1 INTRODUCTION

Modern Industrial Assessments: A Training Manual represents the effort made by the United States' Department of Energy to provide technical training to a range of potential end users interested in performing industrial assessments at small to medium-sized manufacturing plants and the effort of course instructor's to provide the best training methods and materials to these industrial assessors. Industrial assessments, as discussed in this manual, refer to detailed reviews of existing operations with an eye to improving productivity in any of a number of ways.

In this fashion the focus of this manual becomes "re-engineering", the currently popular buzzword interpreted as meaning increased efficiency in the use of resources and just as the industrial assessor seeks to re-engineer a client's manufacturing processes, this manual increases the efficiency of the assessment instructor by combining materials produced over decades in an attempt to organize, assemble and index the collection. Although some of the material and most of the organization methodologies were produced from scratch or updated from existing sources, much of the manual's content was assembled utilizing the work of other professionals in the assessment field and to those who have come before us, we gratefully acknowledge their contributions to this work. In particular, we wish to acknowledge the work of Professor Jendrucko at the University of Tennessee and his staff along with Professor Byron Winn of Colorado State University for contributing much to this document. The Preface to the First Edition introduced this manual as a living document and all engineering libraries contain many references to money saving industrial techniques already out of date as the "latest" book goes to press. Certainly many the ideas contained within this manual will stand the test of time, but when desirable, the structure allows continuous updating.

This section focuses on industrial energy use. As shown in the figure below, industrial sector energy needs accounts for more than 36% of national consumption at a cost of $99.7 billion in 1991. According to the Alliance To Save Energy, the energy savings potential resulting from increased energy efficiency has been estimated at 11-13% over the next two decades and this manual should be used as a tool in the battle for energy efficiency. Source: Energy Information Administration Annual Energy Review 1993

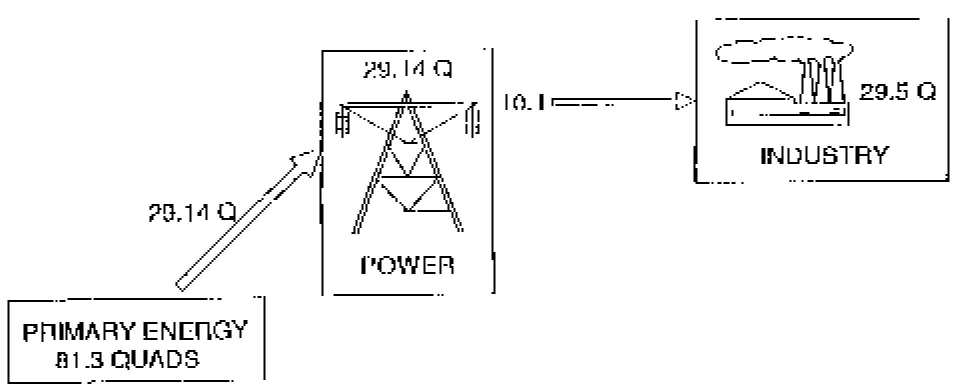

Figure 1.1: US Energy Use

1.1. ENERGY

All nations, particularly those with a strong industrial base, transform energy of one form into another for the benefit of Society. Thus a shared governmental enterprise that spends money wisely while improving the efficiency and minimizing the environmental impact of energy transformation is a simple goal perhaps, but not one without inherent difficulties. Limited resources such as oil reserves or coal deposits illustrate an obvious obstacle overcome chiefly through importation mechanisms but influenced directly by strategic resource allocation requirements. Luckily, not all activities, even essentials such as illumination, require the same amount of energy and different opportunities for resource conservation exist both in the type of energy usage and the industries in which usage occurs. The following pictures from the U.S. Dept. of Energy's Energy Information Agency show a typical profile of energy usage for different activities within buildings and the energy intensity of various industries.

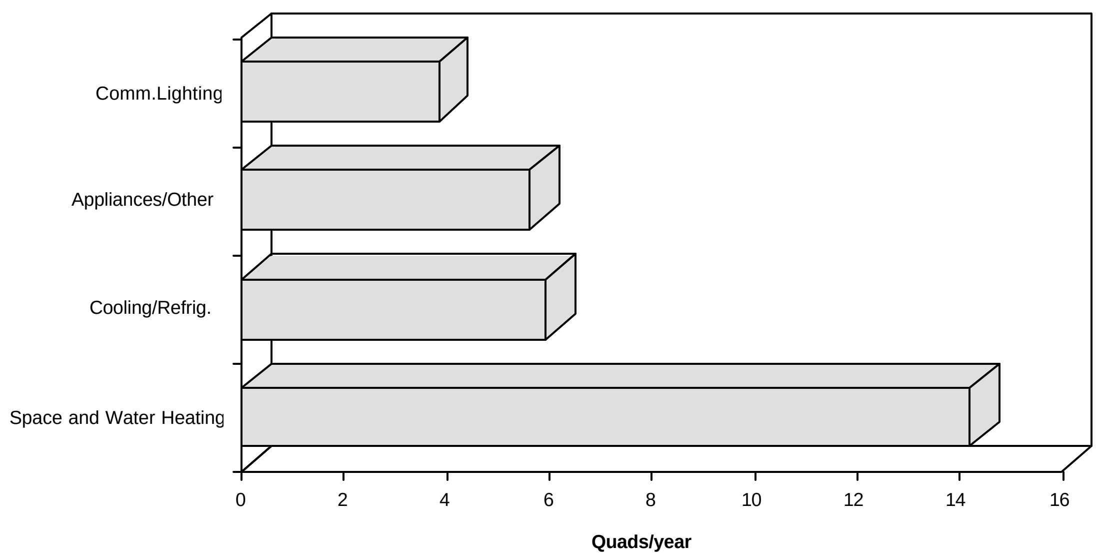

Figure 1.2: Building Energy Use

From these generalities the greatest opportunities for energy conservation occur in the chemical and primary metals industries. Assessments of the energy usage in such plants with recommendations for conservation together constitute one valid strategy for demand-side energy management (DSM). Cutting usage by the consumer decreases the demand on the energy providers as their consumer base increases. Thus, aggressive utility DSM programs may abrogate the need for creation of new power generation plants. Energy conservation on the facility scale translates directly to resource preservation and decreased environmental stress on the larger scale. With the forthcoming deregulation of energy providers, demand side services will become increasingly more important as consumers shop for value added services accompanied by competitive pricing in the energy markets.

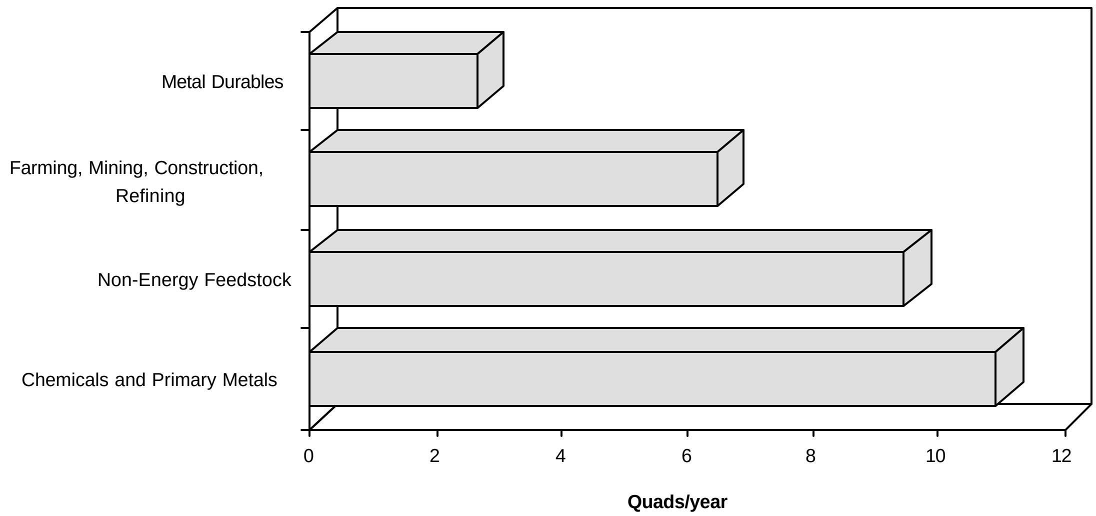

Figure 1.3: Industrial Energy Use

Energy conservation, waste minimization, pollution prevention and productivity enhancement all represent areas investigated during the industrial assessment. Energy conservation strategy research and development since the oil embargo years has enriched the possibilities of use reduction methodology's application to the small and medium sized industrial manufacturer. The Figure 1.4:"Load Shape Changes" on page 4 from Clark W. Gellings presentation to the EEI shows examples of typical load variations resulting from some conservation strategies. An extension of this approach follows the graphic keys with descriptions of a variety of systems typically employed in most of today's manufacturing plants. As can be seen, in some cases more than one approach is available and in the case of demand controls and heat pumps three load shape changes apply. The following and last page of Gellings' summary shows some expected simple payback periods. Paybacks are derived from division of the money saved annually after implementing the recommendation by its associated implementation cost. An important piece of information, presentation of the payback to the assessed industrial client becomes an essential stratagem used in gaining project approval. The role of payback in industrial decision making by small to medium sized manufacturers for whom the window of competitive opportunity is quite small cannot be over-emphasized. The industrial assessor must sell the manufacturer on the recommendation's possibilities before short-term profits can be routed into operational budgets.

The following abbreviations are used in the summary:

PC - peak clipping
VF - valley filling
LS - load shifting
SC - strategic conservation
SG - strategic growth
FLS - flexible load shape

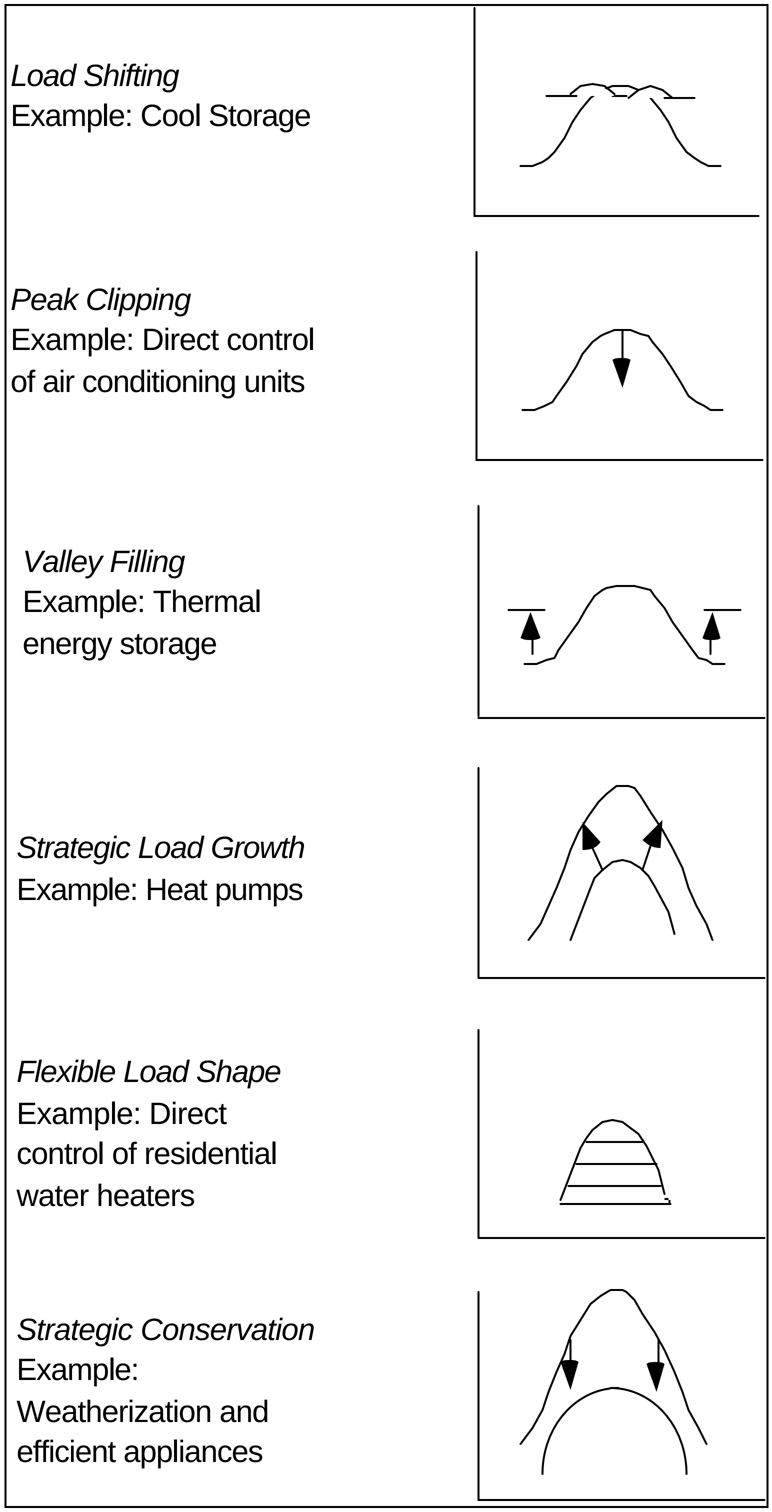

Figure 1.4: Load Shape Changes

Demand-Side Management Strategies: Industrial Measures

	PC	VF	LS	SC	SG	FLS
Cooling Systems						
1. Condenser Water Temperature Reset				x		
2. Chilled Water Supply Temperature Reset				x		
3. Hot-Gas Defrost				x		
4. Two-Speed Motors on Cooling Tower Fan				x		
Heating Systems						
5. Destratification Fans				x		
6. Comfort Radiant Heating Systems				x		
7. Process Radiant Heating Systems				x		
8. Quartz Radiant Heating Systems				x		
Boilers						
9. Combustion Air Blowers Variable Frequency Drives	x					
10. Air/Fuel Ratio Reset				x		
11. Turbulators				x		
12. High-Pressure Condensate Return System				x		
13. Steam Trap Repair				x		
14. Steam Leak Repair				x		
Air Compressors						
15. Outside Air Usage	x			x		
16. Leakage Reduction	x			x		
17. Cooling Water Heat Recovery				x		
18. Waste Heat Recovery				x		
19. Pressure Reduction	x			x		
20. Screw Compressor Controls				x		
21. Compressor Replacement	x			x		
22. Low-Pressure Blowers	x			x		

	PC	VF	LS	SC	SG	FLS
Insulation						
23. Steam Leaks and Hot Water Pipes				x		
24. Chilled Water Pipes				x		
25. Hot Tanks				x		
26. Cold Tanks				x		
27. Injection Mold Barrels				x		
28. Dock Doors				x		
Industrial Process Heat Recovery						
29. Industrial Process Heat Exchangers	x			x		
30. Waste Heat Recovery Boilers	x			x		
31. Cogeneration	x	x				
32. Industrial Process Heat Pumps		x	x	x		
Solar Energy						
33. Solar Industrial Process Heating	x			x		
34. Once-Through Solar Heated Ventilation and Process Air				x		
35. Solar Photocatalytic Water Detoxification				x		
Electric Use Shifting and Controls						
36. Demand Controls	x	x	x			
37. Interruptible and Curtailable Service	x					x
38. Power Factor	x					

PC = peak clipping; VF = valley filling; LS = load shifting; SC = strategic conservation; SG = strategic growth; FLS = flexible load shape

Paybacks[1] for Demand-Side Management Strategies:
Industrial Measures

	<2	2-5	6-10	>10
Cooling Systems				
1. Condenser Water Temperature Reset	x			
2. Chilled Water Supply Temperature Reset	x			
3. Hot-Gas Defrost		x		
4. Two-Speed Motors on Cooling Tower Fan	x			
Heating Systems				
5. Destratification Fans	x			
6. Comfort Radiant Heating Systems	x			
7. Process Radiant Heating Systems	x			
8. Quartz Radiant Heating Systems		x		
Boilers				
9. Combustion Air Blowers Variable Frequency Drives		x		
10. Air/Fuel Ratio Reset	x			
11. Turbulators	x			
12. High-Pressure Condensate Return System		x		
13. Steam Trap Repair	x			
14. Steam Leak Repair	x			
Air Compressors				
15. Outside Air Usage	x			
16. Leakage Reduction	x			
17. Cooling Water Heat Recovery	x			
18. Waste Heat Recovery	x			
19. Pressure Reduction	x			
20. Screw Compressor Controls	x			
21. Compressor Replacement	x			
22. Low-Pressure Blowers	x			
Insulation				
23. Steam Leaks and Hot Water Pipes	x			

	<2	2-5	6-10	>10
24. Chilled Water Pipes	x			
25. Hot Tanks	x			
26. Cold Tanks	x			
27. Injection Mold Barrels	x			
28. Dock Doors	x			
Industrial Process Heat Recovery				
29. Industrial Process Heat Exchangers		x		
30. Waste Heat Recovery Boilers				x
31. Cogeneration		x		
32. Industrial Process Heat Pumps	x	x		
Solar Energy				
33. Solar Industrial Process Heating		x	x	x
34. Once-Through Solar Heated Ventilation and Process Air		x		
35. Solar Photocatalytic Water Detoxification		x	x	x
Electric Use Shifting and Controls				
36. Demand Controls		x		

PC = peak clipping; VF = valley filling; LS = load shifting; SC = strategic conservation; SG = strategic growth; FLS = flexible load shape

1 Paybacks will vary based on climate, fuel costs, system characteristics, implementation cost by geographical area, and other factors.

x - The payback falls in the category indicated

Industrial assessments such as those practiced by the universities participating in the U.S. Department of Energy’s Industrial Assessment Center Program typically begin long before the facility is visited by representatives of the Center. Compiled from over 8,000 assessments and containing and 57,000 recommendations, the IAC program data base is available to public and may be accessed via the internet’s World Wide Web (W3) at the address or uniform resource locator (URL) http://oipea-www.rutgers.edu, downloaded to any computer and analyzed with any data base program recognizing files with a .dbf extension.

Relational form from assessments to recommendations in a one to many manner, study of manufacturing environments through the data base allows assessment of previous recommendations: typical and innovative ideas, dollar savings, energy and resource conservation, implementation likelihood.

Average cost savings broken down by recommendation type provides a good representation of the potential before on site evaluation. Expressed in this case averaged over the entire data set, this can be further broken down (in most cases) by four-digit standard industrial code as a pre-assessment tool.

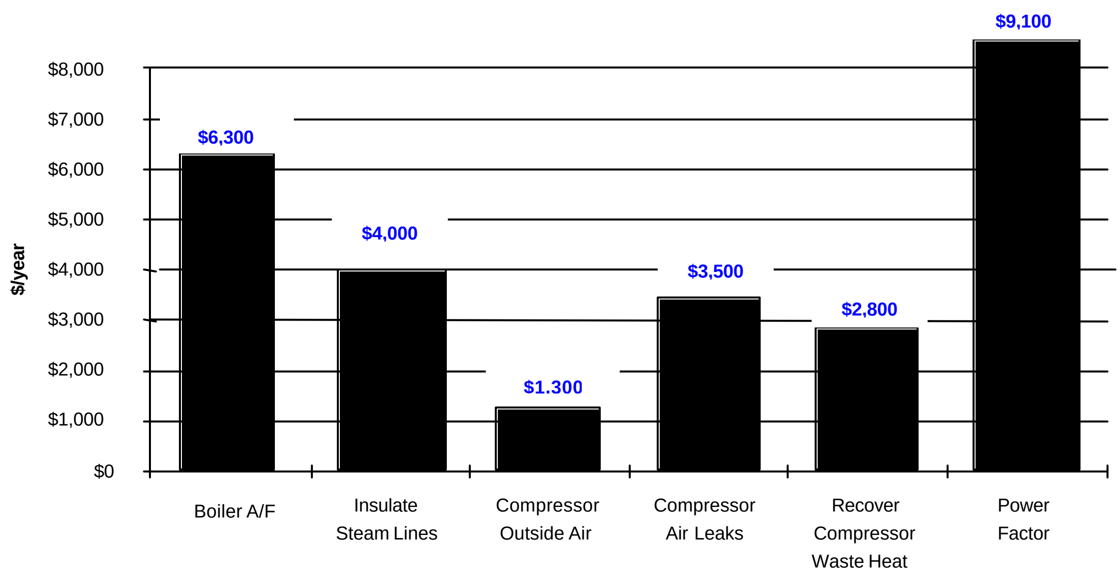

Figure 1.5: Average Cost Savings for IAC Recommendations – 1

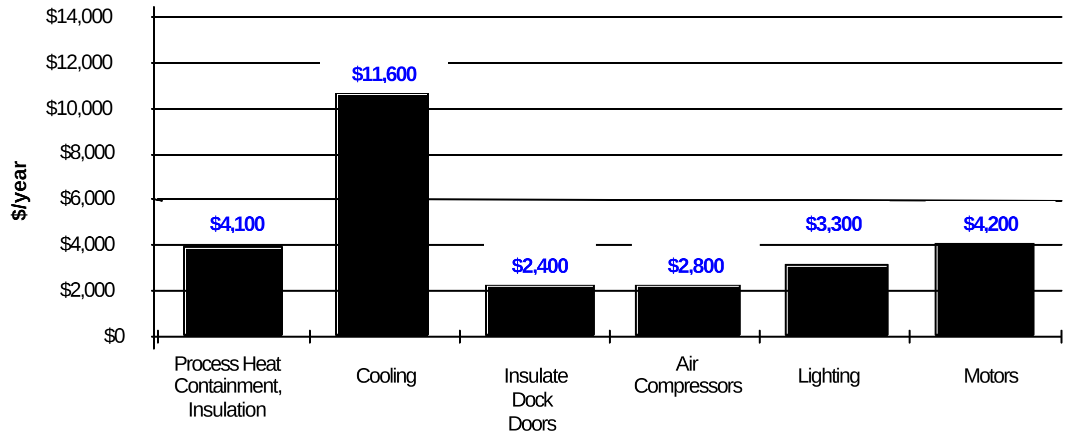

Figure 1.6: Average Cost Savings for IAC Recommendations – 2

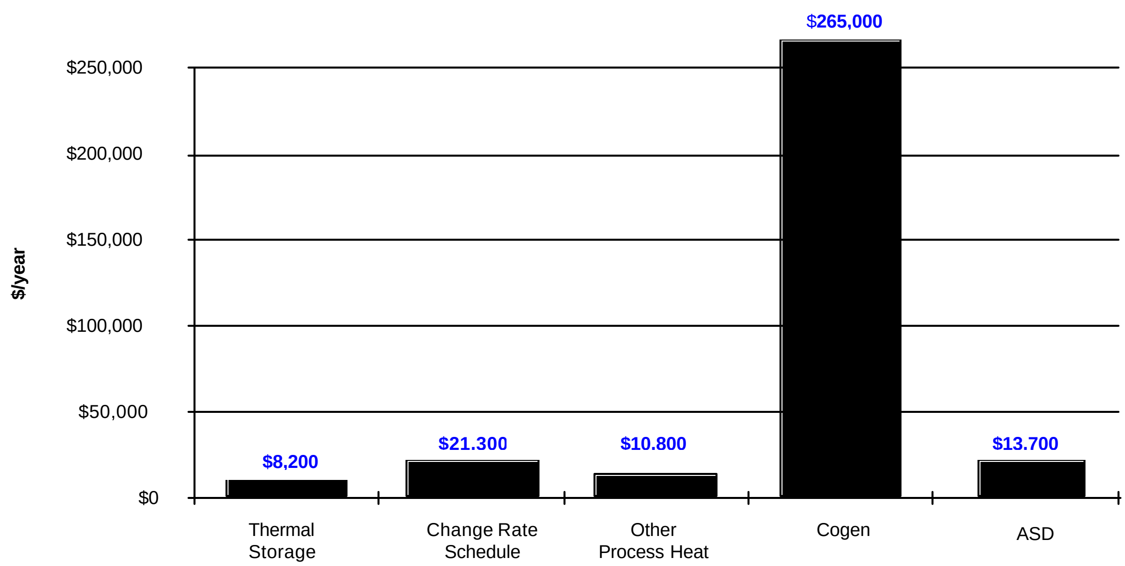

Figure 1.7: Average Cost Savings for IAC Recommendations – 3

1.1.1. Building Energy Summary

When comparing an industrial plant to an office building the common denominator found relates to certain energy costs. Each facility must provide working conditions for the people inside the buildings adequate for the intended product output including heating and/or cooling of the inside air and providing light. However, manufacturing plants incur other energy demands concerning equipment not typically operated in the office environment - motors, conveyor systems, compressors, chillers, ovens and other production components.

On the other hand, the office operates some devices like telecommunication equipment, computers, printers and monitors which although not unique to support functions such as information transfer and data tracking and increasingly located on the manufacturing floor connected to the production line or robotic applications, are found in such quantity as to be a major contributor to the commercial energy demand. The following building summary gives some flavor of what typical annual energy demands for electricity and gas small to medium sized manufacturers' require.

Overall Annual Energy & Cost Summary:
Total Energy - 20,132.4 MMBtu/yr
Total Cost - 349,135.34 $/yr

ELECTRICAL SUMMARY

Month	Energy Usage (kWh)	Energy Charge ($)	Peak Demand (kW)	Demand Cost ($)	Other Costs ($)	Reactive Cost ($)	Total Elect. Cost ($)	Unit Elect. Cost ($/kWh)
Jan	250000	19185.42	584.0	7965.82	215.13	110.15	27476.52	0.078
Feb	254400	19495.87	556.4	7595.74	214.97	116.98	27423.56	0.077
Mar	246800	18979.84	552.8	7530.38	213.21	111.22	26834.65	0.077
Apr	247600	16077.64	551.6	4245.78	194.66	113.77	20631.85	0.065
May	275600	17937.39	590.8	4617.85	201.35	114.30	22870.89	0.065
Jun	313600	20365.63	633.6	4905.38	209.51	116.58	25597.10	0.065
Jul	324800	21582.86	620.0	4919.60	216.13	112.84	26831.43	0.066
Aug	316000	21050.37	620.8	4946.63	214.93	116.75	26328.68	0.067
Sep	273200	17943.95	594.0	4632.62	201.60	108.94	22887.11	0.066
Oct	260000	17058.38	574.0	4468.58	198.46	110.82	21836.24	0.066
Nov	266800	17440.93	580.8	4466.06	199.60	112.29	22218.88	0.065
Dec	237600	18308.30	581.6	7860.44	212.19	108.54	26489.47	0.077

NATURAL GAS SUMMARY

Month	Energy Usage (CCF)	Energy Usage (MMBtu)	Total Cost ($)	Unit Cost ($/MCF)
Jan	10543	906.7	4979	4.72
Feb	8116	698.0	3838	4.73
Mar	1444	124.2	700	4.85
Apr	756	65.0	376	4.97
May	791	68.0	393	4.97
Jun	558	48.0	283	5.07
Jul	816	70.2	404	4.95
Aug	2615	224.9	1251	4.78
Sep	7540	648.4	3567	4.73
Oct	12877	1107.4	6076	4.72

Nov	18244	1569.0	8588	4.71
Dec	19807	1703.4	9466	4.78

Gas Quality - 860 Btu/cf

FUEL OIL SUMMARY

Month	Usage (gallons)	Usage (MMBtu)	Cost ($)	Unit Cost ($/gal)	Tax ($)
Jan	5878	829	3804.35	0.65	11.38
Feb	3024	426	1910.83	0.63	5.72
Ma	-	-	-	-	-
Apr	-	-	-	-	-
May	-	-	-	-	-
Jun	-	-	-	-	-
Jul	-	-	-	-	-
Aug	-	-	-	-	-
Sep	-	-	-	-	-
Oct	-	-	-	-	-
Nov	3515	496	2227.86	0.63	6.66
Dec	-	-	-	-	-

Rate Summary

Prior to visiting a manufacturing facility for assessment purposes information obtained by the assessor becomes a springboard in the determination of possible conservation recommendations. The energy bills yield information that when analyzed may provide recommendations before the visit such as energy demand rescheduling, avoidance of late payment penalties, and energy ratcheting errors. Information obtained from utility billing includes (with examples):

Electrical Rate Data:
Total Energy Usage - 3,266,400 (kWh)
Total Energy Usage - 11,148,2 (MMBtu)
Total Reactive Charge - $1,353.18
Total Electricity Cost - $297,426.38
Total Other Cost - $2,491.74

Natural Gas Rate Data:
Total Energy Usage - 84107 (CCF)
Total Energy Usage - 7233.2 (MMBtu)
Usage Cost - $39921.00

Fuel Oil:
Total Energy Usage - 12,417 (gal)
Total Energy Usage - 1,751 (MMBtu)
Usage Cost - $7,943.04

Average Costs:
Electricity - 0.07 ($/kWh)
Electricity - 26.68 ($/MMBtu
Electricity - 9.81 ($/kW)
Natural Gas - 5.52 ($/MMBtu)
Fuel Oil - 4.52 ($/MMBtu)

Graphical Representation

Graphical representation of the data subsequently provides the assessor the next logical step in the energy usage analysis progression. Experience indicates clients like graphical summaries as easily read and understood indications of relative proportions. Comparison to regional and like industries, normalized usage patterns may indicate abnormalities worthy of investigation. Some examples of graphical representation of data collected for a hypothetical company is presented on the following pages.

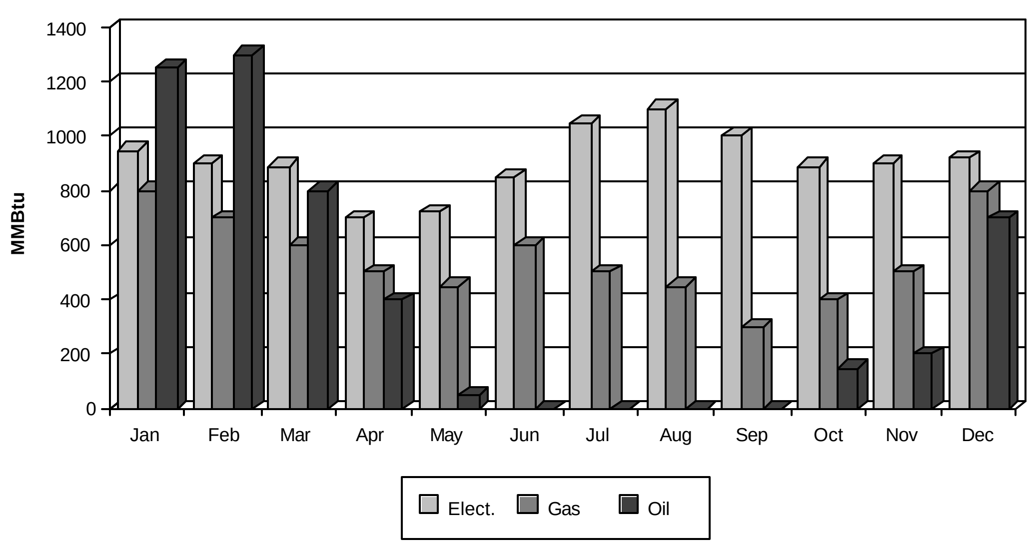

Figure 1.8: Energy Usage

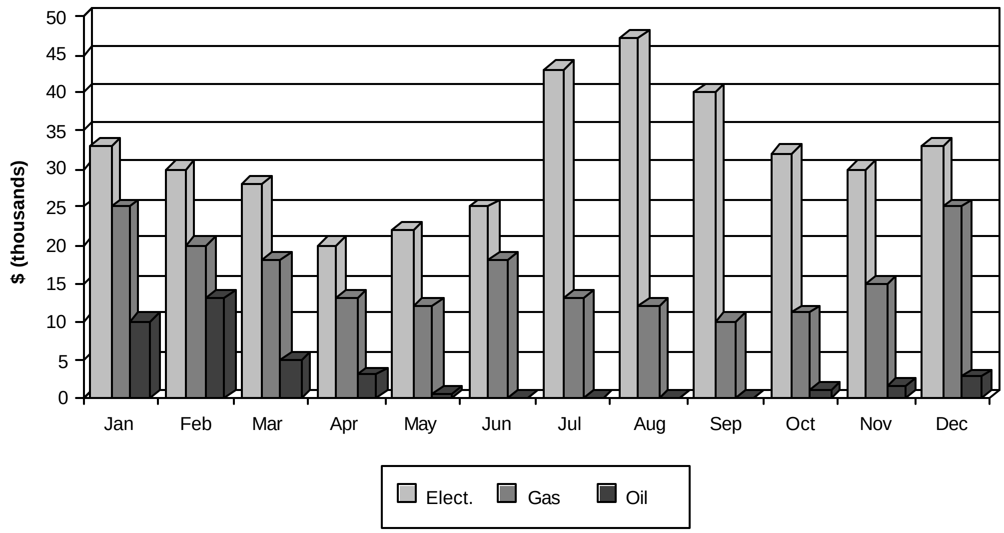

Figure 1.9: Energy Costs

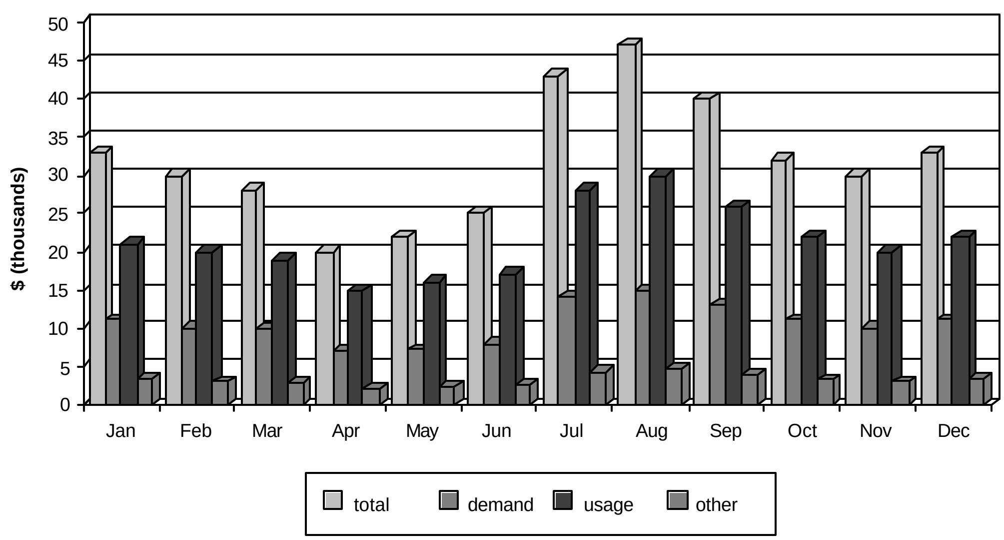

Figure 1.10: Electrical Costs

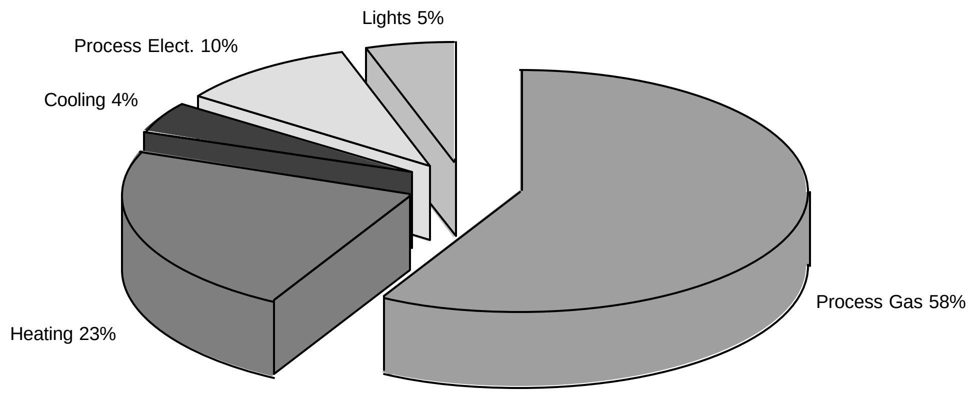

Figure 1.11: Energy Usage

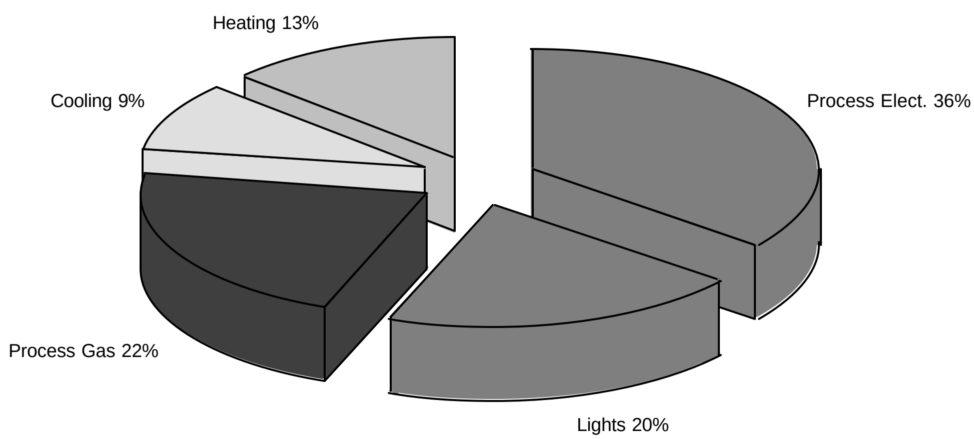

Figure 1.12: Energy Costs

REFERENCES

Clark W. Gellings, Highlights of a speech presented to the 1982 Executive Symposium of EEI Customer Service and Marketing Personnel
The Alliance To Save Energy, Getting in Gear: How energy efficiency can help smaller manufacturers compete in the global Marketplace, January 1995.