

ISSUES CONCERNING THE USE OF WEATHER CORRECTION METHODOLOGIES
BY SCHOOLS AND LOCAL GOVERNMENTS TO DETERMINE ENERGY SAVINGS

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ABSTRACT

Many school districts and local governments have been collecting and analyzing energy use data to determine the effectiveness of energy programs. The energy accounting procedures used have generally not included corrections for annual variations in weather. Thus, these methods often lead to erroneous conclusions concerning changes in energy consumption. To increase the reliability of the calculations, state energy offices have encouraged the use of methodologies that correct for changes in weather. This paper reviews the methods generally in use, makes conclusions regarding their relative effectiveness, and makes recommendations to schools and local governments about specific situations in which different procedures are appropriate.

INTRODUCTION

Although the "Energy Crisis" is now more than ten years old, many public institutions still do not systematically track energy use with formal energy accounting systems. A recent survey of 50 California school districts and local governments (Cook, et al. 1985) found that current energy accounting practices in these agencies, if in place at all, are generally very simplistic. Although 82% of the surveyed agencies said they "monitored" their utility bills, there was usually no regular analysis or formal reporting of the data. The few agencies who analyzed their energy data generally made straight comparisons of energy use from month-to-month and/or year-to-year. In only a few cases did the institutions include adjustments for what can be an important factor affecting energy consumption; weather fluctuations. However, most respondents realized the shortcomings in their current energy accounting practices and said they wanted a better energy accounting system.

WHY SCHOOLS AND LOCAL GOVERNMENTS NEED ACCURATE ENERGY ACCOUNTING

Schools and local governments have a variety of compelling reasons for wanting accurate energy accounting systems. The first and most basic reason is so the school can rank energy efficiency improvements and monitor actual energy and dollar savings. Since conservation efforts in schools and local governments rarely yield savings of better than 15% per year (Duerr, 1982, 1983 and 1985), the energy accounting system used to track energy use must have a margin of error of considerably less than 15% in order to measure these savings. In a large school district where even a 5% energy savings can mean \$150,000 or more, the inability of the energy monitoring system to detect these savings could convince the school to curtail an effective energy management program. Conversely, a false indication of lowered energy use could lead to a continuance of ineffective energy management strategies.

Accurate energy accounting is also important if the school has a monetary incentive or "energy dividend" program. These programs take many forms, but generally, monetary savings realized from energy management efforts are redistributed to those responsible for the savings to provide an incentive for continued energy management. Many school districts in California have tried this strategy (Cornwall, 1986), usually by making each school responsible for its own energy program. As several districts who have tried this strategy will attest, the most important factor in a successful energy dividend program is that participants perceive the distribution of funds as equitable and based on objective criteria. Certainly, if the weather is much colder in the year an energy dividend program is implemented compared to the base line year, non-weather corrected accounting systems might easily conclude that the schools did not save anything. School personnel who had worked all year at making their school energy efficient would not have much faith (and rightfully so) in an incentive system which denied them of their dividend because it did not take the weather into account.

Shared savings contracts have also been used in schools and local governments. In these arrangements, a private company makes the investment in conservation hardware, then shares in the savings generated through these measures. Obviously, the method used to measure savings is the primary factor in determining how much money the agency is going to share with the contractor. If no weather correction is made, the agency is at the mercy of the weather. If they have a five year contract and the weather is generally warmer than the base line period, they will pay out funds for savings which were caused by the weather and not the conservation measures. Since the contractor usually specifies the energy accounting system to be used, it is critical that the agency energy manager understand the type of weather correction methodology included.

Schools and local governments often hire or assign someone to the job of energy manager. The California Energy Extension Service (CEES) has provided contract funding to dozens of public agencies since 1980 for the purpose of developing energy management programs. The contract usually included funding for an energy manager. Once the manager was hired, either through government seed money or by a farsighted administration, their continued existence was often based on their ability to generate energy savings which covered or exceeded their salary. If faculty energy monitoring resulted in lower savings figures, the job might not be renewed and energy management at that agency would decline.

THE PROBLEM

Clearly, then, there are a variety of compelling reasons for school and local governments to engage in accurate energy accounting activities. As the CEES survey of schools and local governments indicated, these agencies have shown a great interest in energy accounting. They were especially interested in energy accounting software for use with microcomputers.

In response to this need for more information about energy accounting software, CEES sponsored four Energy Accounting Workshops in 1985 and 1986 for this population. The main focus of the workshops was to introduce the various energy accounting software systems available, and to present information about the major weather correction strategies used by these programs. In preparing for these workshops, however, it became evident that there was no practical guide available which described the major weather correction options available to energy managers, much less the pro's and con's of weather correction strategies included in the software.

Schools and local governments have several things in common which relate to their ability to implement weather correction methodologies:

1. Staff responsible for energy management in schools and local governments are generally untrained in the field of energy data analysis. These individuals are not likely to be able to evaluate the relative merits of more complex energy use methodologies, such as engineering models or energy use.

2. Energy managers, for whom energy management is usually only one of many responsibilities (Cornwall, 1986), do not have the time to do their own research on local weather fluctuations or gather other complex weather data. The weather data used must be easy to obtain and understand. Heating Degree Days (HDD's) and Cooling Degree Days (CDD's) are the weather measures of choice for the weather correction component of nearly all commercially available energy accounting software, because HDD's and CDD's can be more easily obtained than hourly temperatures or bin data. Obviously, there are much more accurate methods of weather correction, including engineering models; but they generally rely on weather/temperature data which is more precise and harder to get than HDD/CDD's. In fact, it is hard enough just to get current HDD/CDD data since the National Oceanic and Atmospheric Administration (NOAA) does not release its Climatological Data publications until four months after each current month. Therefore, given the difficulty of getting complex weather data and the fact that most energy accounting software used HDD/CDD's, it is the type of weather measure most likely to be used by schools and local governments with time constraints.
3. Energy accounting software is being marketed to schools and local governments with weather correction weighing strongly in the sales pitch. However, while most software does offer weather correction techniques, they are generally poorly documented. In some cases, the manuals do not even describe which correction method is used! It is difficult for even the most sophisticated energy manager to make an informed decision about whether the program is functioning effectively without the information with which to make an analysis. In addition, most programs which offer regression or normalization do not display the correlation coefficient for energy use and HDD's. This statistic is vital in judging the appropriateness of using this model.
4. In many rural schools and local government buildings the heating fuel is propane or oil. Natural gas data is the most readily adaptable for energy accounting because it is metered and reported on monthly utility bills. Propane and heating oil present special problems because they are rarely metered. The only way to get consumption data is to install a meter and record the monthly use, or to estimate the use based on how much fuel was used between deliveries (which rarely follows a schedule). Since the more accurate weather correction models depend on monthly energy use data, it is difficult to apply these models without monthly data.

WEATHER CORRECTION STRATEGIES

In many cases, failing to correct for weather changes can lead to errors large enough to make any meaningful energy analysis impossible. In other situations, though, weather correction may lead to errors larger than those made by not correcting for weather at all. Energy managers need to know which weather correction strategy to use for different situations. Choosing the "best" strategy depends on a number of variables, such as the

fuel types, local weather history, type of building, and the analytical skills of the manager. The remainder of this paper will address the weather correction strategies now in use, as well as site-specific variables which can affect the choice of strategies.

There are three basic strategies for dealing with weather fluctuations which are currently in use by schools and local governments. These methods, and variations on each, are also the predominate strategies employed by energy accounting software.

1. The "No-Adjustment" Method -- The "no-adjustment" method means that energy data is not corrected for weather changes. The CEES survey of schools and local governments concluded that most agencies are currently using this "method". Also, despite the availability of weather correction techniques, some energy accounting software programs offer no weather correction at all. They may include a place to input HDD/CDD's, but then only print them out on the energy report with no analysis. The "no-adjustment" option is included here because, as we shall see, it is sometimes an appropriate strategy.
2. The "Ratio" Method -- This is a method whereby annual fuel use in a base line year(s) is simply divided by annual HDD's to yield the units of energy used per HDD. To adjust for current year use, this method multiplies the current HDD's by the historical units of energy per HDD to predict what the current energy use should be, given current weather effects. The actual energy use is then compared to the predicted amount to yield a savings or increase in use. The major drawback to this method is that it assumes that all energy used needs to be adjusted for weather. Since most buildings have some "base use" (energy used for weather-insensitive use such as water heating), this method will always give somewhat erroneous results.
3. The "Regression-Based" Method -- One of the first uses of this method involved an examination of energy data from 70 California community colleges, conducted in 1979 by Lawrence Berkeley Laboratory (Deckel, Heitzman, Koford, Krieg and York). For this study, they developed a weather correction system based on simple linear regression instead of utilizing the "Ratio" method or none at all. The model used standard HDD's and monthly utility billing data to predict current month energy use based on previous year's data and current HDD's. The advantage of the "Regression" model over the "Ratio" method is that it adjusts only the weather sensitive portion of energy. The strength of the "Regression" model can be measured by examining the correlation coefficient of energy use and HDD's. Stronger correlations mean more accurate predictions of current energy use, and therefore more accurate weather adjustments.

Many other types of weather adjustments appear in the literature after 1980. Most of these are refinements of the "Regression" method. The Washington State Energy Office (Byers, 1985) uses a "Normalization

Constant". This method is based on the "Regression" method, but instead of predicting current year energy use, it normalizes past years and current year energy data. Byers did not compare the accuracy of the "Regression" method to the "Normalization" method, but suggested that where building activity is strongly seasonal, as is the case with school districts, the "Normalization" method may be more accurate.

Princeton University (Fels, 1984) developed a weather correction methodology called the PRISM model. PRISM also used a weather normalization procedure, but has the added feature of an adjustable degree-day balance point. (The balance point is the outside temperature at which a heating or cooling system will turn on. Standard HDD's and CDD's are calculated using a balance point of 65 degrees.) The PRISM model calculates an estimate of each building's true balance point and then adjusts the amount of fuel which will be temperature corrected. The authors "know of no more reliable index for monitoring conservation (p.5)." However, the model was developed for the residential sector and has not been tested (to this author's knowledge) in school or local government buildings.

One researcher, (Eto, 1985) tested several "Regression-based" models (including normalization and variable degree day models) in the commercial sector and found no significant advantage for the more complex models over simple regression. There is a shortage of information, however, about the relative value of these competing methods in the "real world" setting of schools and local government buildings.

Most of the weather correction strategies are intended for use with heating fuels only. Cooling Degree Day adjustments have been tested in several places (Deckel, et al., 1979; Eto, 1985; Fels, 1984) and the results have led each author to conclude that adjusting electrical use for CDD's is problematic (see "Measuring Energy Conservation with Utility Bills," Deckel, et al., 1979 for a clear discussion of the problems of CDD adjustments in school environments). This paper will confine itself to discussing the adjustment of heating fuels using HDD's.

A COMPARISON OF WEATHER CORRECTION MODELS

The hypothesis of this paper is that the choice of a weather correction methodology for school and local government settings depends highly on a number of factors. There is no single "best" strategy. The decision to apply a given weather correction strategy depends most strongly on four factors:

1. The sophistication and time available to the user;
2. The severity of local weather;
3. The amount of "base use" of heating fuels; and
4. The availability of monthly energy consumption data

Each of these factors is explored below:

1. It has already been noted that schools and local governments usually have novice energy managers. Therefore, the weather correction method chosen must be within the ability of the energy manager to understand. This does not mean that the strategy has to be simplistic; just easy to interpret and use. "User friendly" computer software makes it possible to have a strategy with complex algorithms which is easy to use. The danger is that the user may not realize which weather correction system is being used, and therefore may misuse or misinterpret the resulting data. For example, users occasionally will apply weather corrections to electrical data (when electricity is not used for space heating) just because the feature is available on the software.

In each case, the energy manager needs to decide how much time and effort they can invest in learning a weather correction strategy. They should not use a sophisticated model, such as a "Normalization" or variable base use formula, if they do not understand the effect of the adjustment. To use any "Regression" method, they should at least understand the importance of the correlation coefficient between HDD's and energy use. Without this knowledge, they cannot determine whether the regression will yield a reliable prediction of energy use. If the computer software doesn't give the correlation coefficient, they should be able to calculate it by hand (a five-minute task with an advanced calculator).

2. Local weather conditions can affect the applicability of a given weather adjustment method. Figure 1 graphs two years' total natural gas use in two diverse climates; one very mild and one very cold. The graph assumes data for two identical buildings and the same operating conditions. Two year's gas use and HDD's are displayed for two climates at the bottom of Figure 1.

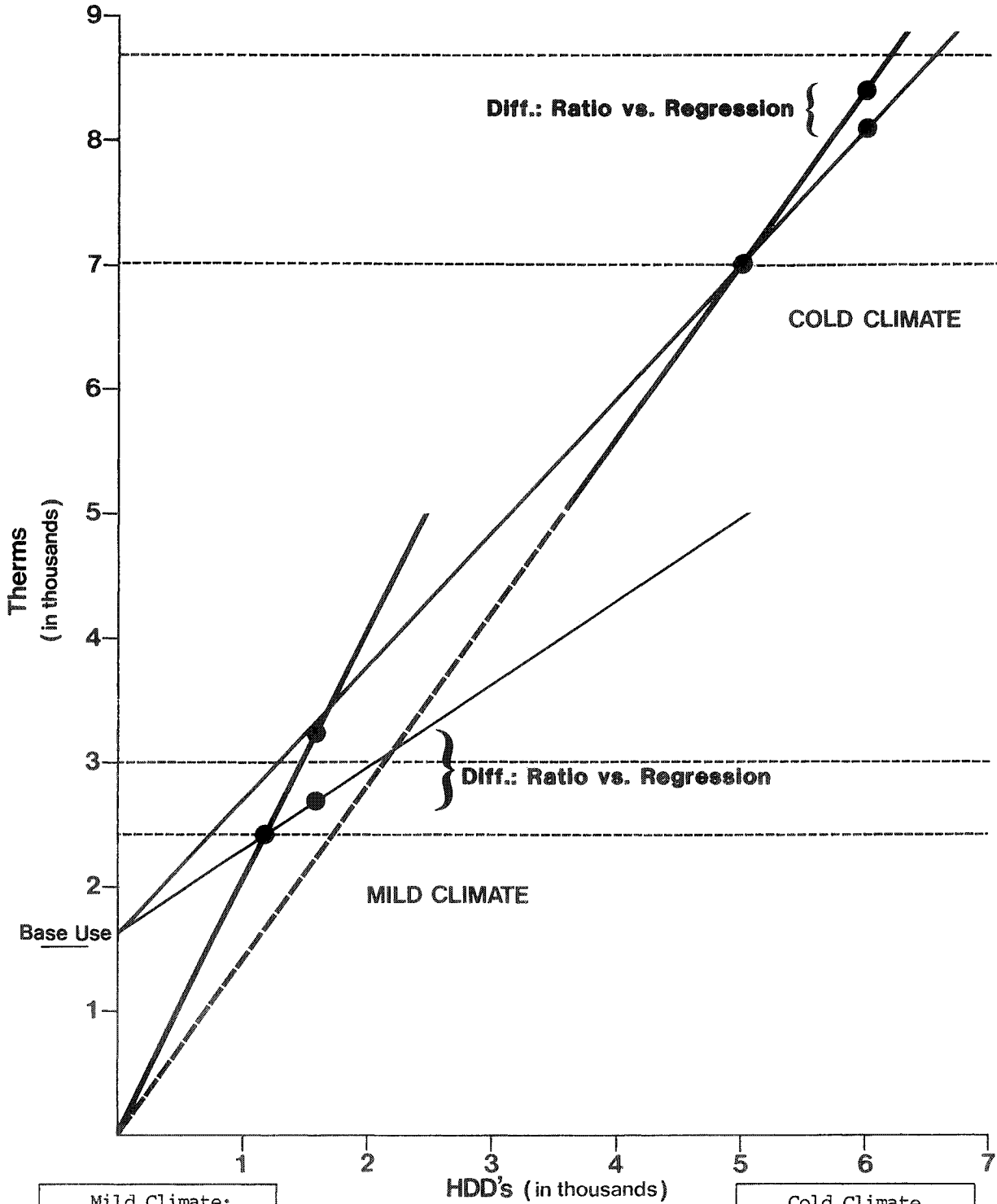
The total therms used in 1985 and 1986 for the mild climate are represented with horizontal dotted lines near the bottom of the graph. The total therms used in 1985 and 1986 for the cold climate are represented with horizontal dotted lines near the top of the graph. In both cases, gas use went up in 1986 by 25%. The "Ratio" model is represented for the cold climate by a line starting at the intersection of the X and Y axis, and running through the intersection point of the 1985 gas use (7,000 therms) and 1985 HDD's (5,000). The "Ratio" model would predict 1985 gas use by locating the intersection of this line with 1986 HDD's. A similar "Ratio" method line is described for the mild climate.

Predictive lines are shown for regression analysis for both of the climates, running from the base use (where the regression line intersects the Y axis) through 1985 gas use. Note that the base use of each identical building is the same, since this use by definition is not weather related.

Several conclusions can be drawn from Figure 1.

- A. First, the difference between the "no-adjustment" method in the cold climate yields larger errors than it does in the mild climate. In both cases, the difference between 1985 and 1986 gas use is a 25% increase; but it is a much more expensive mistake in the cold climate, because the difference in the cold climate is 1,750 therms, not 600 therms as in the mild climate.
- B. Given that the "Regression" method is more accurate, the error in using the "Ratio" method is much smaller in the colder climate than in the warmer. However, the regression should be much stronger (high correlation) in the colder climate, because total building energy use is more temperature sensitive.
- C. Although the difference between the "Ratio" and "Regression" estimates are large for the warm climate, leading to the conclusion that the "Regression" method is better, the correlation for the regression may be very low in warmer climates. Given that the "Ratio" method would lead to a larger error than no adjustment, the issue becomes one of deciding how "bad" a correlation can be before it is abandoned and no adjustment is more accurate. Research from one study (Deckel, et al., 1979) indicates that in climates with fewer than 1,200 annual HDD's, it is often impractical to use regression.

Figure 2 contains an analysis similar to the one in Figure 1, except that different buildings with different base uses are assumed, and weather is held constant. Two year's gas use and HDD's are displayed at the bottom of Figure 2.



Mild Climate:		
	1985	1986
HDD's	1,200	1,600
Therms	2,400	3,000

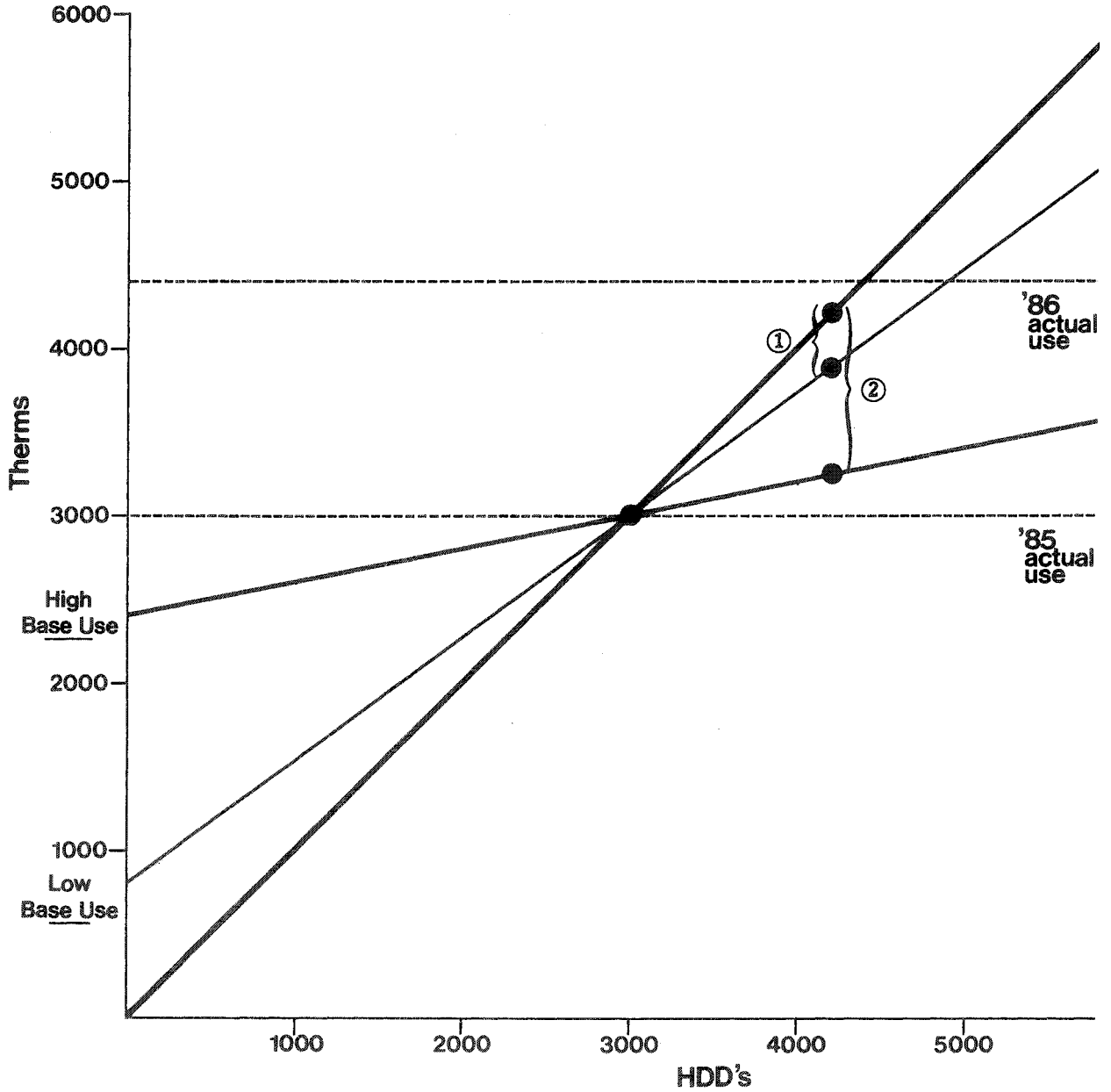
Ratio Prediction Lines

Mild Climate Regression Line

Cold Climate Regression Line

Cold Climate		
	1985	1986
HDD's	5,000	6,000
Therms	7,000	8,750

Figure 1



Ratio Estimation Line (Both Buildings)		<u>1985</u>	<u>1986</u>
Regression Estimation Line, Low Base Use	HDD's	3,000	4,200
Regression Estimation Line, High Base Use	Therms	3,000	4,400

- ① Small difference between Ratio and Regression predictions for low base use building.
- ② Large difference between Ratio and Regression predictions for high base use building.

Figure 2

Only one "Ratio" method line is present in Figure 2, since it would be the same for both buildings. Two regression lines are present, each intersecting the Y axis at the base use of each building. The following information is evident from Figure 2:

- A. Note the difference between the "Regression" prediction of 1986 gas use and the "Ratio" prediction for the high base use case. Then examine the difference between the "Regression" prediction of 1986 gas use and the "Ratio" prediction for the low base use case. Buildings with a high base use have a large error rate with the "Ratio" method, so it should be avoided in these cases.
 - B. Note the large difference between actual 1986 gas use and the "Regression" prediction for the high base use case. It is obvious that using the "Regression" method for buildings with a high base use is important, even though the weather sensitive portion of gas use is small.
4. The availability of monthly energy consumption data is the last major consideration in choosing a weather correction method. As noted earlier, many rural schools and local jurisdictions do not have metered heating fuels. Without accurate monthly energy use data, the "Regression" method cannot be used. Using the information shown in the figures above, it would be wise to use the "Ratio" method (which only requires easily obtained yearly consumption totals) in cases where weather was severe and/or where base use is low relative to total energy use. Most often, the base use is small where temperatures are severe. More research is needed to establish the point at which the "Ratio" method is abandoned in favor of no adjustment.

CONCLUSIONS

Based on the information in this paper, the authors make the following recommendations concerning the use of weather correction methodologies in schools and local government settings:

1. Little additional accuracy will be derived from adjusting fuel use in climates with less than 1200 HDD's per year. The effects of temperature will be small, and will usually not vary significantly from year-to-year in relation to the weather sensitive portion of heating fuel.
2. The "Regression" model is always more accurate than the "Ratio" model, if the regression has a strong correlation. The "Normalization" and balance point adjustment techniques have not been demonstrated, as yet, to offer additional accuracy in school and local government settings. Since they require a great deal more sophistication to understand, they should be avoided by the novice energy manager.

3. Propane, diesel, and heating oil do not usually lend themselves to the "Regression" method because these fuels are not metered on a monthly basis. However, the "Ratio" method should definitely be utilized for annual heating fuel data in colder climates when monthly data is not available. The "Ratio" method, used in this situation, will lead to incorrect estimates of the effects of weather, but the result of not adjusting for weather would lead to greater error. Use of the "Ratio" method in moderate climates is suspect, and it should not be used in warm climates.
4. The correlation coefficient between HDD's and energy use should always be examined before using "Regression-based" methods. Accurate use of these methods depends principally on the strength of the relationship between HDD's and energy use. Unfortunately, the literature search did not uncover any information on how to make a determination of what coefficient is too low. That is, we don't know at what point the "Regression" method yields results which are more in error than those which would be derived from not adjusting for weather at all.
5. Finally, energy managers should not use strategies they do not understand, even if the methodology is incorporated into the energy accounting software they are using or considering for purchase.

Much of the research done in the area of energy accounting and weather correction has been done in the residential and business sectors. Schools and local governments, however, represent a significant portion of energy users and they deserve to have information which will make their energy management programs stronger. Research is continuing in schools and local governments, and in other areas with applications to these users. The areas of CDD adjustments for electricity and determining when to abandon a weather adjustment strategy because it is too weak remain the areas where most research is still needed. Efforts should be made to ensure that energy accounting managers and software programmers are kept informed about advances in weather correction methodologies and strategies as better information becomes available.

REFERENCES

1. Byers, D. Heating Degree Day Normalization. Washington State Energy Office; 1985.
2. Cleary, P., B. Dickinson and R. Sonderegger. Calculations of variable-base degree-days and degree nights from monthly average temperatures. ASHRAE Transactions; 1985, V. 91, Pt. 2.
3. Cook, J. and B. Cornwall. Tracking Utility Costs by Microcomputer. California Energy Extension Service, Sacramento, CA; 1985.
4. Cornwall, B. How to Organize and Communicate Your Energy Data. California Energy Extension Service, Sacramento, CA; 1985.
5. Cornwall, B. Energy Dividend Programs: Issues and Examples. Manuscript; 1986.
6. Deckel, W., et al. Measuring Energy Conservation with Utility Bills. Lawrence Berkeley Laboratory, University of California, Energy & Environment Division, Berkeley, CA; 1979.
7. Duerr, M. Independent Evaluation of the Energy Action in Schools Program. Under contract to the California Energy Extension Service, Sacramento, CA; 1982 and 1983.
8. Duerr, M. Reporting Energy Conservation Results for Natural Gas Use: A Temperature Corrected Method. Under contract to the California Energy Extension Service, Sacramento, CA; 1986a.
9. Duerr, M. Summary Evaluation Report on the 1983-1984 California Energy Extension Service Local Contract Programs. Under contract to the California Energy Extension Service, Sacramento, CA; 1985.
10. Duerr, M. Weather Correction Features in Energy Accounting Software. Chico, CA: Paper not published, 1986b.
11. Eto, J. A Comparison of Weather Normalization Techniques for Commercial Building Energy Use. Lawrence Berkeley Laboratory, Berkeley, CA: 1985.
12. Fels, M. The Princeton Scorekeeping Method: An Introduction. Princeton University, The Center for Energy and Environmental Studies Princeton, NJ; 1984.
13. Gardiner, B. Measured energy performance of new and retrofitted schools. CEEP Journal; September-October, 1985, 19-22.