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Author

Eto, J.H.

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A Comparison of Weather Normalization Techniques for Commercial Building Energy Use*

Joseph H. Eto

Applied Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA. 94720

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ABSTRACT

Compilations of measured energy savings have shown that engineering calculations do not always correlate well with actual performance. One important difference between engineering calculations and real world performance is the effect of weather. Energy service companies, whose profits are a function of energy savings, and building energy researchers have developed weather-normalization formulas or techniques. True tests to determine the adequacy of these methods, however, require careful control of other determinants of building energy use. This paper describes results obtained by using a building energy simulation tool to evaluate some of these methods for commercial buildings.

Degree-day-based normalization techniques designed to account for the effects of weather on commercial building energy use are identified. The normalization techniques are compared using the results of DOE-2 simulations for two office building prototypes using many years of actual weather data for a single location. We conclude that, for the prototypes and location examined, the techniques performed reasonably well, and the sophisticated techniques did not perform noticeably better than the simpler ones.

A Comparison of Weather Normalization Techniques for Commercial Building Energy Use

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INTRODUCTION

Engineering estimates of the savings from conservation measures often fail to explain subsequent changes in utility bills. This failure should come as no surprise since measures designed to save energy are only one of many factors influencing total energy use. When analyzing energy use by buildings, one important and uncontrollable factor is the influence of weather. A cold year can reduce savings as easily as a hot year can increase them, due to a measure implemented to save heating fuel. To measure energy savings attributable to conservation investments in real buildings, techniques must be developed to account for the influence of weather on building energy use.

Energy service companies, whose compensation is a function of energy savings, have begun to develop weather normalization techniques for energy consumption. That is, most shared-savings contracts include provisions to account for the effects of weather in the determination of energy savings. While no method is universally accepted, trends have begun to emerge. For example, heating and cooling degree-days are commonly relied upon to represent weather variations. True tests to determine the adequacy of these methods, however, require careful control of the other determinants of building energy use. With the aid of a building energy simulation model, this requirement forms the basis for our evaluation of several degree-day-based weather normalization methods for commercial buildings.

The outline of this paper is as follows. First, we describe the use of degree-day weather statistics in normalization techniques for building energy use. Second, we describe several degree-day-based weather normalization techniques currently in use and outline our approach for evaluating them. Third, we compare the results of our simulations to those predicted by the normalization techniques. Fourth, we discuss these comparisons and the implications for the normalization techniques examined.

WEATHER NORMALIZATION TECHNIQUES

Two factors have guided the development of weather normalization formulas contained in shared savings contracts. The first is accuracy and the second is ease of implementation. Implementation issues include weather data availability and simplicity of the normalization procedures, which includes such issues as understandability and credibility. While we will address only the issue of accuracy in the present work, it is important to understand that ease of implementation has tended to direct current formulations of these procedures. It is primarily for this reason that the most common techniques for normalization rely on degree-day representations of weather. Degree-days have been published by weather bureaus for many years and are familiar to most building owners and operators as a measure of weather variation. Both heating and cooling degree-days may be used depending on the nature of the conservation measure.

Of course, air temperatures, particularly when expressed as degree-days, are only one component of the many climatic influences on building energy performance. Insolation, humidity, wind speed, and numerous other factors are all part of the effect of weather on energy use in buildings. Therefore, an important goal of the present work is to examine just how well the simplified characterization of weather embodied in the degree-day serves to explain energy use.

Heating degree-days were first developed by heating fuel and district heating suppliers to estimate customer heating requirements (American Gas Association 1980). In the present context, it is important to understand that the suppliers were primarily interested in forecasting the aggregate demands of residential customers, not those of individual residences or commercial structures. Much of the subsequent discussion involving degree-days has continued to center on residential buildings but the focus has shifted to examinations of the appropriateness of the concept for explaining the impact of weather on energy use of individual structures.

Heating degree-days are defined as the sum of the positive differences between a base temperature and the average daily outdoor dry-bulb temperature for a given time period (ASHRAE, 1980). Formally,

$$Heating\ Degree{-}Days = \sum_{i=1}^{N} (Base\ T - Average\ Daily\ T) \qquad (1)$$

where

$$(\text{Base T - Average Daily T}) > 0$$

and

$$\text{Average Daily T} = (\text{Max Daily T - Min Daily T}) \,/\, 2 \,.$$

Cooling degree-days are calculated in an analogous manner by summing the temperature differences between the base and average daily outdoor temperature, when the average exceeds the base temperature.

The base temperature has been traditionally defined as 65 F (18.3 °C), but this is only a rule of thumb. The physical significance of the base temperature can be thought of as the outdoor temperature at which internal plus solar gains offset heat losses. Outdoor temperatures below this threshold indicate the need for additional heat. Correspondingly, outdoor temperatures above this threshold indicate the need for heat removal (cooling). For this reason, the term "balance point" temperature is often used interchangeably with base temperature. The additive nature of the degree-day statistic assumes that the need for cooling or heating varies linearly with these temperature differences.

Work described by Nall and Arens (1979) indicates that, for residential structures, much lower base temperatures are appropriate due to better construction practices, including higher insulation levels. Indeed, it is possible to solve analytically the appropriate balance point temperature by explicitly considering the indoor temperature, internal and solar gains, and the envelope heat loss due to conduction, air leakage, and sky radiation (Kusuda et al. 1981). In this formulation, it is clear that the balance point temperature is uniquely determined by the physical properties, location, and operation of each structure. In practice, however, the analytical solution is extremely difficult to implement, given the enormous data requirement involved.

Researchers have developed a technique for explaining observed building energy performance that by-passes the need for a direct analytical solution for the balance point temperature (Fels 1984). Their approach utilizes statistical techniques to explain energy use with three parameters, a non-temperature-sensitive component or "intercept", and a temperature-sensitive component consisting of a heating "slope", and the number of degree-days to a calculated base temperature. In this approach, the base temperature is defined by the base temperature corresponding to the best fit of energy use to degree-days, as measured by the R-square statistic. While the use of regressions to estimate these parameters does begin to obscure the physical interpretation of the parameters, the researchers have had good success in analyzing the influences of weather on the heating energy consumption of residential structures (Mayer and Benjamin 1977).

Recently, variants of this approach have appeared in more sophisticated shared savings contracts for commercial buildings (Breed 1985). While not identical to the approach described above, these contracts acknowledge the uniqueness of the balance point for each building and attempt to find the appropriate base temperature based on statistical fits of energy use to degree-days to different base temperatures.

A technique well-proven for residential structures is not necessarily appropriate for commercial ones. Commercial buildings differ considerably from residential buildings, both in the types of systems used to provide space conditioning and in the hours the building systems are operated. For example, in residential buildings, degree-days are calculated based on temperatures that may occur throughout a 24-hour period, while commercial buildings are typically operated during only a fraction of these hours. Also, large commercial buildings may have simultaneous heating and cooling requirements due to lower surface-area-to-volume ratios, greater internal gains, and more complex HVAC systems.

ANALYTICAL APPROACH

Field tests of the accuracy of any weather normalization technique for commercial (or residential) buildings are difficult to carry out. The primary reason is that a true test for the accuracy for a weather normalization technique must hold fixed all conditions but variations in weather. Building operation and occupancy must be held constant to ensure that all changes in energy use are due solely to the effects of weather. In real buildings, these conditions cannot be met. For this reason, computerized building energy simulation models are a practical alternative for studying the effects of weather on building energy use.

Our evaluation of degree-day-based weather normalization techniques relied on multiyear computer simulations for two different office building prototypes. For both prototypes, all operating schedules and conditions were held fixed for each year of weather. The monthly results for each building type and fuel, and the corresponding heating and cooling degree-days formed a data set for the evaluations.

The evaluation replicated current application of degree-day-based weather normalization techniques for measuring energy conservation savings. Following these applications, energy use from one year is taken to be the base or preretrofit year of consumption. A normalization technique is then applied to the data set for this base year. Application of a technique yields parameters that relate energy use to degree-days. Our evaluation consisted of using the results from the base year to "predict" consumption in the other years based on the degree-days from the other years. Differences between these predictions and the computer simulation results is then taken to be a measure of the accuracy of the technique in question. Several different base years were used to "predict" consumption in other years to illustrate the effect of the selection of the base year on the accuracy of the technique. In the remainder of this section, we describe the computer model, building prototypes, and weather data used, and the four degree-day-based weather normalization techniques that were evaluated.

Monthly energy requirements were estimated using the DOE-2 building energy analysis program (version 2.1C). The DOE-2 program was developed for the Department of Energy to provide architects and engineers with a state-of-the-art tool for estimating building energy performance (Curtis et al. 1984).

The simulations were performed using 12 years of weather data for Madison, WI. In each of these runs, only weather data were allowed to change; all other aspects of the building were held fixed. The data set was developed to provide building energy researchers quality-controlled, historical hourly solar insolation and collateral meteorological data for 27 U.S. weather stations (National Climatic Center 1984). Figures 1 and 2 present annual heating and cooling degree-days, base 65 F (18.3 °C), for this location. Monthly heating and cooling degree-day statistics for base temperatures 41 F (5 °C) to 79 F (26.1 °C) (in 2 F (1.1 °C) increments) were also generated for each year of weather.

The two simulated office buildings were based on actual buildings of recent vintage, but modifications were made to ensure compliance with ASHRAE Standard 90-1975 (ASHRAE 1975). Operating schedules and temperatures were taken from the Standard Building Operating Conditions developed for the Building Energy Performance Standards (DOE 1979). The HVAC systems were designed so that only electricity would be used for cooling/chilled water and that only natural gas would be used for heating/hot water. Of course, electricity is also used for lighting, fans, pumps, etc. Major features of the two office building prototypes are summarized on Table 1. Figures 3 and 4 illustrate annual variations in energy use normalized by floor area for the two building types.

Heating degree-days were then correlated with natural gas consumption and cooling degree-days with electricity consumption. The correlations took the following general form:

$$Energy\ Use = A + BX \tag{2}$$

where

A = Intercept (BTU)
B = Heating or cooling slope (BTU/DD)
X = Heating or cooling degree-Days

This general form was modified so that four commonly used degree-day-based weather normalization techniques could be studied.

The most elementary technique, No Correlation, ignores weather variations altogether. This technique simply takes one year's consumption and assumes that consumption in other years will be identical. In our general model, this is represented simply by setting the slope term, B, equal to zero.

The next technique, Complete Correlation, assumes that all energy use is correlated with degree-day variations in weather. Referring to our model, the intercept term, A, is set equal to zero. In keeping with its most popular formulation, the base temperature for the degree-days is set at 65 F (18.3 °C).

The third technique, Fixed Base Temperature, relies on both an intercept, A, and a slope, B. The estimates of A and B are developed by regressing monthly degree-days on monthly energy use. Degree-days and energy use were first normalized for varying numbers of days in a month. The base temperature for the degree-days is again set to 65 F (18.3 °C).

The fourth technique, Variable Base Temperature, requires a two stage analysis of statistical correlations between degree-days and energy use. Both degree-days and energy use are again first normalized to daily values. The intercept, slope, and number of degree-days are selected from the best correlation of degree-days, at a given base temperature, with energy use. The best correlation is defined as the correlation having the highest R-square.

For each of these four techniques and for each combination of fuel and building type (large office natural gas, large office electricity, medium office natural gas, and medium office electricity), three different base years were selected and used to "predict" consumption in other years. The selection of these years worked backwards from the fourth technique, Variable Base Temperature. The Variable Base Temperature technique produced a unique set of parameter estimates for the intercept, slope, and best base temperature for each year of data. We selected the years corresponding to the lowest, highest, and median slope for evaluation. For these years (low, high, median), the corresponding sets of estimates for each of the the other three techniques were evaluated. For example, the year in which the best fit for the Variable Base Temperature heating-degree-day correlation with natural gas use by the medium-sized office yielded the highest slope estimate was 1953, the lowest 1960, and the median 1959. For the Fixed Base Temperature technique, the parameter estimates from the correlation with degree-days to base 65 F (18.3 °C) for these same years were evaluated. Similarly, the simple ratio of natural gas use to heating degree days for 1953, 1960, and 1959 was used to evaluate the second technique. Finally, total natural gas consumption in these years, uncorrected for degree-days, was used to evaluate the first technique.

RESULTS

For each building and fuel type, parameter estimates were developed for each normalization technique using a single year of data. Three of these sets of estimates were used to predict energy consumption for each of the 12 years of weather data. In this section, we discuss the parameter estimates and compare the results of the predictions to the original DOE-2 estimates.

Tables 2 through 5 present the parameter estimates developed for each combination of fuel and building type. Also indicated are the base years selected for predicted energy use in other years.

Examination of these tables reveals an important aspect of the regression-based, degree-day weather normalization techniques, Fixed Base Temperature and Variable Base Temperature: The physical significance of the parameters developed by correlating energy use with degree-days is tenuous. The physical basis for the analytical form of the the regression equation (see Equation 2) suggests that the parameters are invariant for different years. That is, for each building, there is a unique balance point temperature, intercept, and slope, such that only variations in degree-days affects total consumption. Between years, we find that the statistical fits yield substantial variation in the estimates of the individual parameters. Indeed, for natural gas consumption in the medium office, the best fits for the Variable Base Temperature technique indicate that the nonweather sensitive component of energy use, the intercept term, is negative in years 1955, 1957, and 1960. The variations are, however, somewhat correlated. A large estimate for the intercept term is associated with a comparatively lower estimate for the slope term.

The physical interpretation of the estimates aside, the worth of these techniques is measured by their accuracy in "predicting" consumption in other years. The net level of error associated with the sets of parameter estimates derived from single years of data for the different techniques is summarized on Tables 6 through 9. Net error is measured by percentage difference between the total of 12 years of predictions and the total of 12 years of DOE-2 estimates. This choice of presentation allows discrepancies between predictions and DOE-2 estimates to offset each other over the years. Our motivation in selecting this form of presentation was that, if errors tended to cancel out one another, the building owner would remain relatively indifferent (save for the time value of money and the escalation rate of energy prices). The statistic, then, is a measure of the bias of the estimators not their efficiency.

Table 6 presents the results for electricity consumption by the large office building. It is apparent that assuming all consumption is correlated with cooling degree-days (Complete Correlation) leads to substantial errors in predictions. This result is consistent with the fact that electricity is used for far more than just cooling in this building. Between the other techniques, a clearly superior technique does not emerge; the net errors are quite small, typically on the order of 2%. Assuming no correlation with cooling degree-days (No Correlation) produces the lowest net error for the weather years examined. Again, this result is a reflection of the large amount of electricity used for noncooling purposes (more properly, noncooling in response to the influence of the outside environment).

Table 7 summarizes the results for natural gas consumption by the large office building. For natural gas, assuming no correlation with heating degree-days (No Correlation) produces estimates with the greatest net errors. These errors are, nevertheless, comparable to those associated with the other techniques, which do take account of heating degree-days. For these techniques, solving for a unique base temperature (Variable Base Temperature) appears to yield the lowest level of error. Somewhat unexpectedly, ignoring the intercept term entirely (Complete Correlation) produces results comparable with the other degree-day-based techniques.

Tables 8 and 9 present the corresponding results for the medium office building. For electricity consumption, the results are qualitatively very similar to those for the large office building. Ignoring the intercept term (Complete Correlation) produces the greatest net error. Including the intercept term (Fixed Base Temperature and Variable Base Temperature) leads to very few errors, which are nearly identical in magnitude.

As for natural gas consumption in the medium office building, there are striking differences from the results for the large office building. Assuming no intercept (Complete Correlation) yields the lowest net error, while the variable base temperature technique (Variable Base Temperature) yields the greatest net error. Thus, even though this technique selects parameter estimates based on the best fit with one year of information, using these parameters to predict consumption in other years leads to greater net error in those years compared to the techniques that use a fixed 65 F (18.3 °C) base temperature.

Comparing individual predictions to DOE-2 estimates so that the magnitude and distribution of individual errors can be seen illustrates the efficiency of the parameter estimates for each technique. Figures 5 through 8 present this information for each building type and fuel in the form of plots of percentage differences between predictions and DOE-2 estimates for the median year selected for each technique. These results are consistent with those for the low and high years selected. For the electricity consumption, plots for the Complete Correlation technique were eliminated because the great size of the individual errors suppressed the relative size of the errors for the other techniques.

DISCUSSION

Comparisons of predicted energy consumption with DOE-2 estimates represent an idealized environment for evaluating weather normalization techniques. By holding all features of the simulations fixed (excluding weather), we assume that variations in estimated energy use are driven by variations in the weather. The accuracy of a normalization technique is thus measured by comparing predictions with the DOE-2 estimates.

The results presented in the previous section indicate that all of the techniques (with the exception of the Complete Correlation technique when applied to electricity consumption) performed reasonably well for the prototypes and climate examined. That is, with the exception of the previously mentioned technique, no error was greater than 10% over the 12 years; most were within 3%. Reasonableness must, of course be evaluated in the context of the anticipated savings, which are being measured indirectly. An absolute error of 10% for a measure designed to save only 5% is very significant. Perhaps the most important result was that, in the long run, the more sophisticated techniques (statistical correlations with degree-days to a fixed or variable base temperature) did not perform noticeably better than the simpler techniques.

These results must be prefaced by a comment. The small net error associated with the No Correlation technique highlights the fact that, for the climate studied, on an annual basis the buildings do not exhibit a great deal of variation in energy use. A technique applied to one year of information, therefore, will probably not be far from the mark for the other years. Put another way, whatever sensitivity there is tends to even out in the long run. For a conservation measure designed to pay-back in short period of time, however, recourse to the long run may not be available.

CONCLUSION

We have described the development of degree-day measures of weather variations and the use of degree-days in energy normalization techniques. To assess the accuracy of techniques, which rely on degree-days, we evaluated four generic normalization techniques with the aid of computer simulations of energy use using many years of real weather data for two office building prototypes. The evaluation consisted of developing several sets of parameter estimates for each technique according to information derived from a single year and using these estimates to predict energy consumption for the other years.

We observed that for the single climate examined the buildings exhibited only small fluctuations in annual energy use. We concluded that, with the exception of relating all electricity consumption to cooling degree-days, the techniques performed reasonably well. We noted in particular that the more sophisticated techniques, which rely on statistical correlations of energy use with variable and fixed base temperature degree-days, did not perform noticeably better than the simpler techniques.

We anticipate future studies to examine the resiliency of our findings by applying the methodology described in the current work to other climates and building prototypes.

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TABLE 1

Summary of Office Building Prototypes

	Large Office	Medium Office
Size	597,500 ft^2	48,600 $ft.^2$
Shape	38 floors, 2 basement levels, flattened hexagon in cross section, approximately 18000 $ft.^2$/floor	3 floors, rectangular in cross section, approximately 16,000 $ft.^2$/floor.
Construction	Steel frame, limestone cladding	Steel frame superstructure, exterior walls of 4" pre-cast concrete panels
Glazing	25% of wall area	36% of wall area
Operation	8 a.m. - 6 p.m. weekdays, with some evening work, 30% occupancy on Saturday, closed Sundays and holidays	Identical to large office
Thermostat Settings	78 F Cooling 72 F Heating (night and weekend setback 55 F)	Identical to large office
Internal Loads	1.7 W/ft^2 lighting 0.5 W/ft^2 equipment	Identical to large office
HVAC Air-side	2 VAV systems zoned separately for perimeter (w/terminal reheat) and core (no reheat), dry-bulb economizer set at 62 F	Four-pipe fan coil for perimeter, single-zone terminal reheat for core
Outside Air	7 $cfm/ft.^2$	Identical to large office
Heating Plant	2 Gas-fired hot water generators (eff. = 75%)	1 Gas-fired hot water generator (eff. = 75%)
Cooling Plant	2 Hermetic centrifugal chillers w/cooling tower (COP = 4.3)	1 Air-cooled hermetic reciprocating chiller (COP = 2.6)

TABLE 2.

Parameter Estimates for Large Office Electricity Consumption

	Variable Base Temperature				Fixed Base Temperature			Complete Correlation	No Correlation
Year	Base T (F)	Intercept (MWh/day)	Slope (MWh/CDD-day)	R-square	Intercept (MWh/day)	Slope (MWh/CDD-day)	R-square	(MWh/CDD-year)	(MWh/year)
1953	53	21.40	.33	.872	21.80	.82	.820	10.94	8596.00
1954	61	21.30	.56	.864	21.42	.83	.847	12.18	8390.54
1955	51	21.71	.26	.848	22.44	.52	.726	9.33	8671.05
1956	67	21.65	1.14	.891	21.60	.86	.882	13.40	8427.34
1957	55	21.46	.33	.868	21.82	.78	.827	14.98	8402.66
1958	53	21.69	.29	.834	22.28	.76	.694	18.25	8488.12
1959	53	21.50	.30	.866	21.89	.78	.829	10.48	8564.42
1960	57	21.50	.47	.844	21.89	1.08	.755	18.09	8484.75
1961	53	21.04	.37	.813	21.32	1.17	.769	15.99	8397.27
1962	65	21.53	1.30	.898	21.53	1.30	.898	17.45	8496.99
1963	53	21.83	.31	.854	22.38	.77	.770	13.74	8658.11
1964	59	21.72	.47	.924	21.94	.78	.903	12.21	8556.39
All Years	53	21.44	.32	.840	21.95	.78	.760	13.28	8511.14

TABLE 3.

Parameter Estimates for Medium Office Electricity Consumption

	Variable Base Temperature				Fixed Base Temperature			Complete Correlation	No Correlation
Year	Base T (F)	Intercept (MWh/day)	Slope (MWh/CDD-day)	R-square	Intercept (MWh/day)	Slope (MWh/CDD-day)	R-square	(MWh/CDD-year)	(MWh/year)
1953	55	2.02	.02	.755	2.04	.06	.723	1.00	785.97
1954	65	2.00	.06	.736	2.00	.06	.736	1.12	768.57
1955	55	2.00	.02	.797	2.04	.04	.730	.84	780.29
1956	67	2.01	.08	.744	2.01	.06	.729	1.22	769.04
1957	59	2.01	.03	.776	2.02	.05	.757	1.37	766.21
1958	59	2.03	.03	.625	2.05	.05	.569	1.66	777.62
1959	53	2.01	.02	.758	2.02	.05	.718	.96	782.05
1960	59	1.98	.04	.690	2.00	.07	.624	1.63	763.38
1961	51	1.99	.02	.671	2.01	.07	.623	1.47	772.78
1962	65	1.99	.09	.806	1.99	.09	.806	1.58	770.99
1963	49	1.99	.02	.798	2.04	.05	.721	1.24	778.15
1964	57	2.02	.03	.774	2.04	.05	.767	1.11	780.63
All Years	57	2.00	.03	.720	2.03	.05	.681	1.10	774.22

TABLE 4.

Parameter Estimates for Large Office Natural Gas Consumption

Year	Variable Base Temperature				Fixed Base Temperature			Complete Correlation	No Correlation
	Base T (F)	Intercept (MBTU/day)	Slope (MBTU/HDD-day)	R-square	Intercept (MBTU/day)	Slope (MBTU/HDD-day)	R-square	(MBTU/HDD-year)	(MBTU/year)
1953	53	3.16	2.98	.986	-4.08	2.15	.963	1.94	13017
1954	55	3.11	2.70	.988	-3.86	2.11	.968	1.91	13265
1955	59	1.69	2.41	.989	-3.25	2.16	.983	2.00	14691
1956	53	4.70	2.70	.961	-3.15	2.04	.948	1.88	13640
1957	55	2.77	2.78	.986	-5.09	2.23	.967	1.98	14502
1958	55	2.74	2.63	.985	-5.48	2.17	.971	1.90	14008
1959	55	1.63	2.59	.986	-4.78	2.10	.968	1.88	14695
1960	59	1.57	2.26	.968	-3.69	2.05	.962	1.88	14629
1961	53	2.52	2.82	.989	-6.23	2.14	.958	1.84	13959
1962	51	3.86	2.98	.991	-6.30	2.22	.968	1.93	15259
1963	53	3.31	2.69	.992	-7.08	2.21	.975	1.89	15055
1964	51	3.97	3.01	.976	-5.93	2.14	.955	1.84	13268
All Years	5	2.67	2.63	.981	-4.92	2.15	.965	1.91	14166

TABLE 5.

Parameter Estimates for Medium Office Natural Gas Consumption

Year	Variable Base Temperature				Fixed Base Temperature			Complete Correlation	No Correlation
	Base T (F)	Intercept (MBTU/day)	Slope (MBTU/HDD-day)	R-square	Intercept (MBTU/day)	Slope (MBTU/HDD-day)	R-square	(MBTU/HDD-year)	(MBTU/year)
1953	49	.05	.14	.987	-.31	.08	.942	.07	453
1954	51	.02	.12	.987	-.33	.08	.946	.07	453
1955	57	-.04	.10	.996	-.27	.08	.983	.07	518
1956	53	.03	.10	.949	-.27	.08	.928	.07	469
1957	51	-.00	.13	.989	-.42	.09	.947	.07	522
1958	51	.03	.12	.981	-.38	.09	.956	.07	486
1959	49	.04	.12	.986	-.34	.08	.944	.07	513
1960	55	-.02	.10	.936	-.31	.08	.921	.06	498
1961	49	.01	.13	.997	-.42	.08	.938	.06	480
1962	49	.01	.13	.994	-.43	.09	.956	.07	545
1963	49	.02	.12	.992	-.49	.09	.955	.07	532
1964	47	.06	.13	.972	-.37	.08	.932	.06	445
All Years	51	.02	.12	.976	-.36	.08	.944	.07	493

TABLE 6

Results for Large Office Electricity Consumption

Normalization Technique	Percent Differences from DOE-2		
	Year of Estimate		
	1955	1960	1962
Variable Base Temperature	0.6	0.9	2.1
Fixed Base Temperature	0.1	1.9	2.1
Complete Correlation	-29.7	36.2	31.3
No Correlation	1.9	-0.3	-0.2

TABLE 7

Results for Large Office Natural Gas Consumption

Normalization Technique	Percent Differences from DOE-2		
	Year of Estimate		
	1960	1956	1964
Variable Base Temperature	-1.8	-0.4	-0.9
Fixed Base Temperature	-1.9	-1.1	-3.0
Complete Correlation	-1.5	-1.1	-3.2
No Correlation	3.3	-3.7	-6.3

TABLE 8

Results for Medium Office Electricity Consumption

Normalization Technique	Percent Differences from DOE-2		
	Year of Estimate		
	1963	1960	1962
Variable Base Temperature	0.4	-0.3	1.4
Fixed Base Temperature	0.5	0.2	1.4
Complete Correlation	2.2	34.7	31.0
No Correlation	0.5	-1.4	-0.4

TABLE 9

Results for Medium Office Natural Gas Consumption

Normalization Technique	Percent Differences from DOE-2		
	Year of Estimate		
	1960	1959	1953
Variable Base Temperature	-4.9	-5.4	8.4
Fixed Base Temperature	-5.2	-1.5	4.1
Complete Correlation	-3.6	-0.9	1.5
No Correlation	1.1	4.2	-8.2

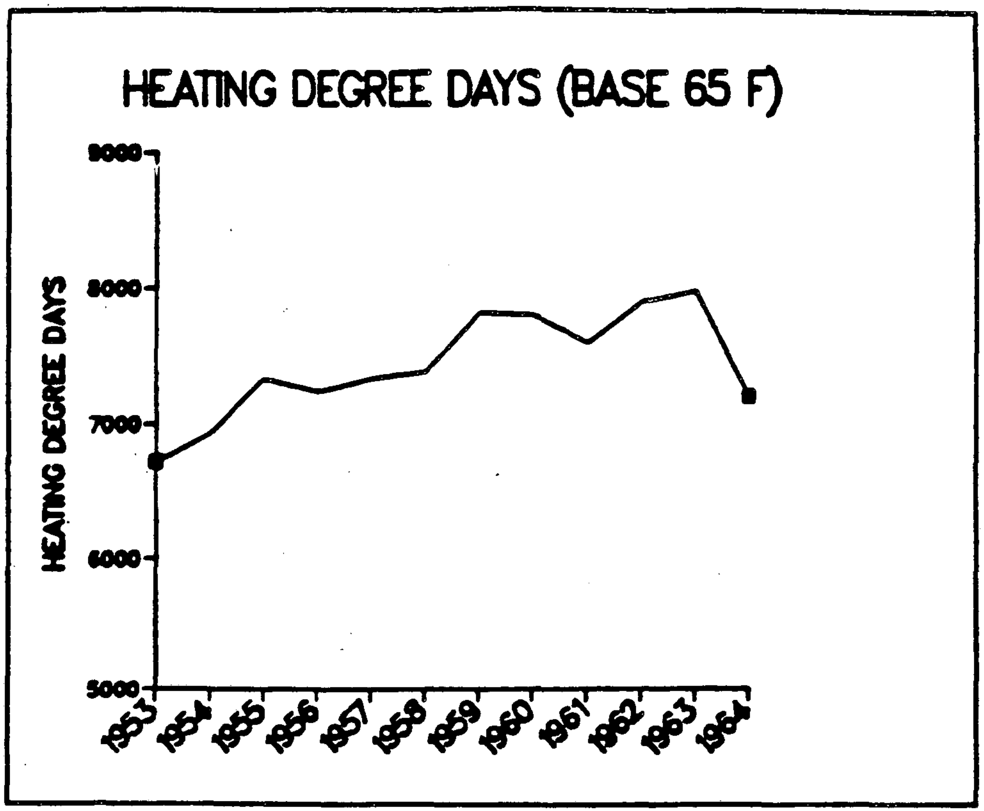

Figure 1. Heating Degree-Days (Base Temperature = 65 F) for Madison, WI.

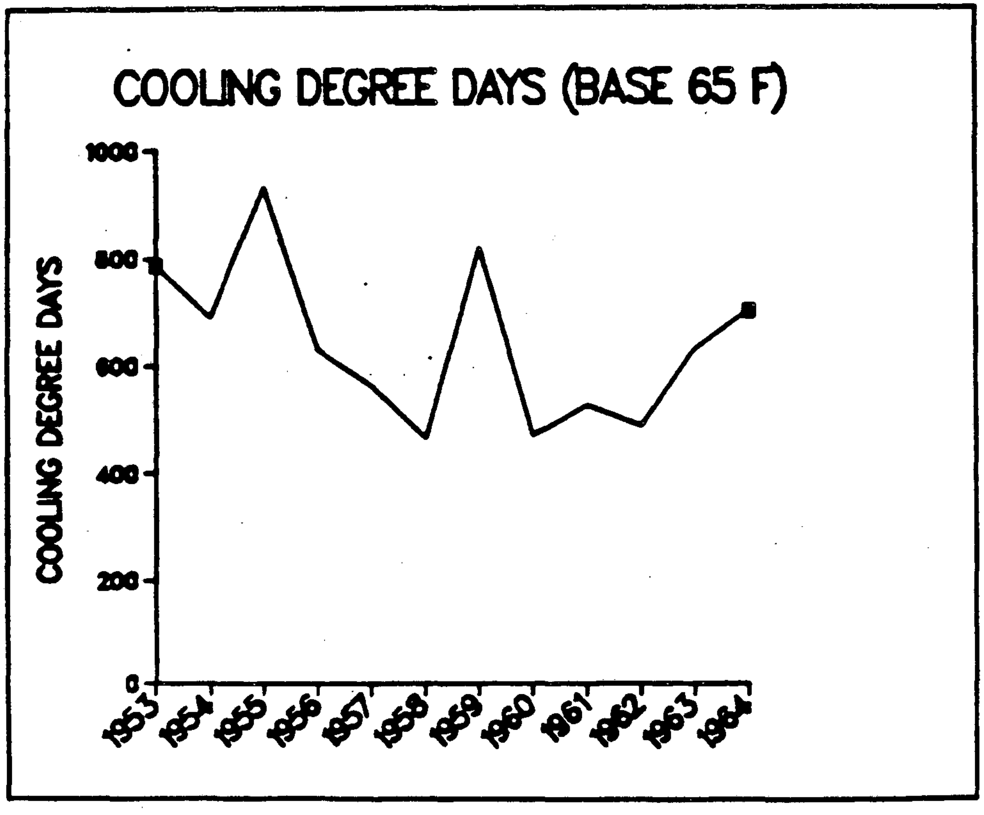

Figure 2. Cooling Degree-Days (Base Temperature = 65 F) for Madison, WI.

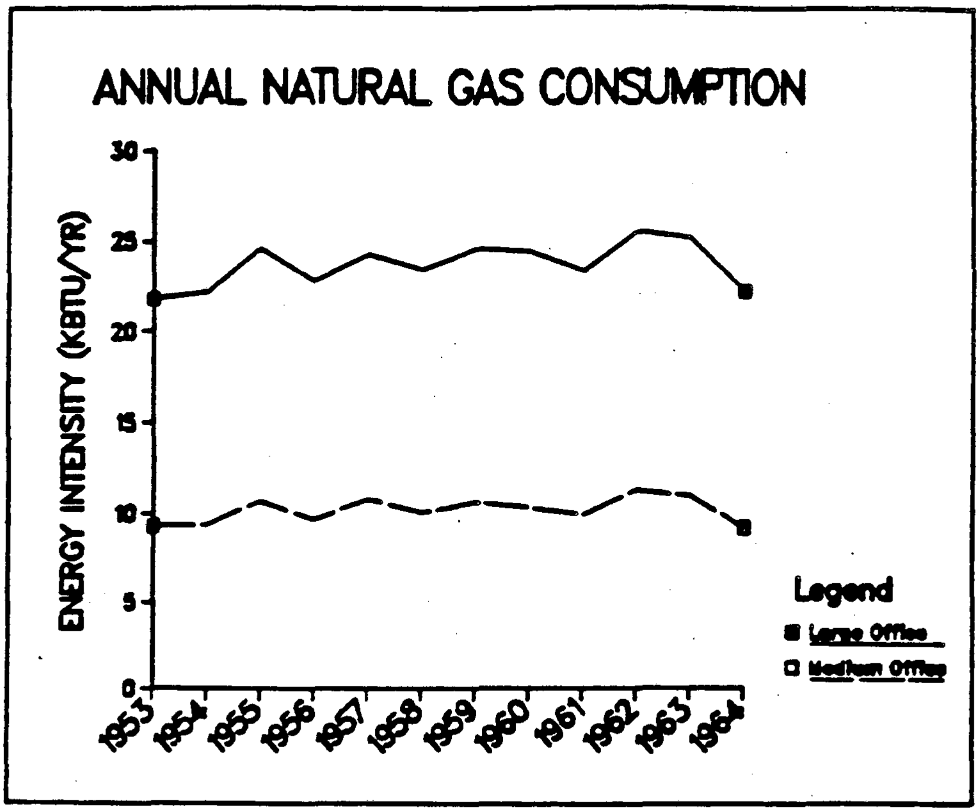

Figure 3. Annual Natural Gas Consumption for the Large and Medium Office in Madison, WI.

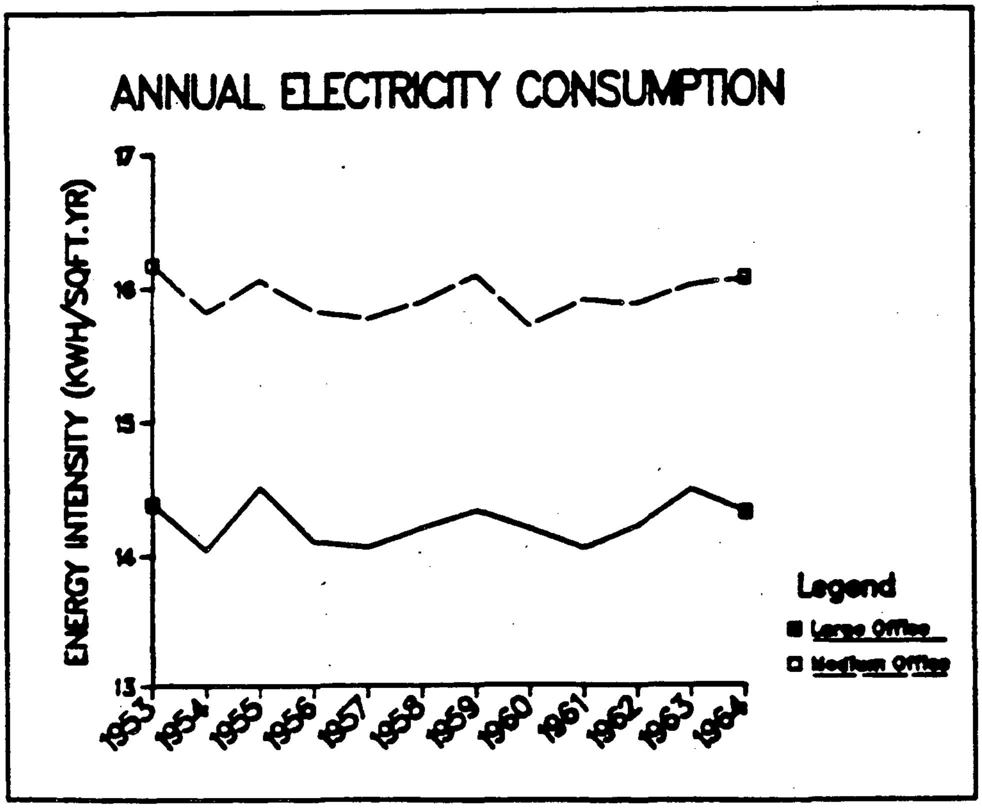

Figure 4. Annual Electricity Consumption for the Large and Medium Office in Madison, WI.

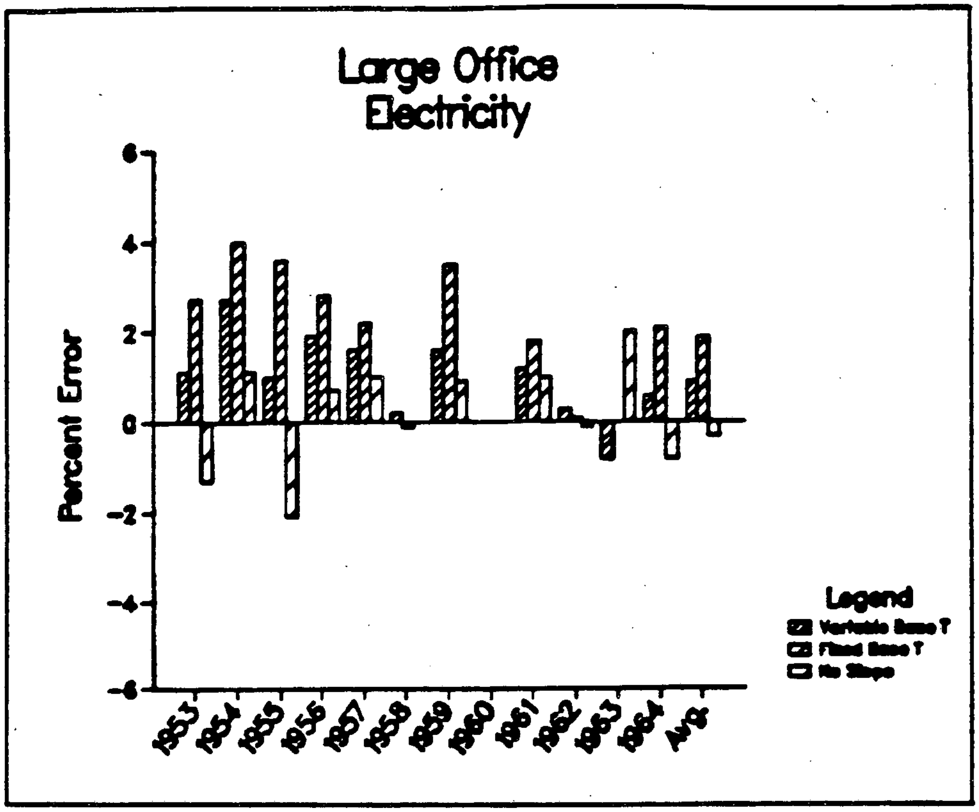

Figure 5. Annual Percentage Differences between DOE-2 Estimates and Degree-Day-Based Weather Normalization Techniques for Large Office Electricity Consumption.

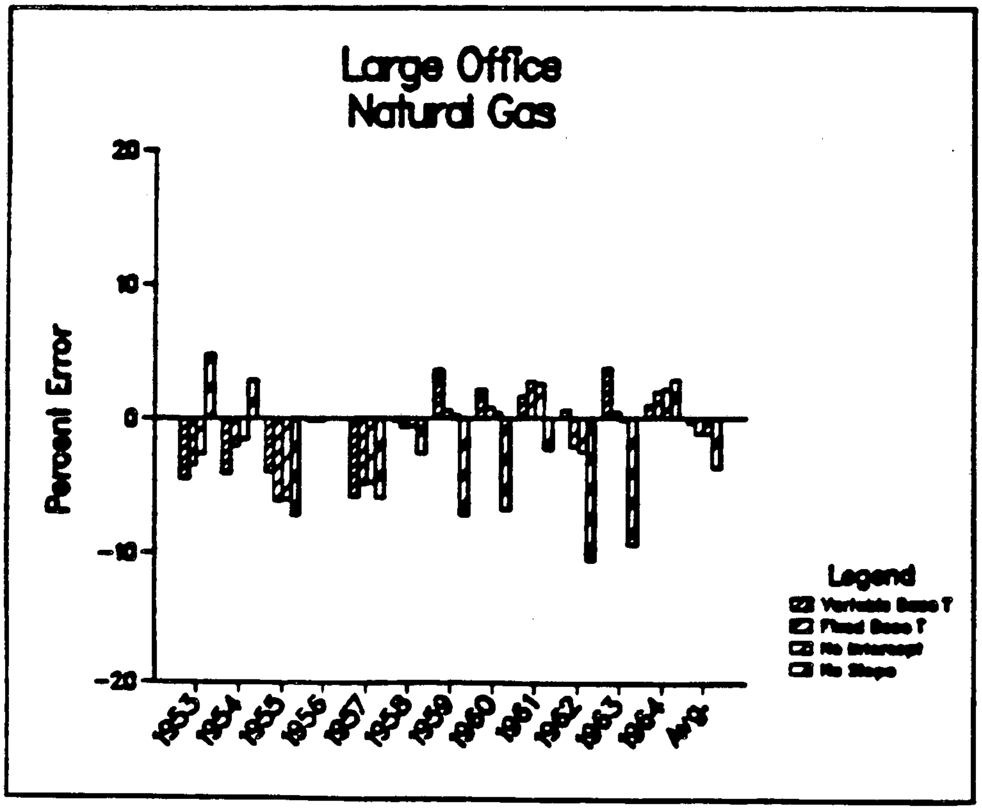

Figure 6. Annual Percentage Differences between DOE-2 Estimates and Degree-Day-Based Weather Normalization Techniques for Large Office Natural Gas Consumption.

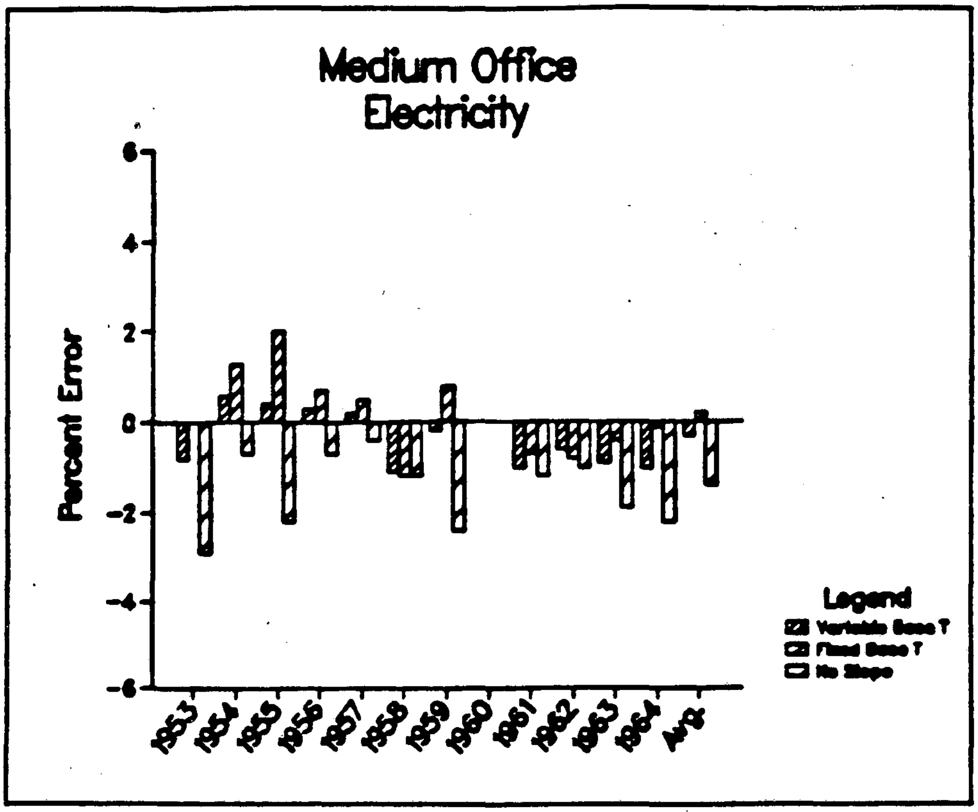

Figure 7. Annual Percentage Differences between DOE-2 Estimates and Degree-Day-Based Weather Normalization Techniques for Medium Office Electricity Consumption.

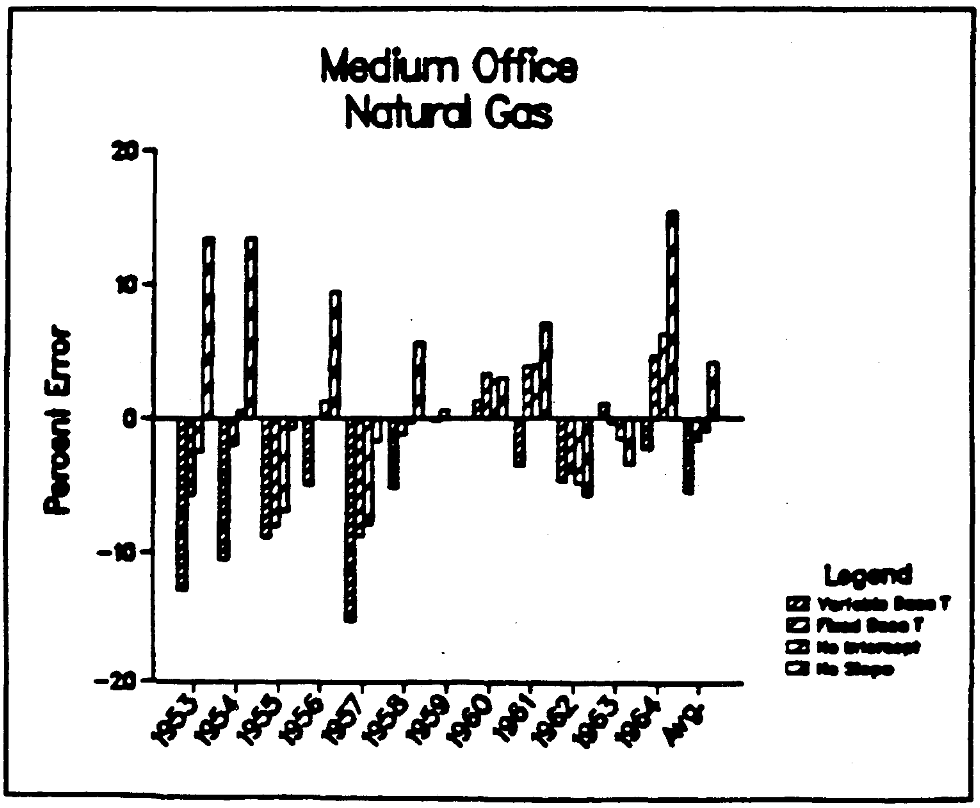

Figure 8. Annual Percentage Differences between DOE-2 Estimates and Degree-Day-Based Weather Normalization Techniques for Medium Office Natural Gas Consumption.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720