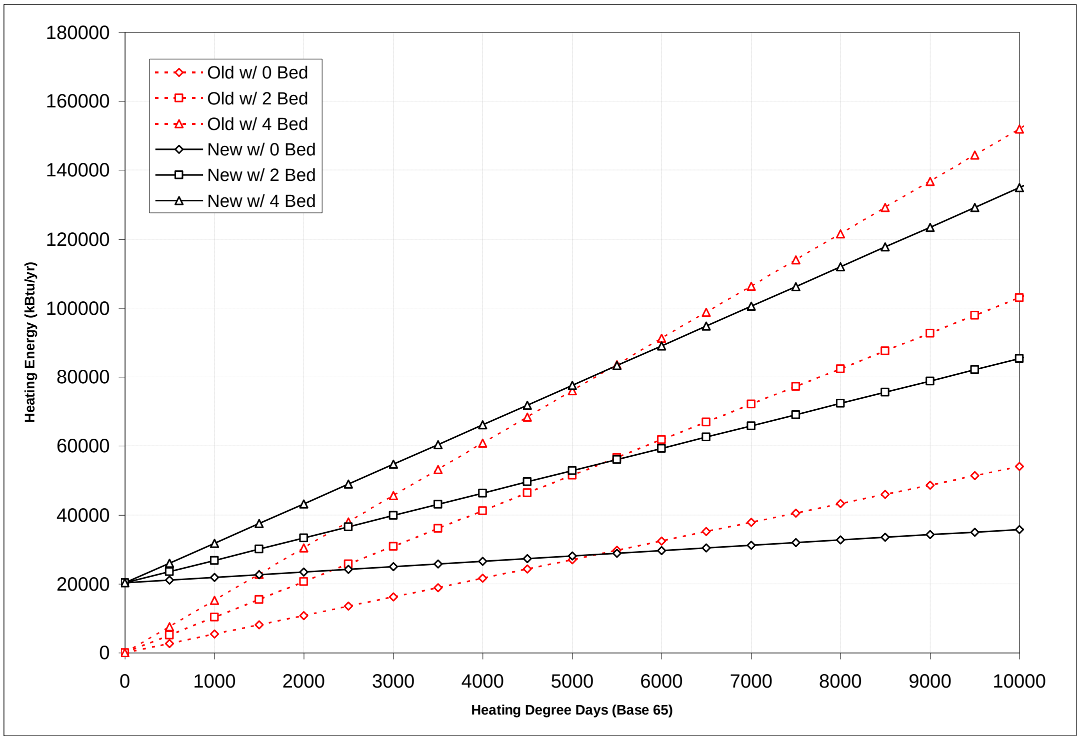


Figure 10 – Natural Gas Heating Energy Consumption Changes for Small Apartment Building

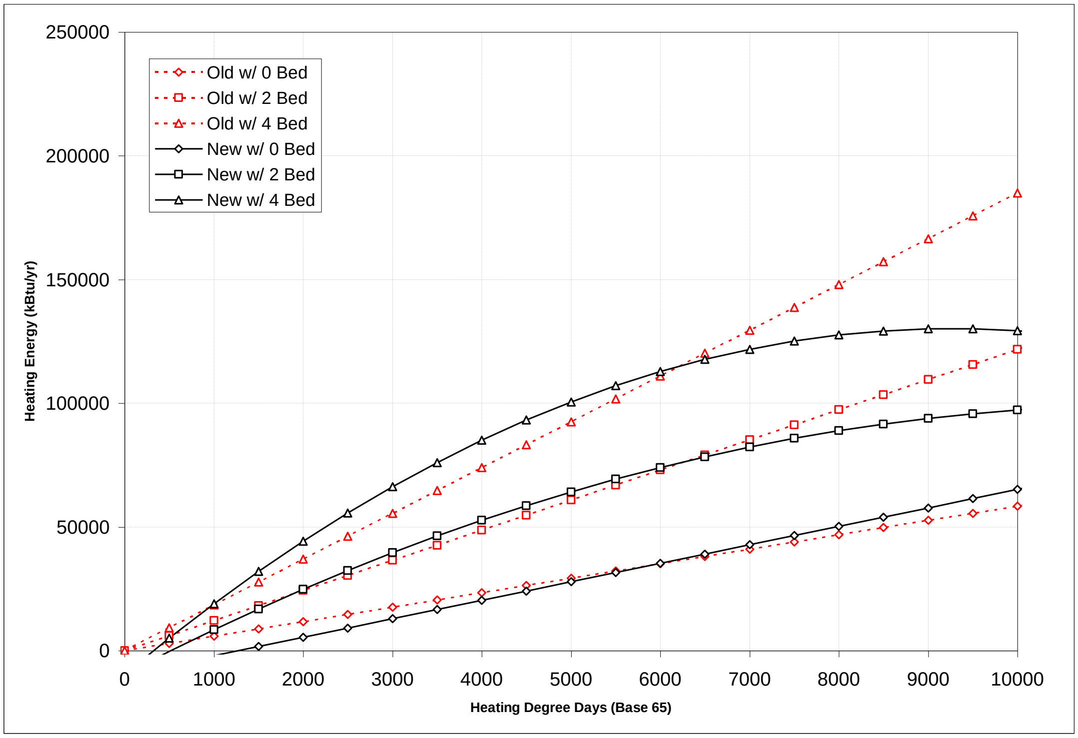


Figure 11 – Natural Gas Heating Energy Consumption Changes for Large Apartment Building

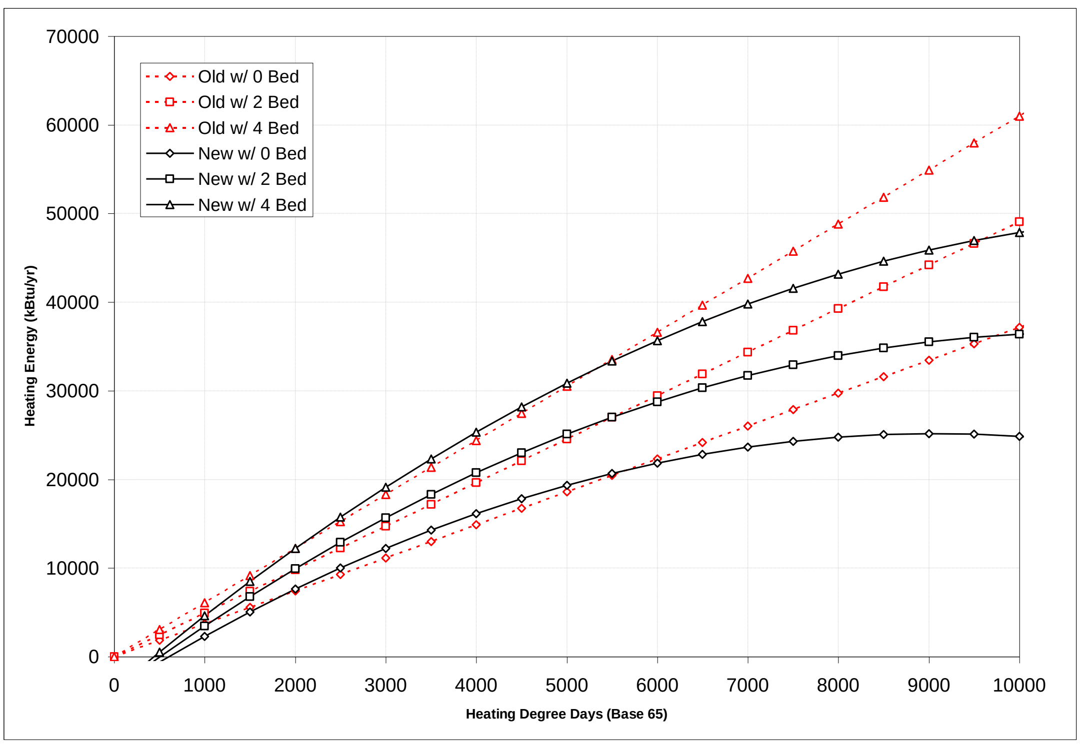


Figure 12 – Electric Heating Energy Consumption Changes for Mobile Homes

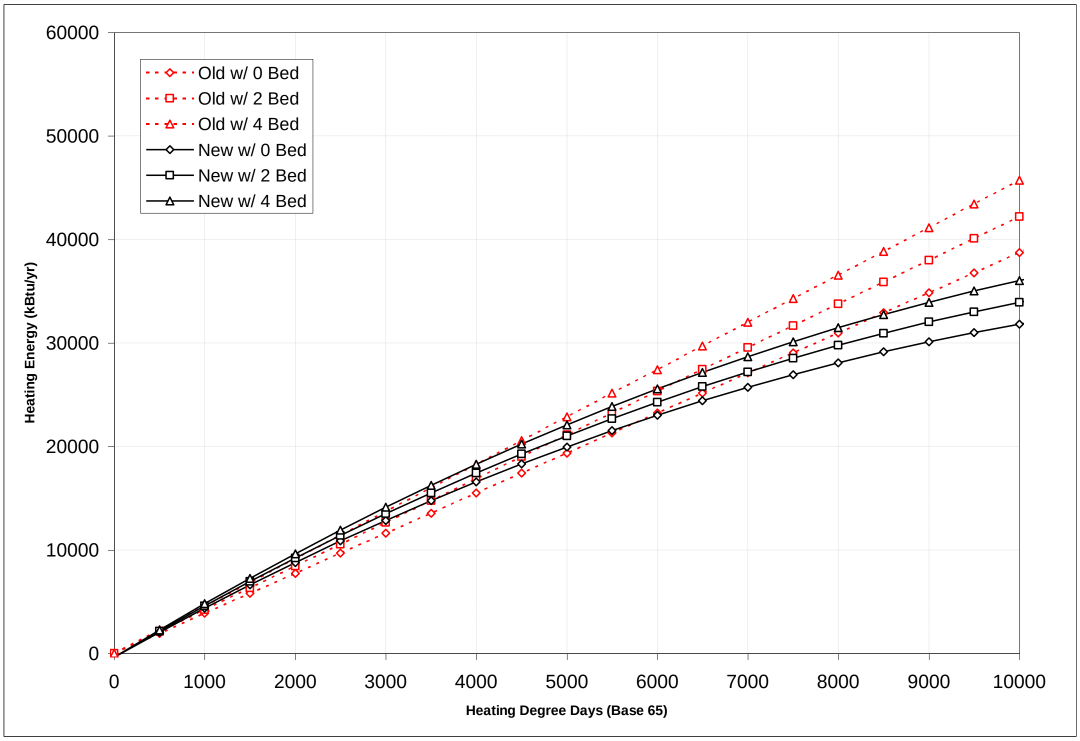


Figure 13 – Electric Heating Energy Consumption Changes for Single-Family Detached

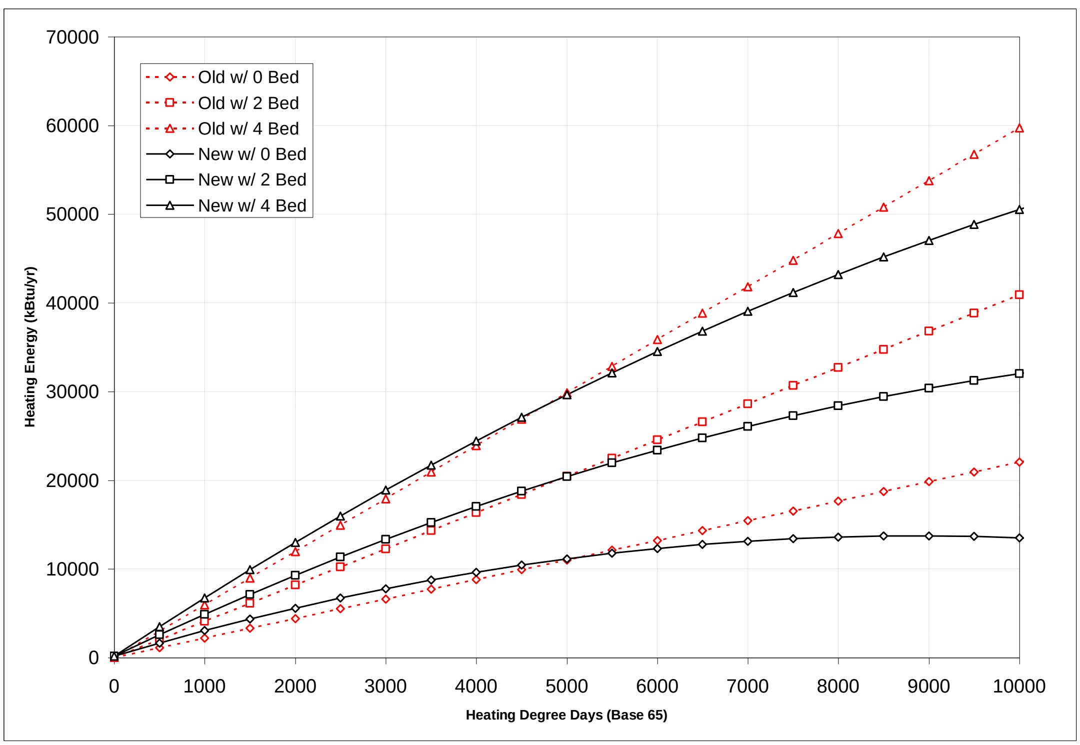


Figure 14 – Electric Heating Energy Consumption Changes for Single-Family Attached

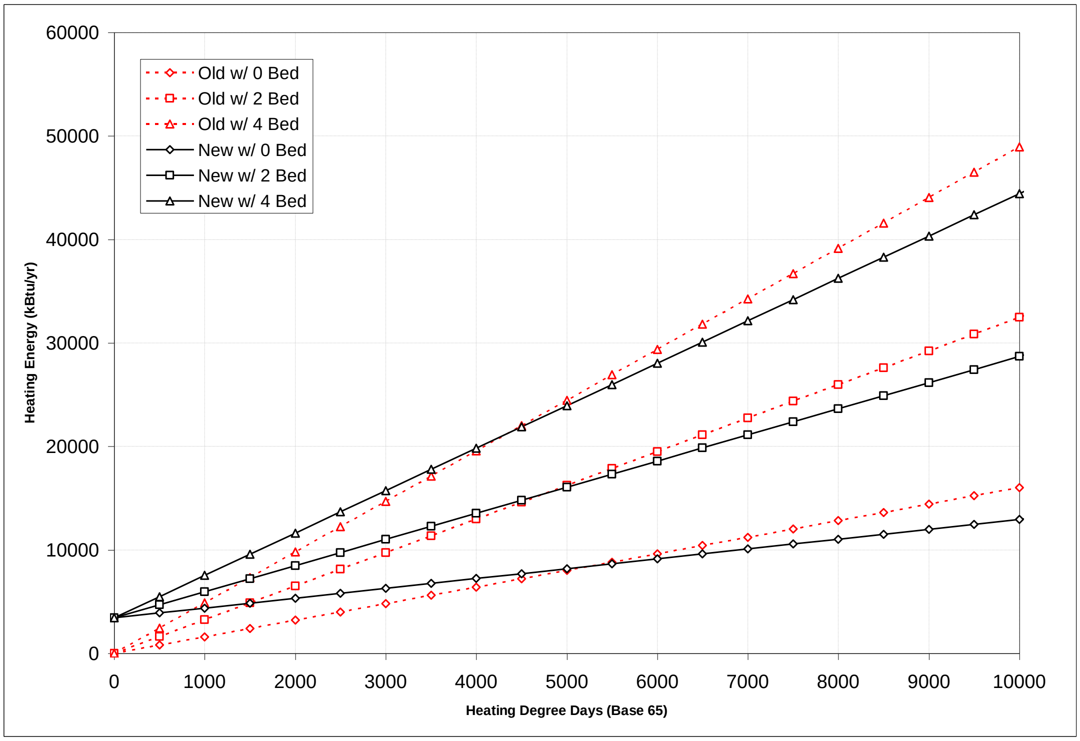


Figure 15 – Electric Heating Energy Consumption Changes for Small Apartment Building

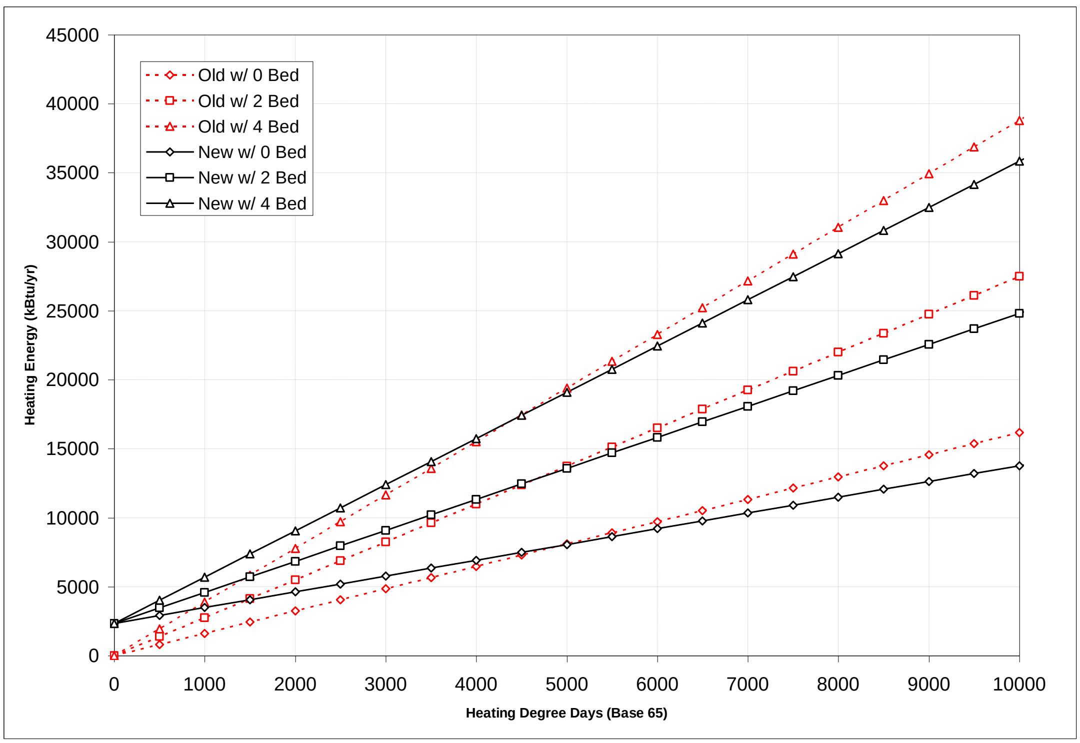


Figure 16 – Electric Heating Energy Consumption Changes for Large Apartment Building

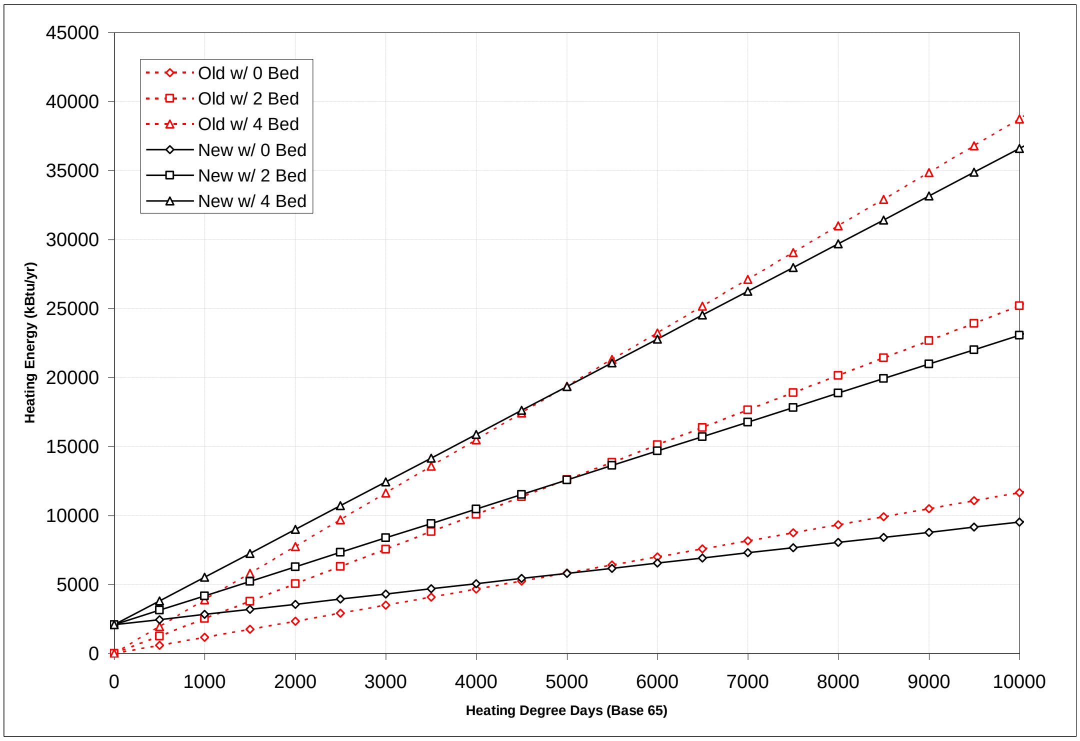


Figure 17 – Fuel Oil Heating Energy Consumption Changes for Mobile Homes

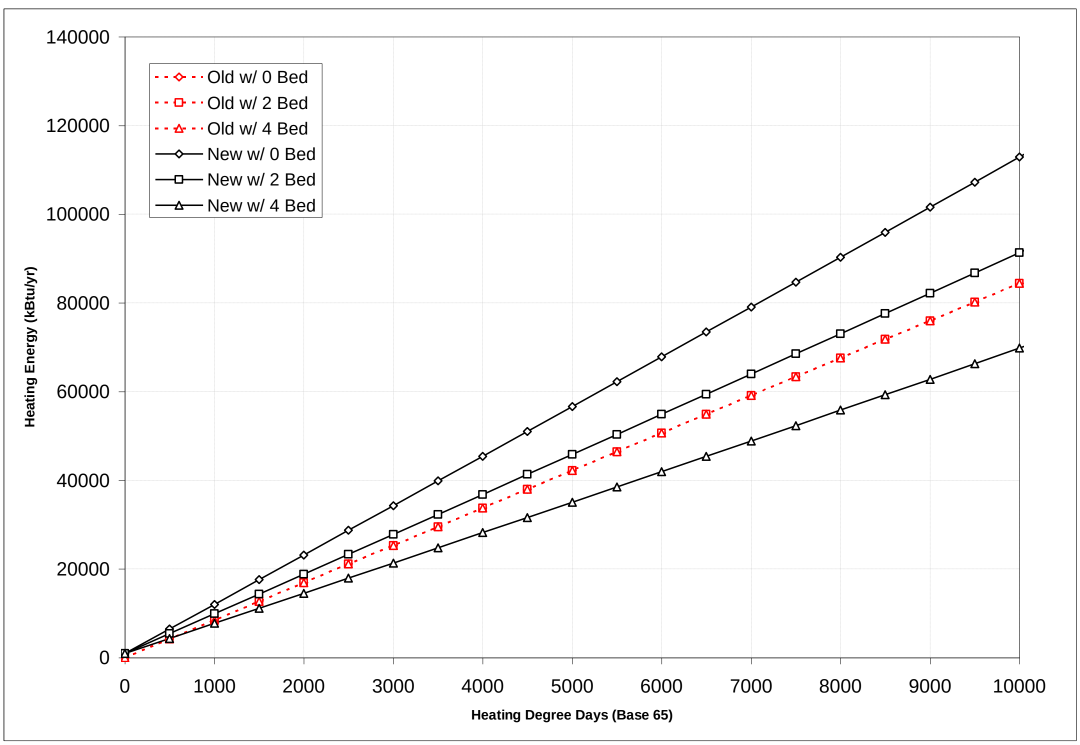


Figure 18 – Fuel Oil Heating Energy Consumption Changes for Single-Family Detached

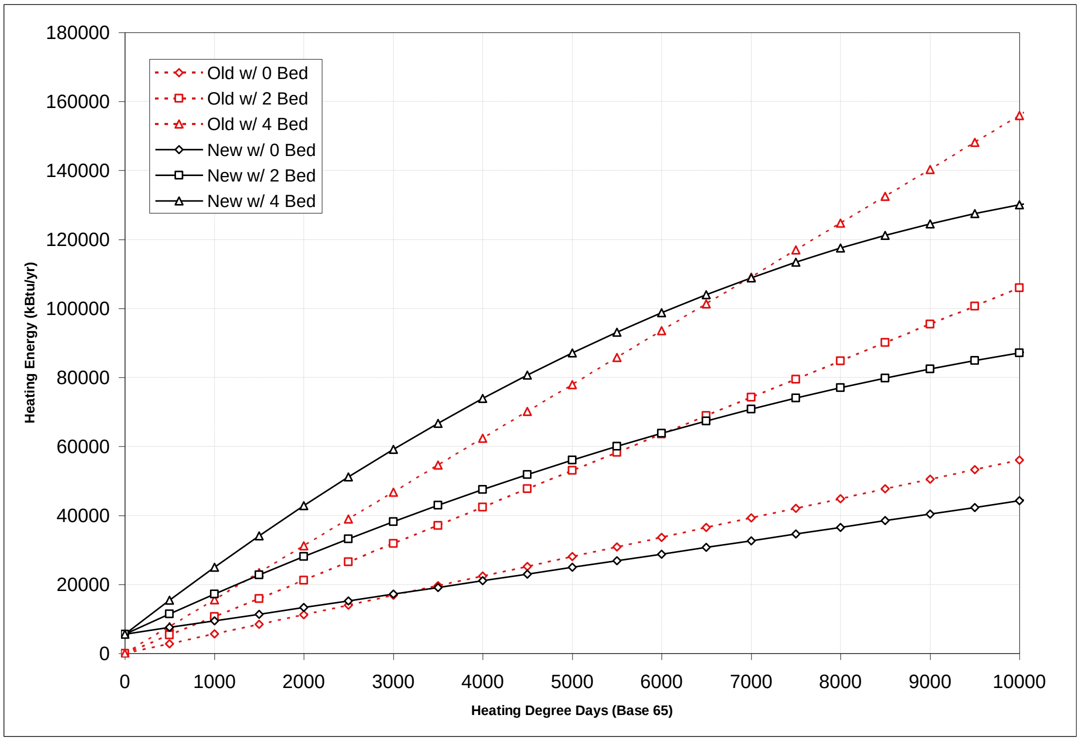


Figure 19 – Fuel Oil Heating Energy Consumption Changes for Single-Family Attached

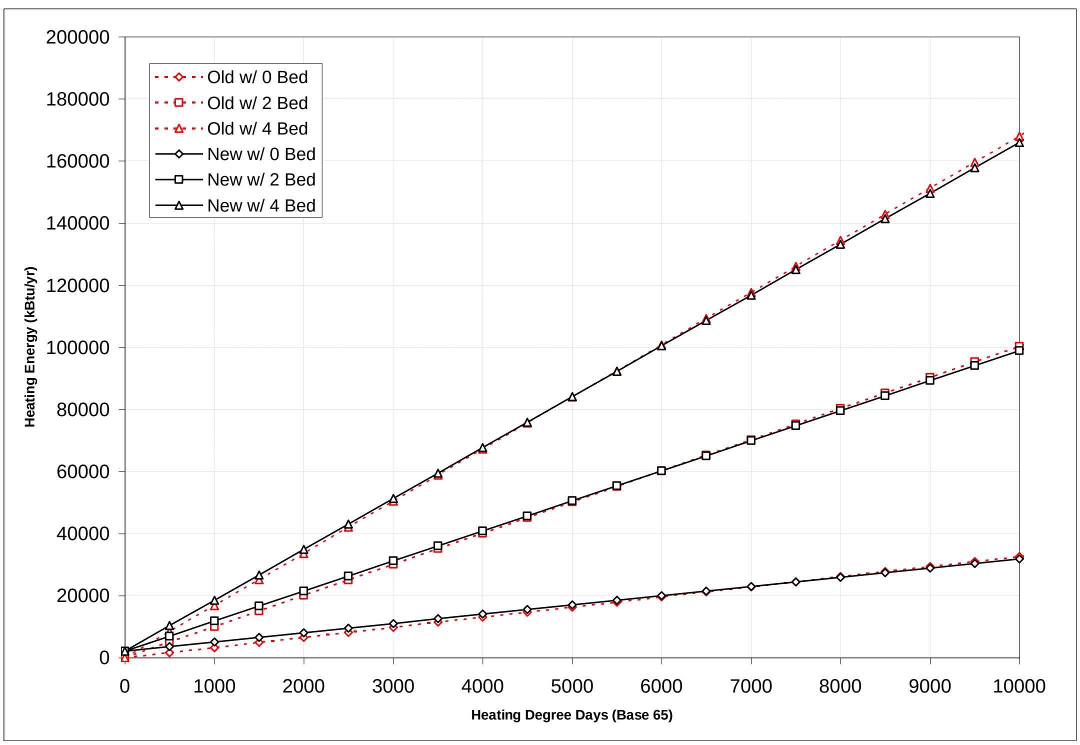


Figure 20 – Fuel Oil Heating Energy Consumption Changes for Small Apartment Building

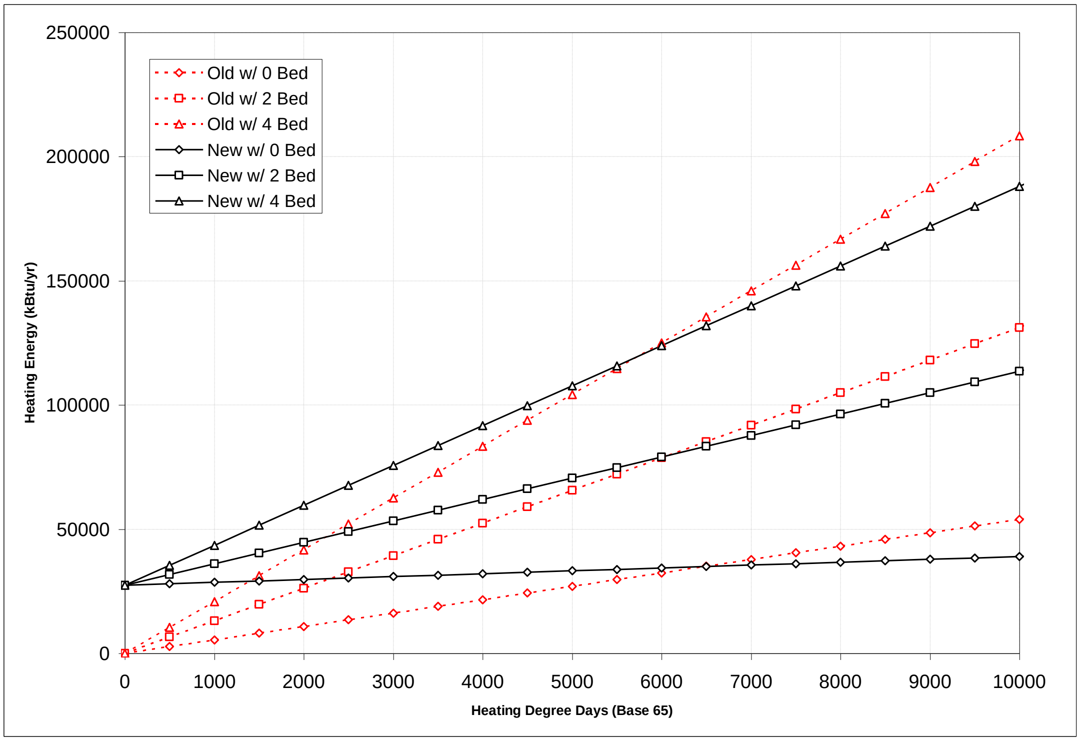
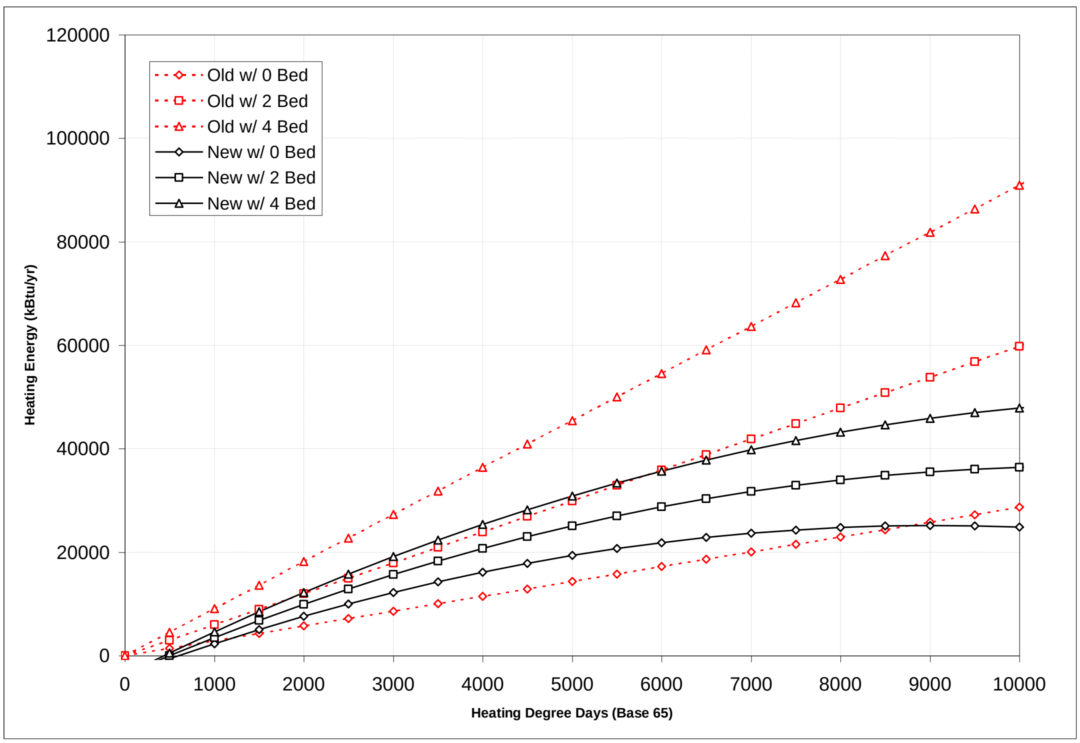


Figure 21 – Fuel Oil Heating Energy Consumption Changes for Large Apartment Building



3. Compare Allowances

3.1 Overview

The revised spreadsheet was used to compare allowances for each end-use with actual HUD-52667 sheets from various housing authorities. The housing authorities included the following cities:

- Buffalo, NY
- Charlotte, NC
- Las Vegas, NV
- Memphis, TN
- Minneapolis, MN
- Norfolk, VA
- Orlando, FL
- Palm Beach County, FL
- Phoenix, AZ
- Richmond, VA
- Riverside, CA
- Rochester, NY
- Salem, OR
- Scranton, PA
- St. Louis, MO
- Stockton, CA
- Tacoma, WA
- Tampa, FL

In both Phoenix and Salem, multiple electric utilities serve the area so two sets of utility allowances are used, one for each electric utility. The HUD-52667 forms, or equivalent, for each city were provided by HUD which show the dollar per month allowance for each end use by the number of bedrooms in the unit. Each type of housing unit is usually described on a separate form. The monetary allowances were converted into annual energy consumptions using average costs per kWh or therm. The estimated energy consumptions were then graphically compared to the results of the model.

3.2 Energy Estimates

HUD provided 49 sets of utility allowances from 18 different housing authorities and cities. Each set was for one or more specific types of housing units. Some housing authorities had allowances on HUD 52667 forms or ones that looked very similar. Other housing authorities included multiple sets of data on a single form or used a different layout for presenting the allowances. The energy-based allowances were entered into a spreadsheet in a standard format for conversion from dollars per month into energy consumption per year. The energy-based allowances included space heating, air conditioning, service water heating, cooking, and other electric used. Allowances change depending on the number of bedrooms. For most unit types, 0, 1, 2, 3, 4 and 5 bedroom allowances were shown. Some housing authorities had fewer options for the number of bedrooms and a few had more options. Allowances related to water, sewer, trash collection, or appliances were not included.

The electric and gas utilities were identified for each city as shown in Table 8. This was performed using Internet searches for city information, state public utility commissions, and utility web sites. Often the tariffs for the electric and gas utilities were available on the Internet and included a list of communities served. Maps provided by public utility commissions also helped identify the appropriate utility for a city. A few of the utilities were ultimately identified by calling city government offices. The tariffs for the utilities were not used directly. Tariffs are complicated and require significant interpretation and the level of accuracy gained by using actual tariffs was not consistent with other assumptions in the comparison. In addition, the utility allowances were not using the latest rates and utilities rarely post historical tariffs.

Table 8 – Electric and Gas Utilities

Location	*Electric Utility Name*	*Gas Utility*
Tampa FL	TECO Tampa Electric	TECO People Energy
Orlando FL	Progress energy	TECO People Energy
Palm Beach County FL	Florida Power and Light	Florida Public Utilities Company
Richmond VA	Dominion Virginia Power	Virginia natural gas
Norfolk VA	Dominion Virginia Power	Virginia natural gas
Charlotte NC	Duke Energy	Piedmont Natural Gas
Scranton PA	PPL	UGI Penn Natural Gas
Rochester NY	Rochester Gas & Electric Corp.	Rochester Gas & Electric Corp.
Buffalo NY	National Grid	National Fuel Gas Distribution Co.
Minneapolis MN	Xcel Energy	CenterPoint Energy/Minnegasco
Memphis TN	Memphis Light Gas and Water	Memphis Light Gas and Water
St. Louis MO	Ameren	LaClede Gas
Las Vegas NV	Nevada Power	Southwest Gas
Phoenix AZ - APS	Arizona Public Service	Southwest Gas
Phoenix AZ - SRP	Salt River Project	Southwest Gas
Riverside CA	Riverside Public Utilities	Southern California Gas
Salem OR – PGE	Portland General Electric	Northwest Natural Gas
Salem OR – SE	Salem Electric	Northwest Natural Gas
Tacoma WA	Tacoma Power	Puget Sound Energy
Stockton CA	Pacific Gas and Electric	Pacific Gas and Electric

The dates for the allowances are shown in Table 9. Also shown in Table 9 is the effective year for the average utility price data. The average utility price data is computed annually so the effective year is either the previous year if before June 1 or the current year if the date is after June 1.

Table 9 – Allowance Dates and Effective Year

Location	*Date*	*Effective Year*
Tampa FL	10/1/2004	2004
Orlando FL	1/1/2005	2004
Palm Beach County FL	8/1/2004	2004
Richmond VA	1/1/2005	2004
Norfolk VA	1/14/2004	2003
Charlotte NC	3/1/2004	2003
Scranton PA	6/1/2004	2004
Rochester NY	10/1/2004	2004
Buffalo NY	10/1/2004	2004
Minneapolis MN	1/1/2004	2003
Memphis TN	10/1/2004	2004
St. Louis MO	1/1/2005	2004
Las Vegas NV	2/12/2003	2002
Phoenix AZ - APS	12/1/2004	2004
Phoenix AZ - SRP	12/1/2004	2004
Riverside CA	FY2005	2004
Salem OR – PGE	4/1/2005	2004
Salem OR – SE	4/1/2005	2004
Tacoma WA	4/1/2004	2003
Stockton CA	10/1/2004	2004

The Energy Information Administration of the U.S. Department of Energy gathers data on utilities including price data. For electric utilities, the “Electric Sales, Revenue, and Average Price” publication includes the average revenue per kWh for residential electric customers. It is available for recent years at:

http://www.eia.doe.gov/cneaf/electricity/esr/esr_sum.html

This is a nearly comprehensive source of information about electric utility sales and revenue and includes over 3000 specific investor owned, public, marketers, and cooperative utilities in the United States. The average cost is shown in Table 10.

Table 10 – Average Residential Price for Electricity

Location	*Electric Utility Name*	*Price (cents/kWh)*
Tampa FL	TECO Tampa Electric	9.89
Orlando FL	Progress Energy	9.34
Palm Beach County FL	Florida Power and Light	9.05
Richmond VA	Dominion Virginia Power	8.43
Norfolk VA	Dominion Virginia Power	8.13
Charlotte NC	Duke Energy	7.56
Scranton PA	PPL	8.27
Rochester NY	Rochester Gas & Electric Corp.	10.38
Buffalo NY	National Grid	12.83
Minneapolis MN	Xcel Energy	7.84
Memphis TN	Memphis Light Gas and Water	7.04
St. Louis MO	Ameren	6.8
Las Vegas NV	Nevada Power	9.33
Phoenix AZ - APS	Arizona Public Service	8.53
Phoenix AZ - SRP	Salt River Project	7.93
Riverside CA	Riverside Public Utilities	11.61
Salem OR - PGE	Portland General Electric	8.05
Salem OR - SE	Salem Electric	6.73
Tacoma WA	Tacoma Power	6.14
Stockton CA	Pacific Gas and Electric	12.62

For natural gas, utilities complete the EIA-176 form annually, which is available publicly through a downloadable database query system at:

http://www.eia.doe.gov/oil_gas/natural_gas/applications/eia176query.html

The EIA-176 query system allows data on each utility to be shown including:

- Heat content of a cubic foot of gas
- Total residential volume
- Total residential revenue

From these values, average prices per therm of natural gas were computed for each of the natural gas utilities and are shown in Table 11. Average annual prices are the most stable but still introduce an uncertainty due to the volatility of natural gas prices.

Table 11 – Average Residential Price for Natural Gas

Location	*Gas Utility*	*$/therm*
Tampa FL	TECO People Energy	1.81
Orlando FL	TECO People Energy	1.81
Palm Beach County FL	Florida Public Utilities Company	1.56
Richmond, VA	Virginia Natural Gas	1.31
Norfolk VA	Virginia Natural Gas	1.25
Charlotte NC	Piedmont Natural Gas	1.06
Scranton PA	UGI Penn Natural Gas (was PG Energy)	1.08
Rochester NY	Rochester Gas & Electric Corp.	1.14
Buffalo NY	National Fuel Gas Distribution Co.	1.17
Minneapolis MN	CenterPoint Energy/Minnegasco	0.83
Memphis TN	Memphis Light Gas and Water	0.89
St. Louis MO	LaClede Gas	1.09
Las Vegas NV	Southwest Gas	0.90
Phoenix AZ - APS	Southwest Gas	1.23
Phoenix AZ - SRP	Southwest Gas	1.23
Riverside CA	Southern California Gas	0.97
Salem OR - PGE	Northwest Natural Gas	1.12
Salem OR - SE	Northwest Natural Gas	1.12
Tacoma WA	Puget Sound Energy	0.79
Stockton CA	Pacific Gas and Electric	0.95

The previous name for each utility was often needed to look up the average cost so that was determined for specific utilities. The utility names that have changed are shown in Table 12.

Table 12 – Utilities with Recent Name Changes

Current Name	*Former Name*
Ameren	Union Electric
National Grid	Niagra Mohawk
Progress energy	Florida Power Corp
UGI Penn Natural Gas	PG Energy
Xcel Energy	Northern States Power

Dividing the monthly dollar allowance from the housing authorities by the average energy costs resulted in estimated energy consumption for each end-use.

3.3 Comparison Approach

The utility allowances from the public housing authorities were compared with the results of the HUD-52667 spreadsheet model. The model included the recent changes for heating to make an adjustment for colder climates and for the use of heat pumps. The first step was to use location specific data for each city based on the data in the zipCodeToDegreeDays-Ver02.xls spreadsheet. This spreadsheet requires ZIP Codes as the first input and those were gathered from the USPS.COM web site. A summary of the location specific data is shown in Table 13 including the ZIP Code and the specific chosen weather station.

Table 13 – Location Summary Data

Location	*ZIP Code*	*Weather Station*	*HDD*	*CDD*
Buffalo NY	14201	BUFFALO NIAGARA INTL	6692	548
Charlotte NC	28202	CHARLOTTE DGLAS INTL AP	3162	1681
Las Vegas NV	89101	LAS VEGAS AP	2239	3214
Memphis TN	38103	MEMPHIS INTL AP	3041	2187
Minneapolis MN	55401	MINNEAPOLIS INTL AP	7876	699
Norfolk VA	23502	NORFOLK INTL AP	3368	1612
Orlando FL	32801	ORLANDO INTL AP	580	3428
Palm Beach County FL	33480	WEST PALM BEACH INTL AP	246	3999
Phoenix AZ	85003	PHOENIX SKY HRBR INTL AP	1125	4189
Richmond VA	23220	RICHMOND BYRD INTL AP	3919	1435
Riverside CA	92501	RIVERSIDE FIRE STA 3	1475	1863
Rochester, NY	14603	ROCHESTER MONROE CO AP	6728	576
Salem OR	97301	SALEM MCNARY AP	4784	257
Scranton PA	18503	WILKES BRE SCTN AP AVOCA	6234	611
St. Louis MO	63101	ST LOUIS INTL AP	4758	1561
Stockton CA	95202	STOCKTON AP	2563	1456
Tacoma WA	98402	TACOMA 1	4650	167
Tampa FL	33602	TAMPA INTL AP	591	3482

The spreadsheet model was used for each location and for each unit type that appeared in the actual allowances provided by HUD. The unit types in the actual allowances did not always match the descriptions used in the spreadsheet model. Table 14 shows how the descriptions were mapped to the types of housing units used internally in the spreadsheet model. The spreadsheet model unit types are based on the types from the DOE/EIA Residential Energy Consumption Survey database that served as the basis of the model.

Table 14 – Unit Type Mapping

Location	*Unit Type Description*	*RECS Types*
Buffalo NY	High Rise with Elevator	Apt 5+
	Mobile Home	Mobile
	Older Home Converted	SF Det
	Older Multi-Family	Apt 2-4
	Row House/Garden Apartment	SF Att, Apt 5+
	Single Family Detached	SF Det
	Two-Three Family/Duplex	SF Att
Charlotte NC	Apartment/Duplex/Townhouse/Row House	SF Att, Apt 2-4
	Single Family	SF Det
Las Vegas NV	Highrise	Apt 5+
	Single Family	SF Det
Memphis TN	Apartment	Apt 2-4
	House	SF Det
Minneapolis MN	Multiple Dwelling (any building with 3 or more units)	Apt 5+
	Single Family Dwelling	SF Det
	Townhouse, Duplex or Double Bungalow	SF Att
Norfolk VA	Duplex 3 Exposed walls	SF Att
	Single Family 4 Exposed walls	SF Det
Orlando FL	High-Rise	Apt 5+
	Single Family	SF Det
Palm Beach County FL	Garden/Apartments	Apt 5+, Apt 2-4
	Single Family	SF Det
Phoenix AZ	Apartment	Apt 2-4
	Single Family Dwelling	SF Det
	Townhouse	SF Att
Richmond VA	1 exposed wall	Apt 5+
	2 exposed wall	Apt 2-4
Riverside CA	Apartments	Apt 2-4
	Houses	SF Det
Rochester NY	Apartment or Townhouse	Apt 2-4, SF Att
	Double	SF Att
	Single Family Dwelling	SF Det
Salem OR	Multifamily Duplex	SF Att, Apt 2-4
	Single Family	SF Det
Scranton PA	Detached	SF Det
	Inner Row	SF Att
St. Louis MO	Apartment-Garden, Mid/High Rise, Loft, Multi Family Attached Flat (3,4 or more family flat)	Apt 5+
	Single Family, Townhouse, Mobile Home, Condominium	SF Det, SF Att, Mobile
Stockton CA	Apartment/Townhouse/Tri+	Apt 2-4, SF Att
	Detached Duplex	SF Att, SF Det
Tacoma WA	High Rise Three Story or More Apartment Building	Apt 5+
	Single Family, Duplex, Triplex	SF Det, SF Att
Tampa FL	Garden Apartment/Highrise	Apt 5+
	Single Family Detached, Manufactured	SF Det, Mobile

3.4 Comparison and Conclusion

The spreadsheet model results, prior to being converted into energy costs were used based on the values shown in the section titled "Consumption Table (kBtu per year)" starting at cell K208 on each building type tab of the spreadsheet. The actual allowances and the modeled results used the same units so they could be directly compared. The method of comparison chosen was to show the values of the actual allowances and the modeled allowances on the same graph so they could be visually compared. The model results are shown as either a single line if they do not change by climate such as for cooking or other electric use or by a high and low line showing the complete range of model results for heating, air-conditioning, and water heating end-uses when climate variation is a factor. The high and low lines were calculated by looking at the end-use across the same climates as the actual results and choosing the highest and lowest climate for each end use. The actual results are shown for each housing authority that had data for the housing unit and end-use shown. Ideally, the actual results from each housing authority would appear between the high and low lines on graphs that show them.

The Appendix A shows the results of each end-use and unit type. The Appendix is an exhaustive exploration of the data which shows every graph produced during the analysis. The table below qualitatively shows how well the model matches the range and shape the of estimated actual energy consumptions.

Table 15 – Analysis of Graphs

End Use	*Unit Type*	*In Model Range*	*Model Shape*
Elec Heat	Apt 2-4	Most	Good
Elec Heat	Apt 5+	Most	Good
Elec Heat	Mobile	Most	Fair
Elec Heat	SF Att	Most	Good
Elec Heat	SF Det	Most	Good
HeatPump	Mixed	Few	Good
Gas Heat	Apt 2-4	Most	Good
Gas Heat	Apt 5+	Few	Good
Gas Heat	Mobile	Few	Fair
Gas Heat	SF Att	Most	Good
Gas Heat	SF Det	Most	Good
Air Cond	Apt 2-4	Most	Good
Air Cond	Apt 5+	Most	Good
Air Cond	Mobile	Few	Fair
Air Cond	SF Att	Most	Fair
Air Cond	SF Det	Most	Fair
Elec WH	Apt 2-4	Most	Good
Elec WH	Apt 5+	Most	Good
Elec WH	Mobile	Most	Good
Elec WH	SF Att	Few	Good
Elec WH	SF Det	Few	Good
Gas WH	Apt 2-4	Few	Good
Gas WH	Apt 5+	Most	Good
Gas WH	Mobile	Most	Good
Gas WH	SF Att	Few	Good
Gas WH	SF Det	Few	Good
Elec Cook	n/a	n/a	Good
Gas Cook	n/a	n/a	Good
Other Elec	Apt 2-4	n/a	Good
Other Elec	Apt 5+	n/a	Good
Other Elec	Mobile	n/a	Fair
Other Elec	SF Att	n/a	Good
Other Elec	SF Det	n/a	Fair

In 17 of the 26 graphs with model ranges, most of the estimated actual energy consumptions fall within the range of the modeled energy consumptions. In 26 of the 33 graphs, the shape of the model results was a good match for the shape of the estimated actual energy consumption. From this, no further changes in the model are needed at this time.

4. Overall Conclusion and Recommendations

The heating energy consumption and the heat pump efficiency adjustment changes improve the overall accuracy of the HUD 52667 spreadsheet model. With these and previous improvements to the spreadsheet model, it has become a robust and useful tool for public housing authorities. Any model can be improved and the HUD 52667 spreadsheet model is no exception. But it has reached a point where further improvements could be done in the future after housing authorities start to use the model. It is likely that future improvements would be based on future comparative studies and by requests for features from housing authorities.

Recommended next steps relate to the deployment of the HUD 52667 spreadsheet model:

a) Develop introductory training materials including slide presentations with speaker notes and internet training systems such as screencasting.

b) Develop more detailed introductory documentation and make available on the internet.

c) Contact small set of housing authorities to test and provide feedback on the spreadsheet model.

d) Refine the model, the training materials, and the documentation based on feedback.

e) Deploy widely for use by housing authorities across the country.

Other steps relate to providing a robust model and continued support for it.

f) Provide support email address for answering questions from housing authorities.

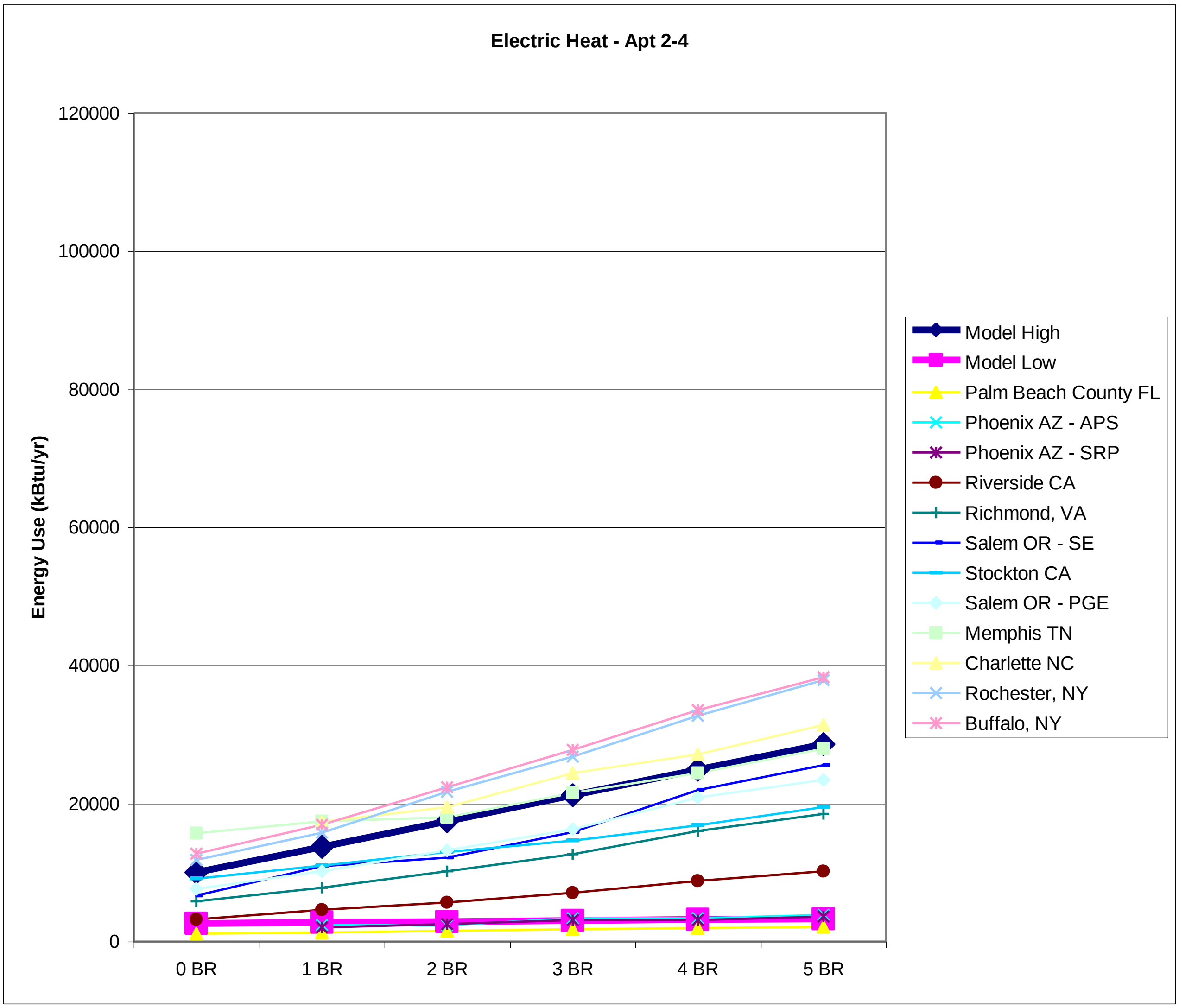
g) Regularly perform validation studies comparing the results with measured residential energy usage.

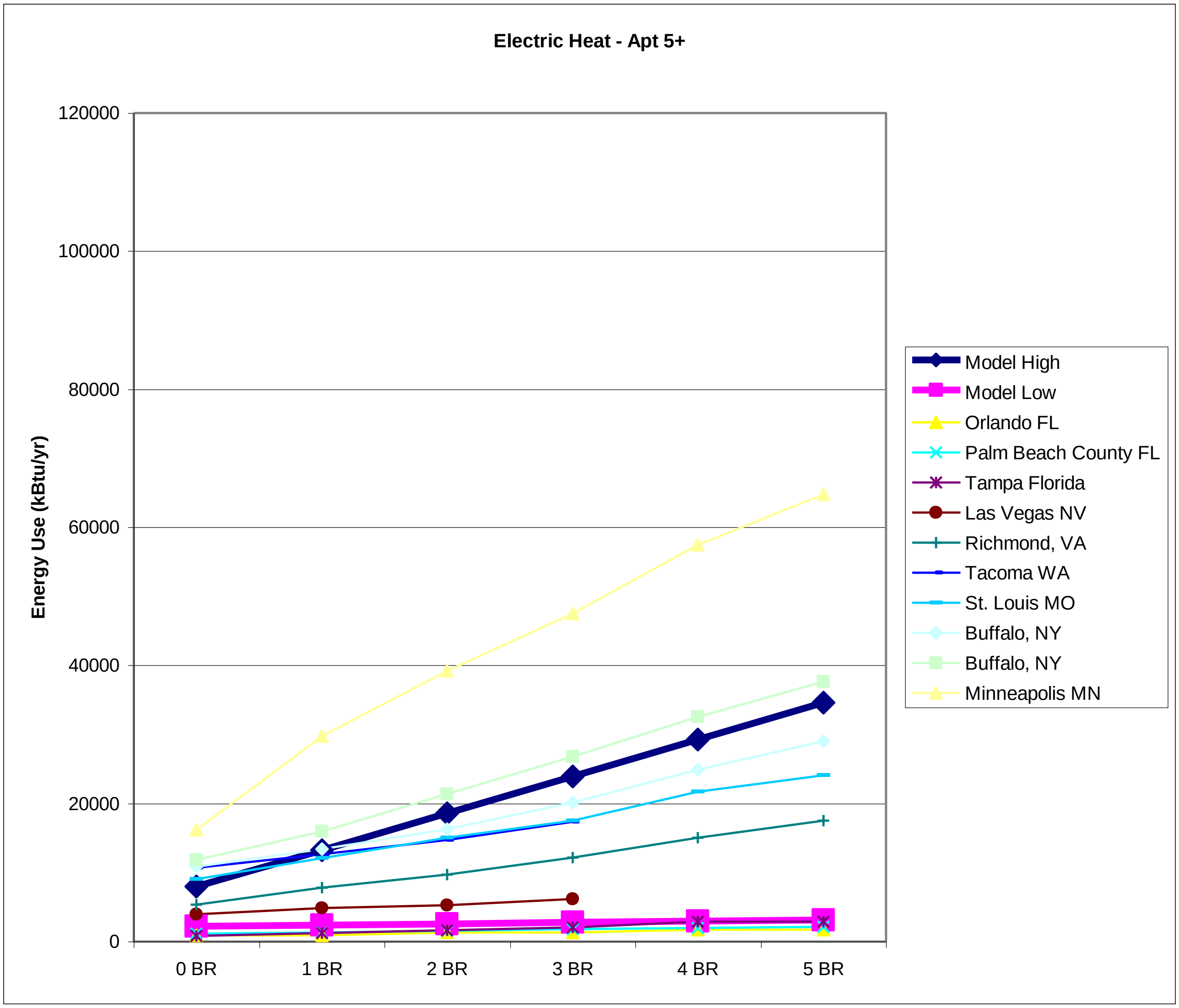
h) Update the spreadsheet for new versions of Microsoft Excel.

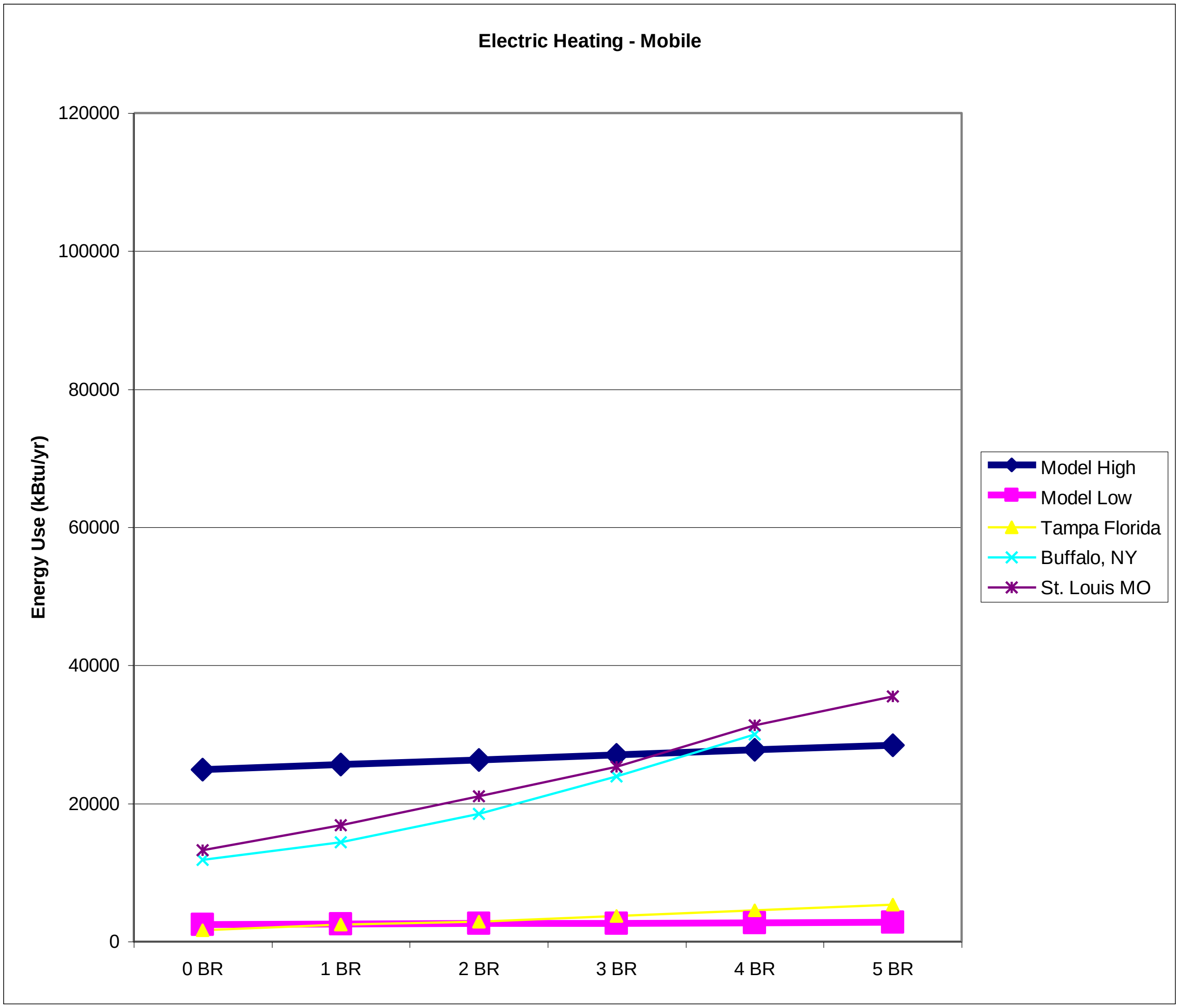
i) Update the spreadsheet when new editions of DOE/EIA’s Residential Energy Consumption Survey data become available.

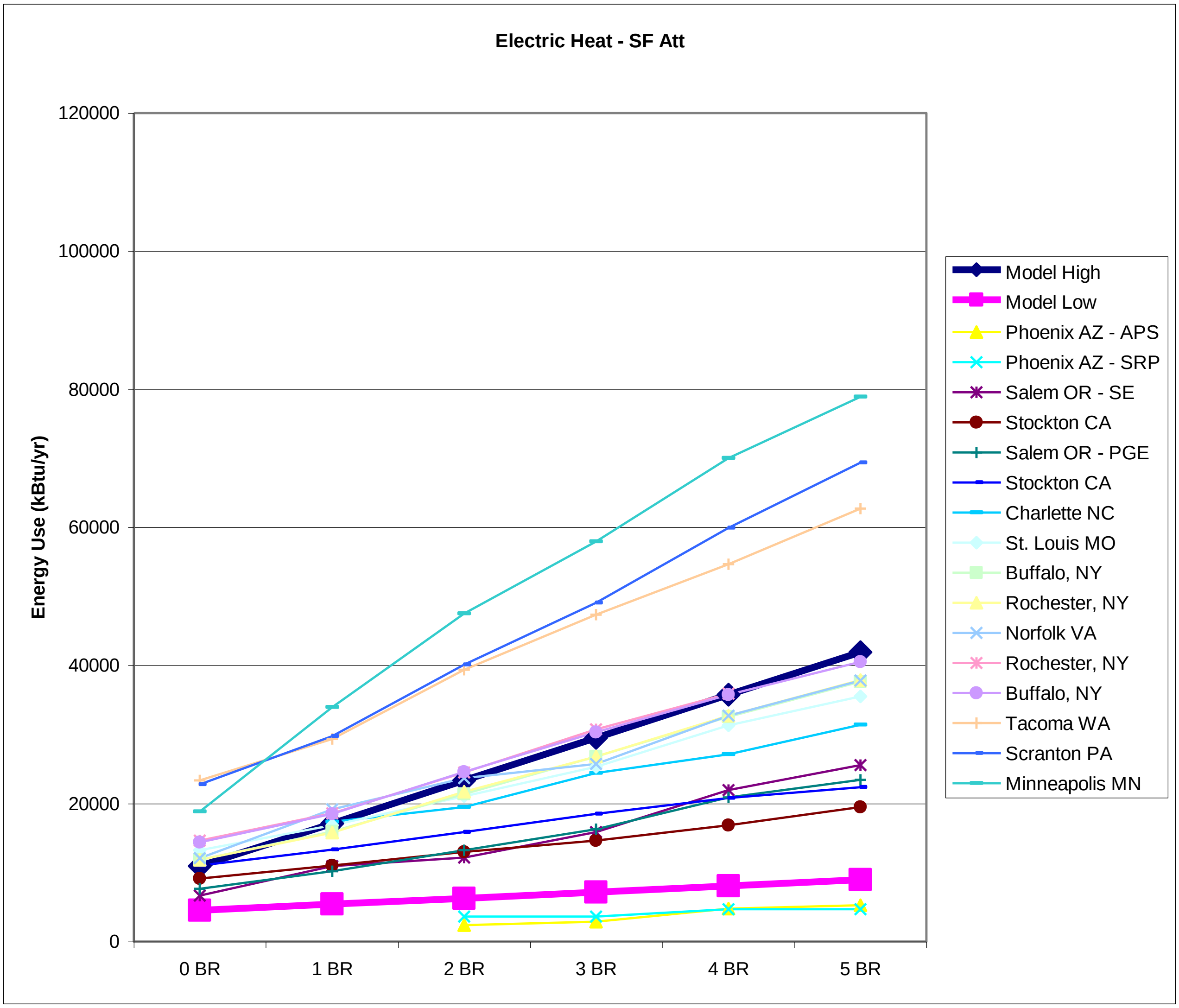
5. Appendix A

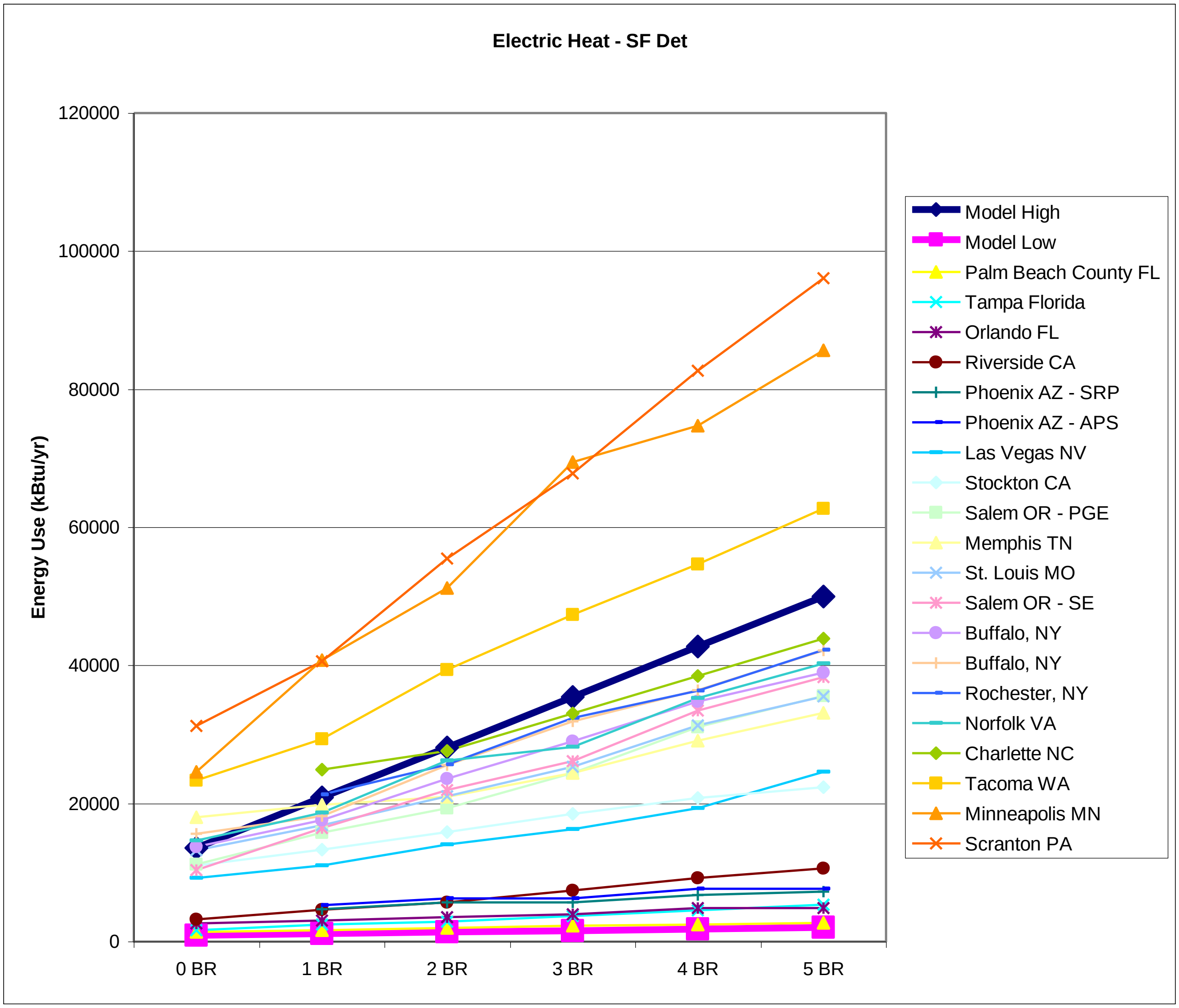
5.1 Electric Heating Graphs

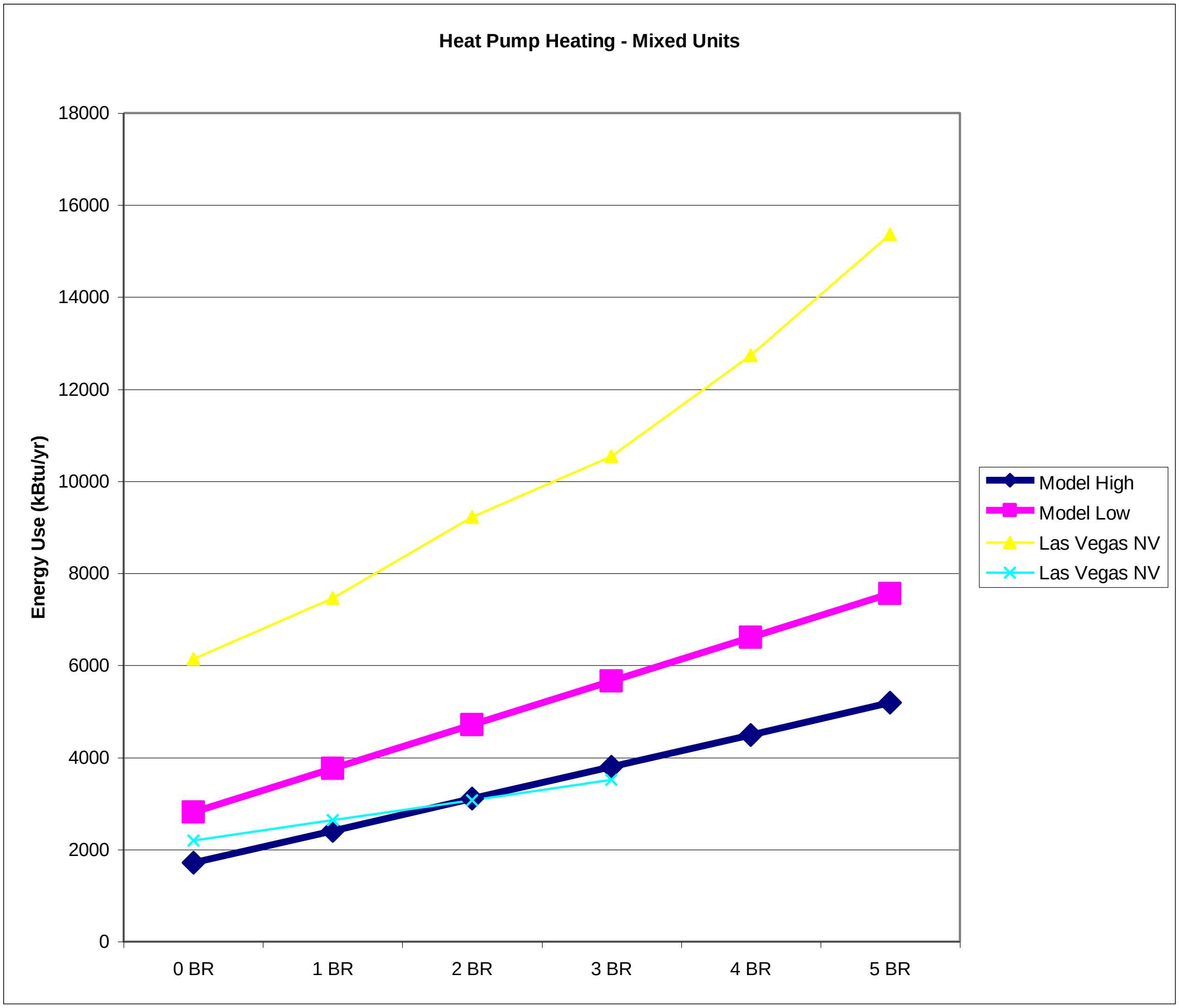



Electric Heat - Apt 5+
Energy Use (kBtu/yr)
120000
100000
80000
60000
40000
20000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Orlando FL
Palm Beach County FL
Tampa Florida
Las Vegas NV
Richmond, VA
Tacoma WA
St. Louis MO
Buffalo, NY
Buffalo, NY
Minneapolis MN

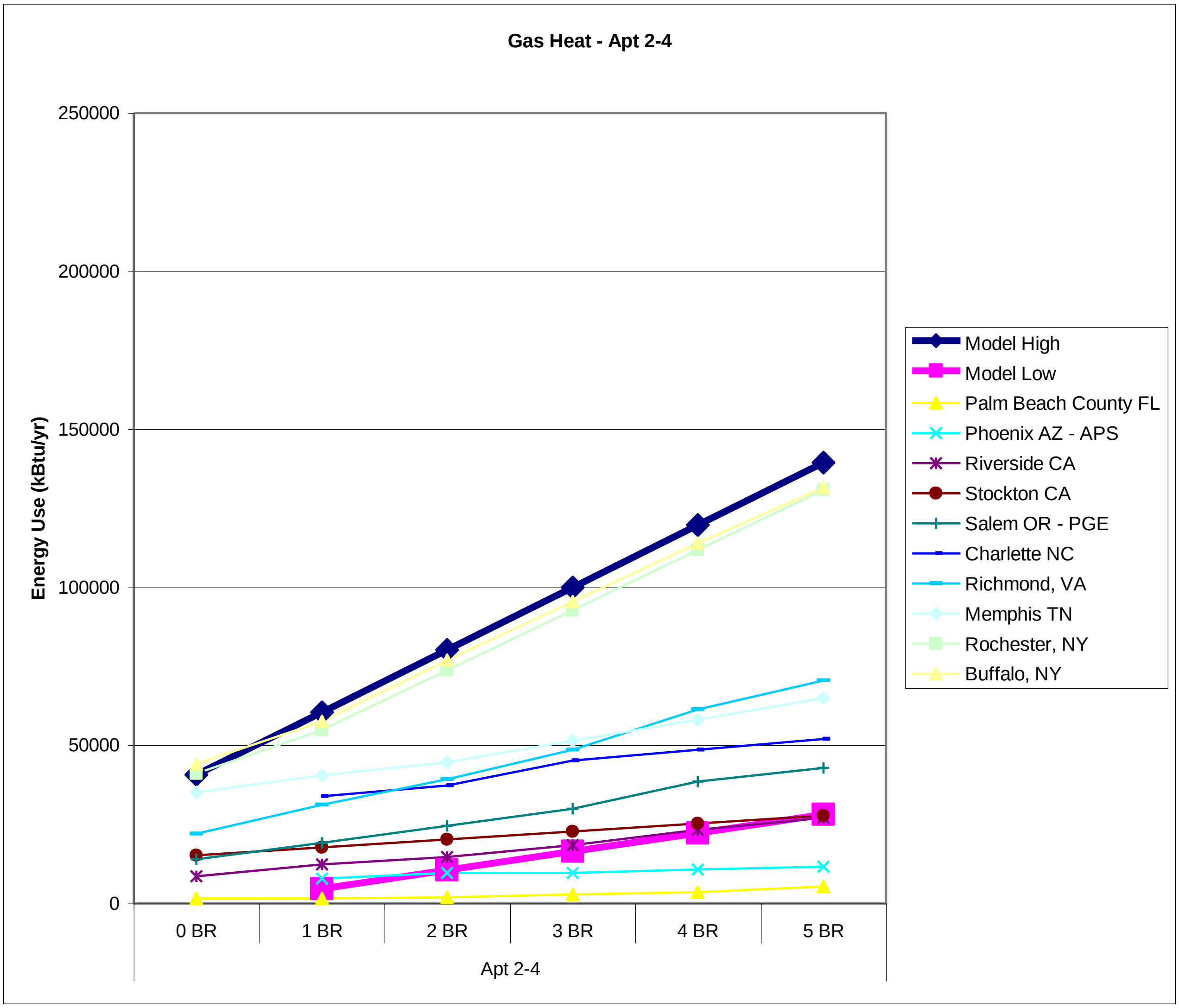

Electric Heating - Mobile
Energy Use (kBtu/yr)
120000
100000
80000
60000
40000
20000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Tampa Florida
Buffalo, NY
St. Louis MO

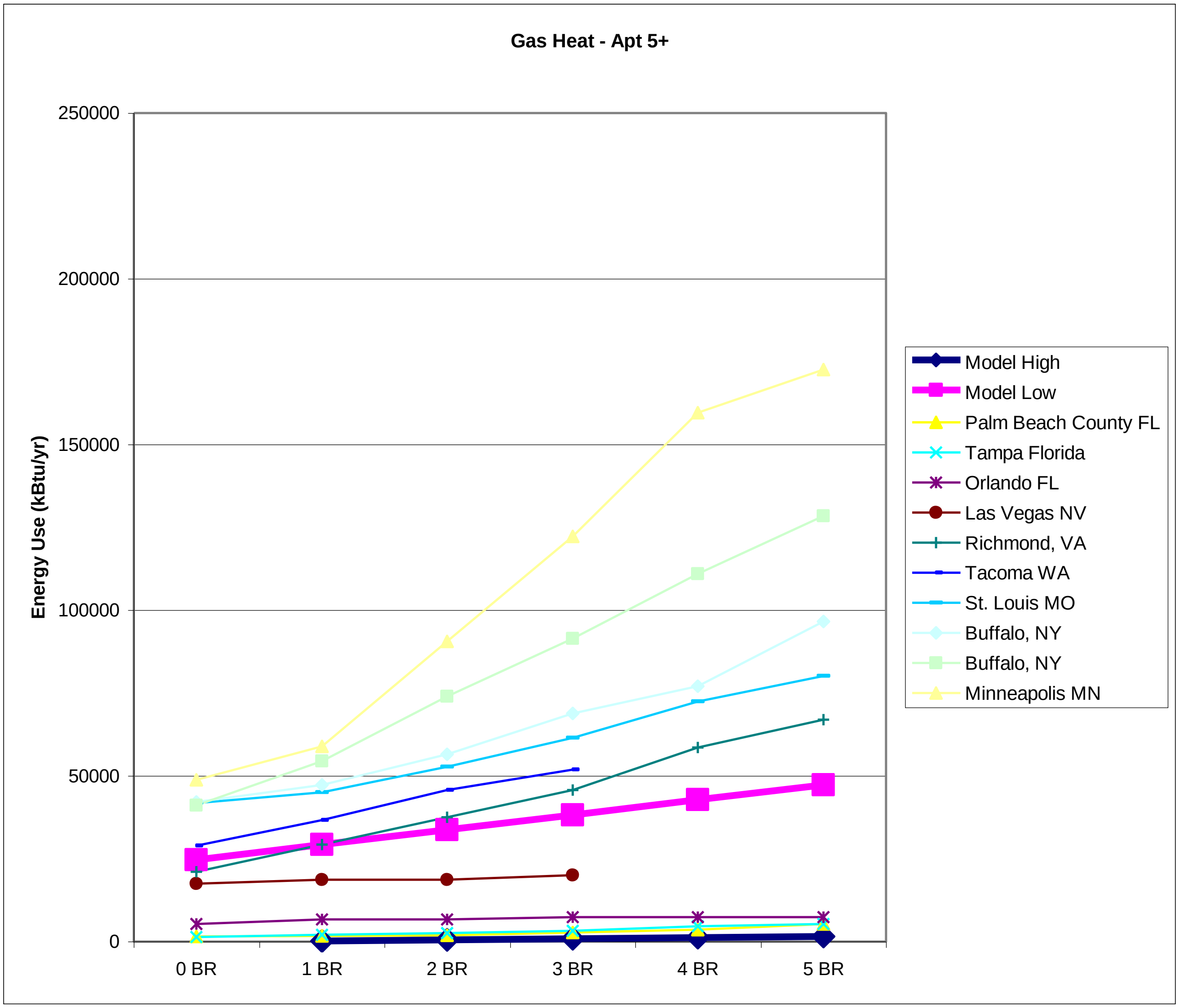

Electric Heat - SF Att
Energy Use (kBtu/yr)
120000
100000
80000
60000
40000
20000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Phoenix AZ - APS
Phoenix AZ - SRP
Salem OR - SE
Stockton CA
Salem OR - PGE
Stockton CA
Charlette NC
St. Louis MO
Buffalo, NY
Rochester, NY
Norfolk VA
Rochester, NY
Buffalo, NY
Tacoma WA
Scranton PA
Minneapolis MN

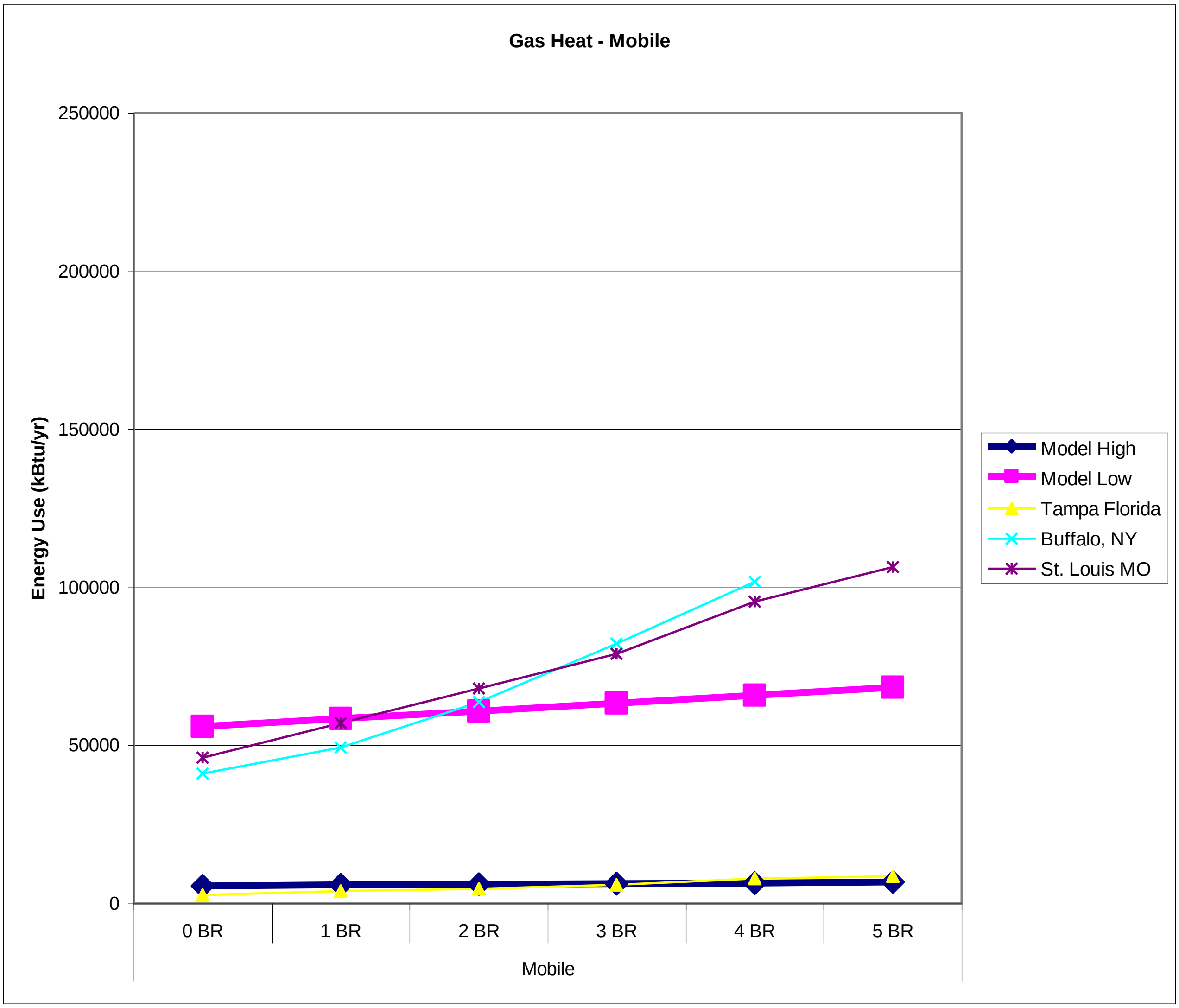

Electric Heat - SF Det
Energy Use (kBtu/yr)
120000
100000
80000
60000
40000
20000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Palm Beach County FL
Tampa Florida
Orlando FL
Riverside CA
Phoenix AZ - SRP
Phoenix AZ - APS
Las Vegas NV
Stockton CA
Salem OR - PGE
Memphis TN
St. Louis MO
Salem OR - SE
Buffalo, NY
Buffalo, NY
Rochester, NY
Norfolk VA
Charlette NC
Tacoma WA
Minneapolis MN
Scranton PA

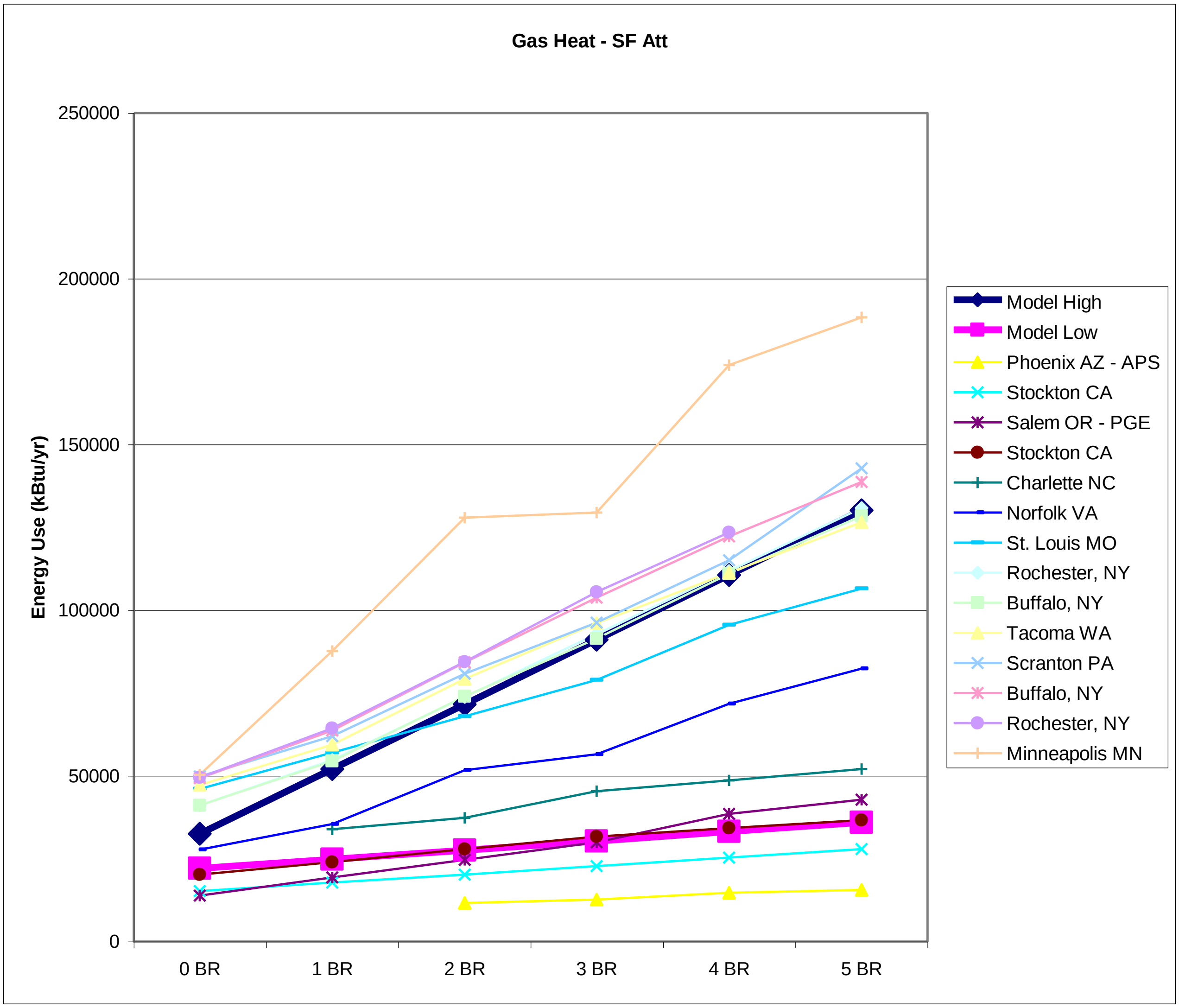

Heat Pump Heating - Mixed Units
Energy Use (kBtu/yr)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Las Vegas NV
Las Vegas NV

5.2 Natural Gas Heating Graphs

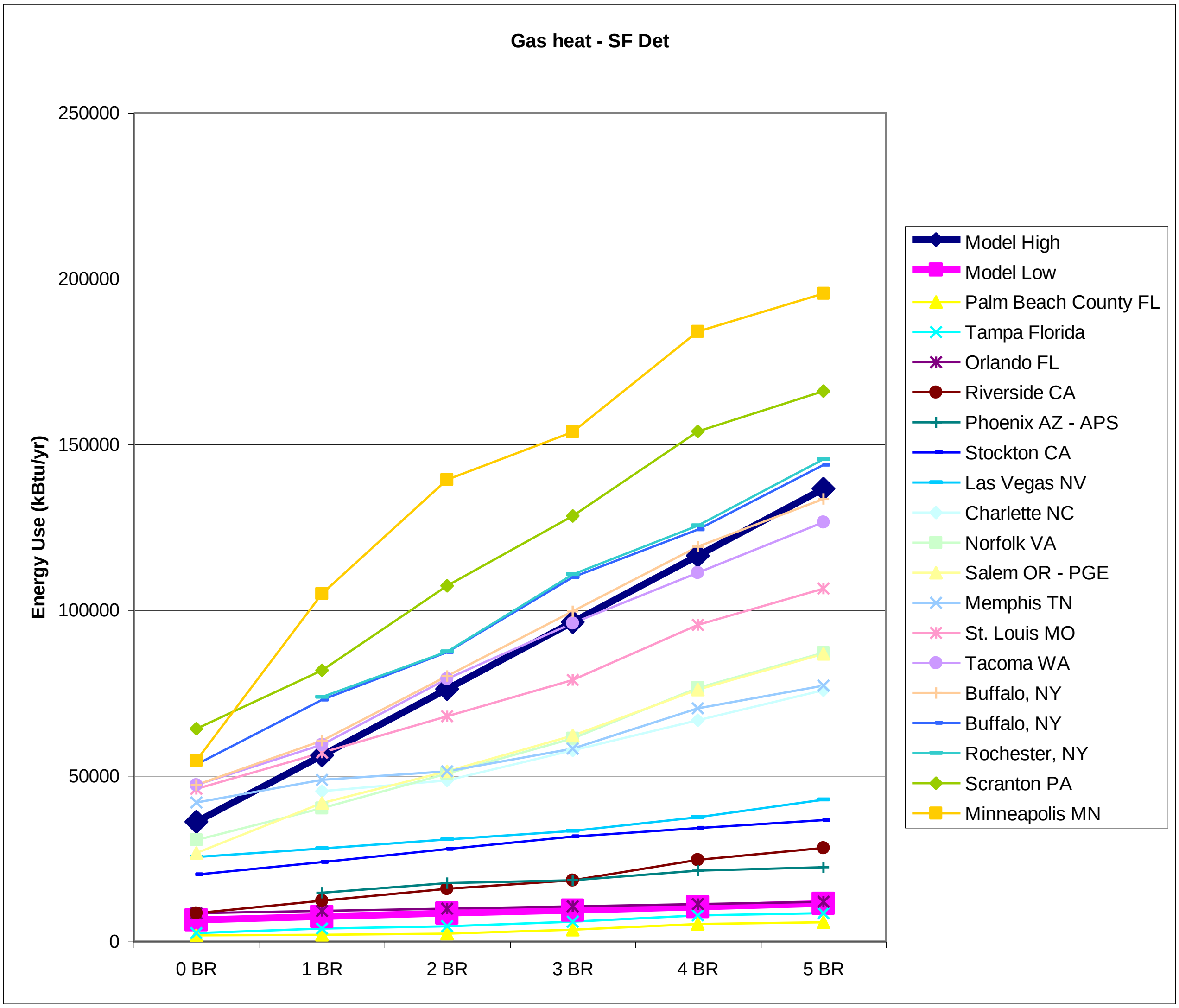



Gas Heat - Apt 5+
Energy Use (kBtu/yr)
250000
200000
150000
100000
50000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Palm Beach County FL
Tampa Florida
Orlando FL
Las Vegas NV
Richmond, VA
Tacoma WA
St. Louis MO
Buffalo, NY
Buffalo, NY
Minneapolis MN

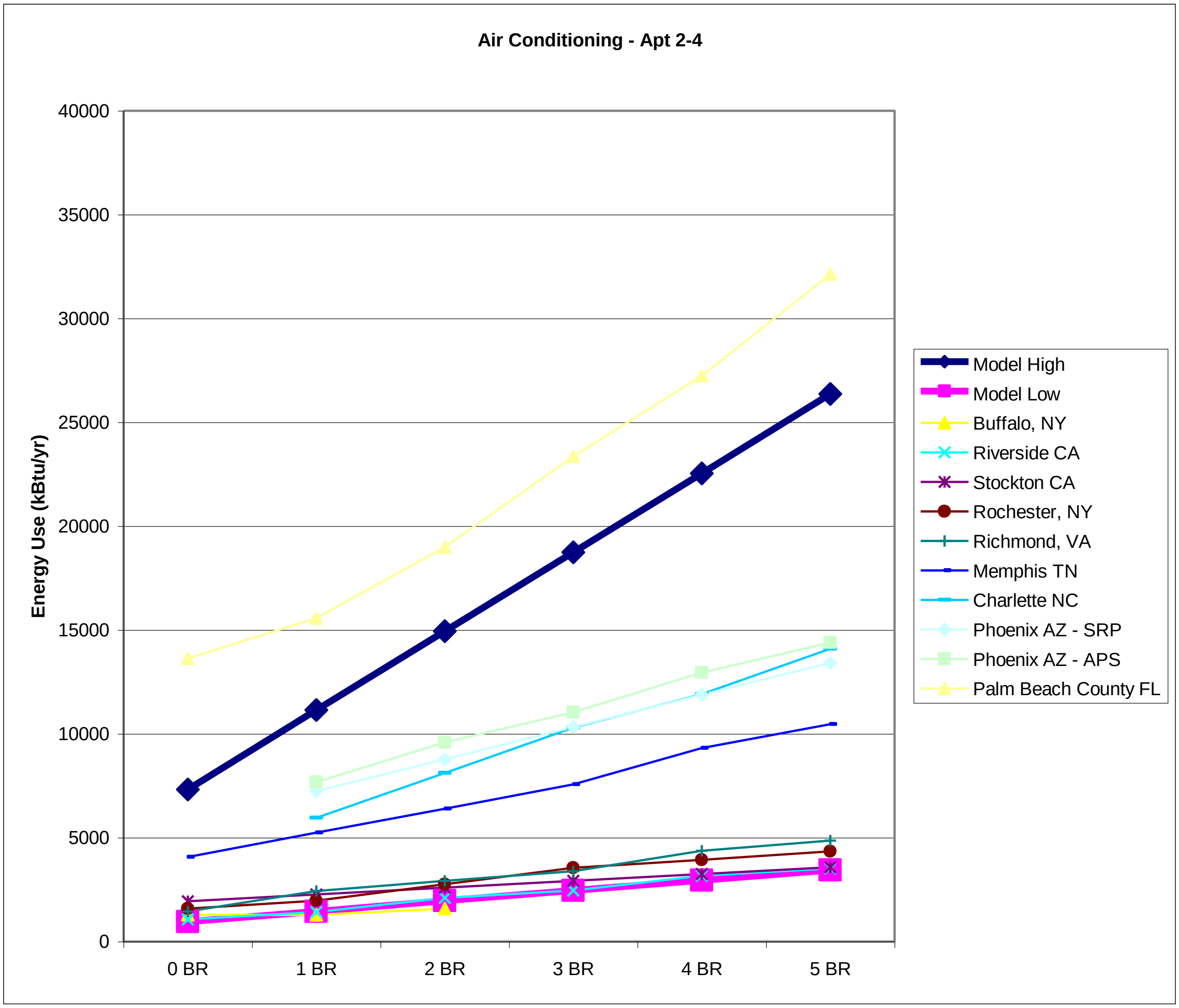

Gas Heat - Mobile
Energy Use (kBtu/yr)
250000
200000
150000
100000
50000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Mobile
Model High
Model Low
Tampa Florida
Buffalo, NY
St. Louis MO

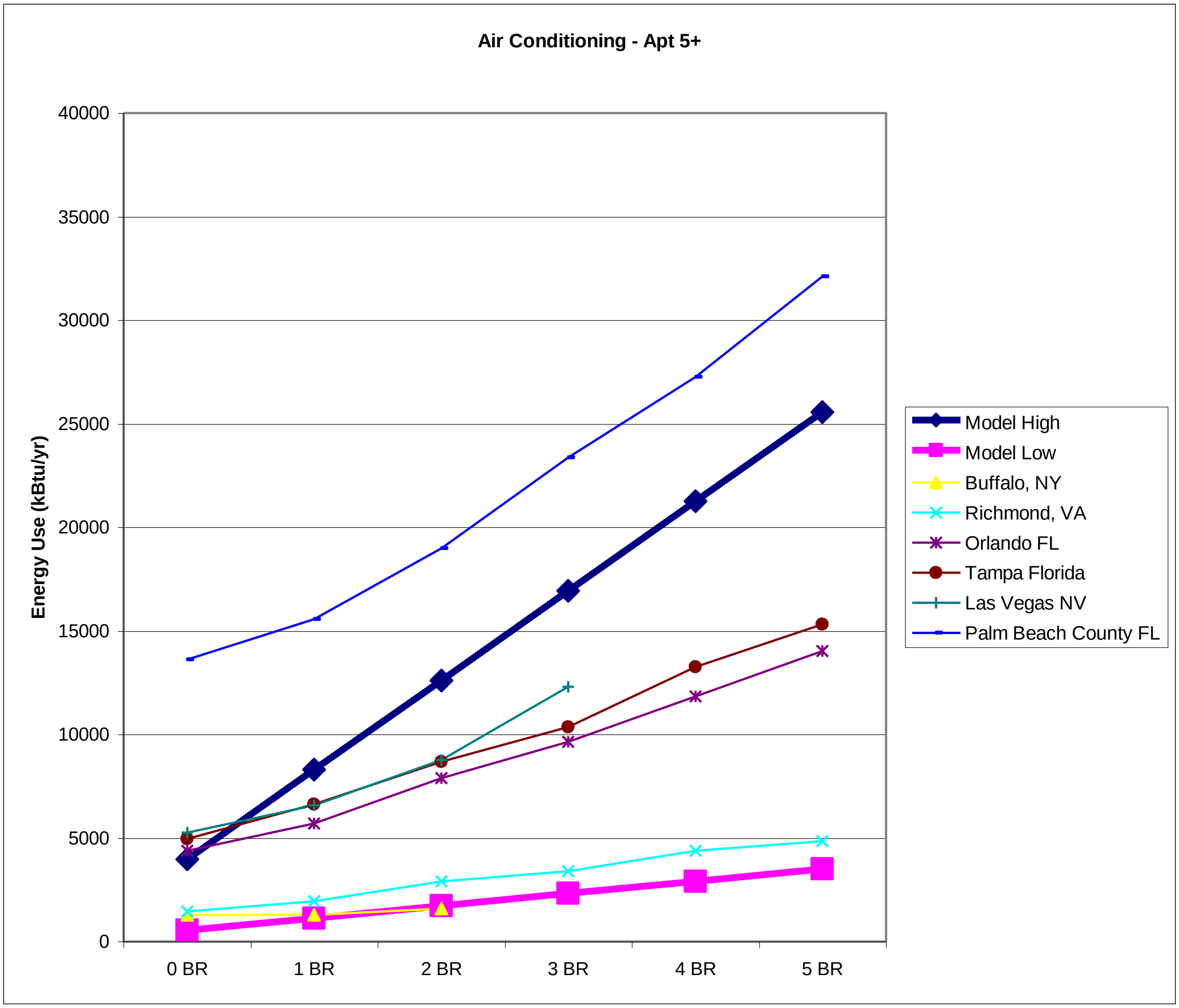


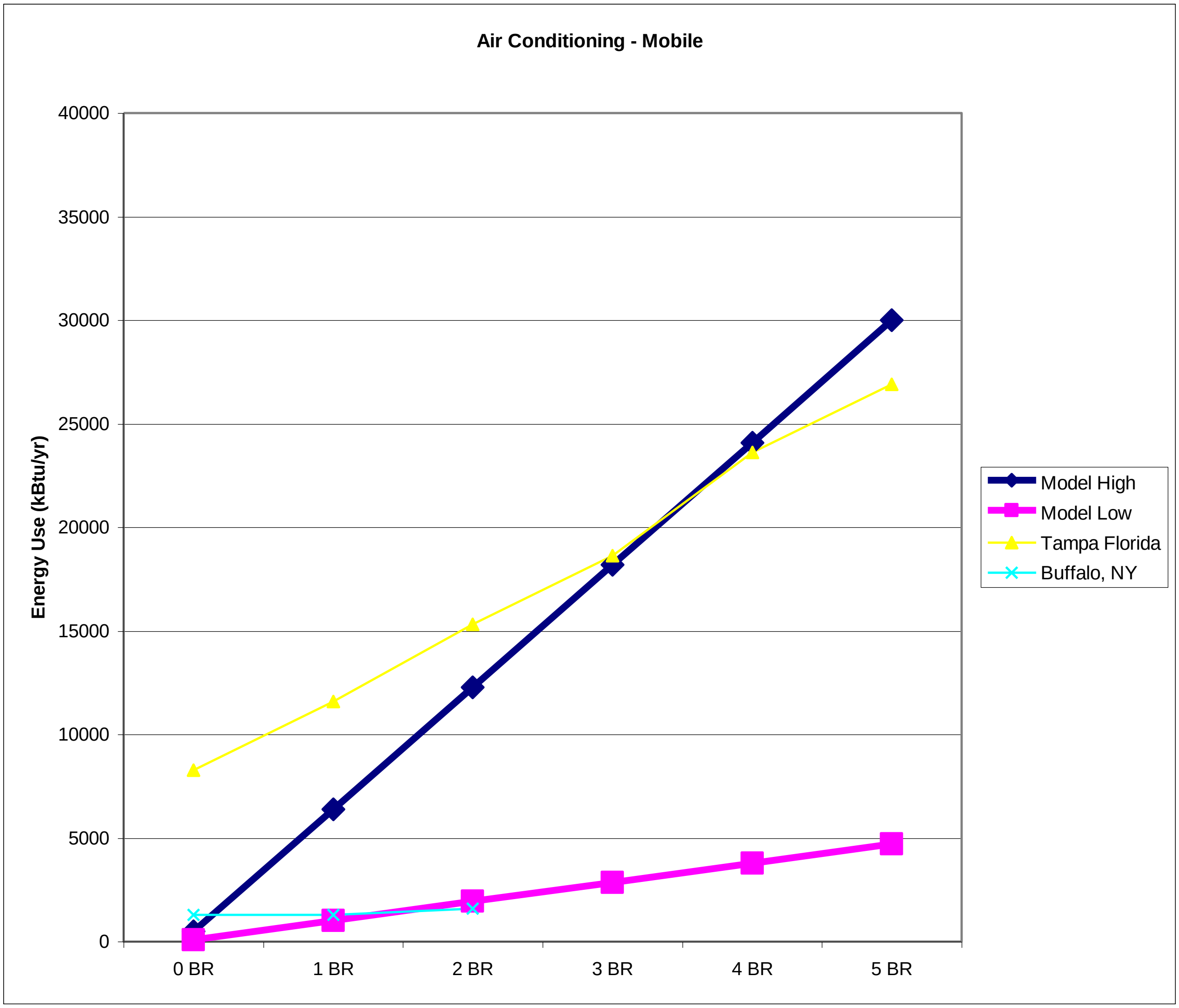
Gas Heat - SF Att
Energy Use (kBtu/yr)
250000
200000
150000
100000
50000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Phoenix AZ - APS
Stockton CA
Salem OR - PGE
Stockton CA
Charlette NC
Norfolk VA
St. Louis MO
Rochester, NY
Buffalo, NY
Tacoma WA
Scranton PA
Buffalo, NY
Rochester, NY
Minneapolis MN

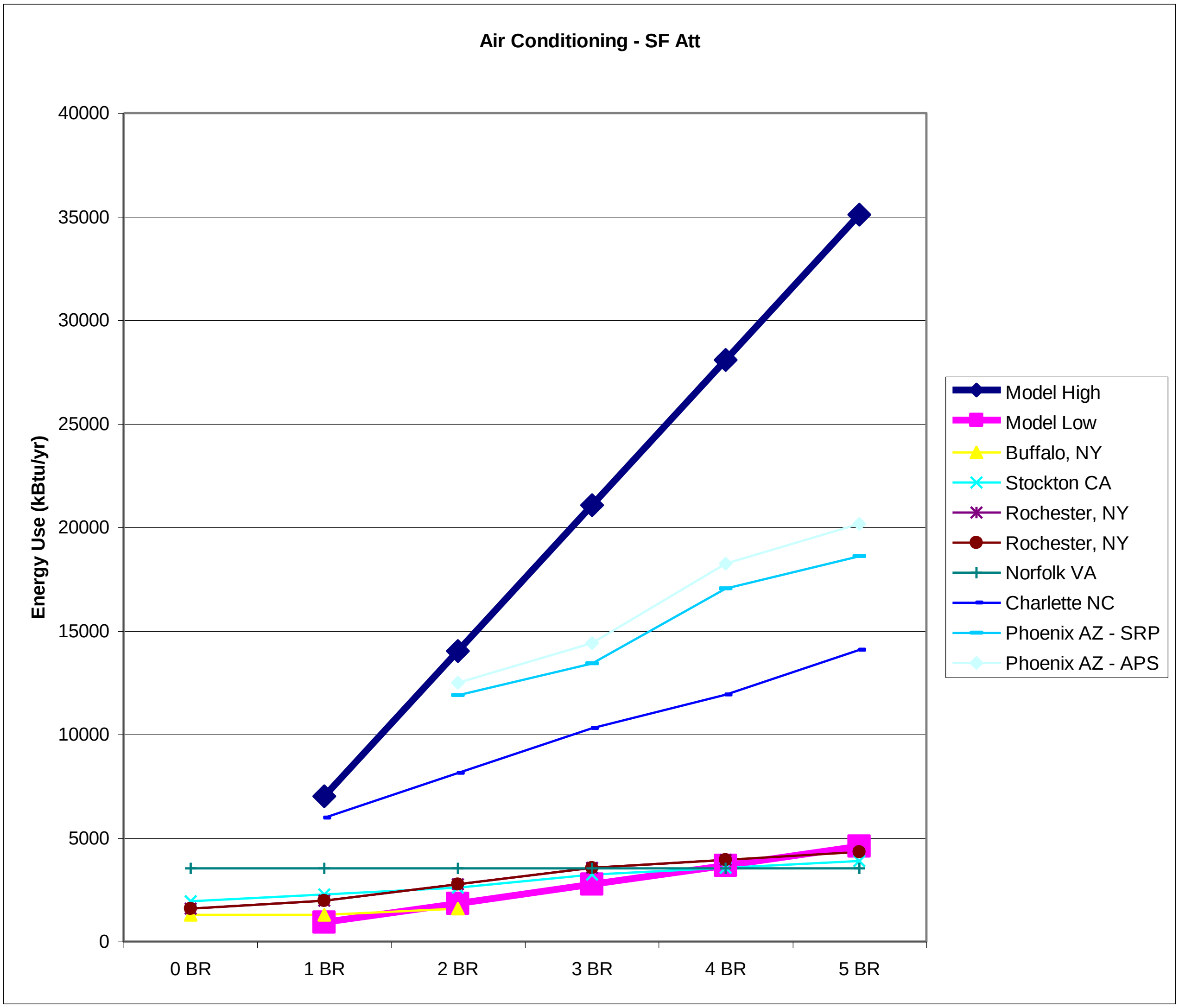

Gas heat - SF Det
Energy Use (kBtu/yr)
250000
200000
150000
100000
50000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Palm Beach County FL
Tampa Florida
Orlando FL
Riverside CA
Phoenix AZ - APS
Stockton CA
Las Vegas NV
Charlette NC
Norfolk VA
Salem OR - PGE
Memphis TN
St. Louis MO
Tacoma WA
Buffalo, NY
Buffalo, NY
Rochester, NY
Scranton PA
Minneapolis MN

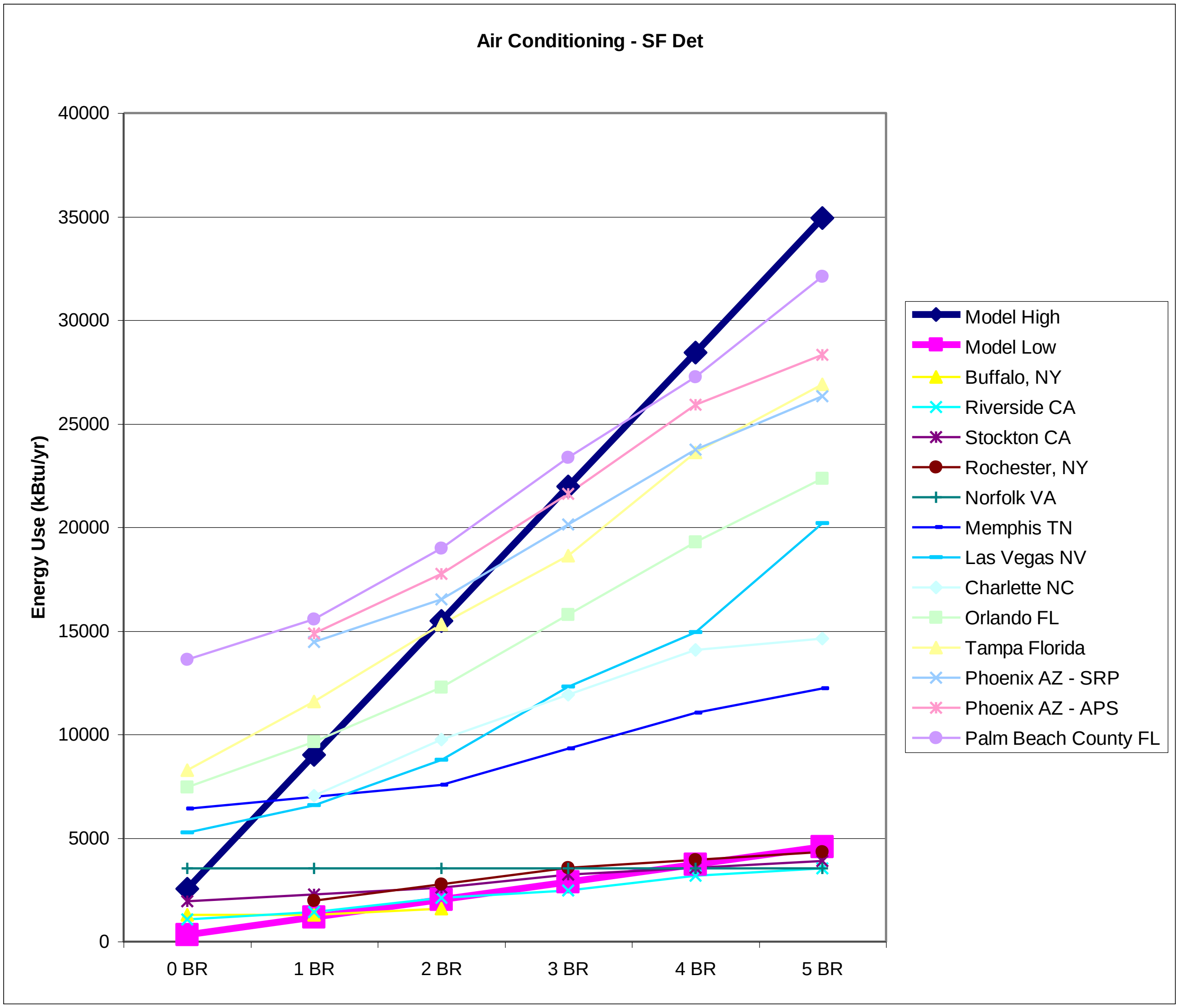
5.3 Air-Conditioning Graphs



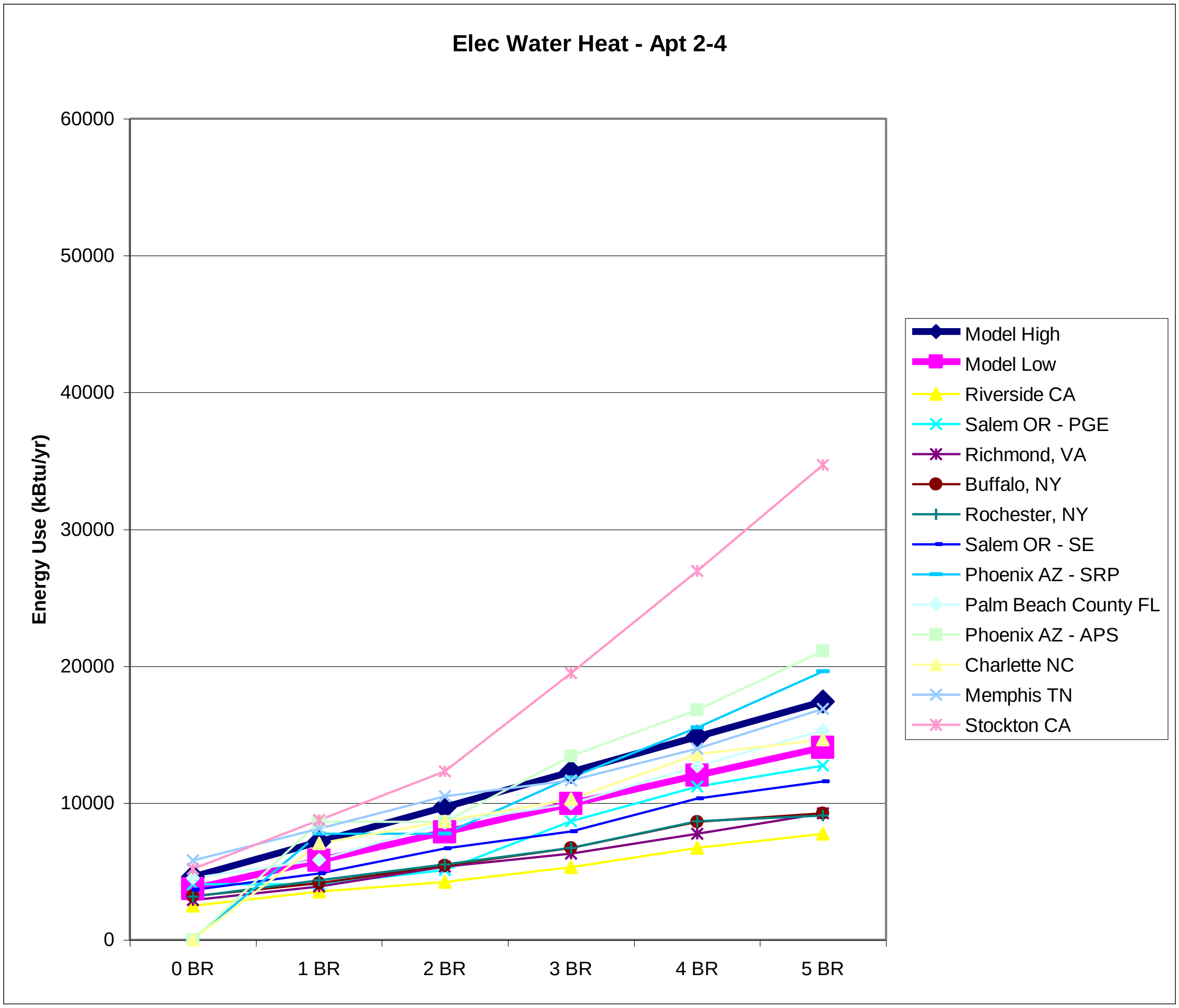

Air Conditioning - Apt 5+
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Buffalo, NY
Richmond, VA
Orlando FL
Tampa Florida
Las Vegas NV
Palm Beach County FL

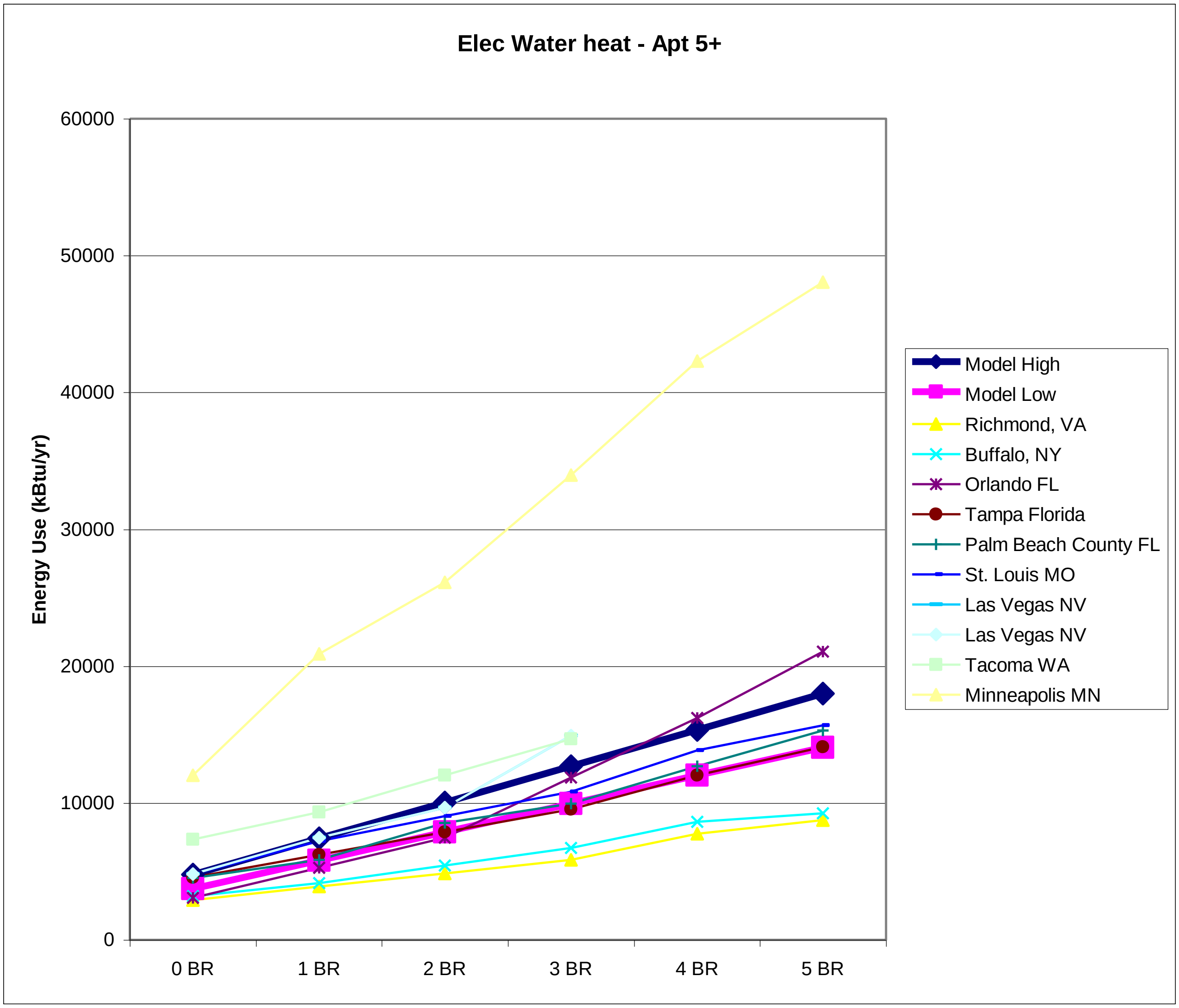

Air Conditioning - Mobile
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Tampa Florida
Buffalo, NY

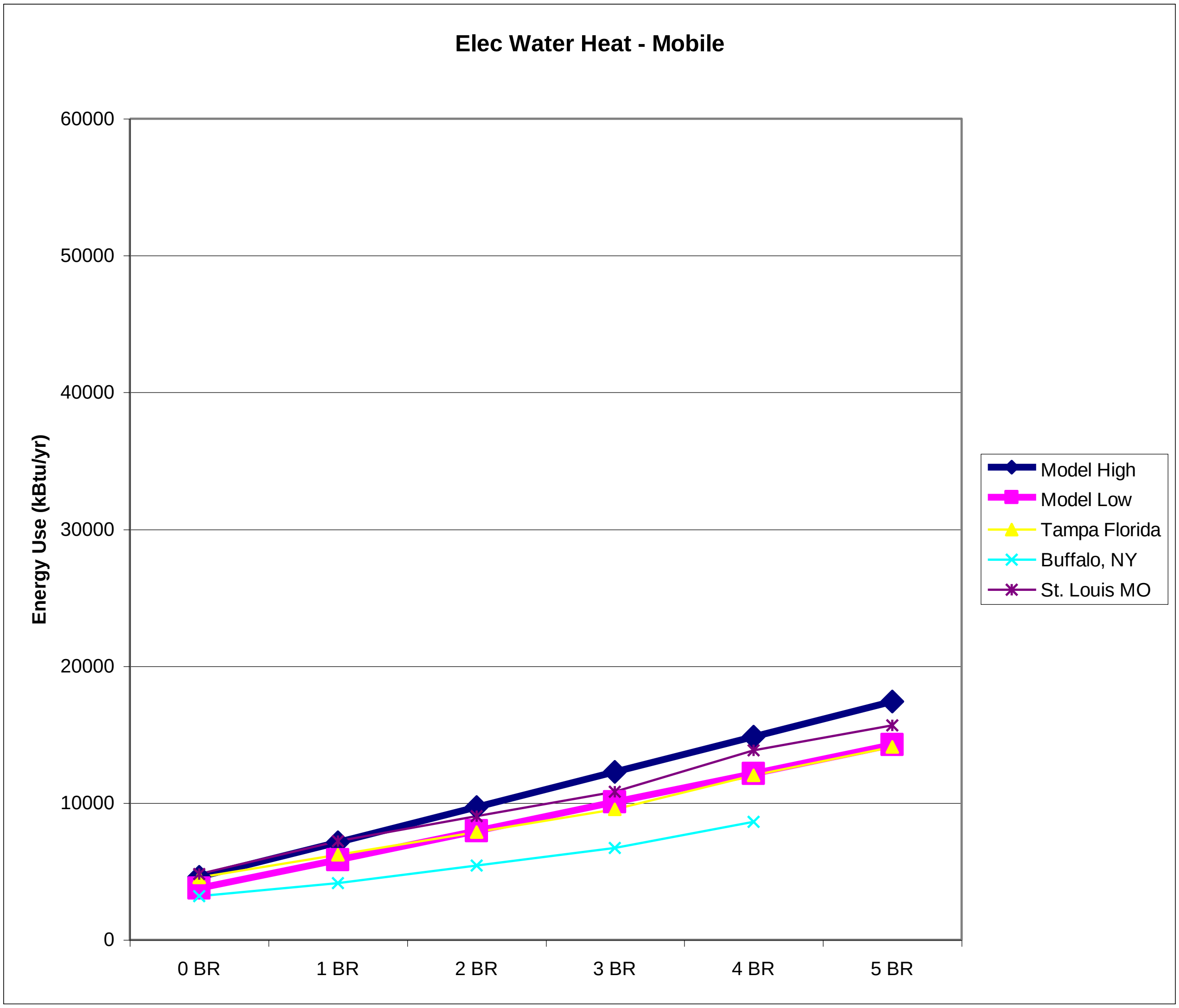

Air Conditioning - SF Att
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Buffalo, NY
Stockton CA
Rochester, NY
Rochester, NY
Norfolk VA
Charlette NC
Phoenix AZ - SRP
Phoenix AZ - APS


Air Conditioning - SF Det
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Buffalo, NY
Riverside CA
Stockton CA
Rochester, NY
Norfolk VA
Memphis TN
Las Vegas NV
Charlette NC
Orlando FL
Tampa Florida
Phoenix AZ - SRP
Phoenix AZ - APS
Palm Beach County FL

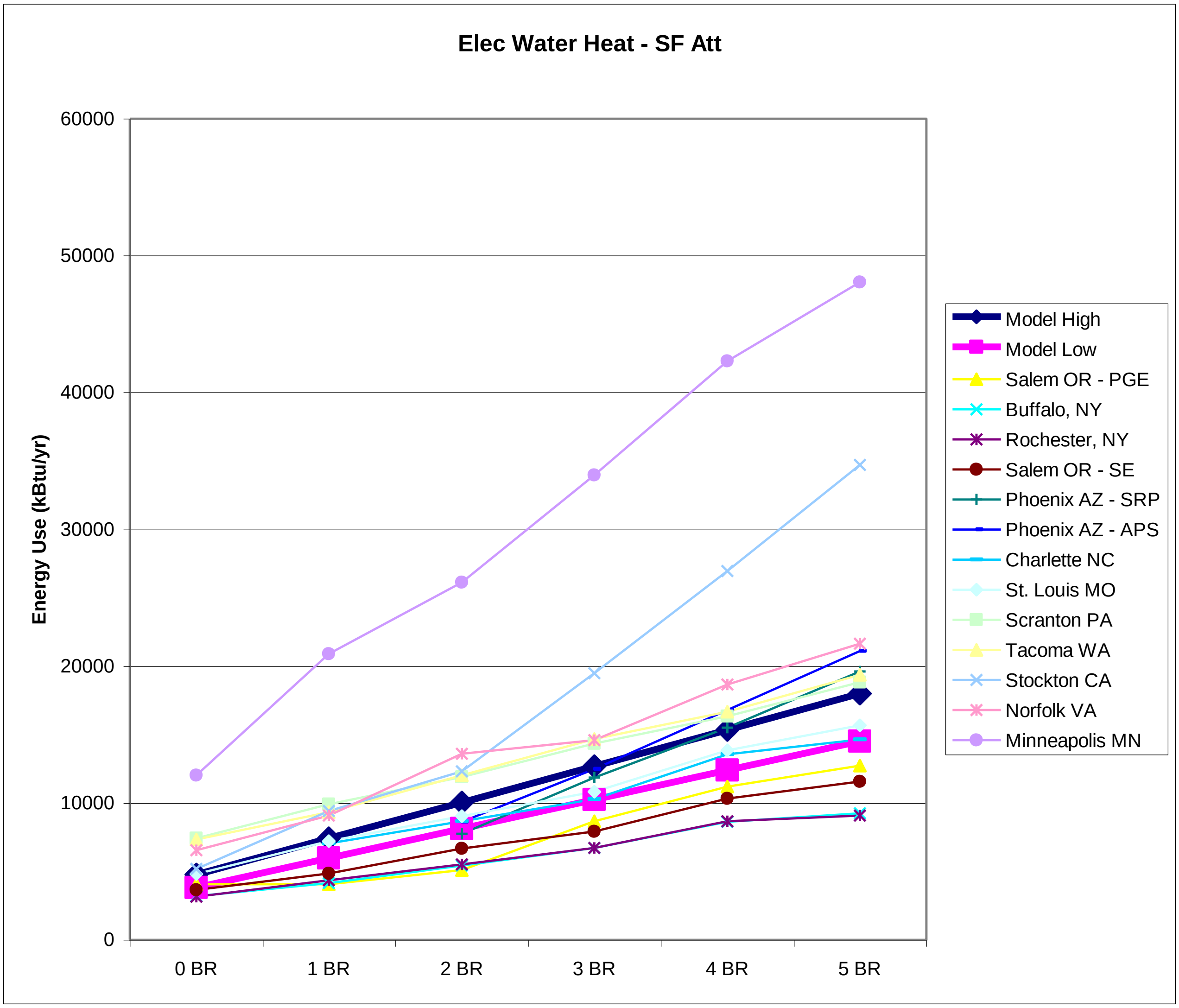
5.4 Electric Water Heating Graphs

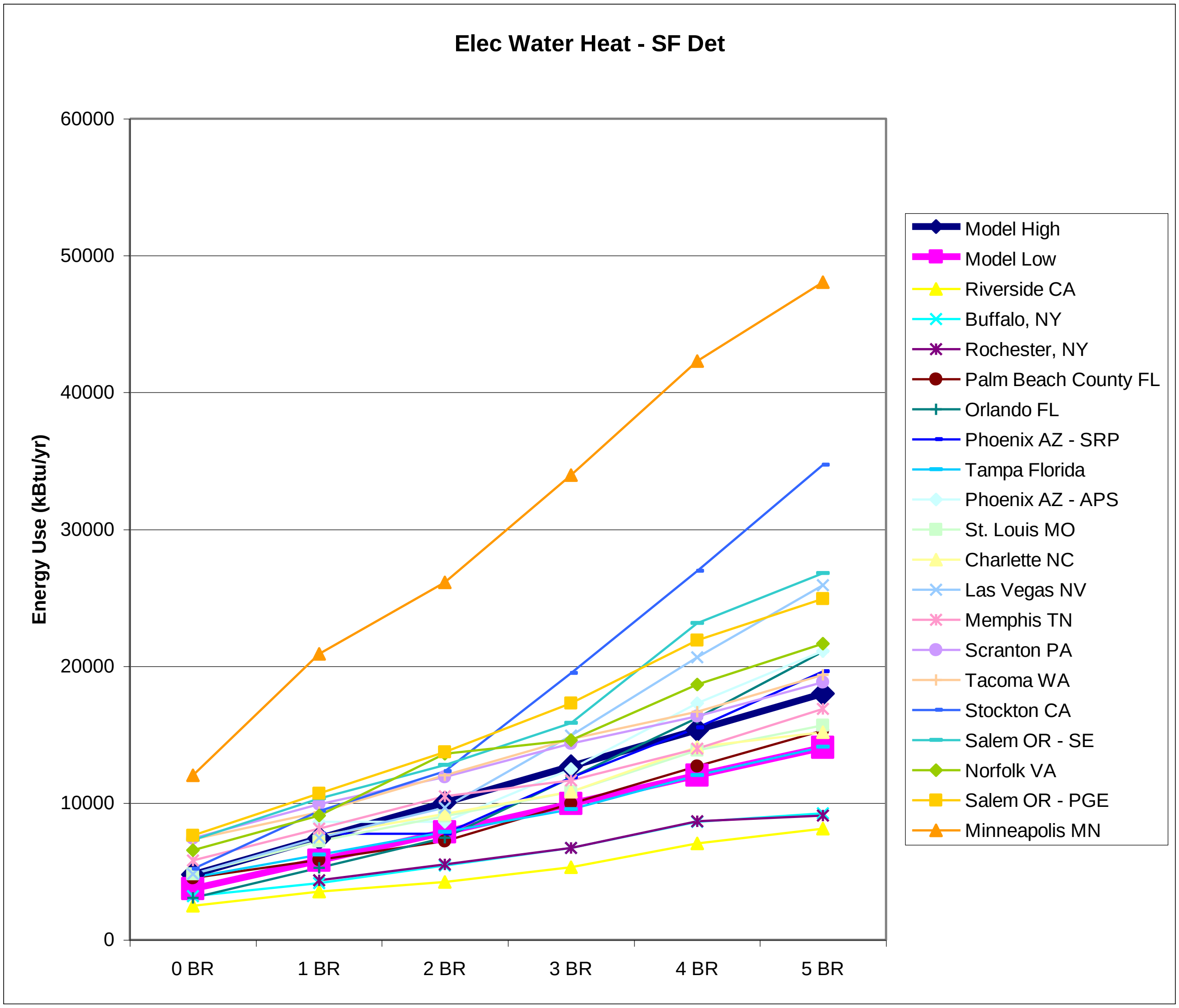



Elec Water heat - Apt 5+
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Richmond, VA
Buffalo, NY
Orlando FL
Tampa Florida
Palm Beach County FL
St. Louis MO
Las Vegas NV
Las Vegas NV
Tacoma WA
Minneapolis MN

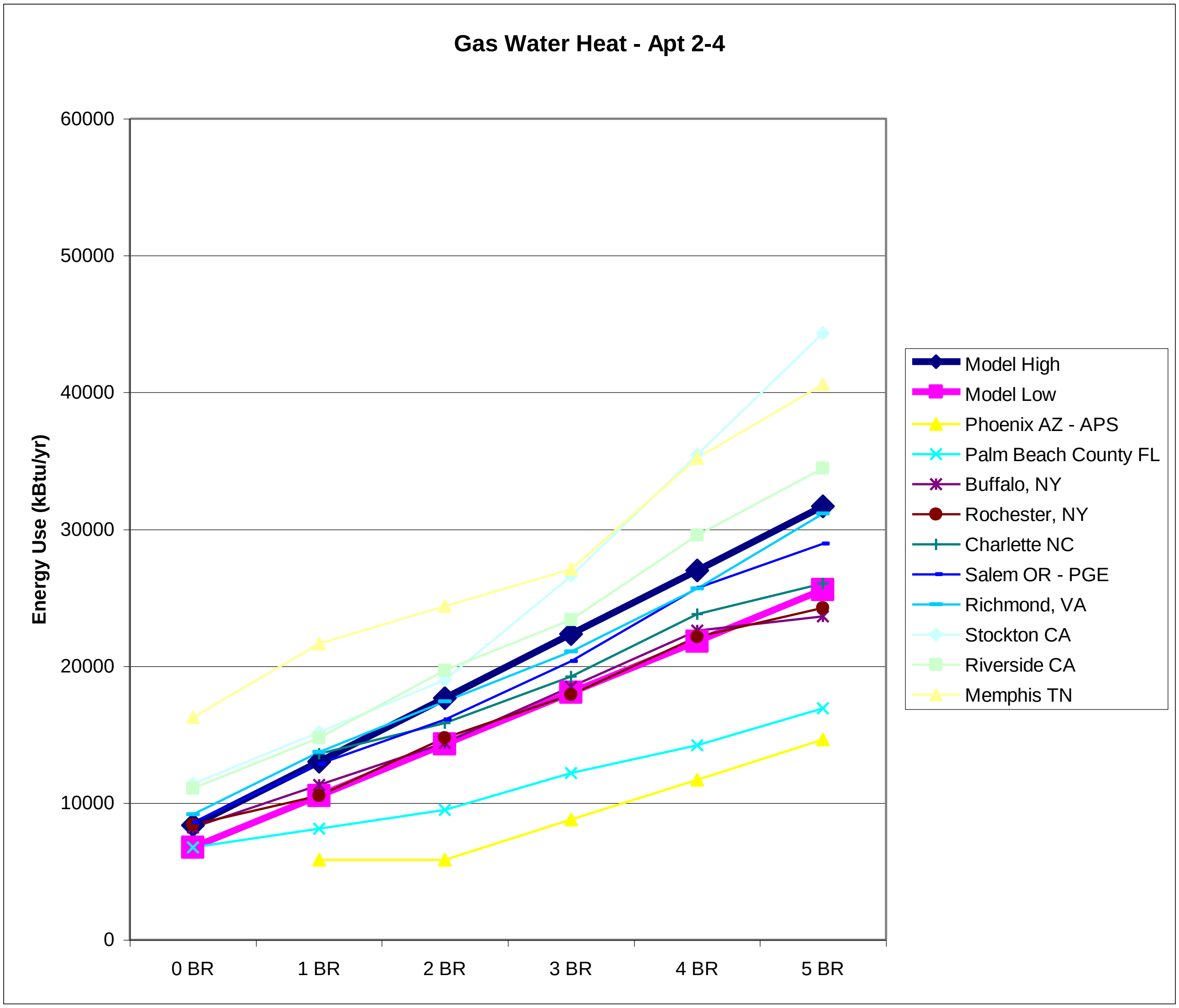


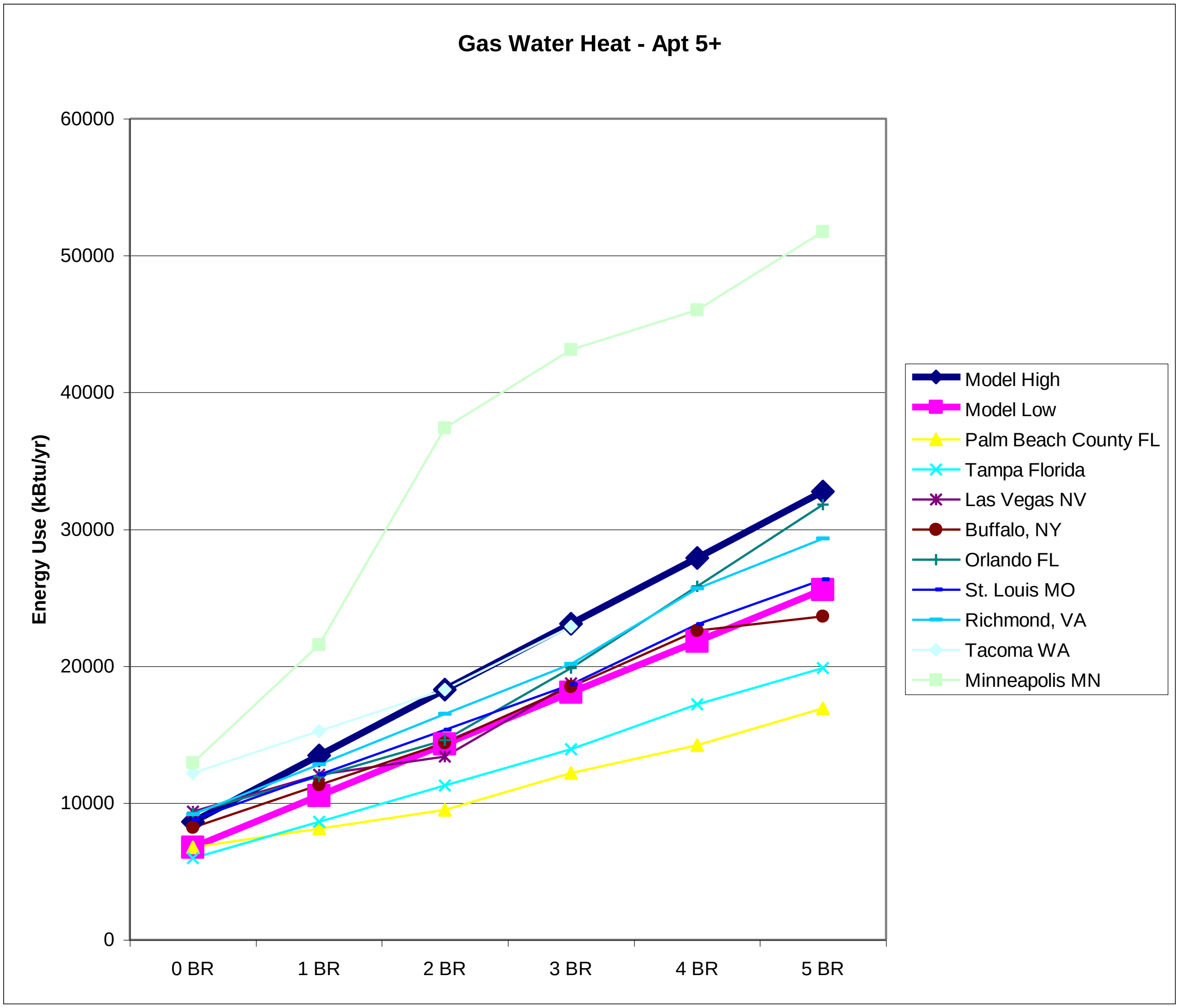
Elec Water Heat - Mobile
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Tampa Florida
Buffalo, NY
St. Louis MO

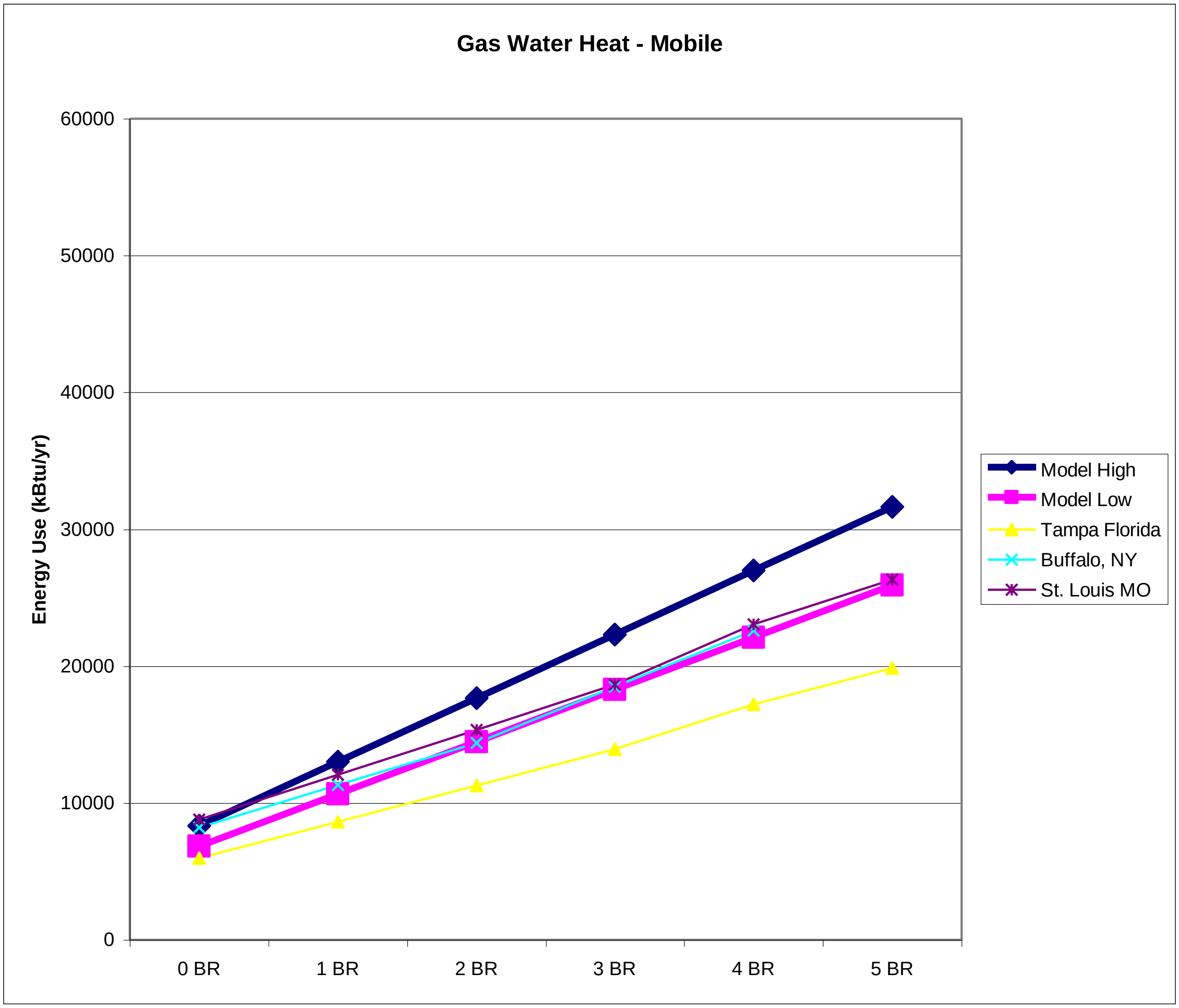

Elec Water Heat - SF Att
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Salem OR - PGE
Buffalo, NY
Rochester, NY
Salem OR - SE
Phoenix AZ - SRP
Phoenix AZ - APS
Charlette NC
St. Louis MO
Scranton PA
Tacoma WA
Stockton CA
Norfolk VA
Minneapolis MN

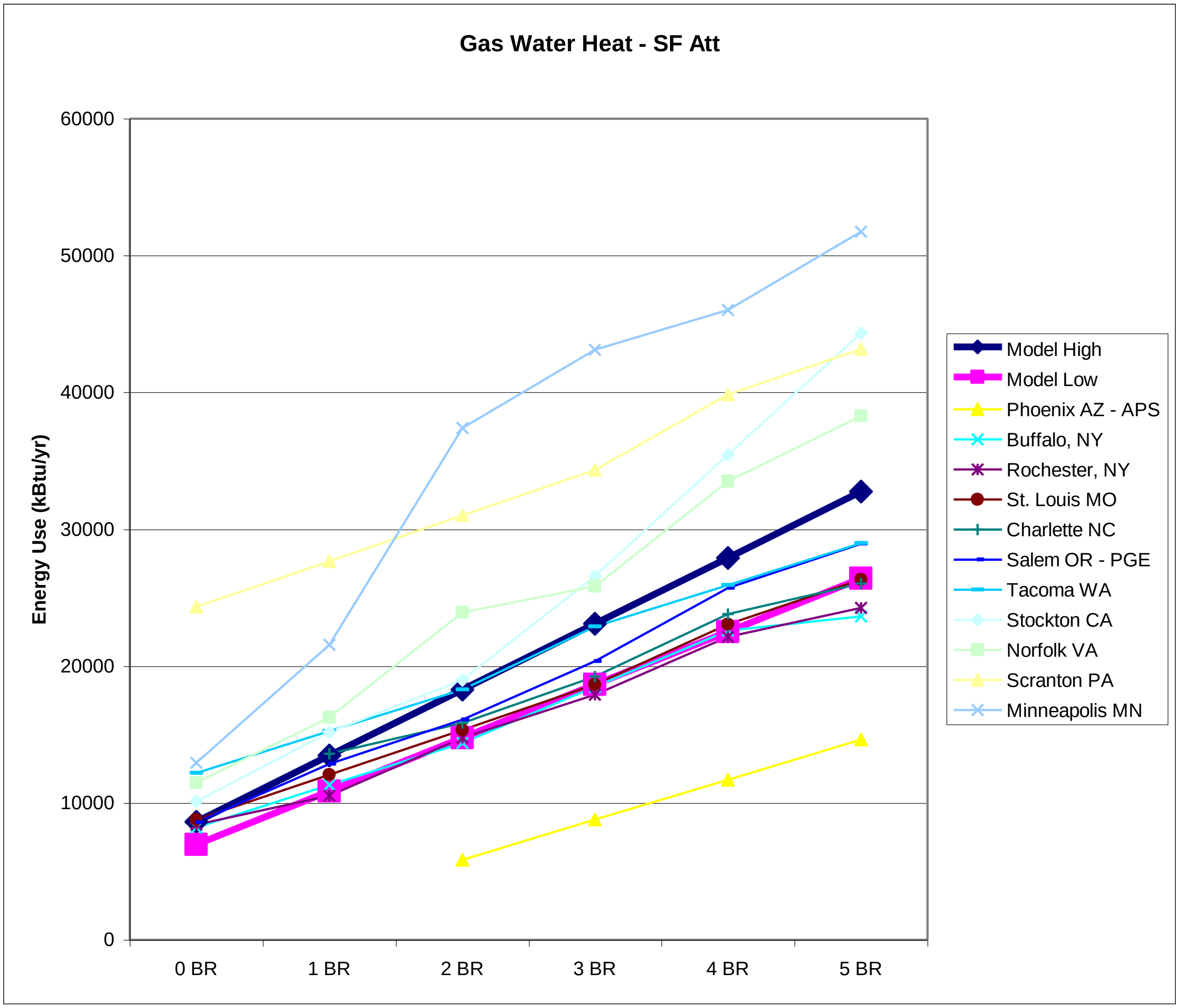

Elec Water Heat - SF Det
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Riverside CA
Buffalo, NY
Rochester, NY
Palm Beach County FL
Orlando FL
Phoenix AZ - SRP
Tampa Florida
Phoenix AZ - APS
St. Louis MO
Charlette NC
Las Vegas NV
Memphis TN
Scranton PA
Tacoma WA
Stockton CA
Salem OR - SE
Norfolk VA
Salem OR - PGE
Minneapolis MN

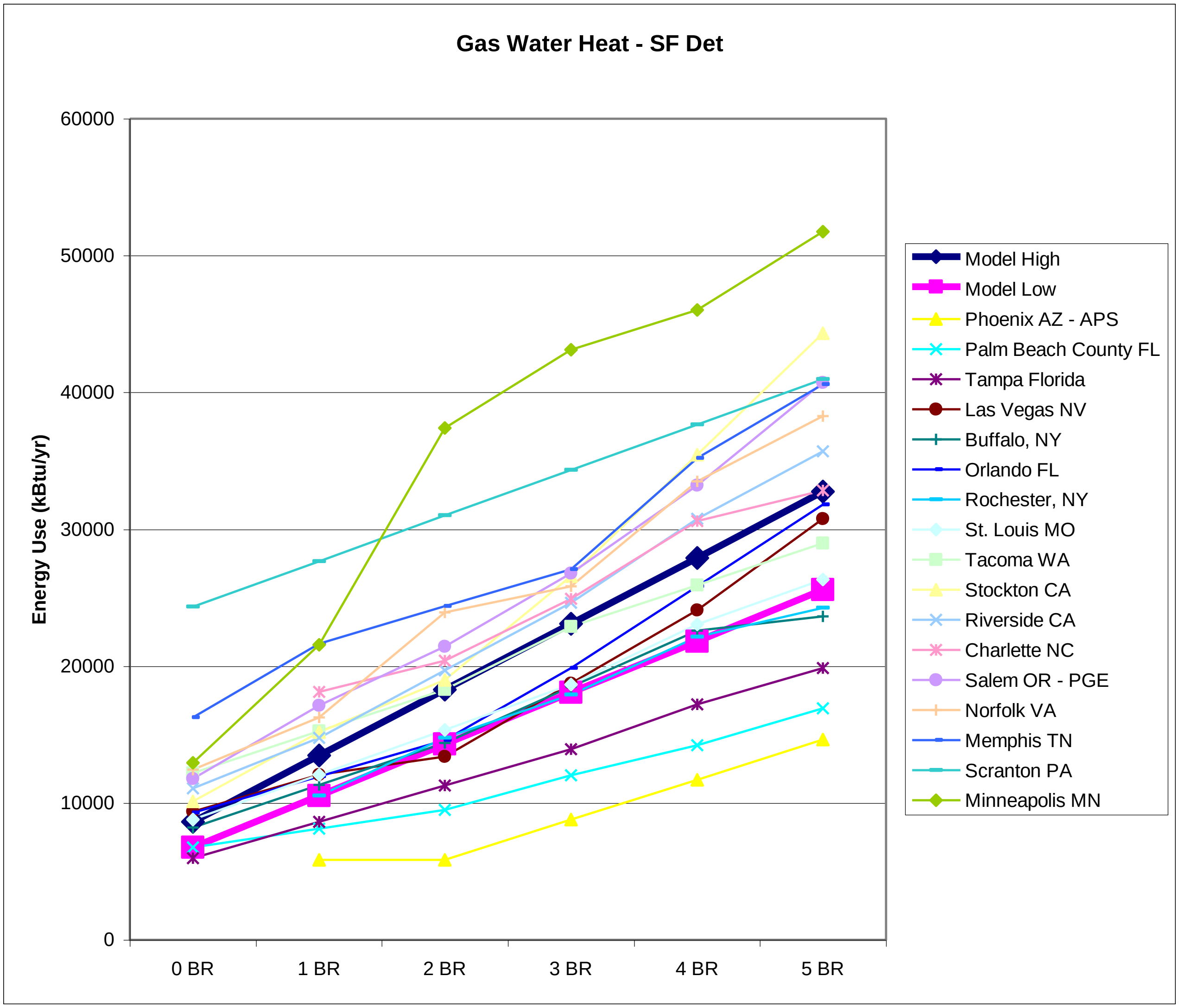
5.5 Natural Gas Water Heating Graphs




Gas Water Heat - Apt 5+
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Palm Beach County FL
Tampa Florida
Las Vegas NV
Buffalo, NY
Orlando FL
St. Louis MO
Richmond, VA
Tacoma WA
Minneapolis MN

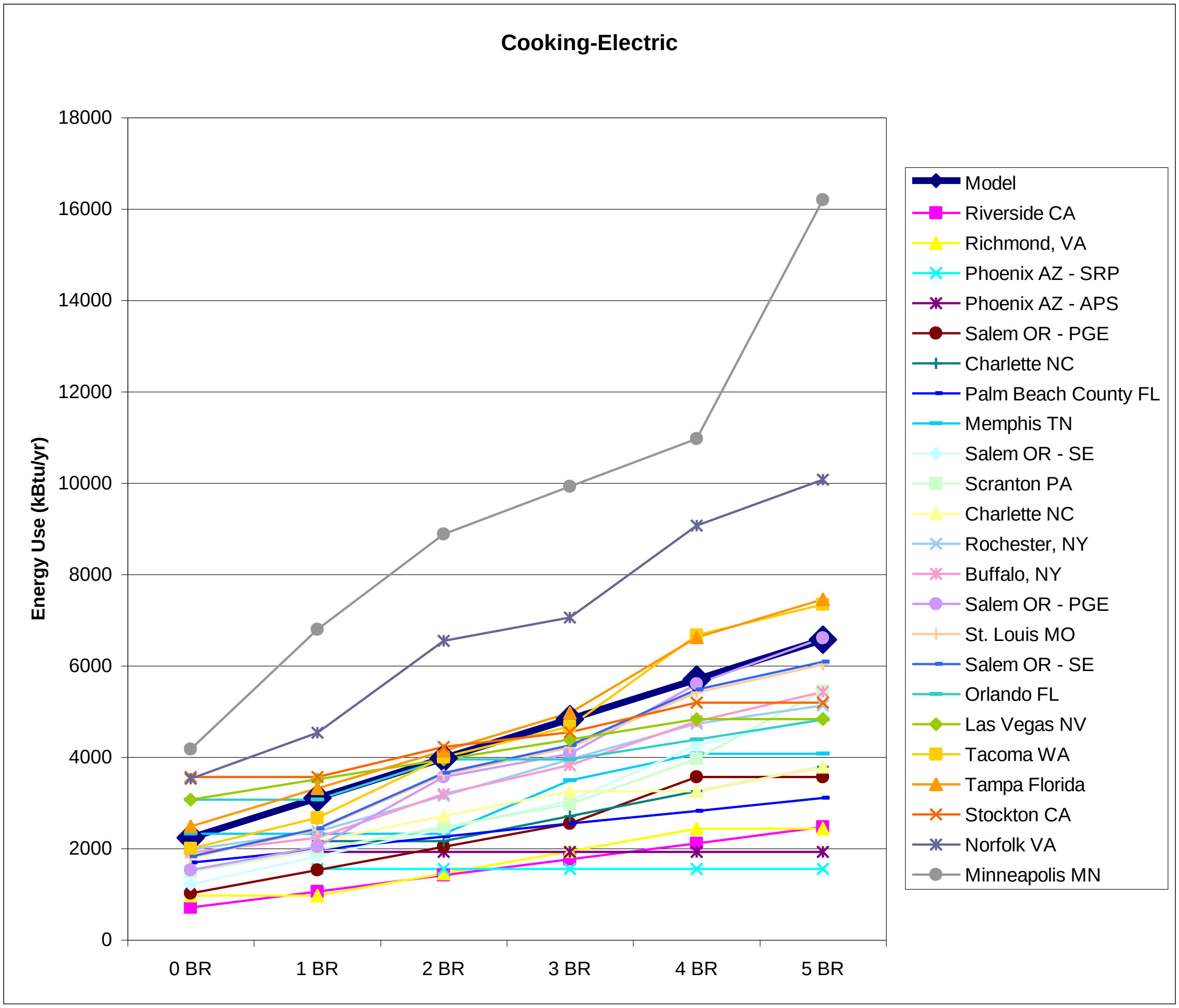

Gas Water Heat - Mobile
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Tampa Florida
Buffalo, NY
St. Louis MO

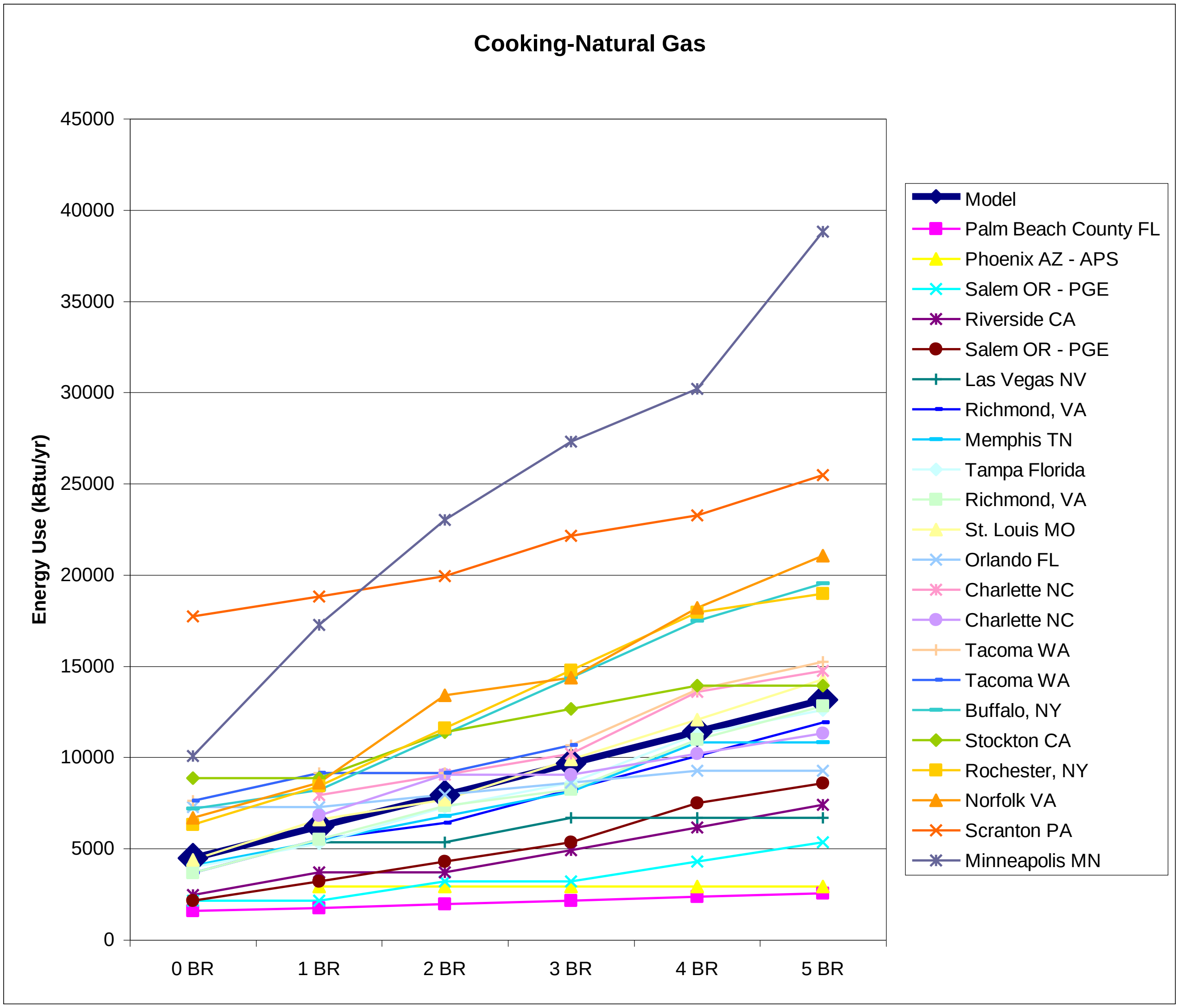

Gas Water Heat - SF Att
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Phoenix AZ - APS
Buffalo, NY
Rochester, NY
St. Louis MO
Charlette NC
Salem OR - PGE
Tacoma WA
Stockton CA
Norfolk VA
Scranton PA
Minneapolis MN



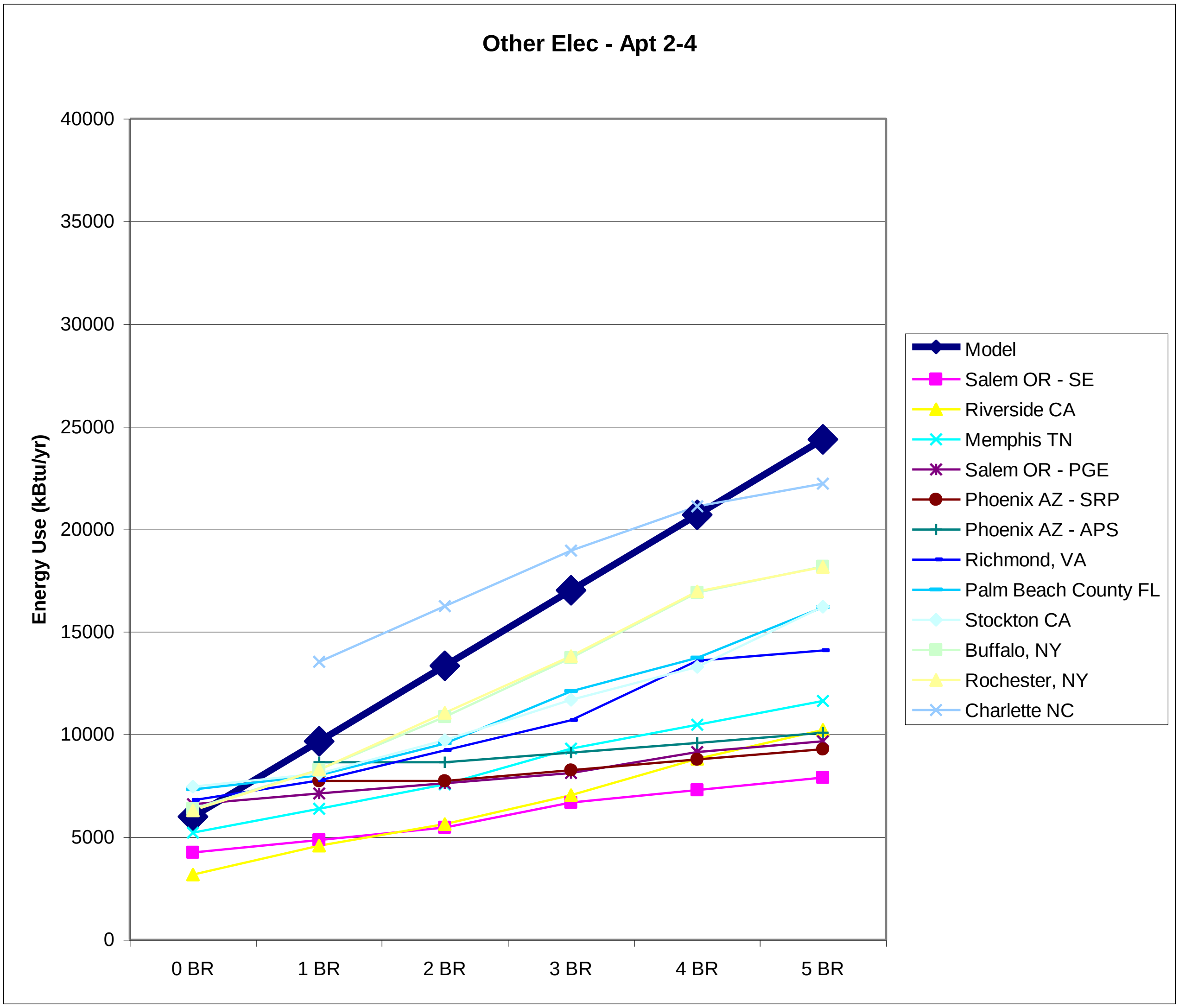
Gas Water Heat - SF Det
Energy Use (kBtu/yr)
60000
50000
40000
30000
20000
10000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model High
Model Low
Phoenix AZ - APS
Palm Beach County FL
Tampa Florida
Las Vegas NV
Buffalo, NY
Orlando FL
Rochester, NY
St. Louis MO
Tacoma WA
Stockton CA
Riverside CA
Charlette NC
Salem OR - PGE
Norfolk VA
Memphis TN
Scranton PA
Minneapolis MN

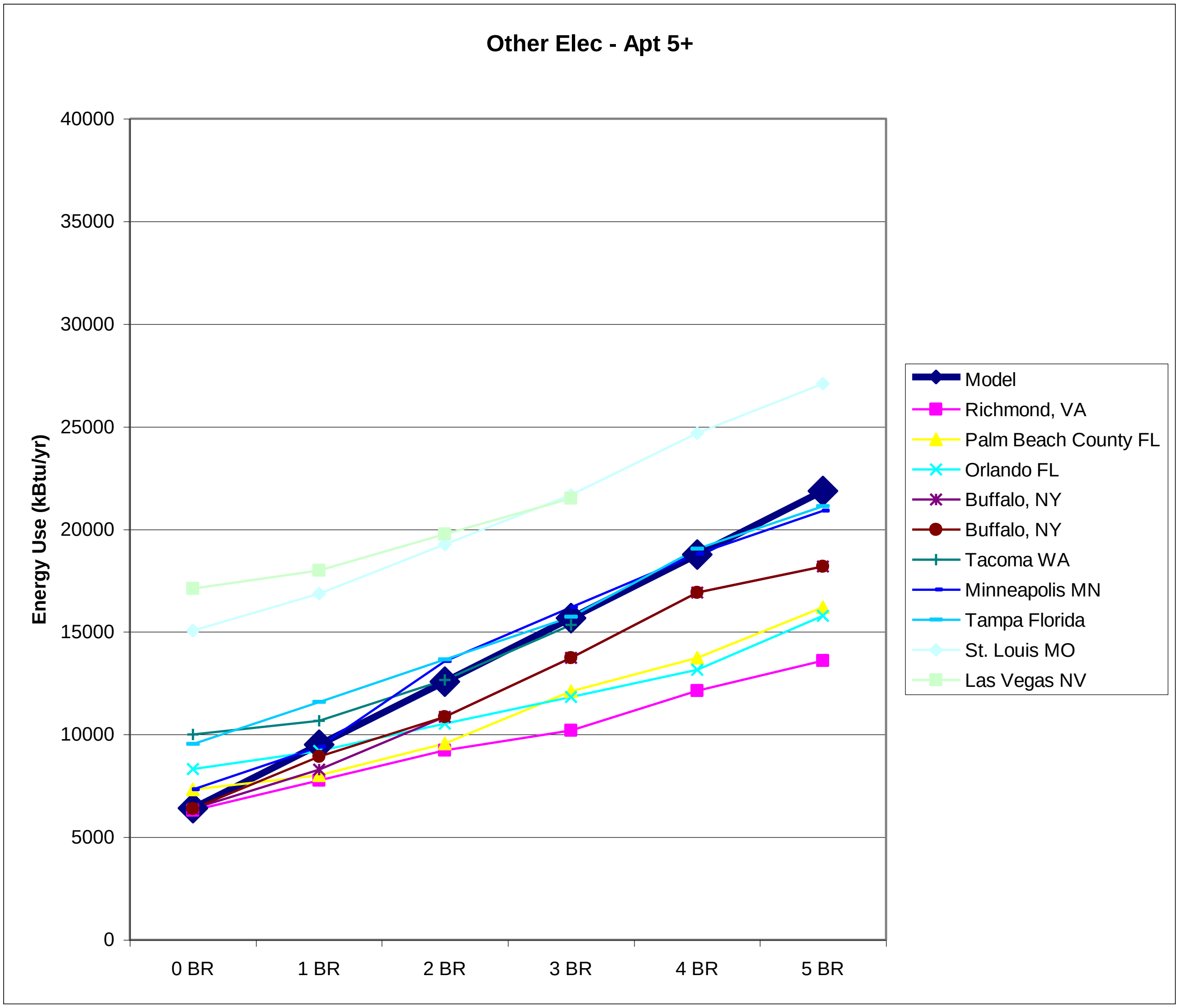
5.6 Cooking Graphs




Cooking-Natural Gas
Energy Use (kBtu/yr)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model
Palm Beach County FL
Phoenix AZ - APS
Salem OR - PGE
Riverside CA
Salem OR - PGE
Las Vegas NV
Richmond, VA
Memphis TN
Tampa Florida
Richmond, VA
St. Louis MO
Orlando FL
Charlette NC
Charlette NC
Tacoma WA
Tacoma WA
Buffalo, NY
Stockton CA
Rochester, NY
Norfolk VA
Scranton PA
Minneapolis MN

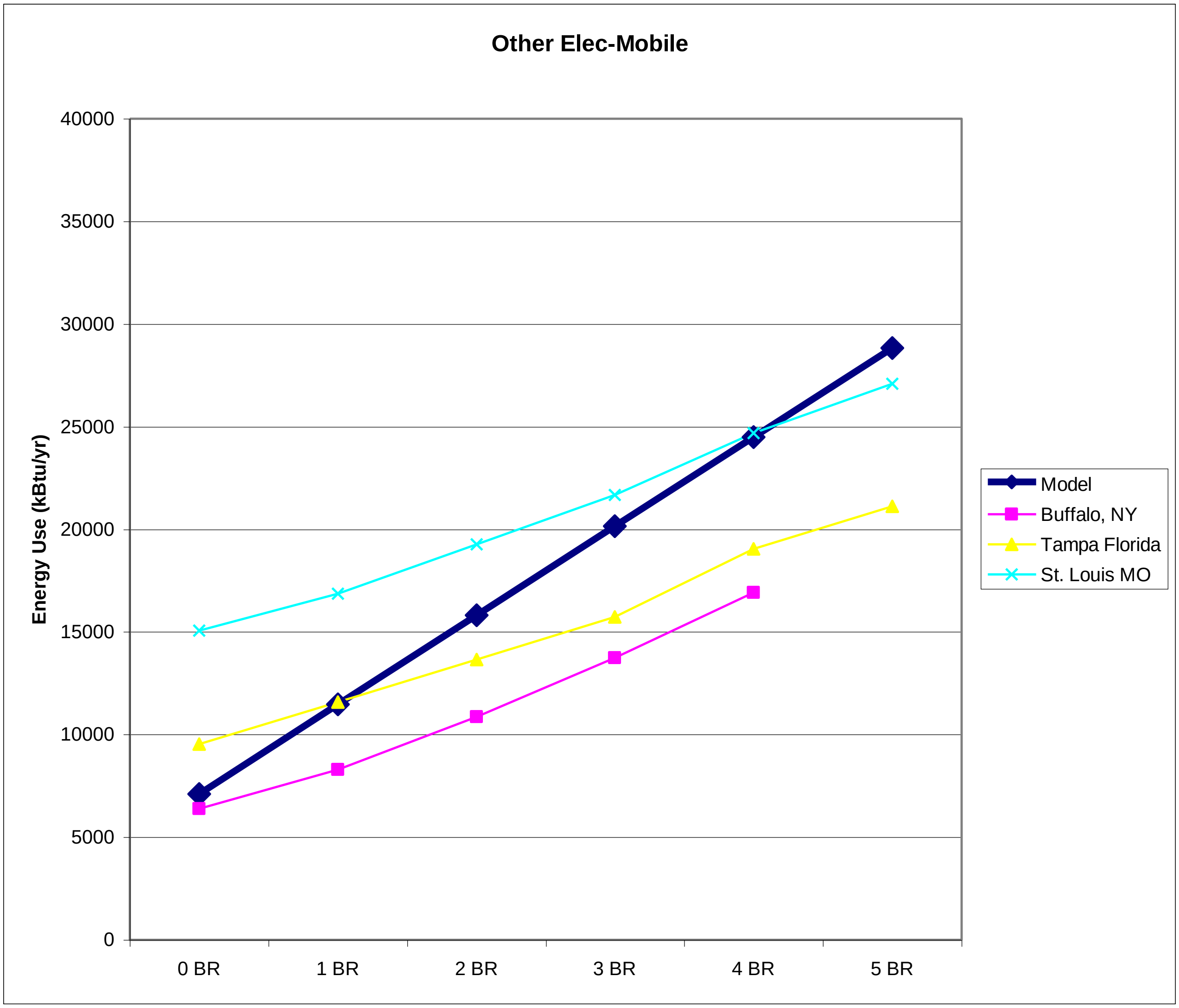
5.7 Other Electric Graphs

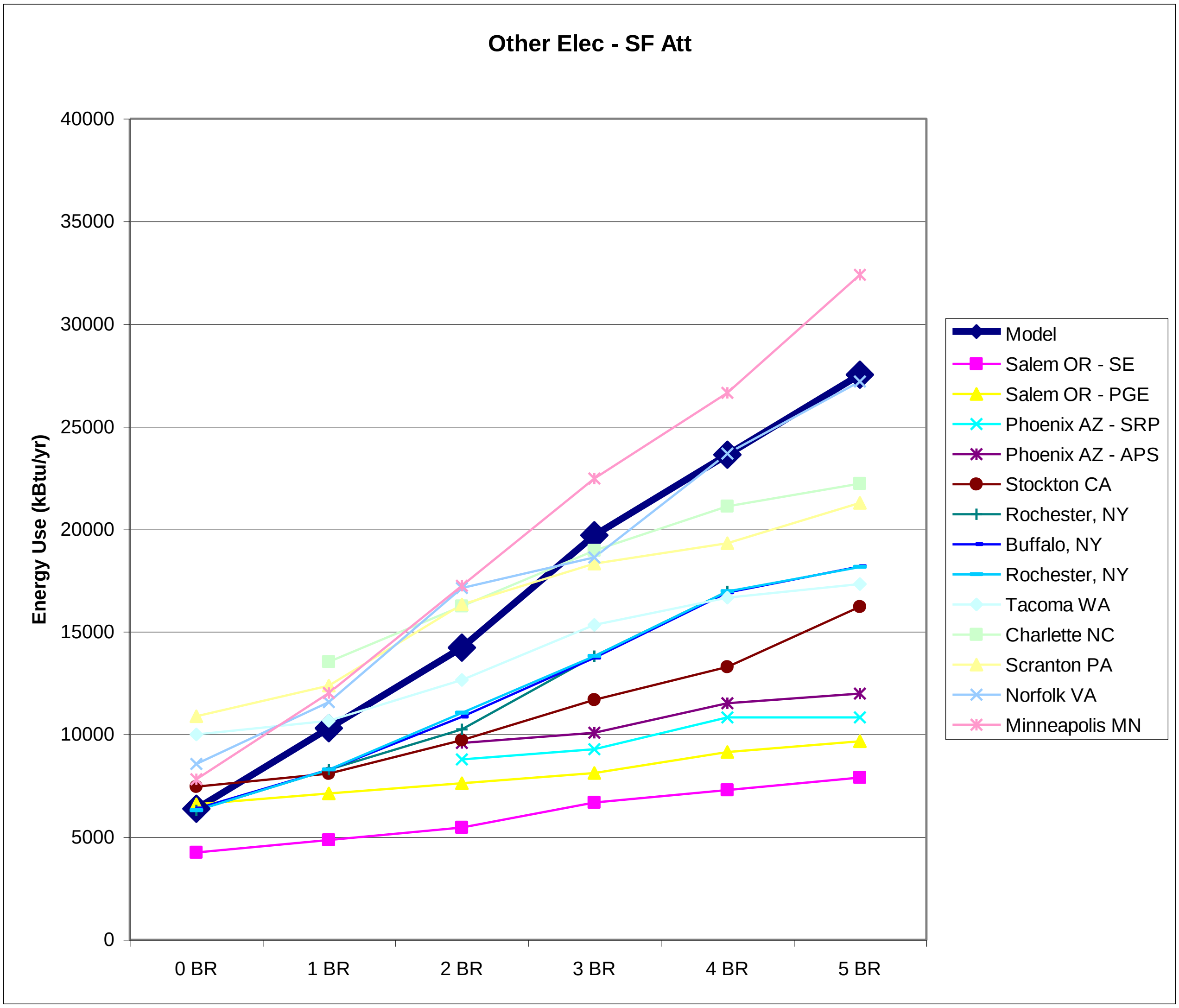


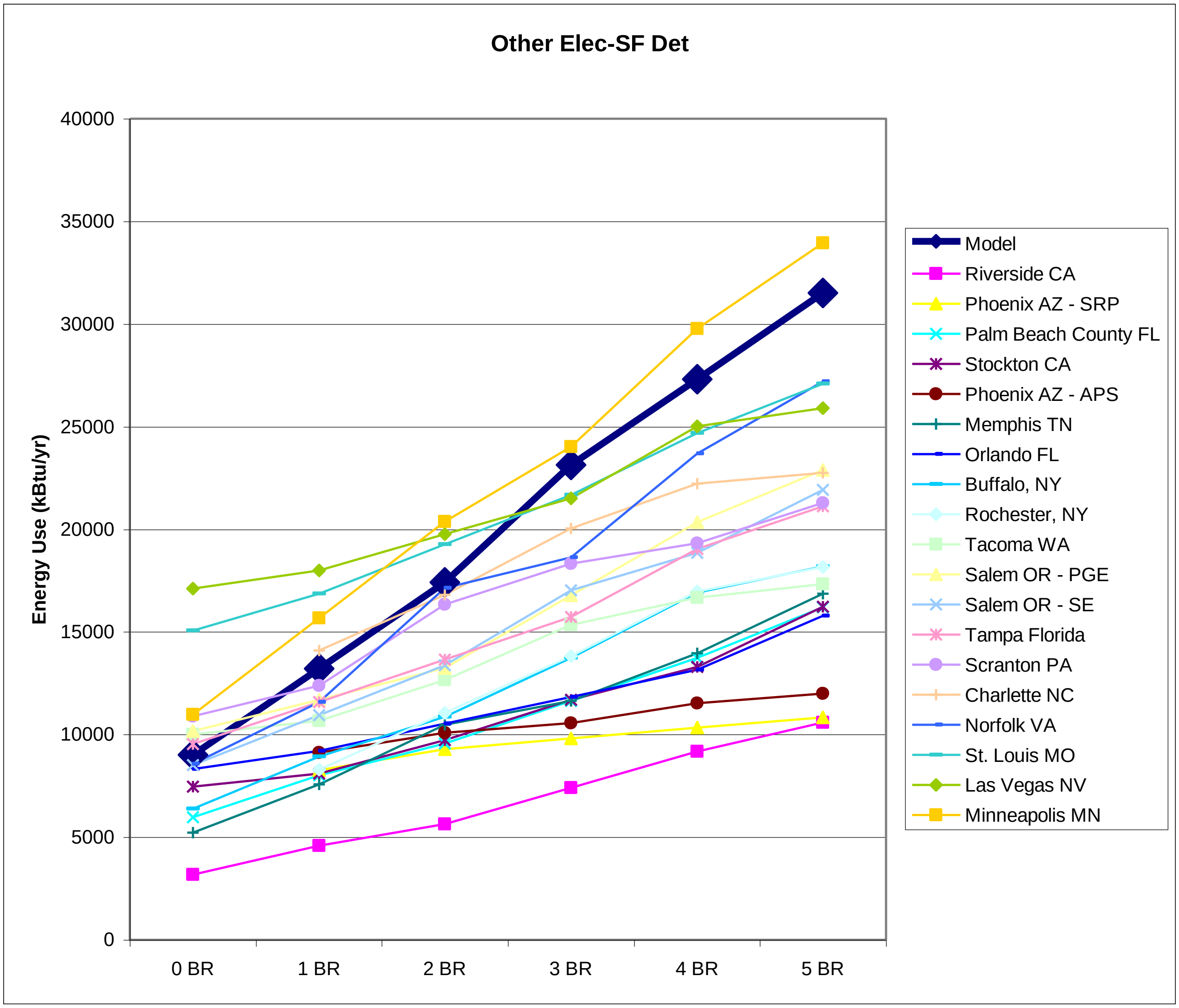


Other Elec - Apt 5+
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model
Richmond, VA
Palm Beach County FL
Orlando FL
Buffalo, NY
Buffalo, NY
Tacoma WA
Minneapolis MN
Tampa Florida
St. Louis MO
Las Vegas NV

Figure X show




Other Elec - SF Att
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model
Salem OR - SE
Salem OR - PGE
Phoenix AZ - SRP
Phoenix AZ - APS
Stockton CA
Rochester, NY
Buffalo, NY
Rochester, NY
Tacoma WA
Charlette NC
Scranton PA
Norfolk VA
Minneapolis MN


Other Elec-SF Det
Energy Use (kBtu/yr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0 BR
1 BR
2 BR
3 BR
4 BR
5 BR
Model
Riverside CA
Phoenix AZ - SRP
Palm Beach County FL
Stockton CA
Phoenix AZ - APS
Memphis TN
Orlando FL
Buffalo, NY
Rochester, NY
Tacoma WA
Salem OR - PGE
Salem OR - SE
Tampa Florida
Scranton PA
Charlette NC
Norfolk VA
St. Louis MO
Las Vegas NV
Minneapolis MN