DEVELOPMENT OF LOAD FORECASTING PROCEDURES FOR THE TEXAS A&M UNIVERSITY SYSTEM

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ABSTRACT

This paper reports on the effort to develop load-forecasting procedures for the Texas A&M University System (TAMUS). Such procedures are being investigated to determine if the TAMUS can benefit from the pending deregulation in the State of Texas. A description of the procedures used to aggregate and forecast the system-wide, 15-minute electric load is presented, including a summary of the forecast load for selected campuses, and individual campus-use statistics. Procedures are also presented that were used to impute missing energy and weather data, and forecast annual data from short-term data.

INTRODUCTION

In order for large, multi-site electricity users to take advantage of the pending deregulation in the State of Texas, it is necessary to have accurate forecasts of energy use in the appropriate time interval. To analyze this opportunity for TAMUS a weather-adjusted, 15-minute load profile for each of the campus of the TAMUS is required. Such load profiles can be obtained using the monitoring procedures established at the Energy Systems Laboratory at Texas A&M University, as part of the Texas LoanSTAR program (Turner et al. 2000). For this study, the completeness of the data needed checking, and missing data for short periods were imputed using simple linear interpolation (Chen 1999; Baltazar-Cervantes 2000). Unfortunately, several sites also contained missing data for longer periods, and therefore, other strategies needed to be developed to complete the annual data sets required for the aggregated TAMUS load profile. This paper presents the procedures used to forecast multi-campus, 15-minute load data, as well as those used to impute missing energy and weather data, and forecast annual profiles from short-term data sets.

GENERAL DESCRIPTION OF THE DATA SETS

The Texas A&M University System (TAMUS) is composed of 10 universities, 5 agricultural agencies, 3 engineering agencies, and one health science center as indicated in Table 1. This study includes the analysis for (7) universities participating in the load forecasting study (i.e., Tarleton State, Texas A&M International, Texas A&M Galveston, Texas A&M Commerce, Texas A&M Corpus Christi, Texas A&M Kingsville, and West Texas A&M at Texarkana).

Table 1. *Universities of the TAMUS that were included in the study.*

NAME	Included
Prairie View A&M University	
Tarleton State University	?
Texas A&M International University	?
Texas A&M University at Galveston	?
Texas A&M University-Commerce	?
Texas A&M University-Corpus Christi	?
Texas A&M University-Kingsville	?
West Texas A&M University	?
Texas a&M University Texarkana	
Texas A&M University -Main Campus	
The Texas A&M University System Health Science Center	
Texas Agricultural Experiment Station	
Texas Agricultural Extension Service	
Texas Veterinary Medical Diagnostic Laboratory	
Texas Wildlife Damage Management Service	
Texas Engineering Experiment Station	
Texas Engineering Extension Service	
Texas Transportation Institute	

Collection of the data for the campuses covered in this study required the merging of a diverse set of data from different sources, including: 15-minute kW data, 15-minute-kWh data, hourly kWh data, and National Weather Service (NWS) data. All data collected contained missing records that needed to be imputed. Some data sets contained only a few months of data.

Table 2. *Initial status of the data for TAMUS.*

Site Name	Data Type	Weather Site	Source*	Units	Starting - Ending Date	Observations
Texas A&M University-Corpus Christi	15min	Corpus Christi, TX (NWS)	ESL	kWh	08/18/00 - 12/19/00	missing data - 33 weeks
Texas A&M University-Corpus Christi	60min	Corpus Christi, TX (NWS)	CP&L	kWh	11/21/98 - 12/03/00	missing data - 14 weeks
Texas A&M International University	15min	Laredo, TX (NWS)	ESL	kWh	09/22/00 - 12/31/00	missing data - 38 weeks
Texas A&M University-Kingsville	15min	Corpus Christi, TX (NWS)	CP&L	kW	03/11/99 - 09/15/00	missing data - 15 weeks
Texas A&M University-Kingsville	60min	Corpus Christi, TX (NWS)	ESL	kWh	11/21/98 - 12/03/00	missing data - 14 weeks
Tarleton State Univerity	15min	Dallas/FW Airport (NWS)	TXU	kW	10/07/99 - 12/31/00	missing data - 146 points
Texas A&M University-Commerce	15min	Dallas Love Field (NWS)	TXU	kW	10/18/99 - 12/31/00	missing data - 230 points
Texas A&M University-Commerce (East Texas St. U	15min	Dallas Love Field (NWS)	TXU	kW	09/30/99 - 12/31/00	missing data - 334 points
West Texas A&M University (Substation)	15min	Amarillo, TX (NWS)	ABB	kWh	08/17/00 - 12/24/00	missing data - 34 weeks
West Texas A&M University (Activity Center)	15min	Amarillo, TX (NWS)	ABB	kWh	08/26/00 - 12/20/00	missing data - 36 weeks
Texas A&M University at Galveston	15min	Galveston, TX (NWS)	ESL	kWh	01/01/95 - 12/31/95	missing data - 52 weeks

*ESL - Energy Systems Laboratory, TAMU
CP&L - Central Power and Light Company
TXU - TXU Electric & Gas Texas Utilities
ABB - Asea Brown Boveri Ltd

All data sets were then converted to 15-minute format for the final load shape analysis. In general the data sets contained data for the year 2000, however special considerations were needed for each data set in order to rehabilitate the data for inclusion in the final analysis. These considerations will be detailed later in the paper.

Additional problems needed to be resolved, as indicated in Table 2. These problems included merging data sets from different time periods, merging data sets that contained different types of data (e.g., kW/15-minute which shows the peak demand for the 15 minute[1] vs kWh/15-minute which shows the electricity use for the 15-minute period[2]), and finally, shifting data sets for daylight savings (i.e., some sites used GMT time[3], others used local time[4]).

METHODOLOGY

In general, the overall methodology included: collection of the interval or time series data, reformatting of the data sets into one format, imputing of small data gaps, synthesis of 15-minute profiles for large data gaps, and matching of the synthetic monthly totals against the actual utility bills (i.e., 15-minute demand and usage). The main goal was to obtain one aggregated 15-minute electricity consumption profile and monthly demand for the year 2000 for all the campuses.

For those cases where only short periods of time series data were available, a weather-daytyping technique was used to generate the 15-minute load profiles (Haberl et al. 1998). This procedure assumed the energy consumption for each campus could be well described by six weather-daytype profiles, specifically: weekday-weekend, 24-hour profiles for three periods described by temperatures less than 45 F, temperatures between 45 F and 75 F, and temperatures above 75 F.

Since the weather data from the National Weather Service was available only in an hourly format, this required converting all data sets into hourly data, merging the campus energy use data with the appropriate, coincident NWS weather data, calculating the six weather-daytypes, forecasting the annual energy use using the weather-daytype profiles and then converting the data back to the appropriate 15-minute format for merging into the aggregated 15-minute data set.

APPLICATION OF THE METHODOLOGY TO THE TEXAS A&M INTERNATIONAL UNIVER-SITY IN LAREDO, TEXAS

As mentioned previously, for various reasons, several of the datasets were missing significant amounts of 15-minute or hourly data. In each of these cases an annual profile of 15-minute electric demand

[1] Time series records of kW/15-minute data contain the correct 15-minute demand information but must be divided by 4 to show the correct kWh/hr usage.

[2] Time series records of kWh/15-minute data show the correct hourly demand information, and therefore must be multiplied by 4 to show the correct 15-minute demand. Time series records of kWh/15-minute data add directly to give kWh/hr data.

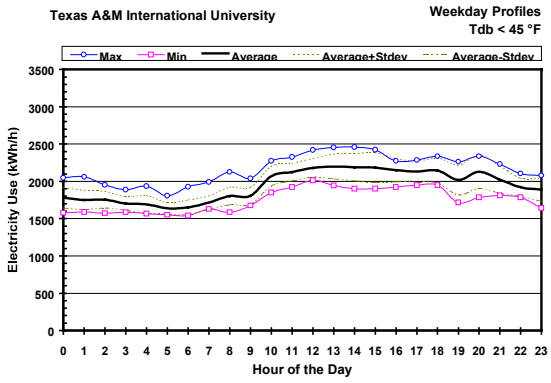
[3] The National Weather Service data uses a GMT time stamp that is not shifted for daylight savings. All other datasets were shifted for daylight savings.

[4] Data sets that were set to local time included data in daylight standard and daylight savings time formats.

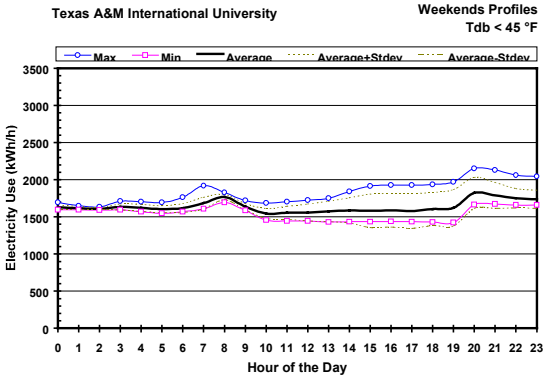
data (i.e., 35,040 records) needed to be created. In the case of the Texas A&M International University at Laredo, TX only 14 weeks of data were available from which needed to be extracted an annual profile. Fortunately, these data were available during the swing season months (i.e., September 22nd, 2000 to December 31st, 2000) which have been shown to be appropriate for constructing long-term estimates from short-term data (Katipamula et al. 1995; Reddy et al. 1998; Reddy and Claridge 2000).

***Table 3**. Weather datatypes used to generate the electric daytype consumption subgroups.*

Daytype A,
Toa < 45 °F
Daytype B,
Toa >=45 °F and Toa <=75 °F
Daytype C,
Toa > 75 °F

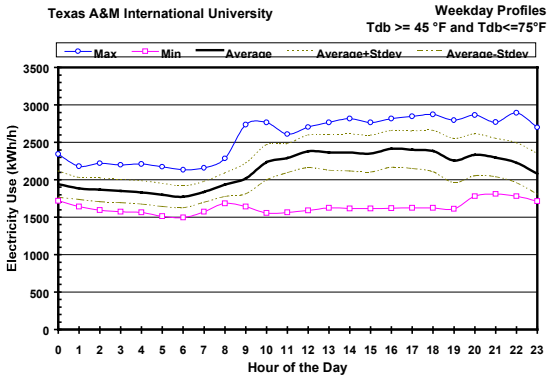


(a)

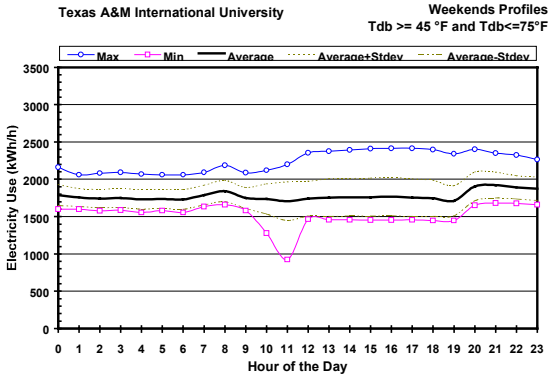


(b)

***Figure 1**. Hourly profiles for Texas A&M Intl. niversity when the dry bulb temperatures are lower than 45 °F: a) weekdays and b) weekends.*



(a)

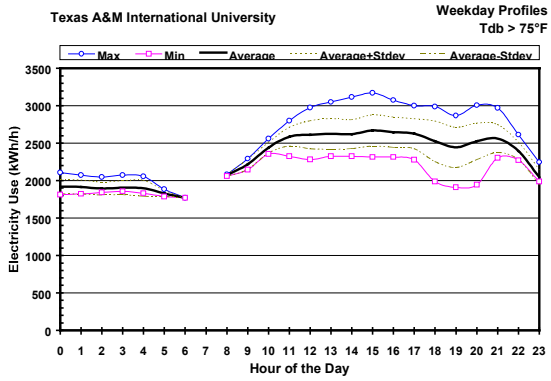


(b)

***Figure 2**. Hourly profiles for Texas A&M International University when the dry bulb temperatures are greater or equal than 45 °F and less than or equal than 75°F: a) weekdays and b) weekends.*

As a first step, the 15-minute data were converted to hourly data and merged with the coincident hourly weather data from the NWS weather station in Laredo. Then, the data were sorted into weekday (i.e., Monday through Friday, excluding holidays), and weekend (i.e., Saturday and Sunday) groups (see Table 3). The data were then further sorted into three groups according to the coincident hourly drybulb temperature: group 1 (temperatures below 45 F), group 2 (45 F to 75 F), and group 3 (above 75 F). Average 24-hour daytype profiles were then generated for each of the six groups, as shown in Figures 1 through 3. Table 4 contains the statistical information regarding the average, standard deviation (StDev - kW) and coefficient of variation of the root mean square error (CV - %), which indicate that the data are well described by the mean values. The average profiles for the weekdays in all three temperature groups show consumption that is typical of university campuses (Haberl et al. 1998), and is characterized

by an 8:00 a.m. to 11:00 p.m. occupied period. Weekend data are almost flat, as expected.



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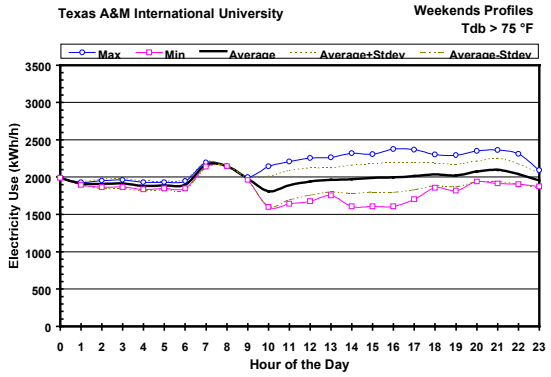


(b)

***Figure 3**. Hourly profiles for Texas A&M International University when the dry bulb temperatures are greater than 75 °F: a) weekdays and b) weekends.*

Figure 4a shows the unadjusted annual forecast of electricity consumption and the coincident drybulb temperature. In Figure 4a it is clear to see that the electricity usage follows ambient temperature. Unfortunately, this initial annual forecast varied from the actual utility bills by 13.5% as shown in Figure 5, with the largest variations occurring during the months of May, June and August. After an adjustment was applied[5] this value was reduced to 2.5% as shown in Table 5, which was considered adequate for the purposes of forecasting the aggregated electricity usage of all the TAMUS campuses.

In Figure 6 the forecast 15-minute electric demand is compared to the billed demand for the campus. Unfortunately, this demand was found to vary significantly for the month of April, followed by March, May and June - months that could not be explained by temperature alone. Since these springtime periods do not correspond to the highest temperature months, the high demand could not be explained by weather-daytype profiles derived solely from data for the months of September through December. Therefore, it was felt that to improve the fit, additional data for the spring period would need to be collected and processed to develop weather-daytype profiles for the spring semester.

***Table 4**. Statistics for the profiles generated for the data of Texas A&M International University*

Range	Weekdays		Weekends	
	StDev (kW)	CV (%)	StDev (kW)	CV (%)
Tdb <45°F	139.6	7.2	115.7	7.1
Tdb>=45°F and Tdb=75°F	213.4	10.0	183.3	10.3
Tdb>75°F	132.2	6.0	114.9	5.8

***Table 5**. Differences between the billed and the aggregate forecasted data, and the billed and the aggregate adjusted data for Texas A&M International University.*

MONTH	BILLED MWh	FORE-CASTED MWh	Diff %	ADJUS-TED MWh	Diff %
Dec-99	825.6	779.5	5.59%	832.6	-0.85%
Jan-00	873.6	704.7	19.33%	839.0	3.96%
Feb-00	820.8	724.3	11.75%	812.1	1.07%
Mar-00	931.2	731.3	21.46%	888.3	4.61%
Apr-00	1,046.4	814.4	22.17%	996.3	4.79%
May-00	1,080.0	781.1	27.68%	997.3	7.66%
Jun-00	916.8	735.5	19.77%	880.9	3.91%
Jul-00	1,041.6	865.4	16.91%	1,013.4	2.71%
Aug-00	816.0	735.2	9.90%	808.0	0.98%
Sep-00	772.8	757.9	1.93%	779.1	-0.81%
Oct-00	720.0	731.6	-1.61%	723.4	-0.47%
Nov-00	926.4	856.3	7.57%	907.1	2.08%

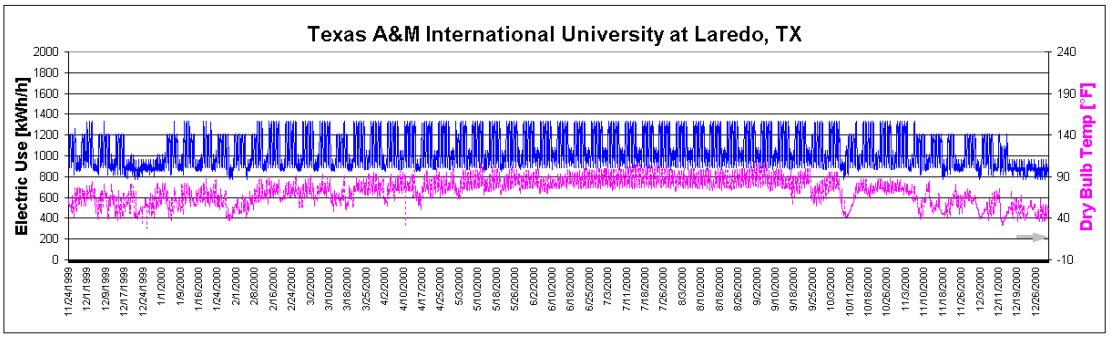
FORECASTING THE AGGREGATED ELECTRI-CITY USE AND DEMAND.

The forecasted total annual, aggregated 15-minute electricity use (MWh) and electric demand (MW) are shown in Figure 7 and 8. The total aggregated monthly electricity use for the 7 campuses ranged from a low of 43,123 MWh in December to a high of 62,617 MWh in August (see Table 7), which represents 145% of the lowest month. The largest electricity use for any single campus was the August use of the Texas A&M Commerce campus at 14,477 MWh. The two campuses with the least electricity use were the Texas A&M Galveston and Texas A&M International in Laredo campuses. In general, the

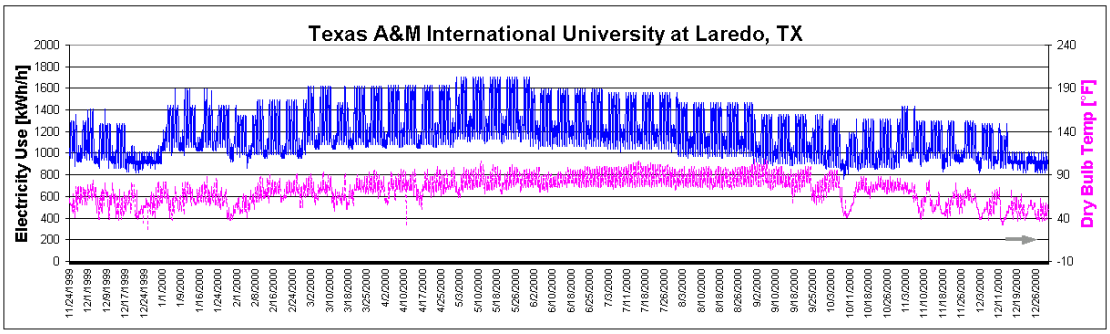
[5] This adjustment used a monthly multiplier that represented the difference between the billed and forecasted consumption (see Table 5).

monthly profile of the aggregated TAMUS campuses reflected the profiles of the individual campuses.

The total aggregated 15-minute electric demand for the 7 campuses ranged from a low of 23,134 kW in January to a high of 30,225 kW in August, which is 131% of the lowest month. The largest demand for a single campus was 6,566 kW in September for the Texas A&M Commerce campus. In a similar fashion as the electricity usage, the two campuses with the least electric demand were the Texas A&M Galveston and Texas A&M International in Laredo campuses. Surprisingly, the aggregated demand profile, which peaked in August, did not reflect the monthly profiles for the individual campuses, with several campuses peaking in September or October.



(a)



(b)

Figure 4. *15-minute profiles for the year 2000 for the Texas A&M International University: (a) original forecasting and (b) final adjusted forecasting.*

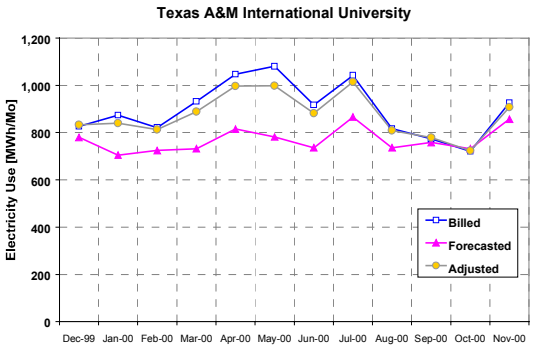


Figure 5. *Comparison between the billed, the forecasted, and the adjusted electricity use.*

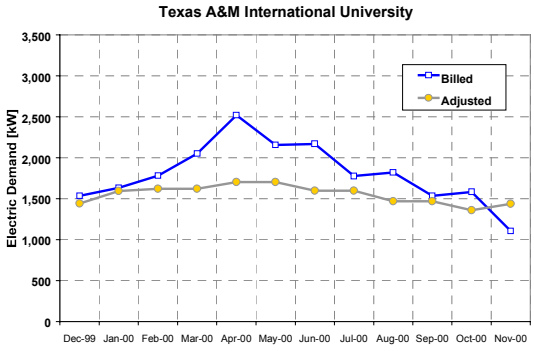


Figure 6. *Comparison between the billed and the forecasted electric demand for the Texas A&M International University.*

***Table 6**. Summary of the actions taken for the generation of the15-minutes profiles of all campuses in TAMUS*

Site Name	Source	Units	Actions
Texas A&M University-Corpus Christi	ESL and CP&L	kW	CP&L data from 01/01/00 to 08/30/00 and ESL data from 08/31/00 to 12/19/00. Missing data from 12/20/00 to 12/31/00 were replaced with CP&L data from 1999
Texas A&M International University	ESL	kW	Estimated through the methodology
Texas A&M University-Kingsville	ESL and CP&L	kW	CP&L data from 01/01/00 to 09/15/00 and ESL data from 09/15/00 to 10/25/00. Missing data from 10/26/00 to 12/31/00 were replaced with CP&L data from 1999.
Tarleton State Univerity	TXU	kW	TXU data from 01/01/00 to 12/31/00. Missing data from 08/26/00 to 08/27/00 were filled with using the linear interpolation.
Texas A&M University-Commerce	TXU	kW	TXU data from 01/01/00 to 12/31/00. Missing data from 11/25/00 to 11/26/00 were replaced with data from 1999.
West Texas A&M University (Substatic	ABB	kW	Estimated through the methodology
Texas A&M University at Galveston	ESL	kW	15-minutes profile generated through interpolation of the hourlyrly data of 1995. Adjusted values with a factor that include the difference of the actual bill and the profile. The difference was reduce in average less than one percent.

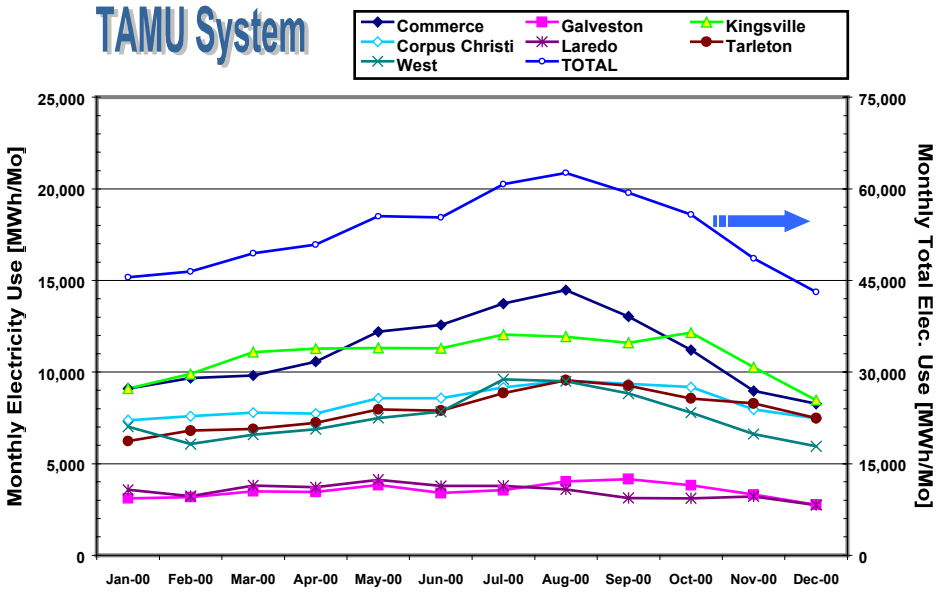


***Figure** 7. Total aggregated electricity use for the (7) TAMUS campuses.*

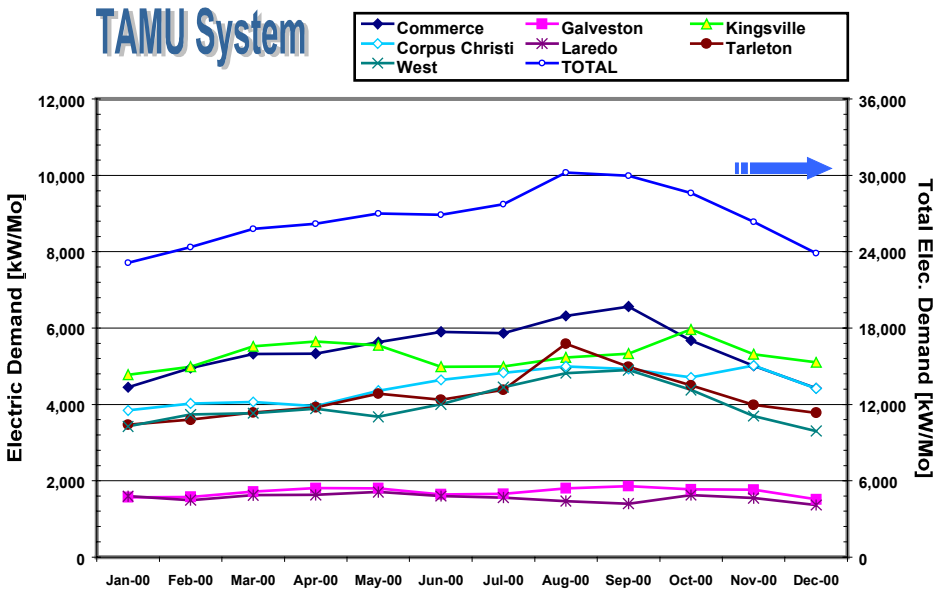


Figure 8. *Total aggregated electric demand for the (7) TAMUS campuses.*

Table 7*. Total aggregated electricity use for the (7) TAMUS campuses.*

TAMU Campus	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commerce	9,106	9,675	9,812	10,565	12,200	12,572	13,736	14,477	13,036	11,204	8,961	8,268
Galveston	3,099	3,180	3,486	3,464	3,826	3,399	3,554	4,028	4,157	3,817	3,315	2,759
Kingsville	9,106	9,899	11,092	11,271	11,323	11,290	12,037	11,928	11,597	12,147	10,262	8,464
Corpus Christi	7,370	7,587	7,784	7,731	8,567	8,577	9,163	9,533	9,357	9,180	7,952	7,464
Laredo	3,575	3,233	3,812	3,722	4,123	3,785	3,791	3,592	3,126	3,111	3,211	2,737
Tarleton	6,236	6,801	6,896	7,233	7,966	7,895	8,853	9,558	9,261	8,558	8,288	7,481
West	7,026	6,063	6,584	6,887	7,489	7,829	9,609	9,500	8,823	7,788	6,619	5,950
TOTAL	45,518	46,438	49,466	50,872	55,495	55,348	60,744	62,617	59,358	55,805	48,608	43,123

Table 8*. Total aggregated electric demand for the (7) TAMUS campuses.*

TAMU campus	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commerce	4,450	4,951	5,324	5,333	5,633	5,901	5,867	6,318	6,566	5,676	5,011	4,424
Galveston	1,570	1,576	1,712	1,808	1,803	1,646	1,658	1,802	1,858	1,770	1,768	1,509
Kingsville	4,781	4,988	5,521	5,648	5,550	4,988	4,994	5,233	5,334	5,965	5,315	5,101
Corpus Christi	3,846	4,023	4,064	3,958	4,362	4,645	4,827	4,995	4,925	4,712	5,017	4,418
Laredo	1,593	1,492	1,621	1,631	1,704	1,599	1,561	1,467	1,400	1,624	1,547	1,365
Tarleton	3,469	3,603	3,789	3,923	4,281	4,121	4,385	5,590	4,985	4,497	3,992	3,780
West	3,426	3,736	3,769	3,889	3,677	4,004	4,455	4,820	4,899	4,379	3,694	3,303
TOTAL	23,134	24,368	25,801	26,190	27,011	26,904	27,746	30,225	29,967	28,623	26,344	23,900

CONCLUSIONS

The procedures used to collect and forecast the aggregated, 15-minute electricity usage data for (7) of the TAMUS campuses has been presented along with the aggregated load profile for all (7) campuses. An example of the application of the procedure to the Texas Texas A&M International University was also presented. The results show that an adjusted weather-daytyping procedure can accurately match the monthly electricity usage. However, in the case of application of the method to the Texas A&M International University, forecasting the springtime electric demand using 15-minute data gathered in the fall semester comes up short of accurately forecasting the electric demand.

The experience of applying these procedures to the different data sets has also shown that the analyst must understand how to resolve database issues such as imputing data, merging different types of electric interval data (i.e., kWh/15-minte and kW/15-minute), and merging data sets with different time stamps (i.e., GMT time stamps and local time stamps).

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