Module 6: Energy Assessment – Load Inventory

Learning Objectives

After completing this module, you will be able to
- Create an energy load inventory, and reconcile it to consumption data

6.1 The Electrical Load Inventory

Organizations use inventories to keep track of many items. An inventory of the uses of electricity will help to develop a baseline that will allow you to focus your energy management efforts upon the areas of greatest opportunity.

Making a list or inventory of all loads in a facility answers two important questions:

- ***Where*** is the electricity used?
- ***How much and how fast*** is electricity used in each category?

Often the process of identifying categories of use allows sources of waste to be easily identified, and this often leads to low cost savings opportunities. Identifying the high-consumption loads lets you consider the best savings opportunities first.

Because the inventory also quantifies the demand (or "how fast") associated with each load or group of loads, it is invaluable in further interpretation of the demand profile.

Table 6.1 is a sample load inventory for an elementary school.

Table 6.1: Sample Load Inventory for Elementary School

Elementary School Load Inventory								
Lighting	**Area**	**Num.**	**kW**	**Total kW**	**Div. Factor**	**Peak kW**	**Hrs**	**Energy kWh**
1'X4' 2 lmp	Cust. Rm.	6	0.096	0.6	1	0.6	250	144
1 lmp fix.	Main Hall	30	0.096	2.9	1	2.9	250	720
2lmp 2 bal.	Class Rms	130	0.105	13.7	1	13.7	250	3,413
U tubes	Class Rms.	25	0.096	2.4	1	2.4	250	600
2 lmp fix.	Class Rms.	9	0.096	0.9	1	0.9	250	216
2 lmp 2bal.	Library	25	0.105	2.6	1	2.6	250	656
2 lmp 2bal.	Book Rm.	2	0.105	0.2	0.1	0.0	25	5
2 lmp fix.	Wash Rms.	18	0.096	1.7	1	1.7	250	432
2 lmp fix.	Stor. Rms.	3	0.096	0.3	0.1	0.0	25	7
15o w. pot	Entry	20	0.15	3.0	1	0.2	250	750
U tubes	Hallway	21	0.096	1.3	1	1.3	275	370
2 lmp 2bal.	Paint Rm	9	0.105	0.9	0.1	0.1	25	24
2 lmp 2bal.	Paper Supl.	3	0.105	0.3	0.1	0.0	25	8
2 lmp 2bal.	Film Rm.	9	0.105	0.9	0.5	0.5	125	118
2 lmp fix.	Lockers	4	0.096	0.4	1	0.4	250	96
150 w. pots	Lockers	4	0.15	0.6	1	0.6	250	150
400 w. M.H.	Gym	9	0.475	4.3	1	4.3	250	1,069
U tubes	Gym Stor.	4	0.105	0.4	0.5	0.2	125	53
2 lmp 2bal.	Gym Office	2	0.105	0.2	0.5	0.1	125	26
150 w. IA	Janitor Rm.	1	0.15	0.2	0.5	0.1	125	19
2 lmp fix.	French Rm.	9	0.105	0.9	1	0.9	250	236
60 w. IA's	Wash Rms.	2	0.06	0.1	0.1	0.0	25	3
60 w. IA's	Staff Hall	3	0.06	0.2	1	0.2	250	45
U tubes	Staff Rms.	14	0.096	1.3	1	1.3	250	336

2 lmp 2bal.	Staff Rms	10	0.105	1.1	1	1.1	250	263
2 lmp 2bal.	Copier Rm	3	0.105	0.3	0.5	0.2	125	39
Utubes	Copier Rm	1	0.096	0.1	0.5	0.0	125	12
60 w. IA	Copier Rm	1	0.06	0.1	0.5	0.0	125	8
2 lmp 2bal.	Music Rm.	12	0.105	1.3	0.5	0.6	125	158
U tubes	Music Rm.	4	0.096	0.4	0.5	0.2	48	18
2 lmp 2bal.	U. P. Room	2	0.105	0.2	0.6	0.1	150	32
100 w. IA's	Mech. Rm.	6	0.1	0.6	1	0.6	250	150
100 w. IA's	Boiler Rm	3	0.1	0.3	0.1	0.0	25	8
2 lmp strip	Boiler Rm.	1	0.096	0.1	0.1	0.0	25	2
	Totals			**44.8**		**37.9**		**10,184**
Motors								
20 H.P.	Vent. Fan	1	15	15.0	1	15.0	250	3,750
0.5 H.P.	Compress.	1	0.4	0.4	0.25	0.1	75	30
0.25 H.P.	Fridges	2	0.3	0.6	0.5	0.3	460	276
0.5 H.P.	Freezer	1	0.5	0.5	0.5	0.3	150	75
0.25 H.P.	Milk Coolers	2	0.2	0.4	1	0.4	300	120
Rooftop Exh - .25 HP		5	0.25	1.3	1	1.3	250	313
Gym H/V Fan		1	2	2.0	1	2.0	250	500
Gym Circ Pmp - 1 HP		1	0.8	0.8	1	0.8	250	200
Sewage plant aeration pumps		2	1	2.0	1	2.0	746	1,492
	Totals			**23.0**		**22.1**		**6,756**
Other Loads								
Dryer		1		3.0	1	3.0	45	135
Portable School Trailer		1	20	20.0	1	20.0	125	2,500
	Totals			**23.0**		**23.0**		**2635**
Building	**Totals**			**90.7**		**83.0**		**19574**

The data in Table 6.1 were obtained from a survey of the facility; a simple spreadsheet was used to calculate the peak demand and energy values according to the calculation method outlined in Table 6.2.

Table 6.2: Sample Load Inventory Calculations

Data-entry Item	Units	Description
Quantity	(a number)	The quantity of this particular item.
Unit Load	kW	The load in kW for one of this particular load.
Total kW	kW	Quantity x Unit Load.
Hrs/Period	hours	The estimated hours of use per period
kWh/Period	kWh	Total kW x Hrs/Period
On - Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Diversity Factor (Div'ty Factor)	0 - 100%	That fraction of the total load that this particular item contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this value equal to the Total kW x Diversity Factor

Finally, the load inventory data can be represented graphically to show the distribution of demand and energy consumption. The difference between the graphs reveals that any given load may have a greater impact upon demand or energy depending upon its size and mode of operation.

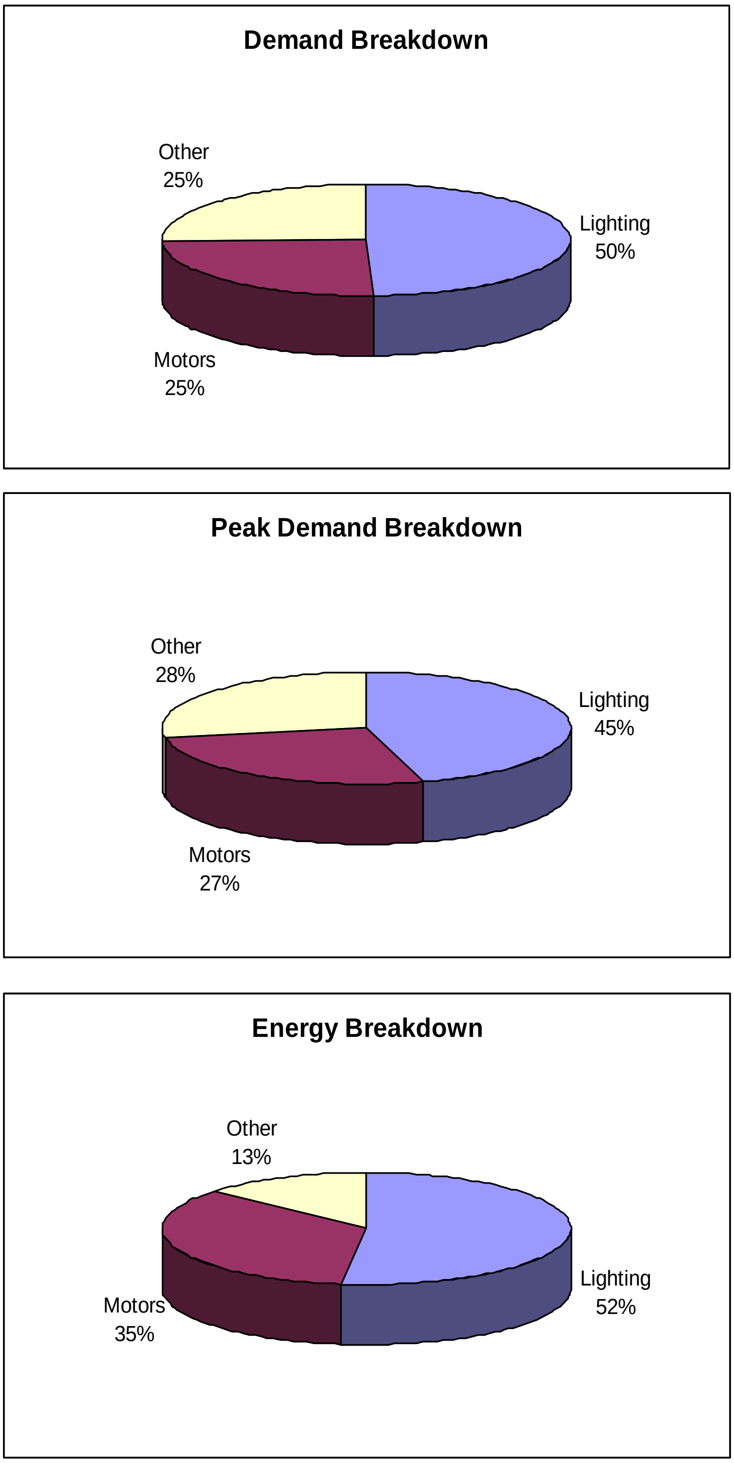


Figure 6.1: Breakdown of Building Demand and Energy

6.1.1 How to Compile a Load Inventory

This section outlines a method for compiling a load inventory using a set of forms, samples of which are given in the next few pages and which are also included as worksheets at the end of this Section. Each form is accompanied by instructions for its use.

In addition to these forms, a clipboard, pencil and calculator are required. Instrumentation is not a necessity; a simple clip-on ammeter is probably adequate in most situations.

STEP 1 To begin, three pieces of information are required**:**

A period of time on which the inventory will be based. Usually this would be a month—corresponding to the utility billing period—but it could also be a day, week or year. Select a period which is typical of operations in your facility.

The actual demand in kilowatts (kW) and **the energy consumption in kilowatt-hours** (kWh) for the period selected. If the period selected is a month, then this information is available from the utility bill. If the facility demand is measured in kVA, then this will require a calculation based on the peak power factor to convert kVA to kW. See **Module 2: Energy Basics** for details.

Record the actual values on the Summary Form LD1, as Actual Demand and Energy.

STEP 2 Identify each of the major categories of electricity use in the facility. This may require that you take a walk through, and list categories as you notice them. Record each category on FORM LD1. When identifying the various categories of use, it is useful to consider both the type of electricity use and the activity in each area. Selecting categories with similar operation patterns is a good approach.

The example on the sample form separates the motor use from the lighting use in each of the office, production (multiple categories), and exterior areas.

STEP 3 Guess the percentage of demand attributable to each category. This may be based on prior knowledge, a rough idea of the size of the loads, the size of the distribution wiring, etc. Also, use any information available from the demand profile when preparing this estimate. Record the demand percentages on Form LD1 and calculate the estimated demand for each category of use based on the actual demand.

STEP 4 Guess the percentage of energy used in each category. This should be based on occupancy, production, or other such factors relating to the intensity of use in each category. Record the energy percentages on Form LD1 and calculate the estimated energy for each category of use based on the actual energy.

STEP 5 Select the category of use in which the largest amount of demand and/or energy is used.

STEP 6 Use Forms LD3, LD4 and LD5 to list each and every load in the category selected. Only record nameplate and kW load information up to and including the Total kW. Each form is designed for a different type of information. For each load, select one method of recording information according to the following criterion:

LD3 - Simple Load Information

Use this form for such things as lighting, electric heat, office equipment, or any load for which the load in kW is known.

LD4 - Current Voltage Method

Use this form to record detailed nameplate data from loads such as coolers, small motors, appliances, etc. when kW load data is not known. This form should also be used for any device that actual measurements are conducted upon.

LD5 - Motor Load Method

This form should only be used for motors. It provides a method of estimating kW load based upon motor horsepower, loading and efficiency. Do not use this method if actual motor currents and voltages have been measured; use Form LD4.

STEP 7 For each load, estimate the hours of operation for the period selected. Also indicate if this load is on during the peak demand period and/or at night. At this point, do not attempt to estimate the diversity factor.

STEP 8 Repeat Steps 6 and 7 for each category of use working down from the categories of highest energy use and demand to the lowest. If the estimated energy use and/or demand in a category is relatively small (less than 5%) then performing a detailed inventory is probably not worthwhile.

6.1.2 Instrumentation Used in the Load Inventory

The instrumentation used in the energy audit has been described in some detail in Module 4. Electrical instrumentation can provide detailed current, voltage and power information for the load inventory. Some care must be taken when interpreting measurements to ensure that the results are not misleading.

All measurements, other than multiple readings taken with a recording device (e.g. the demand profile), are instantaneous. This means that the value measured only indicates the state of the device at the time when the measurement was taken. In the case of lighting (without dimmers) and loads that do not experience varying levels of operation, such readings are a good indication of long term conditions such as power consumption. This is not true for most motor loads such as fans, pumps, refrigeration units and compressors. For measurements on varying loads, a number of supplementary or alternative techniques are available:

- When taking readings, try to determine the level of load on the device in terms of production or operational levels. This can be used to adjust the measured value to a good long term average.
- Always take more than one reading, possibly over a period of time appropriate to the rate of change of the load. Consider averaging the measured values.
- Use a recording device (ammeter, power meter, etc.), an effective means of gathering long term data.
- Use other operational records such as maintenance records and chart recorders to develop long term average values.

Experience in electrical energy auditing has shown the following type of instrumentation to be of value:

- Handheld clip-on meter—for instantaneous current and voltage measurements.
- Power factor meter—for determination of load, distribution, or service entrance power factor. The utility demand meter remains a good method of determining on-peak service entrance power factor.
- AC power meter—for complete motor power measurements.
- Non-contact tachometer—for motor speed measurement, to assist in estimating motor load percentages.
- Flow meters (water and air) and a temperature measuring device for estimating load levels on motors.

6.1.3 Load Inventory Forms

Five data collection forms are provided to assist in the compilation of the load inventory:

Form LD1: Load Inventory Summary
Form LD2: Category of Use Summary
Form LD3: Simple Load Information
Form LD4: Detailed Information (Current - Voltage Method)
Form LD5: Detailed Information (Motor Load Method)

Samples of each form are provided in the following sections, and blank forms are given at the end of the module. Guides for filling them out, are provided on the accompanying pages.

Form LD2   Category of Use Summary for: <u>   The Entire Facility</u>

Form No.	Description	kWh/ Period	Peak kVA	Night kVA
LD3	Simple Load Information	4,087	15.9	.235
LD4	Detailed Load Information	30,680	76.1	0
LD5	Motor Load Information	432	1.9	1.9
Total Calculated		35,199	93.9	2.1

Form LD2: Category of Use Summary

This form is used to summarize the detailed load information from Forms LD3, LD4, and LD5. Enter the total value for kWh/Period, Peak kVA and Night kVA from each of the forms and then total the three columns.

Form LD1 Load Inventory Summary Form

Category of Use	Estimated Demand (%) (a)	Estimated Energy (%) (b)	Estimated Demand (kW) (c)	Estimated Energy (kWh) (d)	Calculated Demand (kW) (e)	Calculated Energy (kWh) (f)	Calculated Night Load (kW) (g)
Air Compressors	22	6	113	13,500			
Lights	10	10	51	22,500			
HVAC	35	33	179	74,250			
Refrigeration	30	50	154	112,500			
Outside	3	1	15	2,250			
Estimated Percentages							
Actual Demand & Energy			512	225,000			
Calculated Demand & Energy							
Calculated Night Load							

Period for Energy Calculations	Day	Week	Month	Year
Hours per Period	24	168	732	8760
Check the period used.			☐	

Form LD1: Load Inventory Summary

This form is the starting point and ending point for the load inventory. Initial estimates of the load breakdown are entered here, and the final totals of calculated loads in each category of use are summarized on this form.

Data-entry Item	Units	Description
Estimated Demand	%	A percentage representing the fraction of demand in this category.
Estimated Energy	%	A percentage representing the fraction of energy in this category.
Estimated Demand	kW	The Estimated Demand % multiplied by the Actual Demand Total.
Estimated Energy	kWh	The Estimated Energy % multiplied by the Actual Energy Total.
Calculated Demand	kW	The total calculated demand from form LD2 for each category of use.
Calculated Energy	kWh	The total calculated energy from Form LD2 for each category of use.
Calculated Night Load	kW	For each category of use, the calculated night load from the detail forms.
Estimated Percentages	%	Should always be equal to 100%, the total of each of the demand and energy percentages.
Actual Demand & Energy	kW & kWh	The actual demand and energy consumption for the period—possibly from the electric bills.
Calculated Demand & Energy	kW & kWh	The TOTAL of the calculated demand and energy columns.
Calculated Night Load	kW	The TOTAL of the calculated night load column.

Form LD3 **Simple Load Information** **Category of Use: Lighting**

Description	Qty (a)	Unit Load (b)	Total kW (c) = a x b	Hrs/ Period (d)	kWh/ Period (e) = d x c	On @ Peak Y or N	Div'ty Factor (f)	Peak kW (g) = f x c	On @ Night Y or N	Night kW
Office fl	50	.047	2.35	290	682	Y	100	2.55	N	0
Warehouse	30	.45	13.5	250	3,375	Y	100	13.5	N	0
Corridor	5	.047	.235	129	30	Y	30	.07	Y	.235
Totals	n/a	n/a	n/a	n/a	4,087	n/a	n/a	15.9	n/a	.235

Form LD3: Simple Load Information

This form is used to record simple load information, and to calculate demand and energy for each item. The total kWh/Period, Peak kW, and Night kW should be entered on the last row of the form.

Data-entry Item	Units	Description
Quantity	(a number)	The quantity of this particular item.
Unit Load	kW	The load in kW for one of this particular load.
Total kW	kW	Quantity. x Unit Load.
Hrs/Period	hours	The estimated hours of use per period
kWh/Period	kWh	Total kW x Hrs/Period
On @ Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Diversity Factor (Div'ty Factor)	0 - 100%	That fraction of the total load that this particular item contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this value equal to the Total kW x Diversity Factor
On @ Night	Yes/No	Is this load on at night?
Night kW	kW	If this load is on at night, then this is equal to the Total kW. Otherwise, it is 0.

Form LD4 Detailed Information (Current - Voltage Method) **Category of Use:____________________**

Description	Qty (a)	Volts (b)	Amps (c)	Phase (d)	PF (e)	Total kW (f)	Hrs/ Period (g)	kWh/ Period (h) = g x f	On @ Peak Y or N	Div'ty Factor (i)	Peak kW (j) = i x f	On @ Night Y or N	Night kW
Roofing Units	10	575	15	3	.85	126.8	242	30,680	Y	.6	76.1	N	0
Totals	n/a	n/a	n/a	n/a	n/a	n/a	n/a	30,680	n/a	n/a	76.1	n/a	0

Total kW = (f) = (a) x (b) x (c) x (d) x (e) for single phase, use (d) = 1
for three phase, use (d) = $\sqrt{3}$ = 1.73

Form LD4: Detailed Information (Current - Voltage Method)

This form is used for collecting detailed data when current and voltage nameplate data or measured data is available. The total kWh/Period, Peak kW, and Night kW should be entered on the last row of the form.

Data-entry Item	Units	Description
Qty	N/A	The number of units in operation?
Volts	volts	The line voltage (measured or nameplate) for this load.
Amps	amps	The current drawn by this load. Either measured or from the nameplate. For a three phase load, record only the current per phase.
Phase	1 or 3	The number of AC phases used by this load.
Power Factor	0 - 100%	The estimated or measured power factor of this load.
Total kW	kW	Qty x Voltage x Amps x 1.73 x Power Factor
Hrs/Period	hours	The estimated hours of use per period.
kWh/Period	kWh	Total kW x Hrs/Period.
On @ Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Diversity Factor	0 - 100%	That fraction of the total kW for this particular load that contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this value equal to the Total kW x Diversity Factor
On @ Night	Yes/No	Is this load on at night?
Night kW	kW	If this load is on at night, then this is equal to the Total kW. Otherwise, 0.

Form LD5 Detailed Load Information (Motor Load Method) **Category of Use: Air Compressor**

Description	Qty (a)	Motor HP (b)	Motor Load % (c)	Motor Eff % (d)	Total kW (e)	Hrs/ Period (f)	kWh/ Period (g) = e x f	On @ Peak Y or N	Div'ty Factor (h)	Peak kW (i) = e x h	On @ Night Y or N	Night kW
5 HP Air Compressor	1	5	75	78	3.6	120	432	Y	5	1.9	Y	1.9
Totals	1	5	75	78	3.6	120	432		5	1.9		1.9

Total kW(e) =(a) x (b) x .746 x (c) ÷ (d)

Form LD5: Detailed Information (Motor Load Method)

This form is used to estimated motor power loads from motor loading and efficiency data. The total kWh/Period, Peak kW, and Night kW should be entered on the last row of the form.

Data-Entry Item	Units	Description
Qty	N/A	The number of units in operation?
Motor HP	HP	The nameplate motor horsepower.
Motor Load %	0 - 100%	The fraction of the nameplate horsepower that this motor is estimated to be delivering to its driven load.
Motor Eff %	0 - 100%	The estimated or measured motor efficiency from electrical power input to shaft power output. This value will depend on the Motor Load %—it is not simply the nameplate efficiency.
Total kW	kW	Qty x Motor HP x 0.746 x Motor Load % ÷ Motor Eff %.
Hrs/Period	hours	The estimated hours of use per period.
kWh/Period	kWh	Total kW x Hrs/Period.
On @ Peak	Yes/No	Is this load on during the peak period identified in the demand profile?
Div'ty Factor (Diversity Factor)	0 - 100%	That fraction of the total load that this item contributed to the peak demand.
Peak kW	kW	If the load is on peak, then this is equal to the Total kW x Div'ty Factor
On @ Night	Yes/No	Is this load on at night?
Night kW	kW	If this load is on at night, then this is equal to the Total kW. Otherwise, 0.

6.1.4 Collecting and Assessing Lighting Information

Data on lighting is generally the easiest to collect. Normally there are only a few different wattages and lamp types in use in any given facility although there might be large quantities of some types. Once the basic types and wattages are identified, a simple checklist would enable you to quickly add up the various types by category and run time. The sample table on the following page could be customized to include only the fixture types in use at your plant. Transfer the totals to Form LD3 when complete.

Note the following when gathering lighting data:

- Don't forget to include the ballast wattage in your total fixture wattage. Here are some typical ballast wattages:

Table 6.3: Fluorescent Ballasts

Ballast Type	Ballast Watts
Standard 4' 2-tube Fluorescent	14
Energy-Efficient 2-tube Fluorescent.	9
Electronic Fluorescent	5
Compact Fl. (7,9,11 or 13 Watts typical)	3

- Check to make sure fluorescent fixtures from which the lamps have been removed have also had the ballasts disconnected. A fluorescent ballast will still consume power even if there are no lamps installed.

- Use time clock settings and/or operation schedules whenever possible to get a good estimate of run times.

Group the load information by lamp type and operating hours in order to make your kWh estimates accurate.

6.1.5 Collecting and Assessing Motor and Other Data

Some rules of thumb and suggestions for data gathering and assessment:

- If motors are supplied at 600V/3-phase, the full-load kVA is approximately equal to the full-load amps (nameplate). This is due to the relationship between kVA and current on 3 phase systems:

  $$kVA = V \times I \times \sqrt{3}$$

  For example, if a motor is rated at 600V/5.7A, then the full-load kVA would be:

  $$600 \times 5.7 \times 1.73 = 5.9 \text{ kVA}$$

  The power factor must then be applied to this to obtain the kW load as noted in Form LD4. This can range from 50% to 90%, depending on motor type and loading and whether power factor correction capacitors have been installed.

- kWh consumption of household and office type equipment such as refrigerators and photocopiers can sometimes be evaluated from tables.

- Loads on refrigeration equipment will vary with the ambient temperature and load. On large refrigeration compressors, it may be useful to actually measure the operating periods over a given time span (time with a stop watch). If this is done at a time when the load on the equipment is typical, then an accurate load factor (% operating time) can be calculated. Note that the load factor during off hours would generally be somewhat less.

Load inventory data can be verified using a clip-on ammeter to measure the amps on a feeder circuit if:

- The feeder circuit serves one specific type of load (e.g. a lighting panel).
- The equipment fed by the feeder is known with reasonable accuracy.
- The loads being measured are not cycling.

This type of spot current metering can sometimes show up loads that may be operating unnecessarily, such as out-of-the-way electric heaters or small motors.

6.1.6 Reconciling the Load Inventory with Utility Bills

Once the load inventory information is collected it can be reconciled against the peak or maximum demand and energy consumption registered by the utility meter. The result will be a detailed breakdown of energy consumption and maximum demand.

6.1.6.1 Peak Demand Breakdown

For each of the loads identified in the load inventory a total load in kVA was calculated. The electrical demand that the particular load contributes to the peak demand must be less than or equal to this value. The question that must be answered at this point is: how much of each total load contributes to the peak demand?

For a given load, the relationship between the total load and the amount that it contributes to the peak demand is:

Peak Demand = Total Load x Diversity Factor

The diversity factor takes into account a number of situations that could lead to less than the total load contributing to the peak demand:

- The load cycles on and off, and is on for less than 30 minutes at a time. After 15 minutes, the utility thermal demand meter will register 90% of the total load.

Table 6.4: Response of Demand Meter

On-Time of Load	Percentage Registered by Utility Meter
1 minute	15%
5 minutes	52%
10 minutes	78%
15 minutes	90%
30 minutes	97%
> 30 minutes	100%

- The particular load may or may not be on during the peak demand periods; the diversity factor in this situation becomes a coincidence factor relating the chance that the load is on coincidentally with the demand peak.

6.1.6.2 Reconciliation of the Peak Demand

Reconciling the peak demand from utility invoices with the calculated peak demand derived from the load inventory involves:

- Determining from the utility bill or the utility meter the peak demand for the period of interest.
- If billed in kVA, converting the billed kVA to kilowatts (kW) using the on-peak power factor.
- Estimating the diversity factor for each load that is on during the peak, calculating the total diversified demand.
- Comparing the calculated peak to the actual peak and adjusting the calculations to reconcile the values as required.

The task of estimating the amount of peak demand that is attributable to a particular load involves two questions:

1. What effect does the duty cycle of any given load have upon the demand meter - considering the response of the meter ?
2. What is the coincidence between the particular load and all other loads in the facility?

As described previously, the diversity factor takes into account these two effects; this is illustrated in Figure 6.2. In the example the duty cycles of various loads are shown along with an estimate of the diversity factor, and it is assumed that the peak period occurs between 2:00 PM and 5:00 PM.

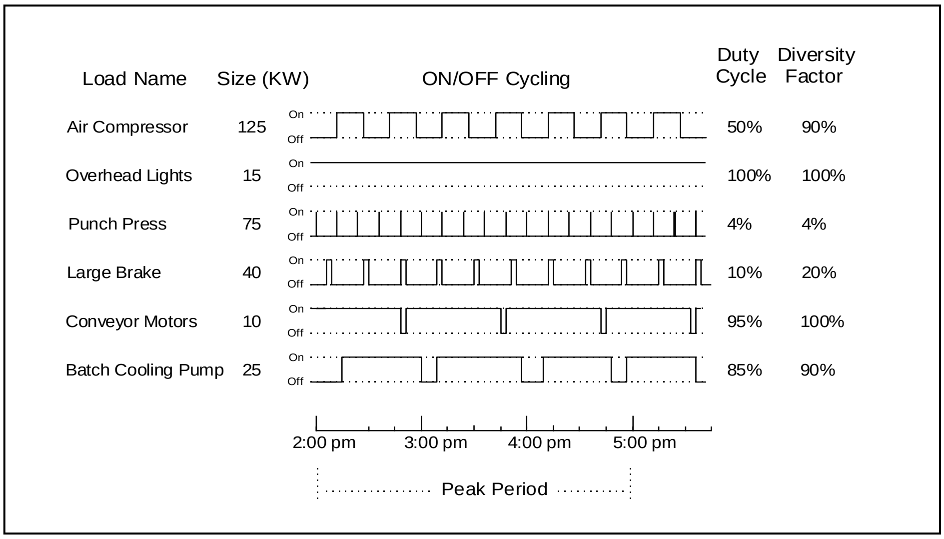


Figure 6.2: Estimating Diversity Factors for Loads

Although some of these systems are not applicable to buildings, the diversity factors were estimated by the following reasoning.

- **Air Compressor** - The unit cycles on and off every 15 minutes. The demand meter will register 90% of demand in 15 minutes. This load is on at the same time (coincidentally with a number of the other loads during the peak period. Therefore the full 90% is used.

- **Overhead Lights** - These are on continuously during the peak period, so the demand meter will register 100% of full load in coincidence with all other load.

- **Punch Press** - The punch press motor operates for only 0.6 minutes; the demand meter would register about 8% in that time. But, this load is not completely coincident with all other loads so a 50% allowance is made for coincidence. The result is a 4% diversity factor.

- **Large Brake** - the motor on this machine operates for 1.5 minutes at full load; and is coincident with the other loads at least once during the peak period. Therefore, the 1.5 minute meter response of 20% is used for the diversity factor here.

- **Conveyor Motors** - the off-time of the conveyors is not significantly long enough to allow the meter indication to drop significantly, so a 100% diversity factor is used.

- **Batch Cooling Pump** - The pump cycles on for a long period (35-40 minutes); the meter should register the entire demand. A 10% allowance is made for the non-coincidence of this load and other short running large loads. Therefore, 90% is used for a diversity factor.

There are alternative methods for estimating diversity factors. One method that may be useful follows:

STEP 1 Assume that all diversity factors are 100%, and calculate the sum of all the total loads. This is called MAXLOAD. This represents the demand that would occur if all loads were on continuously. Subtract the Actual Peak Demand from MAXLOAD. This difference will be referred to as DIFF-A.

STEP 2 Determine which loads are on continuously—for these loads the diversity factor will be 100%. Add each of these loads; this total is called CONTLOAD. Subtract CONTLOAD from the Actual Peak Demand; this difference is DIFF-B.

STEP 3 Divide DIFF-B by DIFF-A and multiply by 100. This value is an average diversity factor for all loads that do not operate continuously (intermittent loads). Call this the AVERAGE FACTOR.

STEP 4 For each of the intermittent loads, determine what factor their duty cycle results in at the utility meter from the table listed above. If this factor is less than the AVERAGE FACTOR, then use this value; otherwise use the AVERAGE FACTOR as the diversity factor for this load.

STEP 5 For each diversity factor that is adjusted downwards, you will need to adjust another load upwards, to maintain the average. Physically, this means that there is a load that contributes more to the peak demand than the AVERAGE FACTOR allows. These adjustments should take into account the coincidence between the loads.

STEP 6 Review each of the loads in this manner and then calculate the peak demand again. Compare this with the actual. If the difference is greater than 5%, repeat Steps 5 and 6. Some judgment will be required when adjusting loads upwards. Remember that the overall objective here is to make the best estimate possible of what each load contributes to the peak demand.

Useful Hints:

- Use the information in the demand profile, such as load patterns and duty cycles.
- It may be necessary to not only adjust the diversity factors but also the basic load data to achieve a reconciliation.
- Many devices use less than their nameplate ratings—use an ammeter.
- It may be necessary to proceed to the reconciliation of energy use (next section) to assist in reconciliation of the peak demand. If the basic load data is incorrect it will affect both energy and demand. The energy reconciliation may provide clues.
- Use a recording meter if possible on groups of loads for which the duty cycle is unknown.
- Differences are usually a result of bad assumptions, not bad nameplate or measured data.

6.1.6.3 Energy Breakdown

The load inventory (kW) information, along with the estimated run times, is used to generate an energy breakdown. As with the peak demand breakdown, the aim is to match the total energy metered in a period to the sum of individual loads calculated for the same period.

The basic relationship for energy consumed by an individual piece of equipment is:

Energy (kWh) = Power (kW) x Operating time (Hours)

- Rated Load (kW) is the equipment nameplate value of power or Volts x Amps x Power Factor (if applicable) x 1/1000 (x $\sqrt{3}$ for 3-phase) x Loading (%).

- Operating Time (Hours) is the total time the equipment is energized during the period being evaluated x Duty Cycle (%).

- Duty Cycle (%) is applicable only for loads that cycle on and off automatically while energized. An example of this would be refrigeration equipment. If they do not cycle, the Duty Cycle = 100%.

- Loading (%) is applicable to equipment that can run under less than full load conditions, such as motors driving centrifugal loads. Note that here we are referring to the percentage of full load kW being drawn by the load.

Examples

1. A refrigeration compressor runs on a 30% duty cycle with a nameplate rating of 600V/22A and its power factor is 75%. The evaluation period is 33 days. The compressor is energized all the time and runs fully loaded. The consumption would be:

600(V) x 22(A) x $\sqrt{3}$ x 75% (P.F.) x 1/1000 x 33 (days) x 24 (hrs/day) x 30% (duty cycle)
= 4,074 kWh

2. A bank of 20 - 400W HID lights is operated 10 hours per day, 5 days per week. Each has a 50 watt ballast. For the same evaluation period of 33 days, the consumption is:

20 lamps x (400 + 50) watts/lamp x 10 hrs/day x 5 days/week x 1/1000 x 33/7 weeks
= 2,121 kWh

3. A 50 HP motor is rated at 600V/50A/83% P.F. It runs for 5 hours per day, 5 days per week at a 75% loading. For 33 days, the consumption is:

600 x 50 x $\sqrt{3}$ x .83 x .75 x 1/1000 x 5 days/wk x 5 hrs/day x 33/7
= 3,812 kWh

6.1.6.4 Energy Reconciliation with Utility Bills

After calculating the energy use of all the different loads in the load inventory, these calculations should be reconciled with the utility bills. If you have evaluated all the loads carefully, the numbers may be reasonably close. If there is a large difference, the following may help reconcile the differences:

- If you have more than one meter or have your own sub-metering, break down the energy to match the individual meters.
- Evaluate the loads you know the most about first—general lighting, equipment on time clocks, motors running at constant loads, etc. Assume these are correct and the errors are in other less constant loads such as refrigeration.
- Go back to your first general assumptions (% breakdown) and see how they match up with your more detailed breakdown.
- Double check schedules, time clocks, etc. to see if equipment is running longer than you thought.
- If you are averaging weeks into a monthly period, this can introduce errors depending on where weekends fall within the billing period.
- When estimating heating equipment run-times, if the oil consumption is known, the operating hours can be calculated as (oil consumed in the period) / (firing rate of the burner). This would only work for a single stage burner.

- If available, use your demand profile to estimate duty cycles of cyclical loads.
- Night loads are often continuous. Try to account for all of your night loads.

Worksheet 6-1 Load Inventory

Compile a simple load inventory of the loads in the workshop room.

Description	Qty	Unit kW	Total kW	Diversity Factor %	Peak Demand kW	Hours per Day	kWh per Day
Totals	**n/a**	**n/a**		**n/a**		**n/a**	

Equations:

1. Total kW = Qty x Unit kW
2. Peak Demand kW = Diversity Factor x Total kW
3. kWh per day = Total kW x Hours per day

Form LD1 Load Inventory Summary Form

Category of Use	Estimated Demand (%) (a)	Estimated Energy (%) (b)	Estimated Demand (kW) (c)	Estimated Energy (kWh) (d)	Calculated Demand (kW) (e)	Calculated Energy (kWh) (f)	Calculated Night Load (kW) (g)
Air Compressors							
Lights							
HVAC							
Refrigeration							
Outside							
Estimated Percentages							
Actual Demand & Energy							
Calculated Demand & Energy							
Calculated Night Load							

Period for Energy Calculations	Day	Week	Month	Year
Hours per Period	24	168	732	8760
Check the period used.				

Form LD2 Category of Use Summary for:______________________________________

Form No.	Description	kWh/ Period	Peak kW	Night kW
Total Calculated				

Form LD3 **Simple Load Information** **Category of Use: _Lighting_**

Description	Qty (a)	Unit Load (b)	Total kW (c) = a x b	Hrs/ Period (d)	kWh/ Period (e) = d x c	On @ Peak Y or N	Div'ty Factor (f)	Peak kW (g) = f x c	On @ Night Y or N	Night kW
Totals	n/a	n/a	n/a	n/a		n/a	n/a		n/a	

Form LD4 Detailed Information (Current - Voltage Method) Category of Use:_______________________

Description	Qty (a)	Volts (b)	Amps (c)	Phas e (d)	PF (e)	Total kW (f)	Hrs/ Period (g)	kWh/ Period (h) = g x f	On @ Peak Y or N	Div'ty Factor (i)	Peak kW (j) = i x f	On @ Night Y or N	Night kW
Totals	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a		n/a	

Total kW = (f) = (a) x (b) x (c) x (d) x (e) for single phase, use (d) = 1
for three phase, use (d) = $\sqrt{3}$ = 1.73

Form LD5 Detailed Load Information (Motor Load Method) **Category of Use: __________________________________**

Description	Qty (a)	Motor HP (b)	Motor Load % (c)	Motor Eff % (d)	Total kW (e)	Hrs/ Period (f)	kWh/ Period (g) = e x f	On @ Peak Y or N	Div'ty Factor (h)	Peak kW (i) = e x h	On @ Night Y or N	Night kW
Totals												

Total kW(e) =(a) x (b) x .746 x (c) ÷ (d)

6.2 Thermal Load Inventory

As we have seen, the rules of energy accounting say that all the energy that enters a facility must leave it—in some form or other. The facility's activities that are said to "use" or "consume" energy do not actually *consume* the energy. Rather, they convert it from one form to another. Purchased energy crosses the energy system boundary as energy *inflows*. After a facility uses that purchased energy, and has transformed it into other forms, the energy in its final form is discharged to the external environment—typically as radiated heat, heated water, heated air, or some other warm fluid. These energy *outflows* may or may not be potentially useful within the building, but they definitely become **unusable** once they have crossed the facility's *energy system boundary* and have entered the external environment.

A useful energy flow diagram will show all energy flows into the facility, all outgoing energy flows from facility to environment, and all important energy flows within the facility. Because the purpose of such a diagram is to illustrate energy flows, not to describe a process in detail, the diagram will not generally show the specific devices and equipment that are found in its various subsystem "blocks." The flows are the important thing here.

The magnitude of the energy outflows must equal the purchased energy inflows. When we have the complete picture—a picture of the important internal energy flows as well as those from and to the external world—it is often possible to see opportunities for energy reduction and recovery.

6.2.1 A Method for Preparing an Energy Flow Diagram

A step by step method for preparing an energy flow diagram is outlined below. .

Step 1 - Define the Facility's Energy System Boundary
Identify where energy enters (the incoming side of the system) and where it is considered unusable or lost (the outgoing side). In an industrial facility, the system boundary is often considered to be the shell of the building that encloses the equipment and processes. It may, however, extend beyond the building structure if parts of the process are outside the building.

Step 2 - Identify External Energy Sources
Identify and list all the external sources of energy that are used in the system (facility), or the particular part of the facility that is described by the energy flow diagram.

Step 3 - Identify Sub-Systems
Identify and list each of the facility's subsystems (processes, or energy-transforming equipment) such as boilers, washing, cooking and refrigeration equipment. Often a subsystem can be defined so that it encompasses a number of pieces of equipment. This will simplify the diagram. For example, a boiler subsystem would include the boiler, burner, condensate tank, flash tank, and fuel storage system.

Step 4 - Identify Subsystem Energy Inflows
Identify and list the inflows of energy to each subsystem. Also identify the source of each inflow. (The source will be either another subsystem or an external energy source.) For a boiler subsystem, the energy inputs are most likely to be fuel oil and electricity.

Step 5 - Identify Subsystem Outflows
Identify and list the balancing outflows for each subsystem. Include in this list an indication of whether the outflow is to another subsystem or to the external environment. Does the energy leave the system (plant) forever? In the case of a boiler subsystem, outflows would include the steam or hot water

produced, and the hot flue gases -- the latter crossing the energy system boundary to the *external* world.

Finally, the energy outflows should be added to the developing energy flow diagram, and the flows between subsystems shown by connecting together the appropriate inflows and outflows.

6.2.1.1 Identification of Energy Flows

The table below can be used as a checklist to assist in the identification of thermal energy flows from a subsystem or a facility. While this list does not contain every possible type of energy flow, it does cover a selection of the more common types -- ones that often lead to savings opportunities.

Table 6.5: Thermal Energy Flow Types

Energy Flow Type	Example	Equipment/Functions
Conduction	Wall, windows	Building structure.
Air Flow - Sensible	General exhaust	Exhaust and makeup air systems, combustion air intake.
Air Flow - Latent	Dryer exhaust	Laundry exhaust, pool ventilation, process drying equipment exhaust.
Hot or Cold Fluid	Warm water to drain.	Domestic hot water, process hot water, process cooling water, water cooled air compressors.
Pipe Heat Loss	Steam pipeline.	Steam pipes, hot water pipes, any hot pipe.
Tank Heat Loss	Hot fluid tank.	Storage and holding tanks.
Refrigeration system output heat	Cold storage.	Coolers, freezers, process cooling, air conditioning.
Steam Leaks and Vents	Steam vent	Boiler plant, distribution system, steam appliance.

Methods of calculating the energy in these situations are given in Module 2.

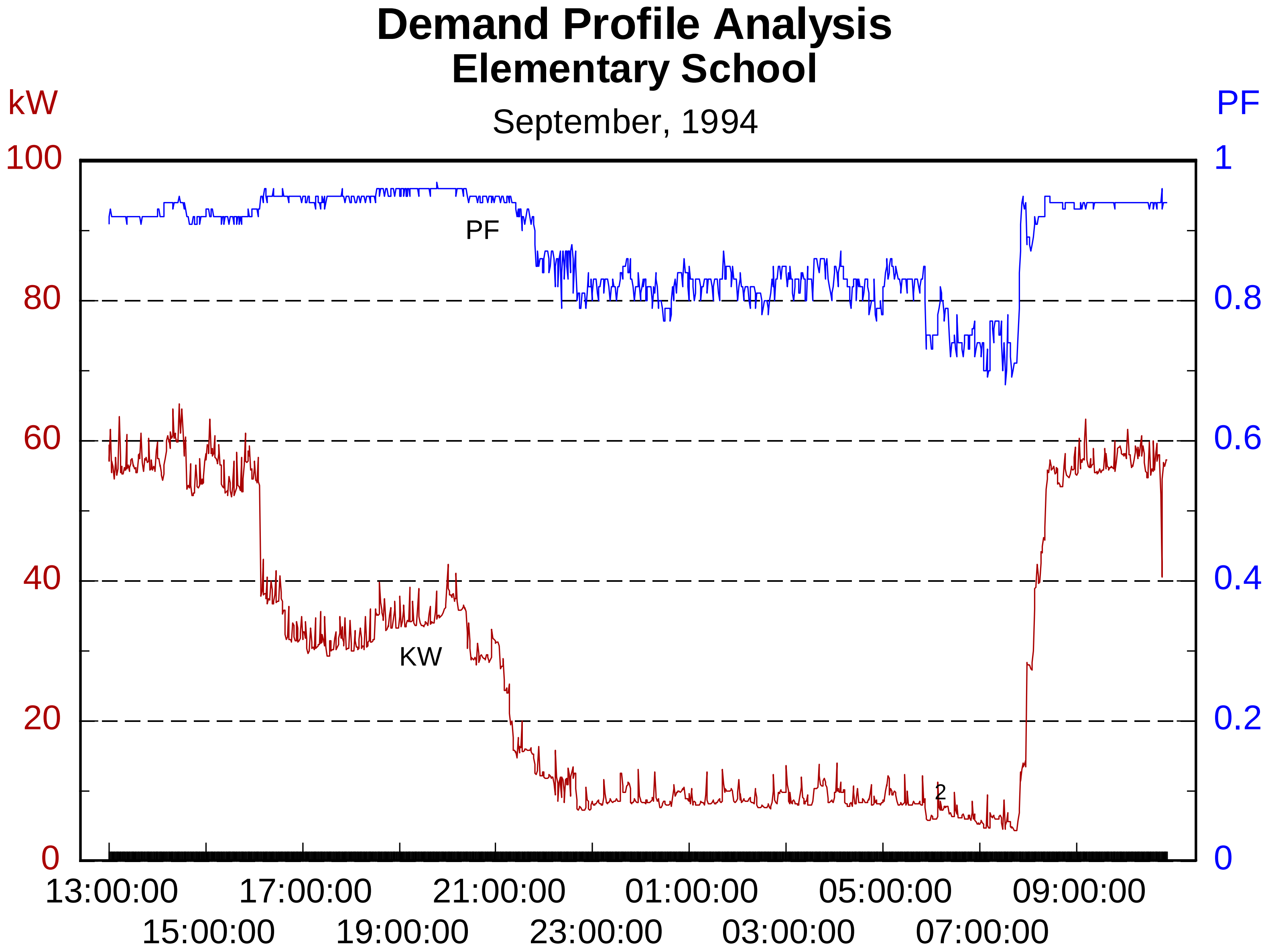
Worksheet 6-2: Elementary School Case Study

Elementary School
Electricity Usage Data

Billing Date	# of days	Demand (kW)	Energy (kWH)
Jan	35	92.7	23040
Feb	28	95.8	22260
March	33	91.2	25920
April	29	89.7	19360
May	28	88.2	17920
June	31	21.9	18880
July	31	79	9760
Aug	32	40.3	5280
Sept	30	71.4	9600
Oct	33	82.1	17600
Nov	29	82.1	19200
Dec	28	88.2	19840
Max/Totals	**367**	**95.8**	**208660**

Elementary School
Electrical Load Inventory

Description	Peak Demand kW	Monthly Energy kWh
Lighting		
Gymnasium		
Halls/Washrooms/Locker	4.3	1,070
Classrooms	7.1	2,520
Other	21.6	5,360
Sub-Totals	5.0	1,240
	38.0	**10,190**
HVAC		
Ventilation System		
Exhaust Fans	15.0	3,750
Gymnasium HVAC	1.3	320
Boiler Room	2.8	700
Sub-Totals	2.0	1,000
	21.1	**5,770**
Other		
Coolers	1.0	600
Sewage Pump	2.0	1,490
Clothes Dryer	3.0	130
Portable	20.0	2,500
Miscellaneous	2.0	580
Sub-Totals	**28.0**	**5,300**
Facility Max / Total	**87.1**	**21,260**


Demand Profile Analysis
Elementary School
September, 1994
kW
PF
100
80
60
40
20
0
1
0.8
0.6
0.4
0.2
0
PF
KW
2
13:00:00
15:00:00
17:00:00
19:00:00
21:00:00
23:00:00
01:00:00
03:00:00
05:00:00
07:00:00
09:00:00

Worksheet 6-3: Extended Care Facility Worksheet

The Energy Analysis Toolkit

File Edit Window Recalc Help

Open workbook file

EXTEND.BWB

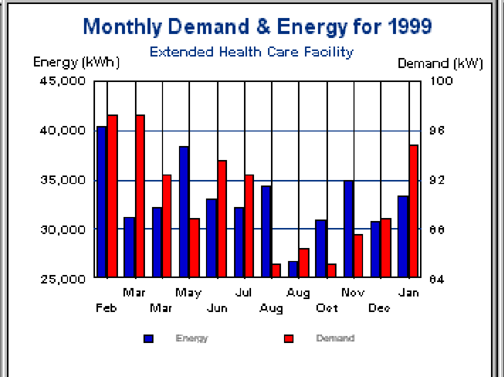
Electricity Consumption Data

Meter #: 12335 **Location:** Extended Health Care Facility

Billing Date dd/mm/yy	Metered kVA	Metered kW	Billed kW	Energy kWh	Days	Weather HDD	Production Tonnes	Load Factor	Demand Cost	Energy Cost	Adjust (+/-)	Total Cost
04/02/99	0.0	97.2	97.2	40,320	34	0	0	51%	$583.20	$3,921.14	$315.30	$4,820
04/03/99	0.0	97.2	97.2	31,200	28	0	0	48%	$583.20	$3,106.73	$258.29	$3,948
31/03/99	0.0	92.4	92.4	32,160	27	0	0	54%	$554.40	$3,176.62	$261.17	$3,992
04/05/99	0.0	88.8	88.8	38,400	34	0	0	53%	$532.80	$3,721.98	$297.83	$4,553
01/06/99	0.0	93.6	93.6	33,120	28	0	0	53%	$561.60	$3,266.31	$267.95	$4,096
01/07/99	0.0	92.4	92.4	32,160	30	0	0	48%	$554.40	$3,176.62	$261.17	$3,992
04/08/99	0.0	85.2	85.2	34,320	34	0	0	49%	$511.20	$3,345.77	$269.99	$4,127
31/08/99	0.0	86.4	86.4	26,760	27	0	0	48%	$518.40	$2,674.62	$223.51	$3,417
01/10/99	0.0	85.2	85.2	30,840	31	0	0	49%	$511.20	$3,035.00	$248.23	$3,794
03/11/99	0.0	87.6	87.6	34,920	33	0	0	50%	$525.60	$3,407.26	$275.30	$4,208
02/12/99	0.0	88.8	88.8	30,720	29	0	0	50%	$532.80	$3,036.16	$249.83	$3,819
01/01/2000	0.0	94.8	94.8	33,360	30	0	0	49%	$568.80	$3,291.70	$270.23	$4,131
Totals	**0.0**	**97.2**	**97.2**	**398,280**	**365**	**0**	**0**		**$6,538**	**$39,160**	**$3,199**	**48,896**

Demand & Energy Comparison

File Edit



Load Factor Analysis

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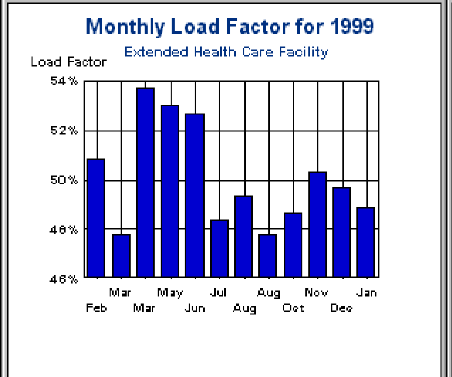

Electricity Cost Breakdown

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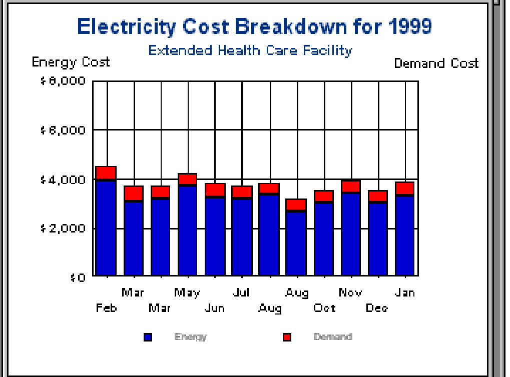
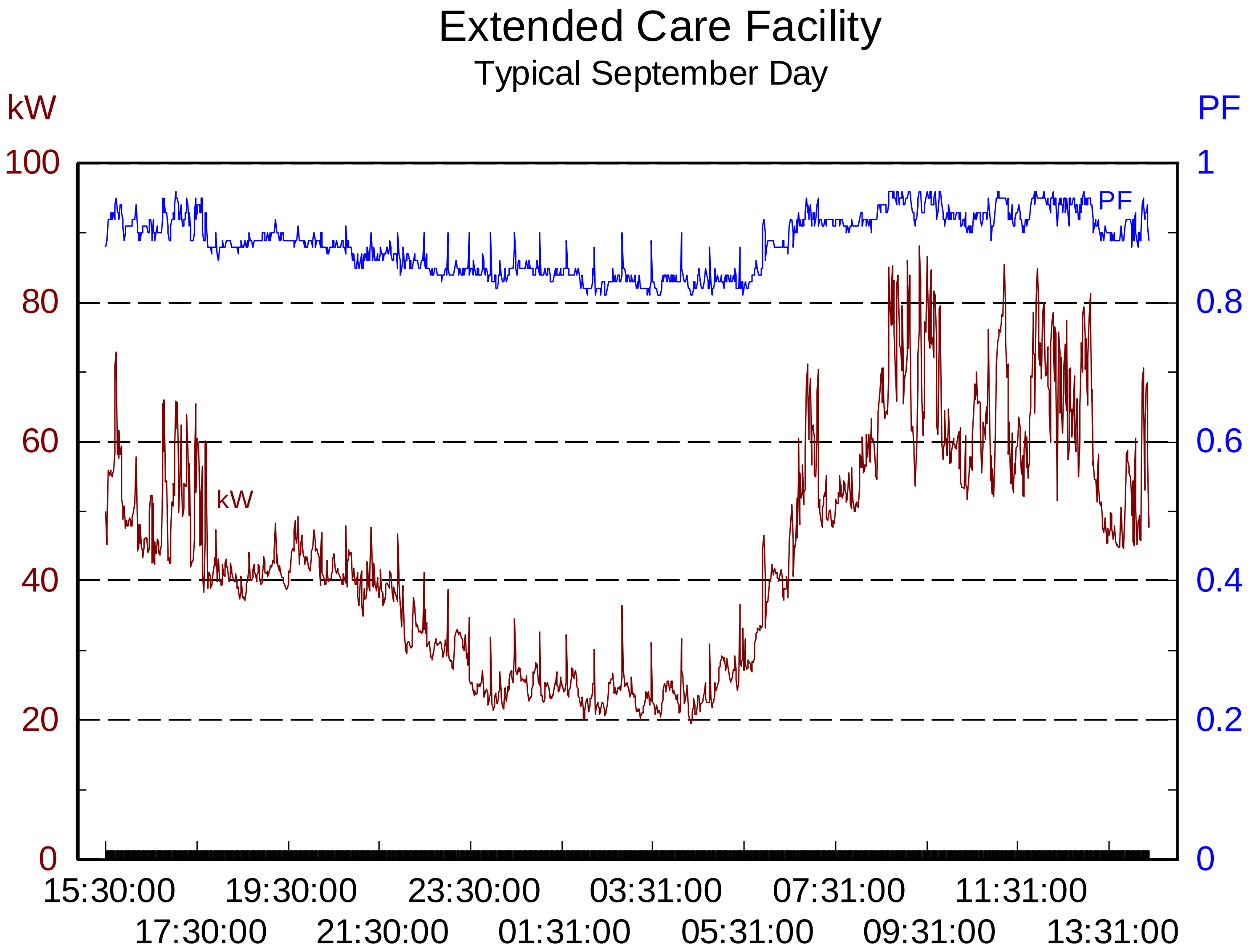


Extended Care Facility
Load Inventory

	Qty	Unit kW	Total kW	Diversity Factor	Peak kW	Monthly Hours	Monthly kWh
Lighting							
Home Care (2lmp) T8's	35	0.07	2.45	1.00	2.45	300	735
Boiler Room (1lmp) T8's	9	0.04	0.33	1.00	0.33	300	100
Workshop (1lmp) T8's	6	0.04	0.22	1.00	0.22	300	67
Laundry (2 lmp) T8's	12	0.07	0.84	1.00	0.84	300	252
Stairs (1 lmp) T8's	3	0.04	0.11	1.00	0.11	720	80
Reception (2 lmp) T8's	24	0.07	1.68	1.00	1.68	300	504
Reception (1 lmp) F30	1	0.04	0.04	1.00	0.04	300	12
Staff Lounge (1lmp) T8's	12	0.04	0.44	1.00	0.44	300	133
Smoke Rm. (2 lmp)T8's	2	0.07	0.14	1.00	0.14	300	42
Dining Rm. (2 lmp) F40's	24	0.10	2.30	1.00	2.30	200	461
Activity Rm.(2 lmp) T8's	12	0.07	0.84	1.00	0.84	100	84
Canteen (1 lmp) T8's	4	0.04	0.15	1.00	0.15	100	15
Lounge (2 lmp) T8's	2	0.07	0.14	1.00	0.14	100	14
Chapel (1 lmp) T8's	6	0.04	0.22	1.00	0.22	200	44
Chapel (60w. IA's)	6	0.06	0.36	1.00	0.36	200	72
Board Rm. (1lmp) T8's	8	0.04	0.30	0.50	0.15	20	6
Double Rms.(60w.IA's)	32	0.06	1.92	0.50	0.96	60	115
Double Rms. (40w. IA's)	16	0.04	0.64	0.50	0.32	60	38
Double Rms. (F30's)	16	0.04	0.64	0.50	0.32	60	38
Single Rms. (60w. IA's)	120	0.06	7.20	0.50	3.60	60	432
Single Rms. (40w. IA's)	60	0.04	2.40	0.50	1.20	60	144
Halls (2 lmp) T8's	38	0.07	2.66	1.00	2.66	720	1,915
Halls (1 lmp) T8's	46	0.04	1.70	1.00	1.70	720	1,225
Kitchen (2lmp) T8's	17	0.07	1.19	1.00	1.19	360	428
Outside 70w. HPS	1	0.10	0.10	0.00	0.00	360	35
Outside 75w. MV	9	0.09	0.83	0.00	0.00	360	298
Unfinished Base.(1lmp)	8	0.04	0.30	0.00	0.00	40	12
Lighting Total			**30.1**		**22.4**		**7,302**
Ventilation & Exhaust							
Central Exhaust (2HP)	1	2.00	2.00	1.00	2.00	720	1,440
Central Supply (2HP)	1	2.00	2.00	1.00	2.00	720	1,440
Timed Exhaust (2HP)	1	2.00	2.00	1.00	2.00	540	1,080
Timed Supply (2HP)	1	2.00	2.00	1.00	2.00	540	1,080
Ecology Supply (5HP)	1	4.70	4.70	1.00	4.70	720	3,384
Ecology Fresh Air (2HP)	1	2.00	2.00	1.00	2.00	720	1,440
Vent & Exh Total			**14.7**		**14.7**		**9,864**

Building Summary	Demand (kW)		Energy (kWh)	
Lighting	21%	22.4	20%	7,302
Ventilation & Exhaust	14%	14.7	27%	9,864
Boiler Room	13%	13.2	26%	9,330
Kitchen	40%	42.0	15%	5,314
Other	12%	12.4	11%	4,076
Building Total		**104.7**		**35,886**

	Qty	Unit kW	Total kW	Diversity Factor	Peak kW	Monthly Hours	Monthly kWh
Boiler Room							
#1 Boiler (1HP)	1	1.00	1.00	1.00	1.00	300	300
#1 Boiler (1/16HP)	1	0.10	0.10	1.00	0.10	300	30
#2 Boiler (3/4 HP)	1	0.85	0.85	0.50	0.43	200	170
#2 Boiler (1/16HP)	1	0.10	0.10	0.50	0.05	200	20
#3 Boiler	1	4.50	4.50	0.00	0.00	100	450
I.D. Fan (2HP)	1	2.00	2.00	1.00	2.00	720	1,440
Circ. Pumps (1/4 HP)	1	0.50	0.50	1.00	0.50	720	360
Circ. Pumps (2HP)	4	2.00	8.00	1.00	8.00	720	5,760
Sump Pump (1/2HP)	1	0.70	0.70	0.00	0.00	1	1
Water Softener (10w.)	1	0.01	0.01	1.00	0.01	720	7
Air Comp.(3/4HP)	1	0.85	0.85	1.00	0.85	720	612
Air Dryer (1/6HP)	1	0.25	0.25	1.00	0.25	720	180
Boiler Room Total			**18.9**		**13.2**		**9,330**
Kitchen							
Freezer (4KW)	1	4.00	4.00	1.00	4.00	300	1,200
Produce Cooler (1KW)	1	1.00	1.00	1.00	1.00	300	300
Dairy Cooler (1.5KW)	1	1.50	1.50	1.00	1.50	300	450
Garbage Cooler (1KW)	1	1.00	1.00	0.50	0.50	300	300
Dumbwaiter (6.2KW)	1	6.20	6.20	0.10	0.62	20	124
Steam Table	1	2.80	2.80	1.00	2.80	180	504
Milk Cooler (1/6 HP)	1	0.25	0.25	1.00	0.25	360	90
Coffee Machine	1	3.70	3.70	1.00	3.70	180	666
Convection Oven	1	5.00	5.00	0.50	2.50	120	600
Garburator	1	1.50	1.50	0.10	0.15	20	30
Dishwasher	1	2.50	2.50	1.00	2.50	60	150
Booster on Dishwasher	2	22.50	45.00	0.50	22.50	20	900
Kitchen Totals			**74.5**		**42.0**		**5,314**
Other Loads							
Clothes Washer	1	2.50	2.50	0.70	1.75	360	900
Clothes Dryer	2	0.80	1.60	1.00	1.60	360	576
Elevator (30HP)	1	27.00	27.00	0.10	2.70	60	1,620
Sprinkler Comp.(1 HP)	2	1.00	2.00	0.00	0.00	10	20
Exhaust Fan (1HP)	1	1.00	1.00	1.00	1.00	300	300
Fridges	3	0.30	0.90	0.50	0.45	300	270
Ice Machine	1	0.50	0.50	1.00	0.50	120	60
Whirlpools	2	3.00	6.00	0.50	3.00	30	180
Blanket Warmers	2	0.40	0.80	0.00	0.00	30	24
Lounge Dishwashers	2	1.20	2.40	0.50	1.20	30	72
Lounge Microwaves	2	0.90	1.80	0.10	0.18	30	54
Other Totals			**46.5**		**12.4**		**4,076**
Utility Metered Data (typical)					**95.0**		**36,000**


Extended Care Facility
Typical September Day
kW
PF
100
80
60
40
20
0
1
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15:30:00
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