DEVELOPMENT OF PRE-SCREENING METHODS FOR ANALYZING ENERGY USE IN K-12 PUBLIC SCHOOLS

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ABSTRACT

This paper describes an investigation of energy use in primary and secondary public schools to develop methods to identify high energy consuming schools, potential energy cost reduction measures (ECRMs) and operation and maintenance opportunities (O&Ms) by using a 3-parameter energy index. Eleven schools in Texas were identified as case studies. Each school studied has electric cooling and natural gas heating. One of the schools also has electric heating. The results show the base electric load at each school as well as the cooling load during the school year (the 3-parameter model), and the mean energy consumption during the summer (underbar). These are good indices for determining if a school is overconsuming energy.

INTRODUCTION

This paper discusses the use of existing and newly developed indices to more efficiently identify energy cost reduction measures (ECRMs) at primary and secondary public schools. This paper discusses annual, monthly, and daily indices for eleven schools in Texas and conclusions about the usefulness of the indices.

METHODOLOGY

The first step in gathering information was to obtain monthly, daily, and hourly electricity and natural gas data from each school. Two years of data were obtained for the period September 1, 1991 through December 31, 1993 to ensure that annual aberrations in temperature and operation could be factored out. This information was obtained primarily from the LoanSTAR Monitoring and Analysis Program (MAP) (Claridge et al. 1994). The LoanSTAR MAP provided hourly data. Supplemental information was also obtained from monthly utility bills provided by the school districts and from site visits.

The next step was to obtain copies of previous audits performed on the schools as part of the original LoanSTAR audit. After gathering as much data as possible the facilities managers at each location were contacted and a tour/audit of each school was performed. At each site the energy manager was questioned about HVAC equipment operation. The principal at each school was also contacted to confirm the school's occupancy (which may vary greatly on a daily basis) and information about equipment run times.

After gathering all consumption, equipment lists, operation schedules, and occupancy profiles, indices were developed to identify potential ECRMs and O&Ms. The first step was to utilize existing indices created in the Princeton shopping center report (Haberl and Komor 1989). The first index utilized was a monthly dry bulb temperature graph with minimum, min-max average, and maximum temperature for each month to determine peak and average weather influences. The second index utilized was monthly electric power levels (MacDonald 1988). The third index consisted of monthly Electric Load Factors (ELFs) and Occupancy Load Factor (OLFs). An additional index was created to provide additional meaning to the Occupancy Load Factor, which is called the People Load Factor (PLFs).

New indices investigated include PLFs, simple comparisons of annual electric and gas consumption versus gross square footage of each school, peak and average electric power levels versus peak and average min-max monthly temperatures. Empirical 1, 2, 3, and 4-parameter energy use models calculated using the EModel software (Kissock 1992) for monthly data based on data for all months, data for school year months only, and summer months. Daily power levels versus average daily temperatures were also investigated including those based on data for all days of the year, data for school year days only, and summer days. Daily 1, 2, 3, and 4-parameter models were also calculated (Landman and Haberl 1996).

INDICES INVESTIGATED

Energy indices can give meaningful insight into how a building is being operated. The following section discusses different types of indices available. The first section discusses annual electricity and gas indices, which use the variation in energy consumption from 1992 to 1993 for each school. The next section is monthly electricity and gas indices, 1, 2, 3, and 4-parameter models, and box-whisker mean plots. The last section are the daily 3 parameter weekday and weekend models.

Annual Indices

The first set of indices investigated are annual indices. Annual indices provide peak demand, average electricity consumption, and average natural gas consumption. They allow a building owner to quickly compare energy consumption changes from year to year. It is also useful because the information is typically readily available. However, annual indices smooth out variations in energy consumption that may be caused by weather or occupancy changes that may have affected individual days, weeks, or months of energy consumption. Therefore, annual indices provide limited but readily available information about a building's energy consumption.

Figure 1 shows the annual power levels. The top graph shows average W/sf versus the school gross square footage. W/sf are computed by dividing the total kWh consumed per year by the number of hours in the year to get the average kilowatts. This is further divided by the gross square footage of the building. The average electricity usage ranged from about 0.8 W/sf to 2.0 W/sf, with an average of about 1.0 W/sf. There is little dependence on the size of the school. Both larger and smaller schools seem to average about 1.0 W/sf, with the exception of one school.

The middle graph measures the peak W/sf versus the school gross square footage. Peak W/sf are computed by taking the peak kW for the entire year and dividing by the gross square footage of the building. Basically, this is similar to taking the peak reading for each month as utilities do for their bills. However, the highest monthly peak is selected for the annual peak. The average peak is about 5.0 W/sf. Smaller schools seem to have a slightly higher peak W/sf than larger schools.

The bottom graph measures the average gas consumption in Btu/(hr-sf) versus the gross area of each school. Btu/(hr-sf) is computed from the sum of the cubic feet of natural gas consumed per hour multiplied by the Btu conversion factor divided by the product of the number of hours in the period times the gross conditioned area. The annual natural gas consumption varies from about 0.25 Btu/(hr-sf) to about 4.5 Btu/(hr-sf). Table 1 provides the names and locations of the schools.

Table 1. School names and locations

School Initials:	School Name:	School District:
SHS	Stroman High School	VISD
VHS	Victoria High School	VISD
SES	Sims Elementary School	FWISD
DMS	Dunbar Middle School	FWISD
NHS	Nacogdoches High School	NISD
CMS	Chamberlain Middle School	NISD
OES	Oppe Elementary School	GISD
WMS	Weis Middle School	GISD
PES	Parker Elementary School	GISD
MES	Morgan Elementary School	GISD
RES	Rosenberg Elementary School	GISD

Chamberlain Middle School is not represented here because it has electric heating for one-half of the building. Two of the small schools have very low natural gas consumption, possibly using an additional or alternative energy source for heating. A third small school has an average Btu/(hr-sf) of about 4.5, more than double the 2.0 Btu/hr-sf average of all the schools. From the indices, it is clear that this school may use natural gas for something other than heating, such as cooking.

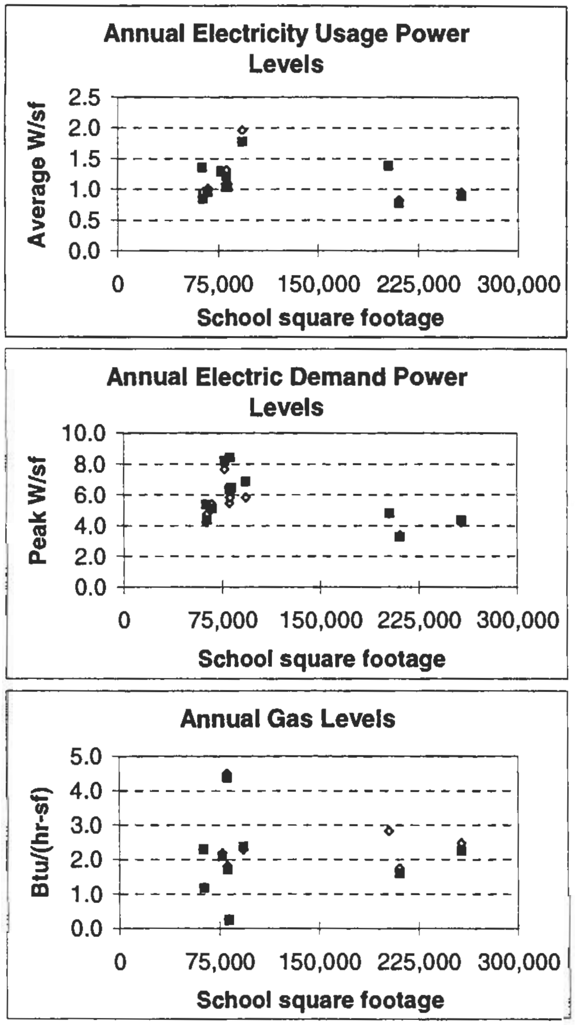

Figure 1. Annual power levels: Average W/sf, peak W/sf, and gas levels in BTU/(hr-sf) for 1992 and 1993.

General Evaluation with the Annual Indices

In general, annual energy indices allow for gross comparison of energy use in schools from year to year. Expressing the energy use per unit area of conditioned space allows for comparisons to be made among similar schools which are using the same fuel types for the same purposes. If a suitable average value can be developed then schools can be ranked as being above or below the group average for the specific fuel type under analysis. For the schools in this analysis, this included a comparison of the peak annual monthly demand using a demand power level (i.e. W/sf), a comparison of electricity consumption using power levels (i.e. W/sf) and an analysis of natural gas consumption (Btu/hr-sf).

Peak W/sf varied from 47 percent above the average peak demand of 5.89 W/sf to about 47 percent below this value with all of the larger schools below the average value and most of the smaller schools above this value.

Electric use per unit conditioned area varied by 32 percent from an average of 1.18 W/sf. Natural gas varied by 88 percent of the average Btu/(hr-sf) of 2.14. The greater variation in gas use is somewhat expected since some schools only use gas for DHW and space-heating purposes while other schools use gas for cooking, DHW, and space-heating.

School Specific Evaluation with the Annual Indices

For each school, the annual indices can be used to begin to describe how their energy use compares to other schools and the energy consumption at each school can be shown in Table 2 as high, medium, or a low energy consuming school based on +/- 25% of the mean value. Those indices greater than the 1.25 times the mean value are classified as high. Those indices lower than .75 times the mean value are low.

Table 2. Ranking of schools using annual indices (+/- 25% of the mean).

	Demand (W/sf)	Consumption (W/sf)	Natural Gas Consumption (Btu/hr-sf)
Mean Value	5.89	1.18	2.14
CMS	Medium	Medium	N/A
DMS	Medium	High	Medium
MES	High	Medium	Medium
NHS	Medium	Medium	High
OES	Medium	Medium	High
PES	Medium	Medium	Low
RES	Medium	Medium	Low
SES	Medium	Medium	Medium
SHS	Low	Low	Medium
VHS	Low	Medium	Medium
WMS	High	Medium	Medium

Monthly Indices

While annual indices can explain the differences from year to year, monthly indices can explain the seasonal differences in energy consumption at a location. Several monthly indices will be explored in this section. The first set of indices explored are average monthly electric power levels (Figure 2) and monthly gas power levels versus temperature (Figure 3), next, a discussion of the Interquartile Range (IQR) Indices for electricity (Figure 4) and natural gas consumption (Figure 5), and for the ELF (Figure 6), OLF (Figure 7), and PLF (Figure 8), and finally, a weather dependent model for each school (Figure 9) is presented.

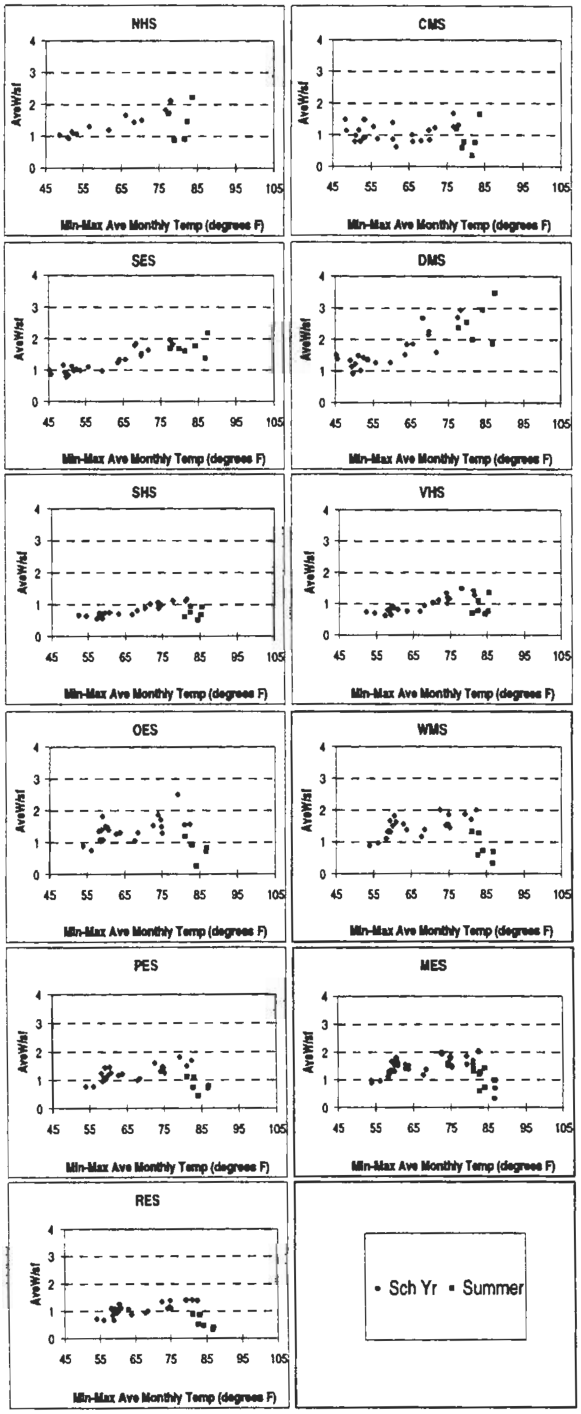

Figure 2. Monthly average consumption: W/sf versus min-max average monthly temperatures for September 1991 through December 1993.

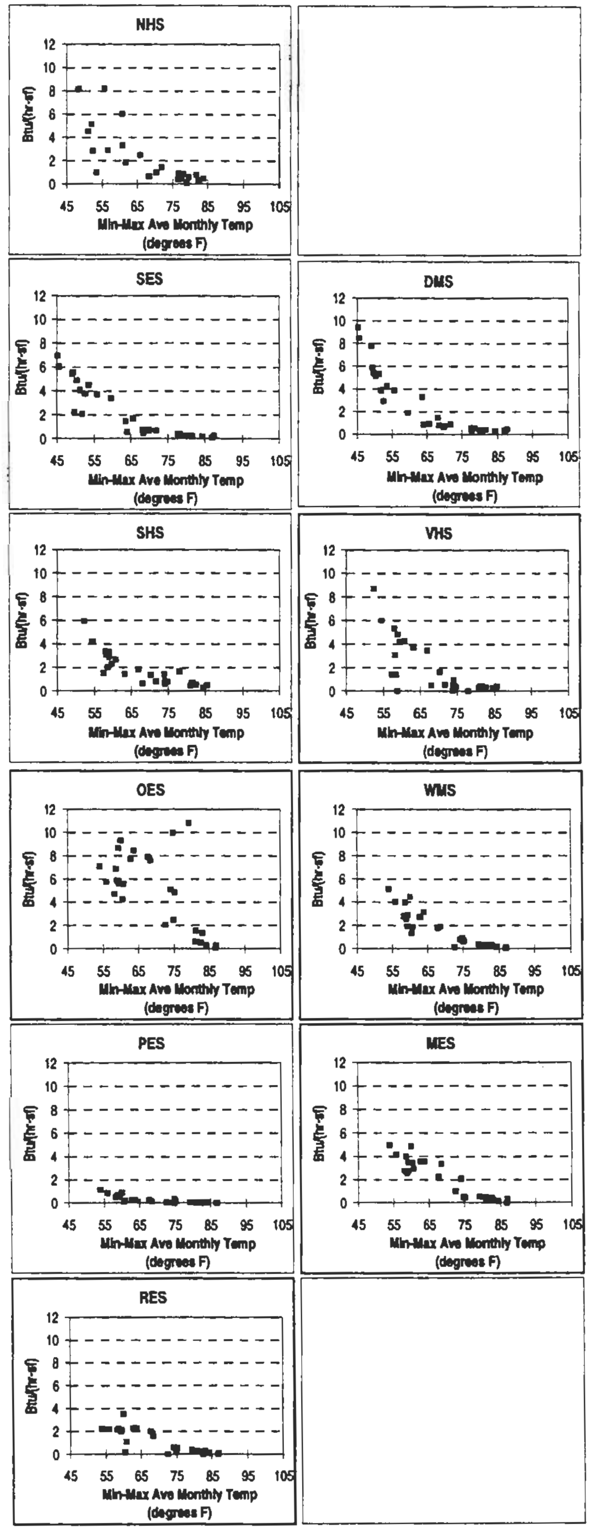

Figure 3. Monthly average natural gas consumption: Btu/(hr-sf) versus min-max average monthly temperatures for September 1991 through December 1993.

General Evaluation with the Monthly Indices

Monthly indices are considered in this section. Previously it was shown that an average annual index could be useful in identifying high energy consumers according to their maximum peak electric load (W/sf), average annual electricity use (W/sf), and annual natural gas use (Btu/(hr-sf)). In this section we take a look at what additional information can be provided with the expansion of monthly data. For each school a box-whisker mean symbol is used to indicate the results of the monthly statistical analysis. Each plus symbol (whiskers) indicates outliers, below the 10th percentile or greater than the 90th percentile. The box indicates the range between the 25th and 75th percentile. The hash mark in the box is the 50th percentile or median value, and the line connecting all schools together connects the mean value for each school.

The quartile analysis of monthly data provides additional information that allows for further insight into how the schools are performing. With the exception of DMS and RES, the data points falling below the 10th percentile for the WBE and natural gas graphs (Figures 4 and 5) usually represent the summer months when many of the schools have reduced operating schedules.

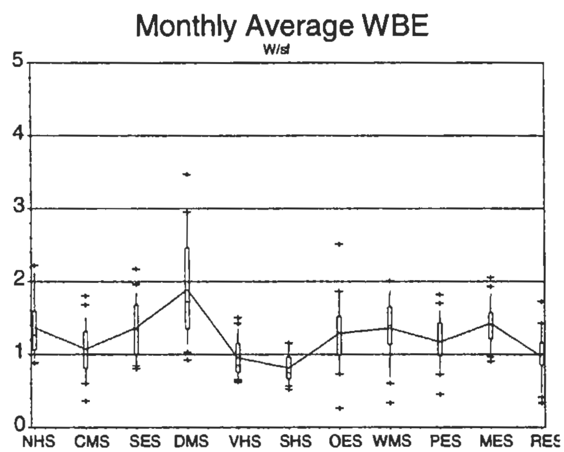

Figure 4. Monthly average WBE: An aggregate monthly analysis for all eleven schools showing the average monthly consumption statistics in W/sf for September 1991 through December 1993.

In the case of DMS and RES, two different stories emerge. First, at DMS the lower kWh consumption months occur during the winter months (Figure 4). This is due to the fact that significant amounts of air conditioning are used all summer long. At RES the lower consumption months occur during the summer and winter which would seem to indicate that a similar shut down practice is applied for both periods.

The second feature worth noting about the quartile plots, with the exception of DMS, is that the data points falling above the 90th percentile occur during the school year. To some extent this is to be expected since those points represent the months in early fall when there is a significant air conditioning load.

The third feature worth noting is that the 25th percentile almost always equals the school year base-level consumption calculated with a 3-parameter change-point model such as PRISM or EModel. This may turn out to be a noteworthy feature of such an analysis. If the school year base-level can be calculated with a simple 25th percentile, then the school year consumption can be subdivided into heating, cooling, and base-level consumption without having to run a 3-parameter analysis, which would include collecting daily weather data. Further analysis may be needed across a broader range of climates to verify if this feature is applicable to other areas of the U.S.

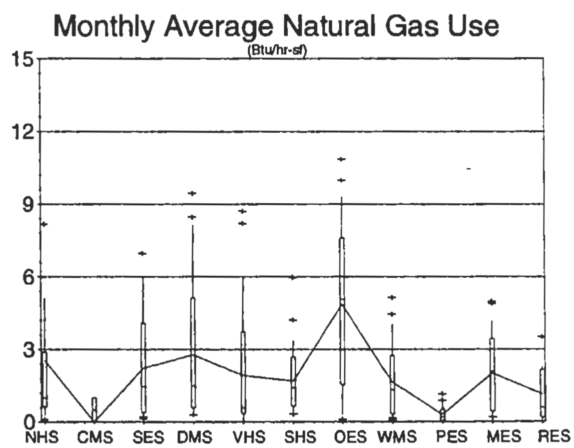

Figure 5. Monthly average natural gas: An aggregate analysis for all eleven schools showing the average monthly natural gas consumption statistics in Btu/(hr-sf) for September 1991 through December 1993.

Figure 5 displays the results of the quartile analysis for the natural gas used by ten of the eleven schools (CMS has electric heating on one floor and natural gas heating on the other which are not separately metered. Consequently, CMS was not included in this heating analysis). This quartile analysis of natural gas use also provides useful insight into how the building is using gas for heating and non-heating purposes. In each of the ten case study schools, the 25th percentile tends to be a good proxy indicator for the base-level gas use. Additional analysis will be needed to determine if this statistic is useful for schools located in other climate regions. Fitting a 3-parameter model to the schools indicates a heating trend as temperatures decrease. There is a clear trend toward heating at lower outside air temperatures in the winter time and a base natural gas consumption with the higher outside air temperatures during the summer time. The baseline natural gas usage primarily indicates domestic hot water consumption.

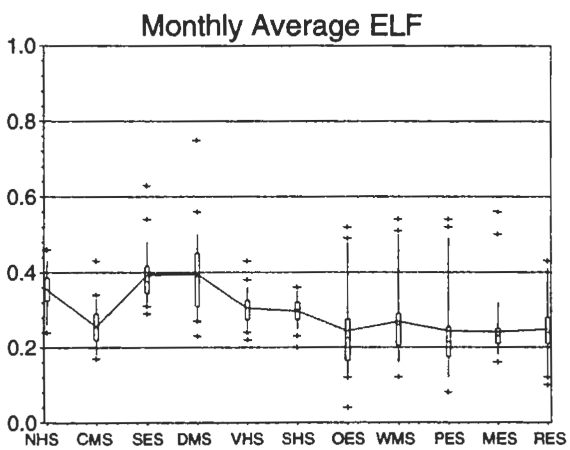

Figure 6. Monthly average ELFs: An aggregate analysis for all eleven schools showing the electric load factor statistics for September 1991 through December 1993.

Figure 6 shows the results of the quartile analysis for the ELF for the eleven schools. ELF is a good indicator of diversity at the schools. The maximum value and the 90th percentile usually indicate September and October usage for schools without much summer usage and July and August for schools that do. The minimum and 10th percentile generally indicates summer usage for schools without any summer school.

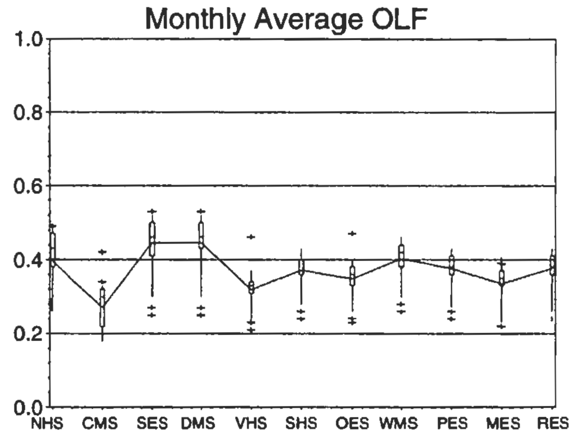

Figure 7. Monthly average OLFs: An aggregate analysis for all eleven showing the occupancy load factor statistic for September 1991 through December 1993.

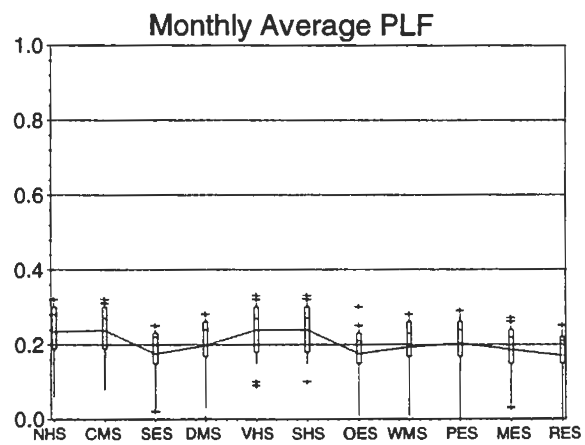

Figure 8. Monthly average PLFs: An aggregate analysis for all eleven showing the people load factor statistics for September 1991 through December 1993.

Figure 7 shows the results of the quartile analysis of the OLF for the eleven schools. The OLF 10th percentile generally indicates months where there has been significant vacation with the minimum usually occurring in June or July. OLF is also consistently higher than PLF (see Figure 8), an indication that custodial workers are in the school during different hours than teachers, students and staff. Minimum PLF values indicate summer vacation for staff. VHS and SHS have school almost year round, hence their minimum PLF values are much higher than other schools.

To improve results when creating temperature related models, it is best to separate all months into two groups: school months and summer months (see Figure 9). With the models, seasonal and operational changes my be compared with the results of other indices such as monthly electric power levels, ELF, OLF, and PLF. A good monthly model is defined as having a CV(RMSE) < 0.25 and an $R^2 > 0.6$. (i.e. having low scatter and being highly weather dependent), which represents a slightly more related criteria than was recommended by Reynolds and Fels (1988).

The models selected had a 3-parameter fit for the school year, and a 1-parameter fit during the summer time. About half the schools fit into this criteria during the school year. All have CV(RMSE) < 0.25. This indicates that all schools had low levels of scatter. However, six of the schools (elementary and middle schools) have $R^2 < 0.6$, indicating schools are more weather dependent than others during the school year. This is because R^2 is a slope-dependent index and yields lower values for lower slopes. Also, for summer months there was indication that a 2 or 3-parameter model may be a better fit. However, since the average monthly temperature only varied by 10 °F over the summer, it was felt that a mean model would be best. A 3-parameter model fits most of the schools during the school year well.

There is clear indication of cooling in schools, starting at approximately 63 °F and a base electricity consumption level of approximately 1.0 W/sf. There is an increase in electricity consumption as temperature increases. The average electricity usage during the all school year months for all schools was approximately 1.4 W/sf. Therefore, on average, cooling was approximately 24 percent of the electric load during the school year for all eleven schools based on the 3-parameter models.

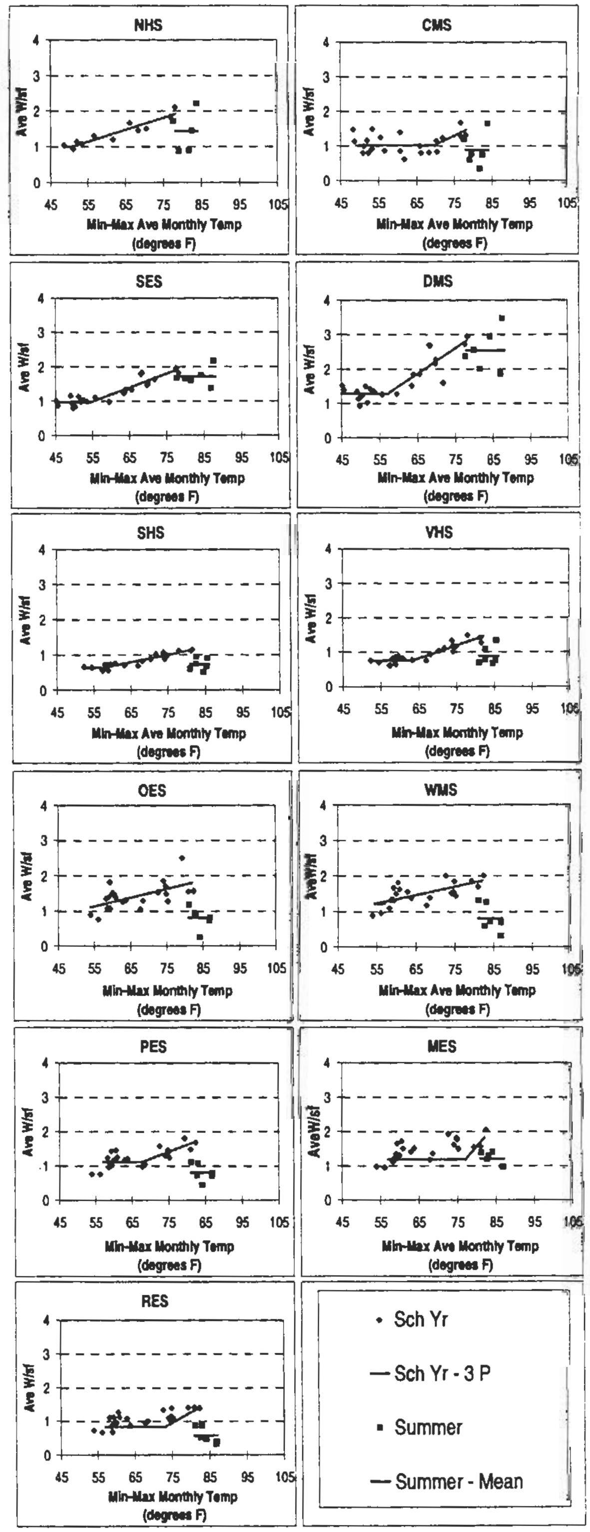

Figure 9. Monthly change-point electricity models: School year & summer.

School Specific Evaluation with the Monthly Indices

For each school, like the annual indices, the monthly indices can be used to describe how their energy use compares to other schools. The indices shown are for school year months (Table 3), some summer months (Table 4), and some all months (Table 5) as high, medium, or a low energy consuming school based on +/- 25% of the mean value. Those indices greater than the 1.25 times the mean value are classified as high. Those indices lower than 0.75 times the mean value is low. Table 6 shows areas that need to be explored during an audit of each school based on findings from the monthly indices.

Table 3. Ranking of schools using monthly indices (+/- 25% of the mean) for school months.

	Demand (W/sf)	Average consumption (W/sf)	Base-level consumption (W/sf)
Mean Value	5.89	1.36	1.02
CMS	Medium	Medium	Medium
DMS	Medium	High	High
MES	High	Medium	Medium
NHS	Medium	Medium	Medium
OES	Medium	Medium	Medium
PES	Medium	Medium	Medium
RES	Medium	Medium	Medium
SES	Medium	Medium	Medium
SHS	Low	Medium	Low
VHS	Low	Low	Low
WMS	High	Medium	Medium

Table 4. Ranking of schools using monthly indices (+/- 25% of the mean) for summer months.

	Demand (W/sf)	Average consumption (W/sf)	Mean model consumption (W/sf)
Mean Value	5.62	1.02	1.13
CMS	Medium	Medium	Medium
DMS	Medium	High	High
MES	Medium	Medium	Medium
NHS	Low	Medium	High
OES	Medium	Medium	Low
PES	Medium	Medium	Low
RES	Medium	Low	Low
SES	Low	High	High
SHS	Low	Medium	Low
VHS	Low	Low	Medium
WMS	Medium	Low	Low

Table 5. Ranking of schools using monthly indices (+/- 25% of the mean) for all months.

	ELF	OLF	PLF	Natural gas consumption (Btu/hr-sf)
Mean Value	0.29	0.37	0.2	0.55
CMS	Medium	Medium	Medium	N/A
DMS	Medium	Medium	Medium	High
MES	Medium	Medium	Medium	Low
NHS	Medium	Medium	Medium	Medium
OES	Medium	Medium	Medium	High
PES	Medium	Medium	Medium	Low
RES	Medium	Medium	Medium	Low
SES	Medium	Low	Medium	Low
SHS	Medium	Medium	Medium	High
VHS	High	Medium	Medium	Low
WMS	High	Medium	Medium	Low

Table 6. Specific items to consider during an energy audit based on index-related information.

	CMS	DMS	MES	NHS	OES	PES	RES	SES	SHS	VHS	WMS
Electric Heating	X										
Check for natural gas or other forms of heating at the school	X	X			X						
Look into summer activity and why systems aren't reduced to match PLF	X				X		X				
Control systems for both summer and school year usage		X									
Cooling system efficiency and size		X	X								
Potential oversized equipment or too much connected load			X								
Control systems for summer time				X	X			X	X	X	X
Heating provided by alternative sources such as oil or propane or separate meter						X	X				
Oversized cooling unit for summer time						X					
Oversized equipment or excess plug load											X

Using monthly indices, one can now delve further into the reasons why a school is using too much energy. For example, using the annual indices, one could see that DMS ranked high in its monthly average electricity use. With the monthly indices, one can see this is because the school over consumes in both the school year and in the summer.

In summary, monthly energy indices allow for comparison of energy use in schools from month to month allowing for seasonal variations. Expressing the energy use per unit area of conditioned space allows for comparisons to be made among similar schools which are using the same fuel types for the same purposes. If a suitable average value can be developed then schools can be ranked as being above or below the group average for the specific fuel type under analysis. For the schools in this analysis, this included a comparison of data of the peak monthly demand using a demand power level (i.e. W/sf), a comparison of average electricity consumption using power levels (i.e. W/sf), and a comparison of base-level of electricity consumption using power levels (i.e. W/sf) during the school year months. There is also a comparison of the peak monthly demand using a demand power level (i.e. W/sf), a comparison of average electricity consumption using power levels (i.e. W/sf), and a comparison of the mean model electricity consumption using power levels (i.e. W/sf) during the summer months. Lastly, ELF, OLF, PLF, and an analysis of natural gas consumption (Btu/hr-sf) were analyzed for all monthly data. This is the second step in understanding energy consumption in a building. The next step is looking at daily indices and what they tell a person about energy consumption at a school.

General Evaluation with the Daily Indices

This next section considers daily indices. In the previous section it was shown that breaking up monthly indices into school year and summer periods reveals more information about how seasons affect a schools operation and consequently provides additional information to identify high energy consumers. In this section we take a look at what additional information can be provided within the analysis of daily data and the ability to further separate data into weekday and weekend models based on scheduling as well as weather related data. While creating daily school year models, taking the weekend data out of the analysis has a significant affect of results when compared to monthly analyses that include weekend results. The average base electric consumption increases approximately 32 percent, ranging from a low of approximately 7 percent for VHS to a high of approximately 65% for WMS. This is shown in Figure 10.

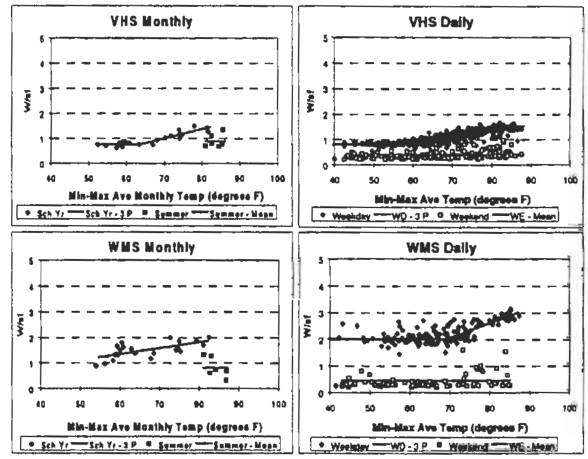

Figure 10. Monthly and Daily Base electric load comparison.

Although a 1-parameter mean model is used for weekend data, there is indication that a 3-parameter model may be as good a fit. There is a significant difference between weekday and weekend usage. A 1-parameter mean model is most useful for the summer use for both weekday and weekend models due to the narrow temperature band. However, at some of the schools a 3-parameter model from the school year fits the summer data possibly indicating significant changes of school operation throughout the summer time.

With a daily model it is easier to point out the cooling and non-cooling electrical usage at a school as well as the weekday and weekend usage. Also, taking out holidays from weekday school year data there is a noticeable 36 percent increase in the WBE base-level and an average 11 percent drop in CV-RMSE. This indicates the complexity of modeling a school because of all the different types of schedules throughout the calendar year (e.g. school year, summer, weekday, weekend). Also of note, when modeling weekday electricity versus monthly electricity, (both using the school year data) it is significant that base-level energy consumption increases by approximately 34 percent indicating that the weekend consumption plays an integral role in modeling a school's consumption. Weekend data varies greatly from school to school, indicating the differences in occupancy at each school (Landman and Haberl 1996).

School Specific Evaluation with the Daily Indices

For each school, like the annual and monthly indices, the daily indices can be used to describe how their energy use compares to other schools and the energy consumption at each school, as shown for school year daily data (Table 7) and some summer daily data (Table 8), as high, medium, or a low energy consuming school based on +/- 25% of the mean value. Those indices greater than the 1.25 times the mean value are classified as high. Those indices lower than .75 times the mean value are low. If one looks again at DMS, it becomes clear that the high annual and monthly ratings are pointing to an HVAC system that runs 24 hours per day, 7 days a week.

Table 7. +/- 25% of the mean value indices for school year days.

	Average WBE (W/sf)	Base-level WBE (W/sf)	Average WBE (W/sf)	Mean model (W/sf)
	Weekday	Weekday	Weekend	Weekend
Mean Value	1.75	1.39	0.45	0.459
CMS	Low	Medium	Medium	Medium
DMS	High	Medium	High	high
MES	High	High	Medium	Medium
NHS	Medium	Medium	Medium	Low
OES	Medium	Medium	Medium	Medium
PES	Medium	Medium	Medium	Medium
RES	Medium	Medium	Medium	Medium
SES	Medium	Medium	High	High
SHS	Low	Low	Medium	Low
VHS	Low	Low	Medium	Low
WMS	High	High	Medium	Medium

Table 8. +/- 25% of the mean value indices for summer days.

	Average WBE (W/sf)	Mean model (W/sf)	Average WBE (W/sf)	Mean model (W/sf)
	Weekday	Weekday	Weekend	Weekend
Mean Value	1.18	1.205	0.63	0.647
CMS	Medium	Medium	Medium	Medium
DMS	High	High	High	High
MES	Medium	Medium	Medium	Medium
NHS	Medium	Medium	Medium	Medium
OES	Medium	Medium	Medium	Medium
PES	Medium	Medium	Medium	Medium
RES	Low	Low	Medium	Medium
SES	Medium	Medium	High	High
SHS	Medium	Medium	Medium	Medium
VHS	Medium	Medium	Medium	Medium
WMS	Medium	Medium	Medium	Medium

In summary, daily indices allow for comparison of energy use in schools comparing weekdays to weekends as well as from month to month. This allows for seasonal and weekday-weekend scheduling variations to be analyzed. Expressing the energy use per unit area of conditioned space allows for comparisons to be made among similar schools which are using the same fuel types for the same purposes. If a suitable average value can be developed then schools can be ranked as being above or below the group average for the specific fuel type under analysis. This is the third step in understanding energy consumption in a building.

SUMMARY

This paper expands on existing techniques developed by Haberl and Komor (1988), develops new comparative educational building energy use indices and demonstrates their effectiveness by analyzing eleven case study schools in Texas. Indices are created to determine how energy is being utilized in a building and how to identify buildings and systems, which are appropriate candidates for energy conservation methods.

Two methods were selected for modeling a school, weather dependent and non-weather dependent. Both methods are divided into subsections based on data frequency (i.e., annual, monthly, and daily).

Annual indices are easy to obtain and can be calculated from monthly data. Annual peak demand can indicate oversized equipment or excess plug load and the need for more efficient equipment. Annual average electricity consumption indicates high or low energy schools. An average annual natural gas consumption index also indicates high or low energy consuming schools. However, annual indices have uncertainty due to possible weather/temperature related variations from year to year, because there is not enough information available as to why indices vary from year to year. Hence, monthly indices can be used to properly understand the energy consumption at a school.

Monthly indices reveal a great deal more about the energy consumption at a school. First, like annual indices, monthly electricity and gas consumption indices indicate over-sizing, excess plug load and control problems at a school, but they also give hints as to what energy systems are inefficient, based on seasonal information (i.e. cooling systems in the summer time, heating systems in the winter time, DHW and cooking in the summer time to name a few).

Secondly, separating monthly data into school year and summer months and using 3-parameter school year change-point models versus mean summer models provides more accurate modeling of a building by matching occupancy scheduling and weather dependency. It is equally impressive that the 25th percentile provides a good approximation of the base-level determined without requiring weather data, and it is very easy to perform a quartile analysis on monthly data. Furthermore, since the application of a quartile analysis can be readily automated, and the square footage is known, it could be applied inexpensively to all K-12 schools that a utility serves to provide an effective pre-screening tool.

Also noteworthy about monthly indices is whether or not ELF, OLF, and PLF are approximately the same throughout the year. If the values for ELF are higher than OLF throughout the year there is potential for energy conservation, because electric usage profiles do not match occupancy profiles. Likewise, if the values for PLF are lower than the values for OLF, there is more potential for energy conservation than reflected by the OLF comparison with ELF. This is because PLF more accurately reflects people hours than OLF. For example, PLF shows a larger difference in summer usage from ELF than OLF, indicating more over-use in the summer time is visible than comparing ELF to OLF.

Daily models can be produced from hourly data which can be collected with a properly programmed EMCS or data loggers. Daily data provides additional information about weekday-weekend variations.

Daily modeling gives more flexibility than monthly modeling. Weekday/weekend modeling shows if equipment is left on during the weekends, i.e. not matching occupancy schedule. As a result, weekend models may be dependent on scheduling as much as weekday models. Daily weekday school year data were slightly higher than monthly school year data, but this was expected due to the fact that systems should be turned-off on the weekend. In general, daily models provide higher resolution at those sites that have on-off schedules (versus those that run 24 hours per day).

CONCLUSIONS

Annual indices provide limited information about energy consumption at a building and require additional information to make accurate energy conservation assessments.

Monthly indices are easily available and are the most useful indices, because they provide season and scheduling information about a building's consumption and occupancy without requiring the installation of data loggers.

Daily indices provide an additional level of detail good for verifying base-level consumption and energy profiles at the schools with significant on-off schedules. They also indicate weekday-weekend operation.

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