Energy Efficiency

The management of energy is the study of *system* efficiency not *component* efficiency, hence the equipment required to study energy efficiency are scale models of typical systems. The following scale system will require either purchasing as a package or purchasing specific components and then constructing the model. As a minimum the following scale models will be required:

Small motor with squirrel cage fan – for Power Factor and Motor performance
Small complete refrigeration unit – can be made from a window air conditioner
Heat exchanger system for demonstating heat recovery
Lighting fixtures T8 and T12 bulbs also CFL's and incandescent
Closed loop centrifugal water pump with instrumention

For stage 3 similar equipment will be required for Biogas, Microhydro and Biodiesel demonstrations

APPENDIX 3

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CIET Energy Mangement Course Nov 2006

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Disclaimer

Every effort has been taken to avoid misrepresenting the realities of energy management and energy consumption analysis in energy-consuming organizations. The techniques and tools provided in this course are, to the best of our knowledge, applicable in those situations described. Nevertheless, in view of the complexities of energy use in such situations, neither the authors of this workshop and its associated software—CIET and TdS Dixon Inc.— accept any responsibility for any actions or decisions taken by workshop participants or any other users of the text or software. Users of these techniques and software tools, by virtue of their use, agree to accept all responsibility for their actions.

APPENDIX 4

Photovoltaic Installers Course
Offered on behalf of CanSIA
By Seneca College, Toronto

PHOTO VOLTAIC

Installer Training Program

Seneca College in partnership with Canadian Solar Industries Association (CANSia) provides a comprehensive understanding of related electric theory and the fundamentals of Photovoltaic Systems.

- By means of individualized distance learning and in-class study students will learn the theory and practice required to use and install a solar energy system.
- Flexible delivery
- College credits
- Partnerships: CANSia

Program subjects:

Level I - Electrical Theory

Introductory to Electricity - PVT10

DC and AC Circuit Analysis - PVT11

Meter Principles & Operation - PVT12

Principles of Electrical Devices - PVT13

Level II - Fundamentals of Photovoltaic Systems

Solar Theory - PVT20

Batteries and Charge Controllers - PVT21

Balance of System Components - PVT22

Level III - Photovoltaic System Desig & Installation

System Integration - PVT30

Installation Practices - PVT31

Seneca College of Applied Arts & Technology

PHOTOVOLTAIC INSTALLER TRAINING PROGRAM

Level I – Electrical Theory

PVT100 – Introduction to Electricity:

This is a basic electrical theory course that covers the essentials of DC electrical theory that is required for the installation of PV equipment. The course covers properties of materials, electrical terminology and the concept of resistance. The student is introduced to the use of wire tables and sizes and calculating voltage drop in wires. Many examples are given to illustrate the concepts being discussed. Upon completion of this course the student will have an understanding of the electrical fundamentals needed for further study.

PVT110 – DC and AC Circuit Analysis:

The course covers the principle voltage, current and power in AC and DC series and parallel circuits. Fundamental electrical equations such as Ohm's Law power law and Kirchoff's law are introduced with explanations of how to use them to analyze circuits. The concepts of AC, inductive and capacitive reactance, impedance and power in AC circuits are also introduced. Many examples are given to illustrate the concepts being discussed. Upon completion of this course the student will be able to analyze basic AC and DC circuits.

PVT120 – Meter Principles and Operation:

This course will give the student a working understanding of how to read and use meters in AC and DC electrical circuits. The use of both analog and digital meters and how they respond to various waveforms will also be covered. Many examples are given to illustrate the concepts being discussed. Upon completion of this course, the student will be able to use analog and digital meters for metering basic electrical characteristics in both AC and DC circuits.

PVT130 - Principles of Electrical Devices:

This course discusses the electrical characteristics of standard electrical equipment that is commonly used with PV systems. Topics include DC motors and generators, single and 3 phase AC motors, universal motors, lighting, DC and AC circuit breakers and fuses. Many examples are given to illustrate the concepts being discussed. Upon completion of this course, the student will understand how the electrical properties of standard devices can impact the selection and use of electrical components in a PV system.

Level II – Fundamentals of Photovoltaic Systems

PVT200 – Solar Theory:

The purpose of this course is to acquaint the student with the PV solar module and its electrical characteristics. The purpose and use of insolation data in predicting energy collection will be introduced. The concept of module shading, orientation and tilt and how it effects module performance will also be discussed. Combining modules in series and parallel and the use of blocking and bypass diodes are also addressed. Many examples are given to illustrate the concepts being discussed.

PVT210 – Batteries and Charge Controllers:

The purpose of this course is to introduce the key characteristics and different types of lead-acid and nickel cadmium batteries. Topics include battery chemistry, charging and discharging characteristics, maintenance and safety. The use of PV charge controllers including types and selection is also covered. Many examples are given to illustrate the concepts being discussed.

PVT220 – Balance of Systems Components:

This course covers systems components that are typically used in a PV system that have not been addressed in PV200 or PV210. Topics include stand-alone and utility interactive inverters including different output waveforms, control centres, array integrators/combiner boxes, circuit breakers and fusing and back-up power generators. Many examples are given to illustrate the concepts being discussed.

Level III – System Design and Installations

(Note: Level III is not available through distance learning - in class study only).

PVT300 – System Integration:

The purpose of this course is to teach the student how the system components discussed in the 200 level courses are integrated together to form a working system. Topics include AC and DC load analysis, defining performance requirements, system losses, safety factors and sizing components. Hybrid and utility –interactive systems are briefly discussed. A system design will be worked through and previous system designs will be reviewed and critiqued. Upon completion of this course, the student will understand how to select the components needed for a basic stand-alone PV system.

PVT310 – Installation:

This course cover the installation of the electrical equipment typically used in PV systems including battery banks, solar modules, inverters, control centres and other standard electrical wiring equipment. Other topics to be reviewed include site preparation, grounding, testing, commissioning and troubleshooting. Safety issues as they apply to the installation, maintenance and operation of PV systems will be addressed as well as Worker's Compensation Board (WCB) rules. Upon completion of this course, the student will have an understanding of how to safely install small and mid-sized PV systems.

PVT320 – Electrical Codes: (description TBA)

APPENDIX 5

Chapter 6
Of the manual
"Energy Managemet in Commercial and Institutinal Buildings"

Chapter 6: Energy Monitoring, Targeting & Reporting

Learning Objectives

After completing this section you will be able to:
- [illegible]
- [illegible]
- Analyze energy consumption as a function of key parameters such as degree days [illegible] the CUSUM technique;
- Set realistic and achievable energy reduction targets;
- Create management reports on energy consumption [illegible]

6.1 Introduction

Monitoring and Targeting is a management technique in which all building utilities such as fuel, electricity, purchased steam or hot water (as in a district heating system), and water, are managed as controllable resources. It may involve a systematic, disciplined division of the building into Energy Account Centres (EAC's). The utilities used in each centre are closely monitored, and the energy used is compared with an appropriate measure of activity or load—occupancy in a commercial building, for example, or weather as indicated by heating or cooling degree days. Once this information is available on a regular basis, targets are set. Subsequent reports highlight variances that can be readily spotted, and then interpreted to allow remedial action to be implemented.

This well established management technique has been used in many sectors in the UK since the early 1980's. The programs have been so effective that results published show typical reductions in annual energy costs in various sectors between 4 and 18%. Organizations surveyed generally credited Monitoring and Targeting with more than half of their energy efficiency measures. Increasingly there is interest in M&T in Canada.

We have chosen to add an "R" to M&T to indicate the importance of the information reporting that arises from the monitoring analysis and target setting. While a function of the management information systems in place in the organization, reporting is nevertheless an important aspect of the energy information management process.

MT&R is integral to the comparative analysis of energy performance introduced in chapter [illegible]. It is also highly valuable as an ongoing management and performance control technique. Finally, it is the basis for savings verification following the implementation of performance improvement[illegible]

6.1.1 The benefits of MT&R

Experience worldwide has demonstrated that monitoring and targeting is a proven strategy for energy management. In addition to energy cost savings, the key benefits for public and private sector organizations alike include:
- Improved control of the indoor environment;
- Improved costing of products and services;
- Improved budgeting;
- Enhanced preventative maintenance;
- General waste avoidance.

Since MT&R is a management technique—one that is intended to be fully integrated with other management systems—its adoption by an organization demonstrates top management commitment to energy efficiency as a corporate priority rather than a temporary, or "one-off", strategy. It is through this commitment that savings are maximized and sustained in the long term.

6.1.2 *Working Definitions*

The three component activities of MT&R are distinct yet inter-related:

- **Monitoring** is the regular collection of information on energy use. Its purpose is to establish a basis of management control, to determine when and why energy consumption is deviating from an established pattern, and as a basis for taking management action where necessary. Monitoring is essentially aimed at preserving an established pattern.

- **Target setting** is the identification of levels of energy consumption, which it is desirable as a management objective to work toward.

The two activities have elements in common and they share much of the same information. As a general rule, however, monitoring comes before target setting because without monitoring you cannot know precisely where you are starting from or decide if a target has been achieved.

- **Reporting** "closes the loop" by putting the management information generated from the monitoring process in a form that enables ongoing control of energy use, the achievement of reduction targets, and the verification of savings.

The reporting phase not only supports management control, but also provides for accountability in the relationship between performance and targets.

6.1.3 *The main elements of monitoring and targeting*

From a practical perspective the essential elements of an M&T system are described below. These would apply to a building, plant, cost centre, process or other logical division of the organization:

- Measuring energy consumption over time;
- Relating energy consumption to a measure of production;
- Setting targets for reduced consumption;
- Frequent comparison of consumption to targets;
- Reporting variances;
- Taking action to correct variances.

6.2 Data and information

Within the activity of M&T, data and information are distinct entities. The activity of monitoring a system or process encompasses both measurement and analysis. Data are raw numbers such as would be the result of a measurement. Information is the result of some type of analysis upon data. Figure 6.1 shows the relationship between data, information, measurement and analysis. It also shows the action, which in an energy M&T system is intended to reduce consumption, the result. In fact all of the elements of monitoring and targeting listed in section 6.1.3 are encompassed by this simple model, since further measurement and analysis are subsequently used to determine whether the target has been met. And, further analysis will lead to action on the variances. Figure 6.2 illustrates this approach in the context of building operations.

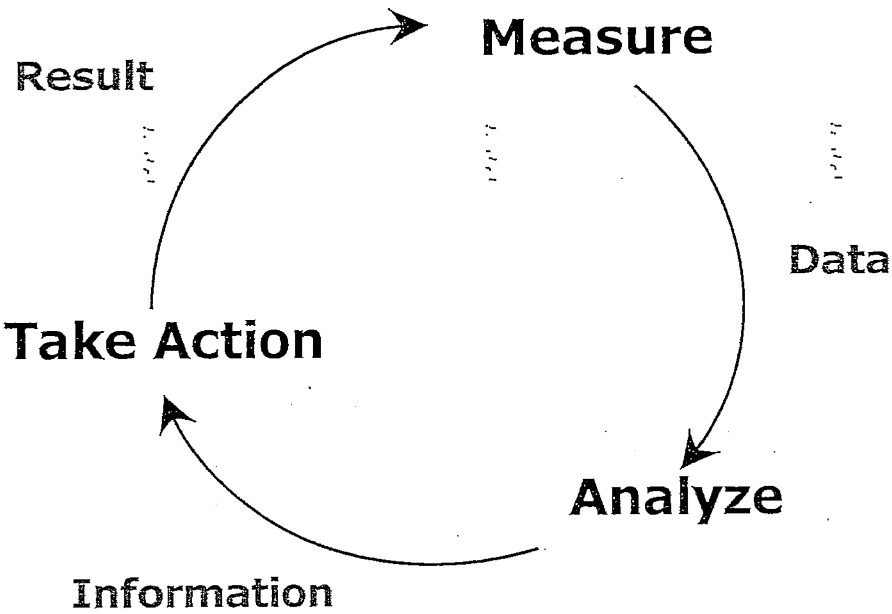

Figure 6.1: Measure-Analyze-Action

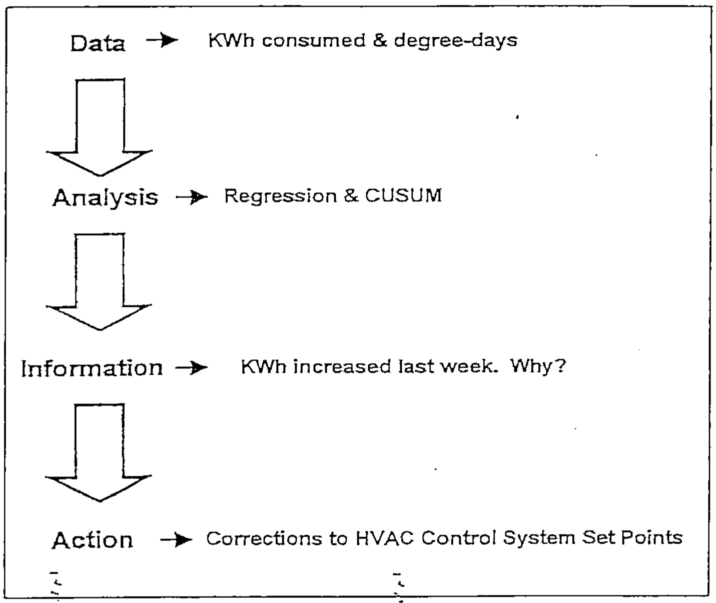

Figure 6.2: One Cycle in Building Operations Improvement

6.2.1 *Data and information needs for monitoring and target setting*

Energy monitoring can be used to find out how much energy is costing you and for obtaining information to use as a basis for controlling consumption.

In a building, human comfort is such a sensitive indicator of change that if the basic energy needs of the building vary by more than just a few per cent, the occupants will know about it anyway—they represent a form of qualitative monitoring. Monitoring energy use by means of meters and gauges provides information in terms of measured quantities, and is called quantitative monitoring.

Look at the energy consumption data in Table 6.1 and presented in Figure 6.3. This shows the energy consumed in two consecutive years, in terms of m^3 of gas during the heating season for a government office building and the heating degree-days recorded for each month. The number of days per month is based on the gas utility billing period. The data appear in time series order and the graph uses the energy consumption per HDD to focus on the impact of the weather; other factors that might impact on the energy consumption would be level of occupancy or hours of operation, but in this case, these are determined to be insignificant.

Now consider some simple questions, answers to which are contained in this data.

- How many energy saving measures have been introduced?
- When did each take effect?
- How much energy has each measure saved?
- Are all the energy saving measures still working?
- Have any breakdowns been restored?
- How much energy will be required for a projected number of heating degree-days next January?
- What further savings can be achieved?

Although all this information is available from the data set, it can only be accessed if the right kinds of analyses are applied. To find out what has been going on in this heating system we have to deal separately with two key questions:

- How does energy use vary with HDD?
- How does the relation between energy use and HDD change with time?

The methods of discovering answers to these questions are addressed in the following sections.

Table 6.1: Energy Consumption for an Office Building

Month	M^3	Days	M^3/day	HDD (°C)	M^3/HDD
1999/2000 Heating Season					
Sep	1402	30	47	76	19
Oct	7235	29	249	287	25
Nov	11256	29	388	456	25
Dec	17724	33	537	824	21
Jan	15475	32	484	663	23
Feb	11675	31	377	639	18
Mar	11185	30	373	499	22
Apr	8368	31	270	316	26
May	3268	27	121	152	21
2000/2001 Heating Season					
Sep	1242	30	41	127	10
Oct	5281	31	170	304	17
Nov	7331	29	253	670	11
Dec	12376	31	399	752	16
Jan	18118	34	533	902	20
Feb	12484	28	446	628	20
Mar	11824	29	408	525	23
Apr	5538	31	179	267	21
May	1982	30	66	109	18

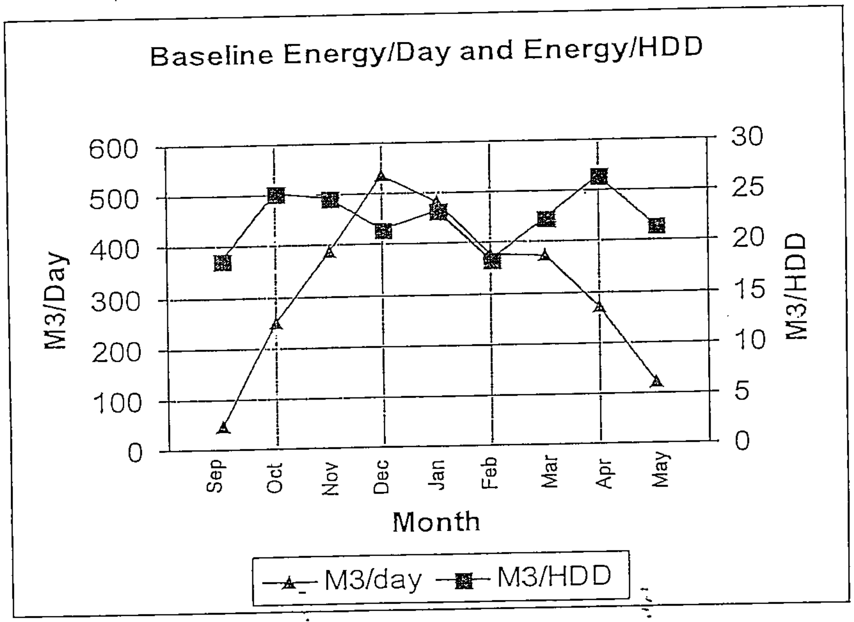

Figure 6.3: Energy and Specific Energy Compared

6.3 Monitoring

When you monitor energy consumption you need a way of analyzing the mass of data to tell you how energy consumption is changing in response to changes in use and building performance. In this section we shall outline the process of monitoring including a key method of analyzing data known as the CUSUM technique.

6.3.1 Energy Accountability Centre Definition

Energy Accountability Centres (EACs) are selected, with the agreement of the various departments, based on a knowledge of the main areas of energy consumption, the utility distribution systems and existing sub-metering. EAC selection should be based, if possible, on the following criteria:

- The potential cost savings must justify the costs of data measurement, sometimes called sub-metering.
- Energy consumption can be measured.
- "Ownership" of EAC cost can be established.
- EAC cost ownership fits the organization's existing structures. M&T is more effective if it is integrated fully into an organization's reporting structures, rather than being seen as outside the main areas of management concern.

6.3.2 Data Collection

There are two basic issues that must be addressed when considering data collection:

- frequency - how often is data measured;
- mechanism - how is data collected.

The selection of the correct data collection frequency is crucial to the success of M&T. If too much data is collected, then the data processing effort could start to cost more than the potential savings. On the other hand, if data is not collected frequently enough, the reasons for cost variances may not be clear and, even if they are known, the variations will continue for longer. The savings potential is thus reduced.

A range of mechanisms may be employed for data collection ranging from a manual to fully automatic system. The method employed will depend upon your resources and budget. Each has distinct advantages and disadvantages:

- Monthly utility invoices.
- Manual data forms periodically.
- Portable data loggers.
- Fully automated measurement.

6.4 Analysis

In the following example we will look at the analysis of the energy consumption of the building considered previously.

Table 6.2 gives energy consumption and HDD data for a municipal government building for a period of about 2 ½ years.

Table 6.2: Energy Consumption Data for Municipal Building

Measured Data				
Month		Weather HDD	Natural Gas m3	Specific Energy m3/HDD
1	Apr-99	321	417,562	1,301
2	May-99	217	353,122	1,627
3	Jun-99	90	200,113	2,223
4	Jul-99	22	173,412	7,882
5	Aug-99	46	133,958	2,912
6	Sep-99	107	212,367	1,985
7	Oct-99	225	343,861	1,528
8	Nov-99	304	387,614	1,275
9	Dec-99	389	468,935	1,205
10	Jan-00	427	506,210	1,186
11	Feb-00	415	421,019	1,015
12	Mar-00	396	452,097	1,142
13	Apr-00	282	360,415	1,278
14	May-00	238	285,237	1,198
15	Jun-00	95	169,547	1,785
16	Jul-00	59	155,738	2,640
17	Aug-00	41	122,305	2,983
18	Sep-00	123	126,511	1,029
19	Oct-00	199	241,150	1,212
20	Nov-00	276	263,930	956
21	Dec-00	395	330,708	837
22	Jan-01	539	410,347	761
23	Feb-01	429	396,079	923
24	Mar-01	408	380,197	932
25	Apr-01	264	309,685	1,173
26	May-01	197	241,795	1,227
27	Jun-01	137	169,631	1,238
28	Jul-01	59	147,037	2,492
29	Aug-01	90	155,188	1,724
30	Sep-01	94	154,056	1,639
31	Oct-01	195	195,491	1,003
32				
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Table 6.2 includes a calculated column, the specific energy, or m^3/HDD. This value can be plotted, as in Figure 6.4; however, it doesn't really provide much in the way of new information.

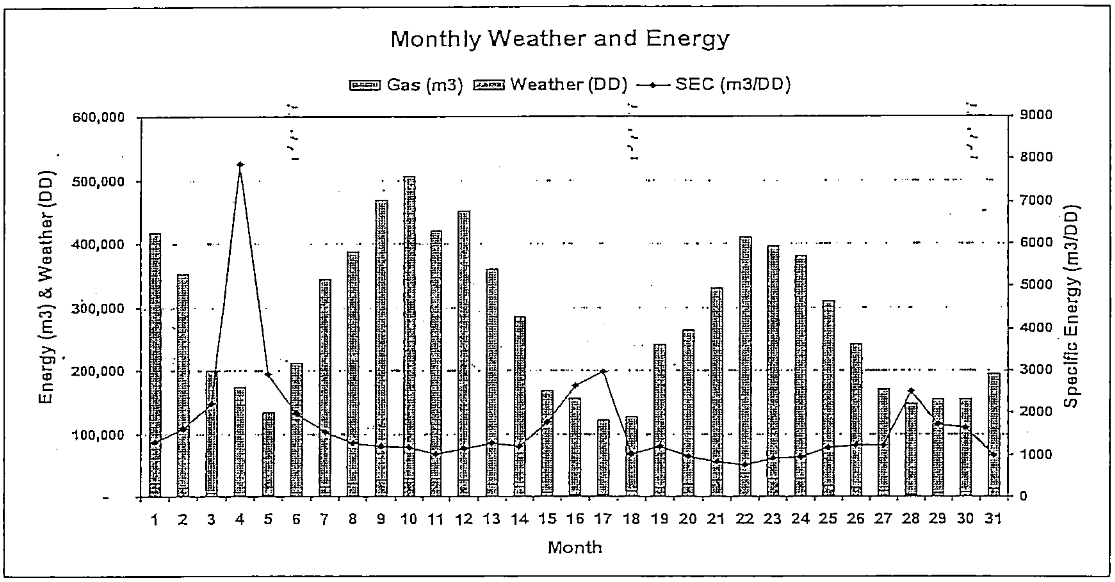

Figure 6.4: Data Plot

What we need is a functional relationship between energy consumption and HDD, or an "energy performance model".

6.4.1 *Relating energy use to weather*

As a basis for our analysis we must establish a simple but physical relationship between energy use and weather in a building. In simple terms, the energy required to heat the building during the heating season is equal to the heat lost from the building into the surrounding environment, through building walls, windows, and vents.

The rate at which heat loss occurs is determined mainly by two key factors: the temperature difference driving force, being the difference between the indoor and outdoor temperature; and the thermal performance of the building.

A convenient way of quantifying this driving force is the heating degree day (HDD), which is defined specifically as the sum of the departures of the daily mean temperature from a reference temperature, such as 18°C (or whatever temperature represents the thermal neutral point—at which neither heating nor cooling is required to maintain the desired indoor temperature—for the building in question), for each day on which the temperature falls below that value in a specified period. So, in Table 6.1 in December 1999, we see the total degree-days indicated as 824 for the 33 days in this billing period. This means that the average temperature over that period was 25 degrees below the reference temperature of 18°C, or an average temperature of –7°C (cold, isn't it?).

Although oversimplifying a complex physical situation, we might think of the overall building having a coefficient of heat loss—let's call it U—which relates the rate of heat loss to the temperature difference driving force. The total heat lost in a period is then the integral of the instantaneous heat loss rate. We can then say that the heat lost is directly proportional to the driving force, or the HDD measure:

Q } HDD

with the constant of proportion being the heat transfer coefficient of the building.

This provides a theoretical basis for the empirical expectation that energy plotted against HDD is a straight line.

6.4.2 Establishing the pattern of energy use compared with HDD

What we have established so far is that it is reasonable to plot energy against HDD and to expect a straight line. Indeed, that is what is commonly found. Plotting the energy use against HDD often produces a straight line of the form

$$y = mx + c$$

where **c**, the intercept, and **m**, the slope, are empirical coefficients.

Figure 6.5 is a scatter plot of energy consumption vs. HDD.

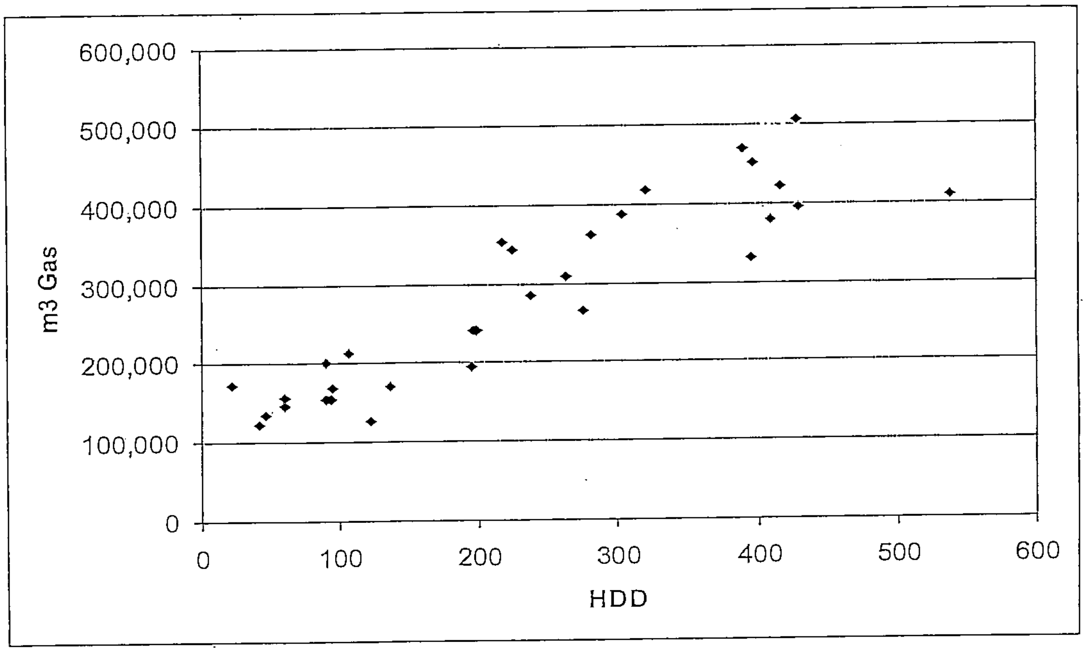

Figure 6.5: Energy Consumption vs. HDD

Clearly energy consumption rises with HDD as we would expect. But the wide scatter of consumption values for the same HDD values indicates that something else is going on.

In Excel, we can apply a trendline to the scatter of points using linear regression, as shown in Figure 6.6.

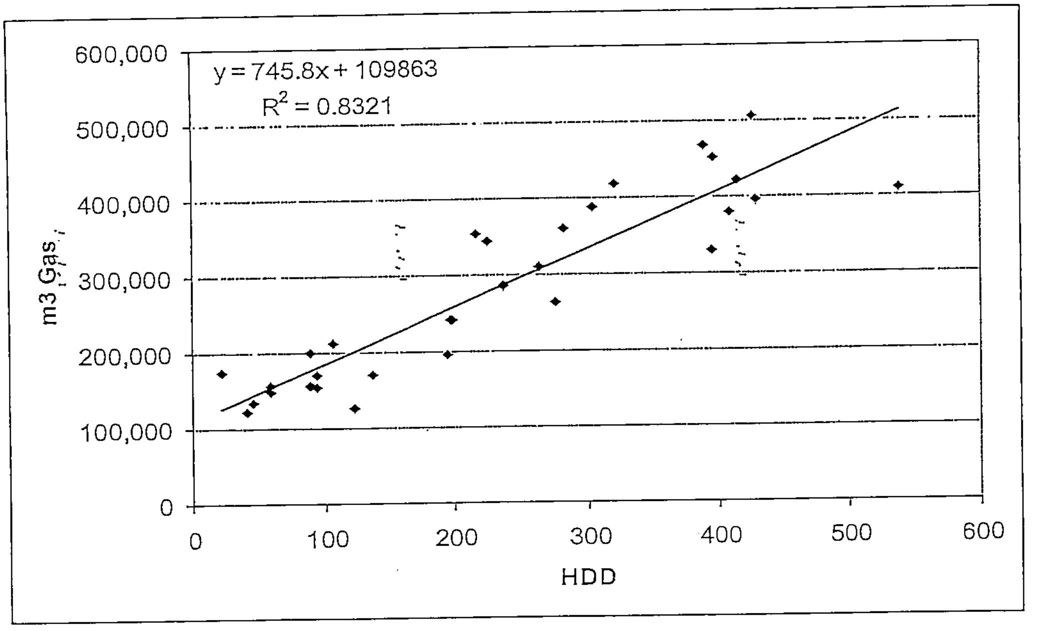

Figure 6.6: Linear Regression of the Data Set

This analysis gives an energy performance model for the entire data set:

$$\text{Energy (m}^3\text{)} = 745.8 \times \text{HDD} + 109{,}863 \text{ (Equation 6.1)}$$

It is important to note that there are two components to the energy load: one component, represented by 745.8 m^3/HDD, is related to building efficiency and is the incremental load that is related specifically to heating. The other component, here 109,863 m^3, is unrelated to weather and might be thought of as a "base load". Recognizing these two components can lead the energy manager in different directions in the search for savings opportunities.

Nevertheless, this plot is of limited usefulness since there may have been significant performance changes during the 30 months of operation; indeed, the wide variation of consumption values for the same HDD values suggests that this may be so.

What we need is an energy performance model based on a period of consistent performance, or a baseline.

6.4.3 The Baseline

Finding a baseline is part art, part science. In principle, any period of consistent performance can serve as a baseline. Usually an iterative approach is needed to find a suitable baseline, although sometimes knowledge about the facility will indicate what period is suitable.

In the case of this example, let's suppose that we know that the building performed consistently for the first 11 months of the period, and that this is a reasonable basis for analysis. Figure 6.7 is a linear regression on just these 11 points.

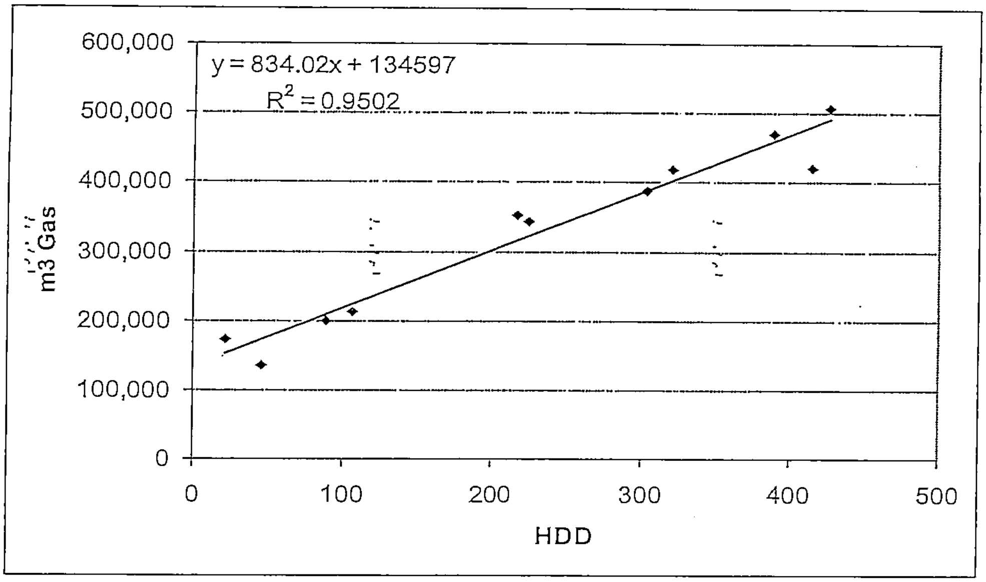

Figure 6.7: The Baseline

Now we have a different performance model, which defines baseline performance:

$$\text{Energy } (m^3) = 834.02 \times \text{HDD} + 134{,}597 \quad \text{(Equation 6.2)}$$

Comparing the models of equation 6.1 and 6.2 confirms what we expected:

Table 6.3: Comparison of Energy Performance Parameters

Model	Slope (Efficiency)	Intercept (Base Load)
Entire Data Set	745.80	109,863
Baseline	834.02	134,597

Since the overall efficiency (slope) and the overall base load (intercept) are both lower than those in the baseline period, it seems apparent that a performance improvement occurred during the 30 month period.

Understanding this further requires the use of a new tool, CUSUM.

6.4.3 CUSUM

CUSUM is a powerful technique for monitoring the performance of facility. Suppose that over time you had collected data on the energy consumption of the building, and you began to make changes to improve efficiency. Or perhaps, you noticed that consumption was up and you wondered whether this was within the range of chance variability. CUSUM helps you to answer these questions.

CUSUM stands for **'CUmulative SUM of differences'**, where 'difference' refers to differences between the actual consumption and the consumption you expect on the basis of some established pattern. Any measurements on a system have associated with them some natural scatter. CUSUM is a technique with the ability to see through random scatter and to detect changes in the underlying pattern.

If consumption continues to follow the established pattern, the differences between the actual consumption and the established pattern will be small and randomly either positive or negative. The cumulative sum of these differences over time, CUSUM, will stay near zero.

Once a change in pattern occurs due to the presence of a fault or to some improvement in the process being monitored, the distribution of the differences about zero becomes less symmetrical and their cumulative sum, CUSUM, increases or decreases with time. The CUSUM graph therefore consists of straight sections separated by kinks; each kink is associated with a change in pattern, each straight section is associated with a time when the pattern is stable.

CUSUM is a general technique; the nature of the established pattern can be as simple as a single number average or a complex relation involving many variables.

In this case, the basis for the CUSUM analysis is the baseline energy performance model. Equation 6.2 is used to calculate "predicted" or theoretical values of energy consumption for the actual HDD values tabulated. The difference between the actual consumption and this predicted consumption is then accumulated algebraically to give CUSUM values as shown in Table 6.4.

It is customary to compute CUSUM in a way such that the initial period runs horizontally, as in our example. That is, as a first attempt the initial period may be a reasonable baseline. CUSUM then displays in a very simple way the changes in consumption since the period of this initial, or baseline pattern.

Table 6.4: CUSUM Calculations

Slope	834.02	Target slope
Intercept	134,597	Target intercept

Measured Data					Baseline		
Month		Weather HDD	Natural Gas m3	Specific Energy m3/HDD	Predicted m3	Difference m3	CUSUM
1	Apr-99	321	417,562	1,301	402,317	15,245	15,245
2	May-99	217	353,122	1,627	315,579	37,543	52,787
3	Jun-99	90	200,113	2,223	209,659	-9,546	43,241
4	Jul-99	22	173,412	7,882	152,945	20,467	63,708
5	Aug-99	46	133,958	2,912	172,962	-39,004	24,704
6	Sep-99	107	212,367	1,985	223,837	-11,470	13,234
7	Oct-99	225	343,861	1,528	322,252	21,610	34,843
8	Nov-99	304	387,614	1,275	388,139	-525	34,318
9	Dec-99	389	468,935	1,205	459,031	9,904	44,223
10	Jan-00	427	506,210	1,186	490,724	15,486	59,709
11	Feb-00	415	421,019	1,015	480,715	-59,696	13
12	Mar-00	396	452,097	1,142	464,869	-12,772	-12,759
13	Apr-00	282	360,415	1,278	369,791	-9,376	-22,135
14	May-00	238	285,237	1,198	333,094	-47,857	-69,992
15	Jun-00	95	169,547	1,785	213,829	-44,282	-114,273
16	Jul-00	59	155,738	2,640	183,804	-28,066	-142,340
17	Aug-00	41	122,305	2,983	168,792	-46,487	-188,826
18	Sep-00	123	126,511	1,029	237,181	-110,670	-299,497
19	Oct-00	199	241,150	1,212	300,567	-59,417	-358,914
20	Nov-00	276	263,930	956	364,787	-100,857	-459,770
21	Dec-00	395	330,708	837	464,035	-133,327	-593,097
22	Jan-01	539	410,347	761	584,134	-173,787	-766,884
23	Feb-01	429	396,079	923	492,392	-96,313	-863,197
24	Mar-01	408	380,197	932	474,877	-94,680	-957,877
25	Apr-01	264	309,685	1,173	354,778	-45,093	-1,002,970
26	May-01	197	241,795	1,227	298,899	-57,104	-1,060,074
27	Jun-01	137	169,631	1,238	248,858	-79,227	-1,139,301
28	Jul-01	59	147,037	2,492	183,804	-36,767	-1,176,068
29	Aug-01	90	155,188	1,724	209,659	-54,471	-1,230,539
30	Sep-01	94	154,056	1,639	212,995	-58,939	-1,289,478
31	Oct-01	195	195,491	1,003	297,231	-101,740	-1,391,218
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A plot of CUSUM vs. time yields Figure 6.8.

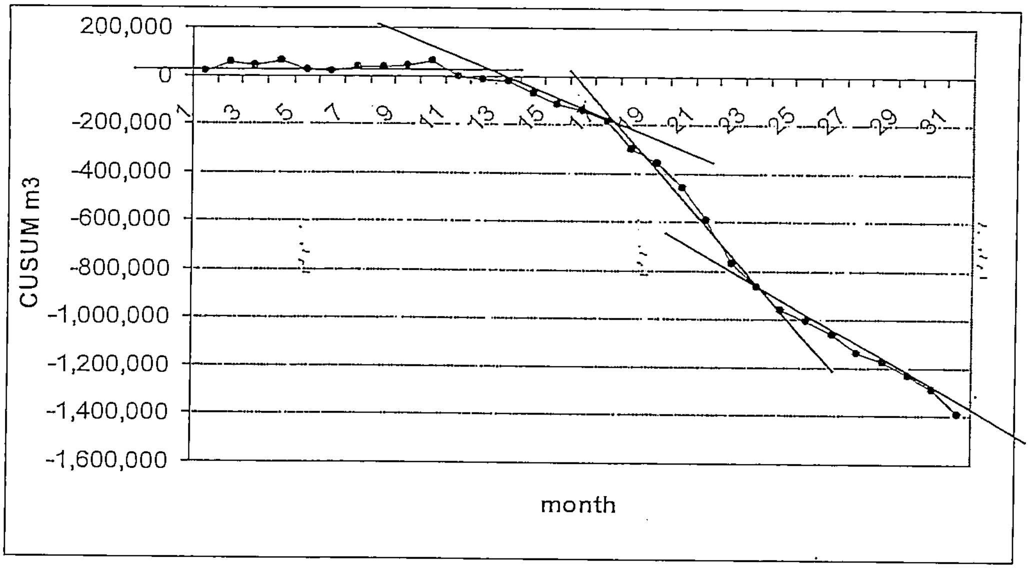

Figure 6.8: Energy Savings CUSUM

The critical features of the CUSUM graph are the following:

- Periods of consistent performance are indicated by more or less constant slope line segments, as indicated on Figure 6.8;
- Therefore, changes in performance are indicated by changes in slope;
- A downward sloping line represents energy savings compared to baseline performance, and the cumulative savings can be read from the graph.

This CUSUM graph indicates:

- There have been two measures to reduce consumption, one that was implemented around month 14, and a second around month 18.
- The first measure had saved a total of about 200,000 m^3 before the second measure was implemented, and together they saved a total of about 850,000 m^3 up to month 25 when it appears that something went wrong.
- It appears that one of the measures stopped functioning at month 25 and that situation continued to the end of the data set.

Nevertheless, the total savings in the 30 months of operation were about 1,400,000 m^3 compared to the “business as usual” performance of the baseline period.

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6.5 Target Setting

Having established the present level of energy consumption we should now try to set a target for reducing it. Target setting is a vital part of energy management as it encourages us to determine how low a level of energy consumption is achievable. In this section we are concerned with how to decide on an appropriate target.

Target setting is quite distinct from monitoring. In monitoring you are trying to maintain an existing level of efficiency. In target setting you decide to what level energy consumption can be reduced.

All targets need two elements:

- measure of the level to which consumption can be reduced;
- the time by which the reduction will be achieved.

To be worthwhile, these must be realistic. Targets related to those achievable by better, or more skilled operators and management need to be distinguished from those which involve capital investment.

The simplest form of target is an across-the-board reduction in consumption, e.g. 5% in two years. Apart from the fact that it is obviously arbitrary and not derived on the basis of what is possible, such a target has enormous practical difficulties. It asks the same of all sites, irrespective of how efficient or inefficient they are already. In any organization where there has not been any attempt at all to reduce consumption in the past, there will be a disparity between parts of the organization in what has been achieved already.

Furthermore, and importantly, the arbitrary target ignores the fact that there are two components to the energy load as discussed previously. Different tactics are likely required to attack the base load and the incremental (i.e. heating-related) load.

6.5.1 Preliminary Targets

When setting up M&T, it is often appropriate to use current consumption rates as the target, at least for the first few weeks.

In the case of the building example, this would involve maintaining the performance of the last several months of the data set period. The energy performance model for this period can be obtained just as for the baseline by doing regression on those last several points alone.

6.5.2 Revision of Targets

After M&T has been in operation for a while, the preliminary target based on current performance will be easily attainable and should be reset. This can be done in a number of ways, including:

- Using the period of best performance as a target. This yields a modest but generally attainable target.
- Selecting the best historical months—whether or not they occurred in sequence—as the target; this will produce the most demanding, but with effort still an attainable target.

- Basing a target upon an agreed upon set of actions designed to yield specific and quantifiable savings.

- Setting a target for an arbitrary percentage improvement upon current performance. Although arbitrary, if chosen properly this target will be attainable. If this target exceeds the best historical performance it will likely not be attainable and therefore avoided. This method is not recommended.

Whichever method is used, it is essential that operational personnel are involved in the process of setting the targets and in fact have input to what is or is not realistic. Otherwise, key personnel may not "buy-in" to the M&T approach and targets will not be achieved.

To illustrate, a target can be developed based on the period in our example when both measures were functioning. This involves doing a regression on this period, as shown in Figure 6.9.

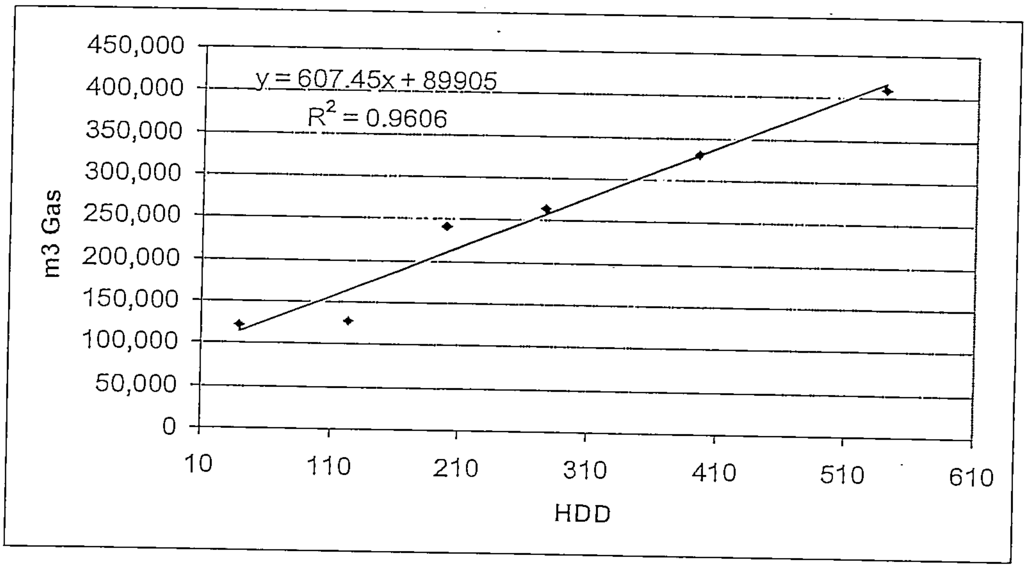


Figure 6.9: Target Based on Period of Best Performance

Once again, there is a new performance model:

$$\text{Energy } (m^3) = 607.45 \times \text{HDD} + 89{,}905 \text{ (Equation 6.3)}$$

Revisiting Table 6.3, with the addition of the parameters from Equation 6.3 gives us Table 6.5:

Table 6.5: Comparison of Energy Performance Parameters

Model	Slope (Efficiency)	Intercept (Base Load)
Entire Data Set	745.80	109,863
Baseline	834.02	134,597
Target	607.45	89,905

Now it is obvious why the entire data set showed lower efficiency and base load numbers than the baseline; it is because of the periods of superior performance in which the lowest efficiency and base load numbers were produced.

6.5.3 *Managing performance with the control chart*

Control charts are commonly used in manufacturing to manage product quality amongst other things. The same approach can be used to manage energy performance in buildings. This involves using the target performance model as a basis for not only monitoring and CUSUM analysis, but also for the creation of control charts that can give better "real time" information to building operators and managers.

When the target model is used as a basis for predicting new theoretical energy consumption values, Table 6.6 results.

Table 6.6: Data Set with Control Chart Calculations

Slope	834.02
Intercept	134,597
Target slope	604.45
Target intercept	89,905

Measured Data					Baseline			Control Chart	
Month		Weather HDD	Natural Gas m3	Specific Energy m3/HDD	Predicted m3	Difference m3	CUSUM	Predicted m3	Difference m3
1	Apr-99	321	417,562	1,301	402,317	15,245	15,245	283,933	133,629
2	May-99	217	353,122	1,627	315,579	37,543	52,787	221,071	132,051
3	Jun-99	90	200,113	2,223	209,659	-9,546	43,241	144,306	55,808
4	Jul-99	22	173,412	7,882	152,945	20,467	63,708	103,203	70,209
5	Aug-99	46	133,958	2,912	172,962	-39,004	24,704	117,710	16,248
6	Sep-99	107	212,367	1,985	223,837	-11,470	13,234	154,581	57,786
7	Oct-99	225	343,861	1,528	322,252	21,610	34,843	225,906	117,955
8	Nov-99	304	387,614	1,275	388,139	-525	34,318	273,658	113,956
9	Dec-99	389	468,935	1,205	459,031	9,904	44,223	325,036	143,899
10	Jan-00	427	506,210	1,186	490,724	15,486	59,709	348,005	158,205
11	Feb-00	415	421,019	1,015	480,715	-59,696	13	340,752	80,267
12	Mar-00	396	452,097	1,142	464,869	-12,772	-12,759	329,267	122,830
13	Apr-00	282	360,415	1,278	369,791	-9,376	-22,135	260,360	100,055
14	May-00	238	285,237	1,198	333,094	-47,857	-69,992	233,764	51,473
15	Jun-00	95	169,547	1,785	213,829	-44,282	-114,273	147,328	22,219
16	Jul-00	59	155,738	2,640	183,804	-28,066	-142,340	125,568	30,170
17	Aug-00	41	122,305	2,983	168,792	-46,487	-188,826	114,687	7,618
18	Sep-00	123	126,511	1,029	237,181	-110,670	-299,497	164,252	-37,741
19	Oct-00	199	241,150	1,212	300,567	-59,417	-358,914	210,191	30,959
20	Nov-00	276	263,930	956	364,787	-100,857	-459,770	256,733	7,197
21	Dec-00	395	330,708	837	464,035	-133,327	-593,097	328,663	2,045
22	Jan-01	539	410,347	761	584,134	-173,787	-766,884	415,704	-5,357
23	Feb-01	429	396,079	923	492,392	-96,313	-863,197	349,214	46,865
24	Mar-01	408	380,197	932	474,877	-94,680	-957,877	336,521	43,676
25	Apr-01	264	309,685	1,173	354,778	-45,093	-1,002,970	249,480	60,205
26	May-01	197	241,795	1,227	298,899	-57,104	-1,060,074	208,982	32,813
27	Jun-01	137	169,631	1,238	248,858	-79,227	-1,139,301	172,715	-3,084
28	Jul-01	59	147,037	2,492	183,804	-36,767	-1,176,068	125,568	21,469
29	Aug-01	90	155,188	1,724	209,659	-54,471	-1,230,539	144,306	10,883
30	Sep-01	94	154,056	1,639	212,995	-58,939	-1,289,478	146,723	7,333
31	Oct-01	195	195,491	1,003	297,231	-101,740	-1,391,218	207,773	-12,282
32									
33									
34									
35									
36									

The differences between the actual and target consumption values are calculated as in CUSUM analysis, but for control chart purposes the variances alone (rather than the cumulative sum of differences) are plotted against time to produce the control chart, Figure 6.10.

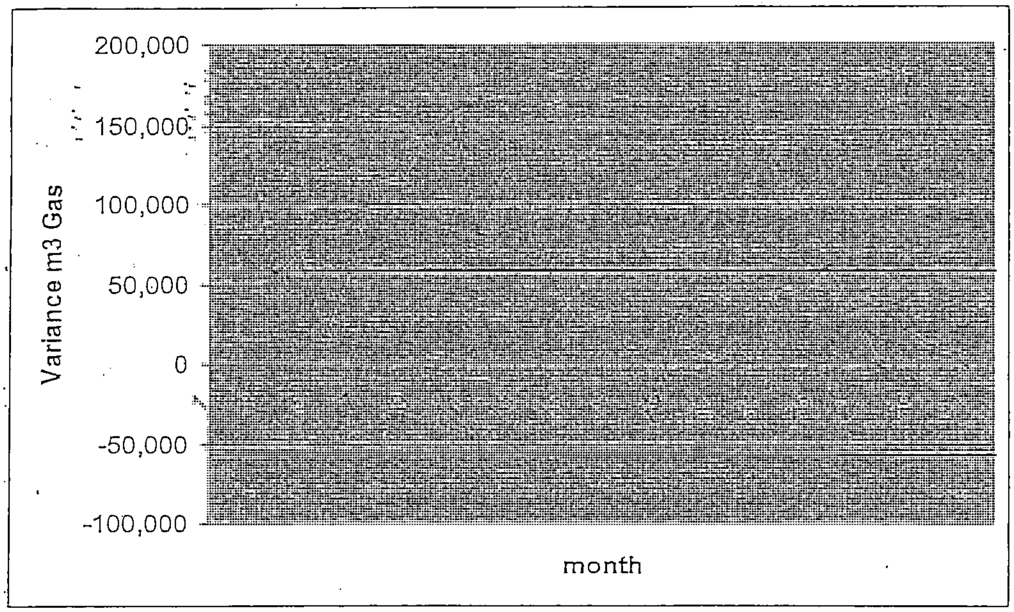


Figure 6.10: Control Chart

Bands have been added to the control chart for upper and lower control limits. A good value for the control limits is +/-1.4 times the average of the differences in the current pattern ignoring the signs.

6.5.4 Monitoring as a basis for actions

A number of actions can result from monitoring fallingl into a number of categories ranging from control to budgeting and comparisons.

6.5.4.1 Monitoring as a basis for control

Monitoring starts with information gathered at regular time intervals. By using techniques like CUSUM it is possible to isolate the time related variation and by regression or x-y graphs to isolate variations such as the weather and occupancy. In this way monitoring information is useful as a basis for precise control.

CUSUM uses readings from the same meter. Provided that there are no inconsistencies in the way the meter reads as it accumulates data (exceedingly rare), the precision of the meter, the consistency of weather information and the characterization of the pattern are the only limits to the resolution of a trend.

There are two limits to the resolution of a fault. One is the size of fault that might appear in one month and whether this can be detected as an isolated incident. The other is a change in pattern and whether this can be detected over time. In a building, an example of the first is whether one could detect an occupant leaving a window open over a weekend, the second is whether one could detect someone having reset a time clock.

In a well managed building the resolution of a fault of +/-3% as an isolated incident ought to be possible and longer-term changes in pattern of better than +/-1% are possible. The limit to the detection of isolated faults in many cases is the reliability of the degree-day itself as a measure of the weather.

6.5.4.2 Monitoring as a source of budget information

Having produced a formula for the target pattern, if the building is not expected to change, it is possible to use the projections of weather into the future to produce a budget. For buildings one might use a projection based on the 20-year average weather expressed as degree-days, which are readily available.

The example below illustrates an energy budget calculation.

6.5.4.3 Monitoring as a of source summary information

As we have seen, monitoring in this way isolates from a long time series of data a small number of parameters which summarize the pattern of energy use in the building—the slope and the intercept in the case of a straight line.

These parameters provide an extremely valuable means of comparing energy use between buildings. It is a valuable form of management summary information for many kinds of decision—costing, operating cost comparisons, etc.

Examples of summary information obtainable from monitoring are:

- the degree day- related and unrelated consumption for different buildings;
- energy intensity, i.e. consumption values expressed per unit area of floor for buildings;
- the fraction of electricity units used at night;
- electrical load factors (kWh/maximum demand).

APPENDIX 6

Presentations made to the

Consejo Ejecutivo,

October 6 2006

and to the

Zamorano Energy Committee

September 25 2006

Energy Efficiency Through Energy Management

10 October 2006

Charles R. Price P.Eng.
Energy Management and Solar Consultant

What is my energy efficiency role at Zamorano?

My role here is:

1. to investigate the potential for energy reduction and renewable energy sources for Zamorano;
2. to assist in the development of a strategy that will move Zamorano toward energy efficiency;
3. and, to identify opportunities which if implemented will reduce Zamorano's utility costs.

What is Energy Efficiency

Definition

> *Energy efficiency encompasses all changes that result in a reduction in the energy required by any activity (heating, lighting, manufacturing, or a process). This reduction in energy consumption is not only due to technical changes since a change in organization and/or management of activities may result in reduced energy use by that entity.*

Several words have been underlined because they are extremely important. Achieving energy efficiency always involves *change*. And, those changes are a combination of both *technical and behavioral changes*.

There are three additional things that I want to emphasize:

- that by definition, energy efficiency is not a state of being but an unending and ongoing process of achievement;
- that energy is everyone's concern;
- and, that energy is a manageable expense, and can be managed like other organizational expenses.

What is different about an organization that moves toward energy efficiency?

First of all, it is an organization that successfully fosters an *"energy efficiency culture"*, and even more specifically, it is an organization where energy is managed just as every other aspect of the organization is managed. Taken together it means that energy efficiency is the result of energy managment and energy efficiency is achieved when all people in the organization have a commitment to it.

What are the Potential Benefits of Energy Efficiency?

The obvious and general benefits are:

- reduced utility costs (in Zamorano's case, possibly electrical self sufficiency);
- reduced maintenance costs;

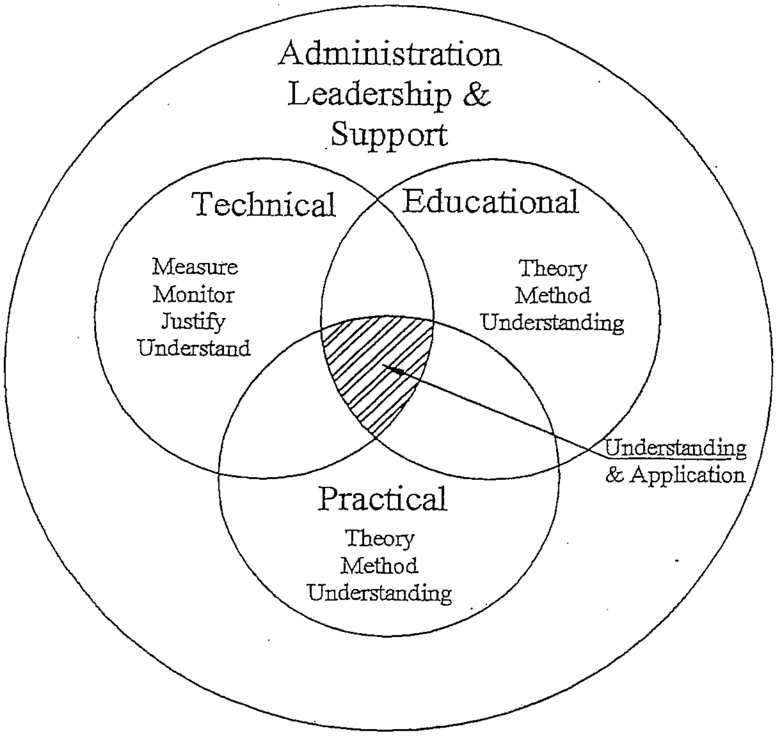
- reduced environmental impact;
- a reduction in a country's energy imports (specifically oil).

And, in Zamorano's case there are many additional benefits:

- it provides community leadership[1];
- it is consistent with Zamorano's motto of 'learning by doing'[2];
- it will enhance Zamorano's academic and practical programs[3];
- and, it will increase Zamorano's ability to attract outside funding.

How does Zamorano become Energy Efficient?

It begins with the Zamorano administration. It is important that the administration provide the leadership and support so that energy efficiency can flourish. Leadership and support will be important for all aspects and at all levels of the organization.



Spheres of Influence Impacting Energy Efficiency
Figure 1

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[1] As Zamorano becomes more energy efficient, Zamorano will be known as the 'Center of Excellence' for energy efficiency and renewable energy technologies. A logical extension of these practices is the development of an outreach program on energy efficiency and renewable energy technologies.

[2] Zamorano's motto of 'learning by doing' is entirely appropriate. Energy efficiency cannot be imported it must be implemented by the users!

[3] Since the implementation of energy efficiency and the use of alternative and renewable energy sources will have student involvement, each academic program will be expanded to include the study and practical operation of energy efficiency and renewable energy technologies.

Figure 1 illustrates some spheres of influence at Zamorano as they impact energy efficiency. The diagram indicates that there are many spheres of influence within an organization and only when they work together (the overlapping portion) will energy efficiency become a reality. From an energy management point of view, all spheres of influence are interlinked.

What are the opportunities for energy savings and how long will it take?

It is risky to make predictions at this time. It depends upon the current state of energy efficiency, the restraints on the organization, the availability of alternate energy sources (both non-renewable and renewable), the funds available for a program, the enthusiasm of the organization for energy efficiency, the ability of the organization to make a change and many other factors.

In spite of all of the above, I think that it would be possible to reduce Zamorano's utility costs by up to 40% over a 10 year period. Some of these reductions would be the result of operational changes; some would be the result of technical changes and some could come as a result of introducing renewable energy technologies.

What might be examples of operational changes that may result in reduced energy use?

1. the introduction of a checklist for building shutdowns;
2. rescheduling of non-critical daytime electrical loads so as to reduce electrical demand;
3. a review of utility bills to detect possible billing errors;
4. the introduction of a preventative maintenance program;
5. and, regular recording of plant and building utility inputs and the introduction of benchmarking.

Examples of technical changes could be:

1. installation of utility meters to all plants and buildings (this to be done in conjunction with #5 above);
2. installation of newer more energy efficient equipment;
3. discontinue the purchase of incandescent bulbs in favor of compact fluorescent bulbs;
4. installation of T8 fluorescent bulbs in favor of the existing T12 bulbs and more appropriate placement of fixtures[4];
5. install solar water heating where appropriate and practical;
6. install photovoltaics where appropriate and practical;
7. install biodigesters where appropriate and practical;
8. install a small hydro system.

What are the potential challenges of implementing energy efficiency?

In the order of difficulty:

- the human factor of introducing change within an organization;
- maintaining enthusiasm for the program;
- maintaining a reduced level of energy usage;
- locating funds to implement the program.

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[4] I note that (as with all other buildings in the world) light fixtures are mounted on the ceiling rather than where the illumination is required.

How does Zamorano get started on an energy efficiency program?

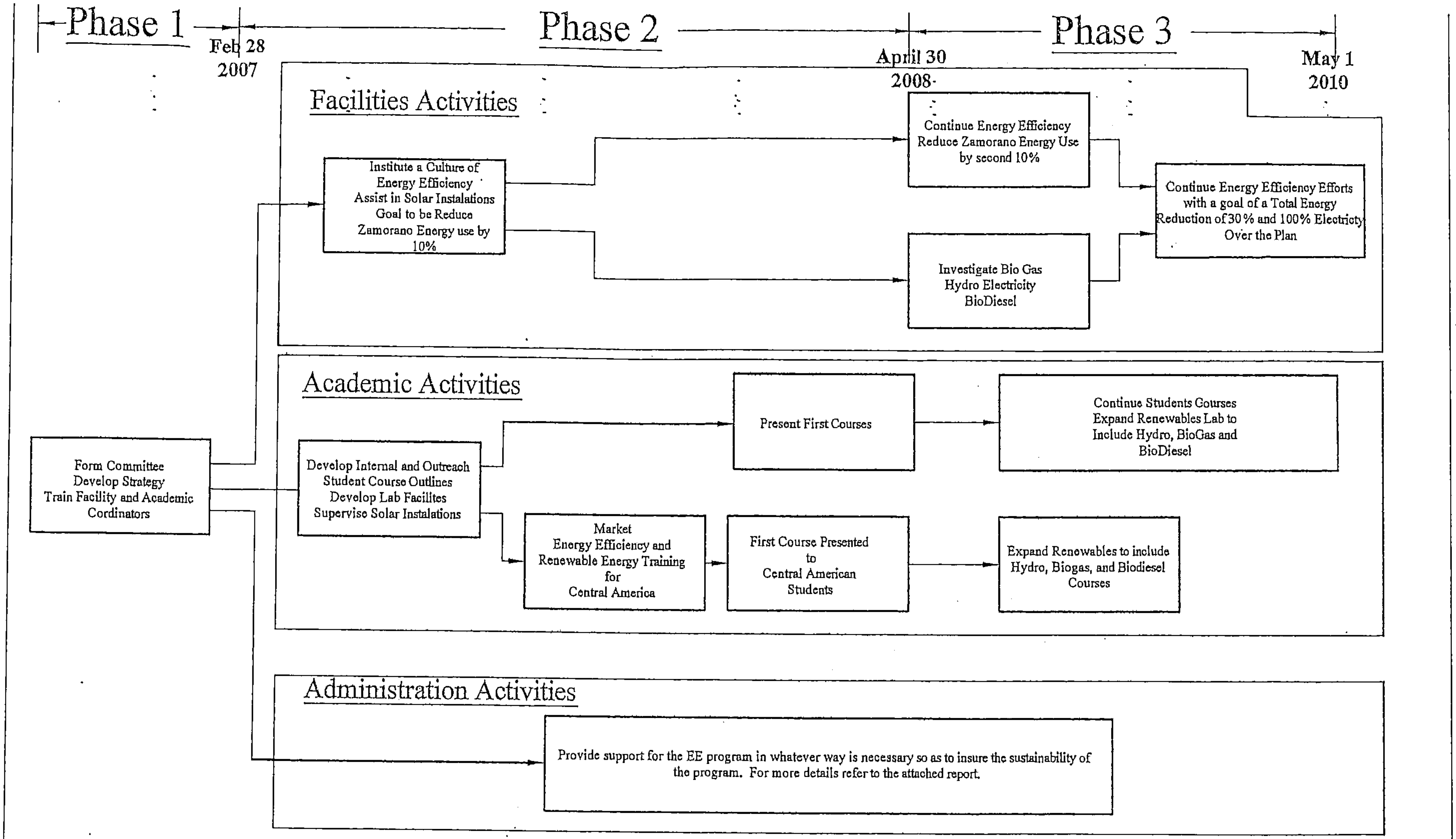
- by formulating a vision;
- by promoting the vision;
- and by providing the conditions by which the vision can be realized.

I have formulated a vision and strategy by which the vision can be realized. Attached to this document are two flow charts. Chart 1 outlines a 4-year Zamorano strategy. Chart 2 provides an expanded view of phases 1 and 2.

And, finally:

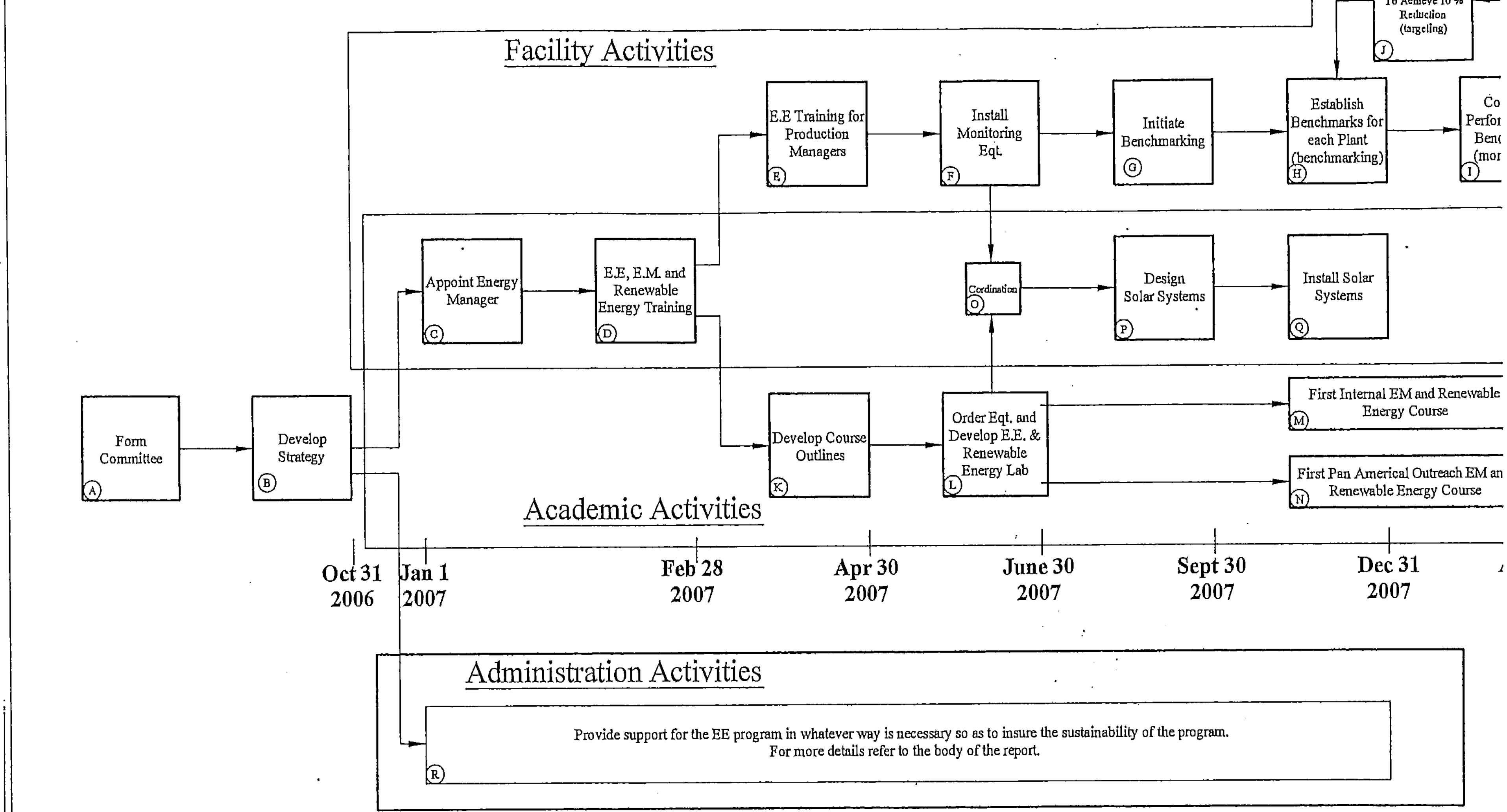
The implementation of energy management is an on-going activity, it will never end, but eventually it will become a 'normalized' activity, as are all other Zamorano activities. It is important that energy management be appropriate and sustainable for the organization. For this to happen the plan and application must include all people and levels of the organization and meet the needs of the organization. I am sure that my strategy will have to be modified somewhat to suit your situation. Regardless of the adopted strategy, modifications will be required from time to time in order to maintain currency and appropriateness.

Use Zamorano's motto – "Learn by doing".

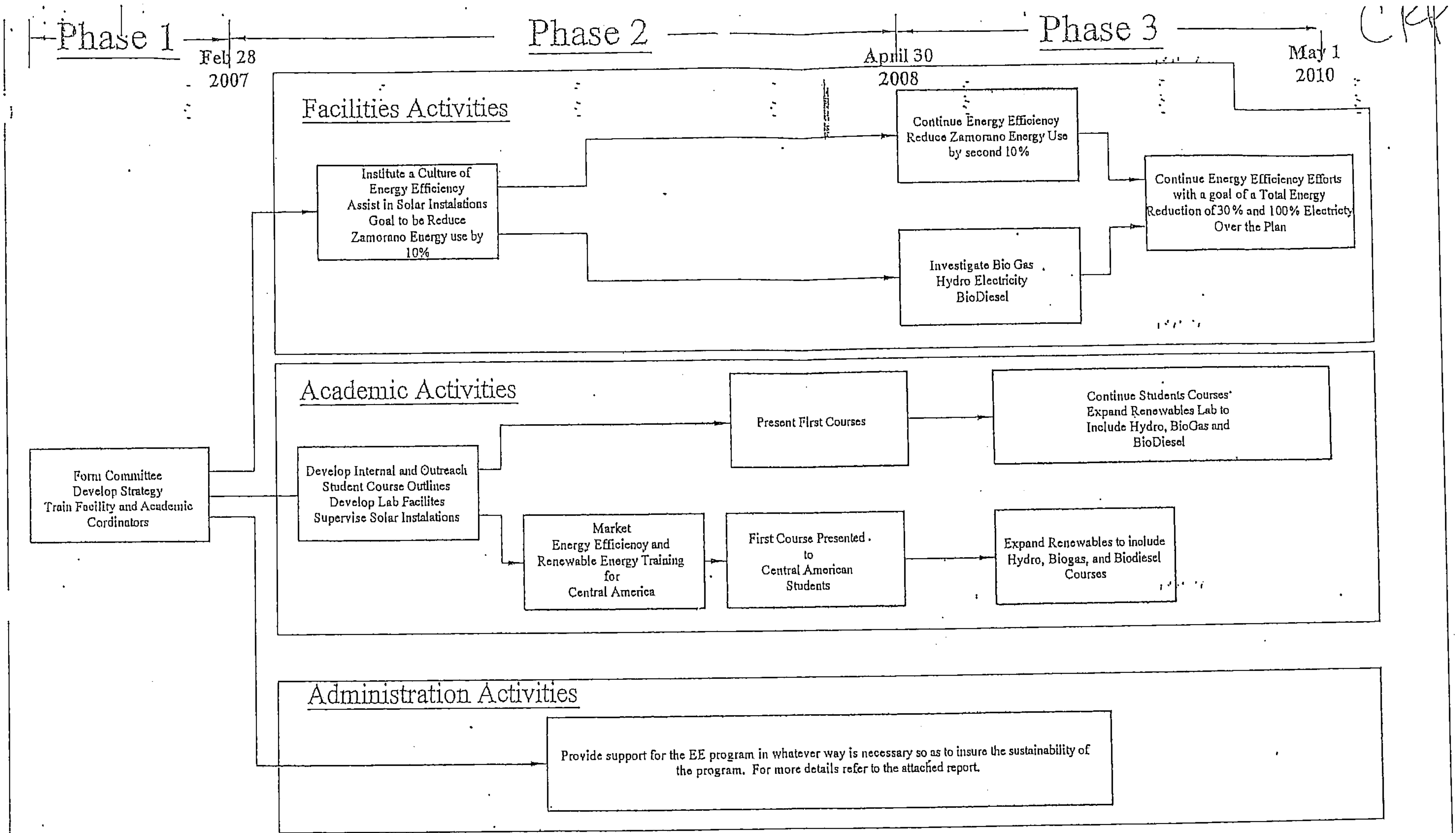


A VISION FOR ENERGY EFFICIENCY AND SUSTAINABILITY
ZAMORANO 4 YEAR PLAN 2006 TO 2010

Chart 1

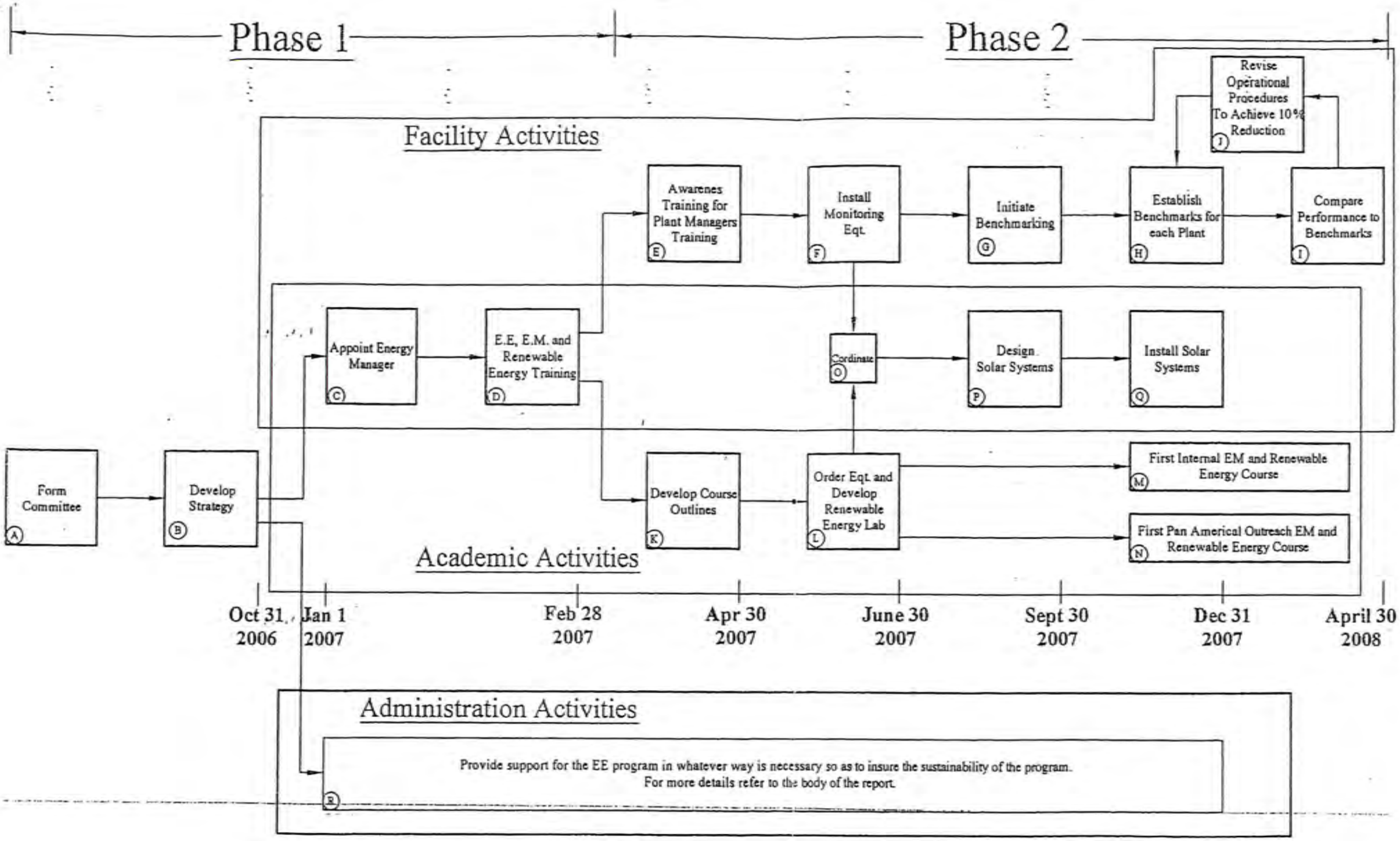


A VISION FOR ENERGY EFFICIENCY AND SUSTAINABILITY



A VISION FOR ENERGY EFFICIENCY AND SUSTAINABILITY
ZAMORANO 4 YEAR PLAN 2006 TO 2010

Chart 1



A VISION FOR ENERGY EFFICIENCY AND SUSTAINABILITY
ZAMORANO 18 MONTH PLAN

Chart 2

Presentation
Wednesday Sept 26 2006

Energy Efficiency

My role here is:

1. To investigate the potential for energy reduction and renewable energy sources for Zamorano.
2. To assist in the development of a strategy that will move Zamorano toward energy efficiency and;
3. To identify opportunities which if implemented will reduce Zamorano's utility costs;

What is Energy Efficiency

Definition

Energy efficiency encompasses all <u>changes</u> that result in a reduction in the energy required by any activity (heating, lighting, manufacturing, or a process). This reduction in energy consumption is <u>not only</u> due to technical changes since a change in organization and/or management of activities may result in reduced energy use by that entity.

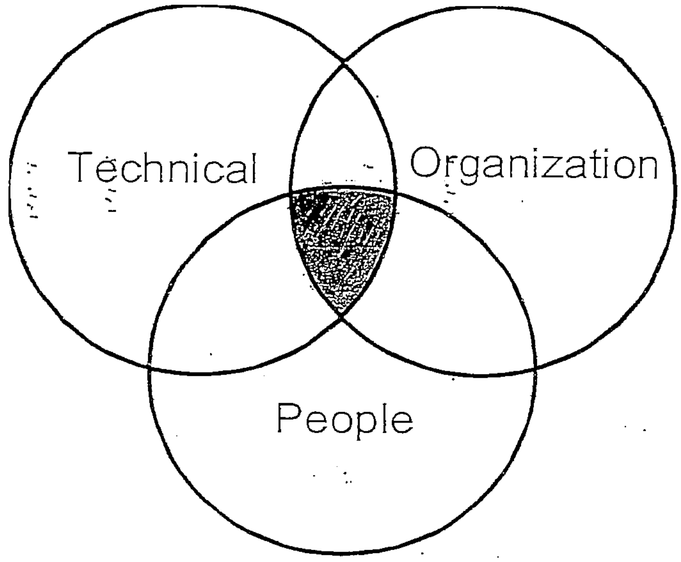
Several words have been underlined because they are extremely important. Achieving energy efficiency always involves *<u>change</u>*. And, those changes are a combination of both *<u>technical and behavioral changes</u>*.

This leads to the statement that; *"It is not possible for an organization to reach a stable state of being Energy Efficient"*. This is because what may be the least amount of energy use for an activity today may not be the same tomorrow because of other factors that have changed.

Energy Efficiency therefore by definition is not a state of being but an unending and ongoing process of achievement.

Who is Responsible for Energy Efficiency?

Everyone at Zamorano is responsible because everyone at Zamorano controls the use of energy. The principals and management promote energy efficiency programs and also controls his/her office lighting and length of time the computer is on. The maids control apartment daytime energy use (lights, fans refrigerator and TV), the students control energy use in the laboratories and dormitories, Instructional staff control office and classroom energy. Administration uses energy and also have control over financial decisions regarding energy, Plant managers have the ability to analyze energy densities hence make informed decisions regarding plant operation and the purchase of energy efficient equipment. Maintenance personnel have a very large impact on energy use as well-maintained equipment is more energy efficient and has a longer life than poorly maintained equipment. An organization moving toward energy efficiency involves all staff and the more they co-operate the more effective and successful the management of energy will be. The diagram on page 2 shows this more effectively. Each circle represents a group of people at Zamorano. Each individual group has their sphere of influence and goals. The diagram illustrates that only when all of the groups have the same goal (the intersecting area) will effective change occur. The more the circles overlap the more effective the program. There is a human side to energy efficiency and this can be one of the greatest challenges in reducing energy use and maintaining that reduced energy use. An organization moving toward energy efficiency must foster a culture of energy efficiency, and it is the task of the energy manager or the energy management committee and administration to promote and instill that culture.



What are the Potential Benefits of Energy Efficiency at Zamorano

- Reduced utility costs
- Reduced maintenance costs
- Community leadership[1]
- Consistency with Zamorano's motto of learning by doing
- Enhancement of el Zamorano academic and practical programs[2]
- Assist in reducing the Nations need for importing non-renewable energy
- Reduced environmental impact
- Ability to attract increased outside funding

What are the Potential Challenges of Implementing Energy Efficiency?

In the order of difficulty

- The human factor of introducing change within an organization
- Maintaining enthusiasm for the program
- Maintaining a reduced level of energy usage
- Locating funds for an energy manager/committee
- Locating funds for technical changes (equipment)
- Providing training for all Zamorano staff
- Implementing energy efficiency information into the existing curriculum

What is the Opportunity for energy savings and how long will it take?

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1 As Zamorano becomes more energy efficient, Zamorano will be known as the 'Center of Excellence' for energy efficiency and renewable energy technologies. A logical extension of this expertise is the presentation of seminars on energy efficiency and renewable energy technologies.

2 Since the implementation of energy efficiency and the use of alternative and renewable energy sources will require student involvement, each academic program will be expanded to include the study and practice operation of energy efficiency and renewable energy technologies.

It is risky to make predictions at this time. It depends upon the current energy efficiency, the restraints on the organization, the availability of alternate energy sources (both non renewable and renewable), the funds available for a program, the enthusiasiam of the organization, the ability of the organization to make a change and many other factors.

In spite of all of the above, I think that it would be possible to reduce Zamorano's utility costs by up to 40%. Some of these reductions would be the result of operational changes (i.e. plant scheduling); some would be the result of technical changes (newer and more efficient equipment) and some could come as a result of introducing renewable energy technologies. Some of the changes would be high profile and some would be less evident.

The program will be on going. In time energy efficiency will not be seen as a program, it will become part of the normal operation as are other functions, such a budgets, and equipment maintenance.

What are examples of activities that will result in reduced energy use?

Examples of Operational Changes might be; (no cost or low cost)

1. The introduction of a checklist for plant equipment and lighting shut down.
2. Rescheduling of non-critical daytime electrical loads so as to reduce electrical demand
3. A change in supplier of fuel oil, propane or other fossil fuel
4. A review of utility bills to detect possible billing errors.
5. Where heating equipment has the ability to use an alternate fuel, a switch to a less expensive fuel.
6. Introduction of a preventative maintenance program.
7. Regular recording of plant and building utility inputs and the introduction of benchmarking

Examples of Technical Changes might be

1. Installation of power factor correction
2. The testing and repair of all steam and compressed air leaks
3. The detection and repair of all plant piping water leaks
4. The detection and repair of underground water pipe and supply pipe leaks
5. Installation of utility meters to all plants and buildings (this to be done in conjunction with #7 above
6. Discontinue the purchase of incandescent bulbs in favor of compact fluorescent bulbs
7. Installation of T8 fluorescent bulbs in favor of the existing T12 bulbs and more appropriate placement of fixtures[3]
8. Installation of sky lights where possible
9. Installation of insulated storage tanks to utilize waste process hot water for other applications.
10. Sourcing of more energy efficient process equipment when replacements are required
11. Installation of timers and light sensors on lighting and other equipment
12. Install solar water heating where appropriate and practical
13. Install Photovoltaics where appropriate and practical
14. Install Biodigesters where appropriate and practical
15. Small scale Hydro Installation

[3] I note that (as will all other buildings in the world) light fixtures are mounted on the ceiling rather than where the illumination is required.

Examples of Management Activities/directives facilitating Energy Efficiency

1. The endorsement of an energy efficiency program
2. The development and endorsement of short and long term energy efficiency goals.
3. A campus wide advertisement of energy efficiency accomplishments.
4. Allocation of funds for energy efficiency projects
5. Active sourcing of outside funding for energy efficiency projects
6. The implementation of internal incentives for energy efficiency
7. Providing human resources.

Where do the Funds come from?

There are a variety of funding sources. The easiest are those funds that are a result of "no-cost" operational changes. Some organizations are able to self-finance a program. That is – no-cost opportunities are identified, implemented and the resulting savings are earmarked for energy efficiency projects that require funds. Remember – savings are continuous and increasing once a program has been implemented. Zamorano may wish to include an Energy Efficiency line item in the annual budget. I also understand that external aid funds are available. And, I think that many countries (Canada included) are positively disposed toward the allocation of aid funds for visible energy efficiency projects (solar, wind, hydro, biogas etc.)

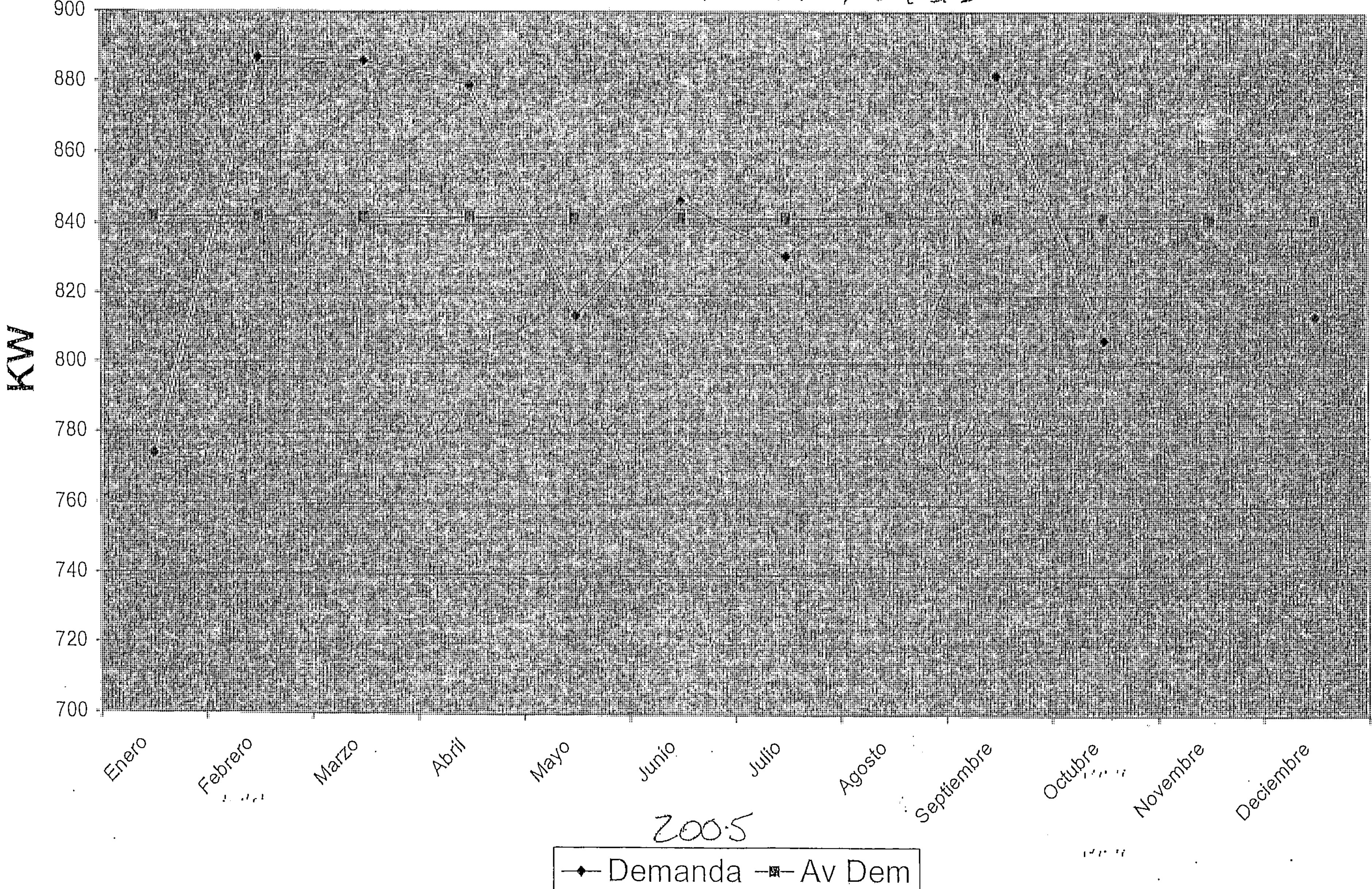
What about Training?

All Zamorano staff will require training, but it must be appropriate for the job function. Plant managers, instructors, and technical maintenance staff will require technical training; administration will require opportunity awareness training. Even cleaning staff will require training.[4]

[4] It has been shown that awareness training for hotel cleaning staff results in considerable energy savings if they consistently shut off all lights, TV's, and refrigerators upon completion of daily room maintenance.

Zamorano Electric Supply

DEMAND ANALYSIS



Possible Savings – 35,293 LPS