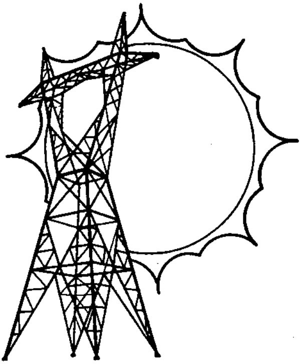
DSM Pocket Guidebook



Volume 4: Industrial Technologies

Western Area Power Administration
and
U.S. Department of Energy

Conversion Table

To convert from	To	Multiply by
Btu (British thermal unit)	kWh (kilowatt hour)	2.928×10^{-4}
cfm (cubic feet per minute)	m^3/s (cubic meter per second)	4.719×10^{-4}
°F (degree Fahrenheit)	°C (degree Celsius)	(°F-32)/1.8
ft (foot)	m (meter)	3.048×10^{-1}
ft^2 (square feet)	m^2 (square meter)	9.290×10^{-2}
ft^3 (cubic feet)	m^3 (cubic meter)	2.831×10^{-2}
gal (gallon)	m^3 (cubic meter)	3.785×10^{-3}
gpm (gallon per minute)	m^3/s (cubic meter per second)	6.309×10^{-5}
hp (horse power)	w (watt)	7.460×10^{2}
in (inch)	m (meter)	2.540×10^{-2}
lb (pound)	kg (kilogram)	4.536×10^{-1}
psi (pounds per square inch)	Pa (pascal)	6.895×10^{3}
ton (short, 2,000 lb)	kg (kilogram)	9.072×10^{2}

DSM Pocket Guidebook

Volume 4: Industrial Technologies

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FOREWORD

In previous years of low-cost energy, many demand-side management (DSM) technologies simply were not cost-effective. Today, however, with rising energy prices and the mandate to conserve, utility DSM programs and advanced energy-efficient technologies offer utilities significant opportunity for economic means to reduce operating costs and shift or defer load growth. Furthermore, recent developments in DSM technologies have improved energy quality and reduced customer maintenance costs.

This series of guidebooks is intended as a tool for utility personnel involved in DSM programs and services. Both the novice and the DSM expert can benefit from the information compiled.

PREFACE TO THE DSM POCKET GUIDEBOOK

■ INTRODUCTION

It has been estimated that if electricity were used more efficiently with currently available end-use technologies, 24%-44% of the nation's current demand for electricity could be eliminated. Almost all major electric utilities in the West are investigating such DSM opportunities. Even utilities that currently have excess capacity are finding that DSM offers an opportunity to build end-use stock to help them meet their future load shape objectives.

Utility DSM programs typically consist of several measures designed to modify the utility's load shape (for example, innovative rate structures, direct utility control of loads, promotion of energy-efficient technologies, and consumer education). The coordinated implementation of such measures requires planning, analysis of options, engineering, marketing, monitoring, and other coordinated activities. This guidebook addresses one facet of an overall DSM progrom: selection of end-use technologies within the electrical utilities.

■ TECHNOLOGY SELECTION

All facets of a utility's DSM program, including technology selection, must be planned with the utility's overall objectives in mind. Selected technologies must make the utility better able to serve its customers by providing low-cost, reliable power. Yet the utility must also be able to recover its fixed and operating costs. In practice, this usually means that the technology must provide the same or expanded cost-effective energy service to the customer while also smoothing out the utility's load curve and delaying the need for additional power plants. This guidebook directly addresses these requirements by estimating the simple payback (to the end user) for energy-efficient end-use technologies and their impacts on the utility's load curve.

A number of additional factors must be considered in technology selection. Primary among these are customer acceptance of different end-use technologies, the type of morketing effort required to promote each, and the potential impact on the utility's revenues. These are not addressed in this guidebook.

INTENDED AUDIENCE

This guidebook is intended to be a quick reference source both for utility field representatives in their customer interactions and for utility planners in the early stages of developing a DSM program. It is designed to allow a quick screening of commercially available electric end-use technologies for the industrial sector.

This guidebook is directed primarily at small municipal utilities and rural electric cooperatives within the Western Area Power Administration (Western) service area (see Figure P-1). Large utilities with more abundant resources may find the guidebook useful as only a starting point. Their technology selection process will undoubtedly also include review of other source documents and detailed system and engineering analyses of the options.

METHODOLOGY/DATA

This guidebook contains two major sections. The first section describes DSM technologies. The second section provides sources for more information on DSM options for each (two-digit) standard industrial classification. In Section 1, for each technology the guidebook presents a short, numbered technology brief—text that describes the option, its relevant applications, and its potential impact on the utility's load duration curve. Each brief also includes a summary table (usually not specifically referred to by number) with quantitative estimates of initial costs, energy savings, and simple payback to the customer.

The data for the briefs on heating systems, cooling systems, boilers, air compressors, insulation, and electrical usage shifting and controls were provided by Colorado State University (CSU) from the national Energy Analysis and Diagnostic Centers (EADC) data base. CSU is one of 22 EADCs funded by the U.S. Department of Energy to conduct energy audits in manufacturing and industrial facilities. A listing of all EADCs is found in Appendix A. Each EADC provides services in a unique geographic region. CSU audits and makes recommendations for small manufacturing facilities in Colorado, Wyoming, and Nebraska that meet the following criteria: (1) 500 employees or fewer; (2) gross sales not to exceed $75 million per year; (3) energy bills not to exceed $1.75 million per year; and (4) no in-house energy engineer. Two other EADCs in Western's service territory are located at the University of Kansas and Texas A&M University. The costs in the EADC data base are in 1992 dollars. The data base contains reports from 2423 sites that were audited by an EADC and that implemented some of the recommended measures. The reports were submitted by the companies following implementation of the measures. The retrofit costs represent an average of actual installed costs. The energy cost savings represent an average of actual cost savings based on local utility rates. For measures that save electricity, the savings are expressed in kWh. For measures saving gas, the savings are presented in MMBtu. The EADC data is footnoted regarding frequency of implementation. The frequency refers to the number of times the measure was implemented divided by the number of times the measure was recommended. No monitoring of energy cost savings has been done under the EADC programs. The energy savings reported are often based on the estimated energy savings that the EADC provided to the client following the audit but may also be based on actual utility bills.

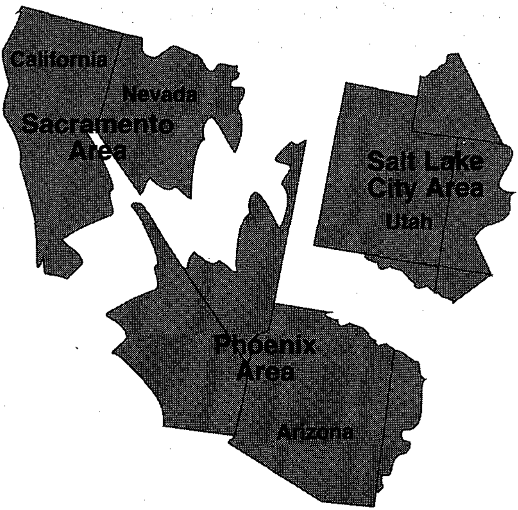
For measures on solar energy and process waste heat, cost and energy savings were taken from existing literature, including documentation of completed utility DSM programs, field studies and experiments, manufacturers' data, laboratory experiments, and computer simulation and analysis. The sources used varied, depending primarily on the availability of data and the complexity of the technology. The dollar savings were calculated based on a nationwide average rate of $0.05/kWh for the industrial sector.

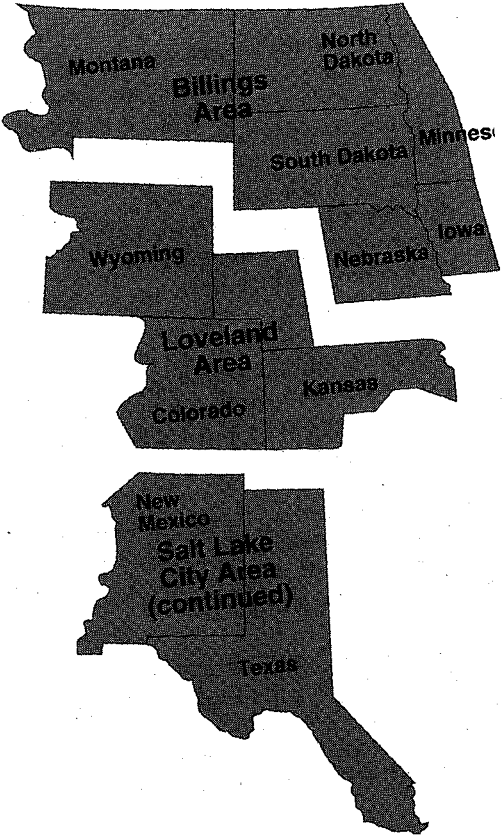
Unlike the first three volumes, the industrial volume includes electric and nonelectric measures. The nonelectric measures are included in the guidebook in the interest of making the guidebook more complete. Most manufacturing plants have at least one boiler, and there are many opportunities to reduce energy consumption of boilers. A goal in preparing this guidebook is to help utility customers save energy; therefore, these measures have been included.

The purpose of Section 2 is to provide concise information on the leading DSM options in each (two digit) standard industrial classification and direct the reader to reports and trade associations that can provide more information on DSM technologies in specific industries. The section includes a screening matrix that indicates which technologies have widespread application in each industry.

Because of the condensed nature of this guidebook and our desire to keep it simple, we have provided only limited references for the source materials and computations. The guidebook is not intended to substitute for a detailed analysis, but rather to point the reader toward those technologies most likely to benefit both the end user and the utility. For more details, the reader should consult the references (in sections titled For More Information) at the end of each brief.

P-1. Western Area Power area map




Montana
Billings Area
North Dakota
South Dakota
Minnes
Iowa
Nebraska
Wyoming
Loveland Area
Colorado
Kansas
New Mexico
Salt Lake City Area (continued)
Texas

■ DATA VARIABILITY AND UNCERTAINTY

A problem with guidebooks like this is that the data can, at best, present only a simple overview of each technology. Yet hundreds of volumes have been written describing the application of these technologies. Consequently, the cost and performance estimates presented here should be used with a clear understanding of the sources of variability and uncertainty.

Performance varies with climate and with the technology's design and configuration, the system within which it is applied, and the way it is used. Cost varies with the quality or brand of an individual component, the size of the retrofit, the existing conditions found at the site, the quantity ordered (e.g., cost per lamp for a major commercial lighting retrofit will be less than the retail purchase price of a single lamp), and/or the time of purchase (inflation and technological improvements change costs over time). When dealing with retrofits and the variation found in unique manufacturing facilities, very few, if any, rules of thumb about costing apply.

Similarly, there are significant sources of uncertainty in the performance data. As previously mentioned, the savings are based on estimated savings and have not, in all cases, been verified through performance monitoring.

The EADC data base represents the most comprehensive source of existing data on industrial retrofits. For the other measures, we have identified the best sources of data we could find and allowed for numerous peer reviews of the information.

We are more confident of some of the results than we are of others. Thus, for many technologies, we have included a rough measure (high, medium, low) of our confidence and the extent of the data variability and uncertainty. We expect that future revisions of this guidebook will provide the opportunity to reduce some of these uncertainties.

ORGANIZATION AND USE OF THE GUIDEBOOK

The guidebook series consists of five pocket-sized volumes. The first volume considers end-use technologies for the residential sector. The second volume includes technologies for the commercial sector, as well as motors and variable-speed drives applicable to the commercial, industrial, and agricultural sectors. The third volume discusses energy-efficient technologies for the agricultural sector, with an emphasis on the central and western United States. The fifth volume addresses renewable resources for utility supply-side power generation and buildings application.

A number of technologies presented in this guidebook series apply to more than one end-use sector. Where applicable, cross references are provided in the briefs.

Technologies that may be of interest to the industrial sector, but appearing in other volumes, are summarized in Table P-1. Note that motors and lighting were extensively addressed in the commercial volume and therefore are not addressed in this volume other than in the brief sections Motors—Update to Motors Briefs in *DSM Pocket Guidebook, Volume 2: Commercial Technologies* and Lighting—Update to Lighting Briefs in *DSM Pocket Guidebook, Volume 2: Commercial Technologies.*

Table P-1. Cross-Sector References
Technology End-Use Sector/Volume Number

	Residential 1	Commercial 2	Agriculture 3	Industrial 4	Renewable 5
Insulation	1,3	■		23-28	
Windows	4,5,6	1		■	
Weatherstripping	7	■		■	
Duct leaks	15	■		■	
Passive solar	8	2			15, 16
Heat pumps	9	9		32	17
Efficient air conditioners	13	8		1,2,3,4	
Energy management	■	10	■	36-38	
Hot water efficiency	17	16	7	-	
Solar hot water	19	■	■	33	14
Fluorescent lamps	21	11		*	
Cooking	25	18		■	
Swimming pools	26	■			
Motors		19-28	■	**	
Air compressors		■	15-22	■	

* In this volume, fluorescent lighting is addressed in the section called Lighting—Update to Lighting Briefs in Volume 2: Commercial Technologies.

** In this volume, motors are addressed in the section called Motors—Update to Motors Briefs in Volume 2: Commercial Technologies.

Each number refers to a written brief that describes the technology. A solid box (■) indicates that the technology is of interest in the sector.

The introduction to the industrial sector volume contains two sets of matrices to allow a quick screening of the technologies. One matrix addresses payback values, and the other identifies the most likely impact of each technology on the utility load duration curve—based on the categories identified in Figure P-2. A utility planner who has identified the types of load changes desired and the appropriate end-use sectors can use the matrices to quickly identify candidate technologies.

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SECTION 1—DSM MEASURES INTRODUCTION

At the national level, industrial energy use accounts for 37% of U.S. energy use. At some utilities, the total industrial share exceeds 50%. Moreover, electricity's share of energy use in the manufacturing sector has grown from 9% in 1973 to 14% in 1988. There are numerous opportunities to reduce energy consumption without affecting manufacturing operations. By reducing energy consumption, and thereby reducing the cost of operations, U.S. manufacturing can become more competitive.

Industrial customers represent an attractive market for utility DSM programs because relatively few customers often account for a large portion of total industrial sales. Customized utility DSM programs can often pay off significantly even if only a few large customers can be enrolled.

There are challenges in working with the industrial sector. Industrial loads are more cyclical than any other type of load. It is the sector most affected by economic cycles because the changes in final demand for customer goods are magnified by the time they get to intermediate goods (the mainstay of industrial activities).

Also, industrial plants may relocate to other service areas because of interplant competition between U.S. regions, or international competition between domestic and foreign producers; industrial customers may decide to cogenerate heat and power rather than buy electricity from the electricity grid.

Finally, in response to worldwide structural changes, the U.S. economy is continuing its transition to a post-industrial society. The outlook for many U.S. commodities is uncertain in the face of rapid industrialization along the western Pacific Rim and in other regions.

Table I-1 identifies technologies that can be used to reduce or shift peak load, increase demand during off-peak periods (valley filling), provide strategic conservation or load growth, or allow for flexible load management. Table I-2 shows the simple payback for the energy-efficient options evaluated.

Table I-1.
Demand-Side Management Strategies: Industrial Measures

	PC	VF	LS	SC	SG	FLS
COOLING SYSTEMS						
1. Condenser Water Temperature Reset				●		
2. Chilled Water Supply Temperature Reset				●		
3. Hot-Gas Defrost				●		
4. Two-speed Motors on Cooling Tower Fan				●		
HEATING SYSTEMS						
5. Destratification Fans				●		
6. Comfort Radiant Heating Systems				●		
7. Process Radiant Heating Systems				●		
8. Quartz Radiant Heating Systems				●		
BOILERS						
9. Combustion Air Blowers Variable-Frequency Drives				●		
10. Air/Fuel Ratio Reset				●		
11. Turbulators				●		
12. High-Pressure Condensate Return Systems				●		
13. Steam Trap Repair				●		
14. Steam Leak Repair				●		
AIR COMPRESSORS						
15. Outside Air Usage	●			●		
16. Leakage Reduction	●			●		
17. Cooling Water Heat Recovery				●		
18. Waste Heat Recovery				●		
19. Pressure Reduction	●			●		

	PC	VF	LS	SC	SG	FLS
20. Screw Compressor Controls				●		
21. Compressor Replacement	●			●		
22. Low-Pressure Blowers	●			●		
INSULATION						
23. Steam Lines and Hot Water Pipes				●		
24. Chilled Water Pipes				●		
25. Hot Tonks				●		
26. Cold Tanks				●		
27. Injection Mold Barrels				●		
28. Dock Doors				●		
INDUSTRIAL PROCESS HEAT RECOVERY						
29. Industrial Process Heat Exchangers	●			●		
30. Waste Heat Recovery Boilers	●			●		
31. Cogeneration	●					
32. Industrial Process Heat Pumps		●	●			
SOLAR ENERGY						
33. Solar Industrial Process Heating	●			●		
34. Once-Through Solar Heated Ventilation and Process Air				●		
35. Solar Photocatalytic Water Detoxification				●		
ELECTRIC USE SHIFTING AND CONTROLS						
36. Demand Controls	●	●	●			
37. Interruptible and Curtailable Service	●					●
38. Power Factor	●					

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

Table I-2.
Payback[1] for Demand-Side Management Strategies: Industrial Measures

	No. of Years			
	2	2-5	6-10	10
COOLING SYSTEMS				
1. Condenser Water Temperature Reset	●			
2. Chilled Water Supply Temperature Reset	●			
3. Hot-Gas Defrost		●		
4. Two-speed Motors on Cooling Tower Fan	●			
HEATING SYSTEMS				
5. Destratification Fans	●			
6. Comfort Radiant Heating Systems	●			
7. Process Radiant Heating Systems	●			
8. Quartz Radiant Heating Systems		●		
BOILERS				
9. Combustion Air Blowers Variable-Frequency Drives		●		
10. Air Fuel Ratio Reset	●			
11. Turbulators	●			
12. High-Pressure Condensate Return Systems		●		
13. Steam Trap Repair	●			
14. Steam Leak Repair	●			
AIR COMPRESSORS				
15. Outside Air Usage	●			
16. Leakage Reduction	●			
17. Cooling Water Heat Recovery	●			
18. Waste Heat Recovery	●			
19. Pressure Reduction	●			
20. Screw Compressor Controls	●			
21. Compressor Replacement	●			
22. Low Pressure Blowers	●			

	No. of Years			
	2	2-5	6-10	10
INSULATION				
23. Steam Lines and Hot Water Pipes	●			
24. Chilled Water Pipes	●			
25. Hot Tanks	●			
26. Cold Tanks	●			
27. Injection Mold Barrels	●			
28. Dock Doors	●			
INDUSTRIAL PROCESS HEAT RECOVERY				
29. Industrial Process Heat Exchangers				
30. Waste Heat Recovery Boilers			●	
31. Cogeneration		●		
32. Industrial Process Heat Pumps	●—	—●		
SOLAR ENERGY				
33. Solar Industrial Process Heating		●—	—●	
34. Once Through Solar Heated Ventilation and Process Air		●		
35. Solar Photocatalytic Water Detoxification		●—	—●	
ELECTRIC USE SHIFTING AND CONTROLS				
36. Demand Controls	●			
37. Interruptible and Curtailable Service	●			
38. Power Factor		●		

- ● The payback falls in the category indicated.
- ●–● The payback falls in the range of time indicated.

1. The paybacks shown were determined based on conditions described in the text. Paybacks will vary based on climate, fuel costs, system characteristics, implementation cost by geographical area, and other factors. See the text of the technology brief for more information.

I. COOLING SYSTEMS

For process cooling it is always best—from the standpoint of energy conservation—to use the lowest form of energy first. That is, for a piece of equipment or a process that is air cooled, first use outside air (an economizer) if the outside air temperature is low enough. The next step, in appropriate climates, would be to use direct evaporative cooling. This is a process in which air passing through water droplets (a swamp cooler) is cooled, as energy from the air is released through evaporation of the water. Evaporative cooling is somewhat more energy intensive than the economizer but still provides some relatively inexpensive cooling. The increase in energy use is due to the need to pump water.

Indirect evaporative cooling is the next step up in energy use. Air in a heat exchanger is cooled by a second stream of air or water that has been evaporatively cooled, such as by a cooling tower and coil. Indirect evaporative cooling may be effective if the wet-bulb temperature is fairly low. Indirect evaporative cooling involves both a cooling tower and swamp cooler, so more energy will be used than for the economizer and evaporative cooling systems because of the pumps and fans associated with the cooling tower. However, indirect cooling systems are still less energy intensive than systems that use a chiller. The final step would be to bring a chiller on line.

Many plants have chillers that provide cooling for various plant processes. Chillers consist of a compressor, an evaporator, an expansion valve, and a condenser and are classified as reciprocating chillers, screw chillers, or centrifugal chillers, depending on the type of compressor used. Reciprocating chillers are usually used in smaller systems (up to 25 tons [88 kW]) but can be used in systems as large as 800 tons (2800 kW). Screw chillers are available for the 80 tons to 800 tons range (280 kW to 2800 kW) but are normally used in the 200 tons to 800 tons range (700 kW to 2800 kW). Centrifugal chillers are available in the 200 tons to 800 tons range and are also used for very large systems (greater than 800 tons [2800 kW]). The evaporator is a tube-and-shell heat exchanger used to transfer heat to evaporate the refrigerant. The expansion valve is usually some form of regulating valve (such as a pressure, temperature, or liquid-level regulator), according to the type of control used. The condenser is most often a tube-and-shell heat exchanger that transfers heat from the system to the atmosphere or to cooling water.

This section contains information pertaining to cooling systems, particularly chiller systems. Refer to Brief #4, "Outside Air Economizers," Brief #5, "Evaporative Cooling," Brief #6, "Cool Storage," and Brief #7, "Heat Recovery from Chillers" in *DSM Pocket Guidebook, Volume 2: Commercial Technologies* for information relating to cooling systems that may be found in industry. Topics discussed in this section include condenser water and chilled water temperature reset at the chiller, hot-gas defrost of chiller evaporator coils, and the use of two-speed motors on cooling tower fans.

CONDENSER WATER TEMPERATURE RESET

DESCRIPTION

The power consumption of any chiller increases as the condensing water temperature rises. This is because, as the condenser temperature increases, the pressure rise across the compressor increases and, consequently, the work done by the compressor increases. Condensing water temperature setpoints ore typically in the range between 65° and 85°F, but con be as low as 60°F. In many cases the setpoint temperature is in the middle of the range, at about 75°F. The efficiency of the condensing water system con be increased by decreasing the condensing water temperature. A rule of thumb is that there is a 1/2% improvement in chiller efficiency for each degree Fahrenheit decrease in the setpoint temperoture for the condenser water. The improvement tends to be higher near the upper range of setpoint temperatures and decreases as the setpoint temperature decreases. The amount of allowable decrease in the setpoint temperature must be detennined by a detailed engineering analysis that includes the following: the system capacity, minimum requirements for the plant process served by the condenser water system, and number of hours per year that the wet bulb temperature is below a given value.

DEFINITIONS AND TERMS

CONDENSER The unit on the chiller in which heat is transferred out of the refrigerant. Cooled condensing water flows over tubes containing a vaporized refrigerant in a tube-and-shell heat exchanger. As the refrigerant cools, it condenses into a liquid and releases heat to the condensing water.

CONDENSING WATER Water that has been cooled in a cooling tower that is used to condense vaporized refrigerant in the condenser.

■ APPLICABILITY

FACILITY TYPE Any facility that has a chiller.

CLIMATE All. It is advantageous to reduce the condensing water temperature in both humid and dry climates.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

ASHRAE Handbook, 1988 Equipment, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1988, ch. 17.

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Table I-3. Condenser Water Temperature Reset: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Condenser Water Supply Temp. Reset	255	68,800	3,440	0.1	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. Systems ranged in size from approximately 20 tons to approximately 500 tons. The frequency of implementation for this measure was 90%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Resetting the condenser water temperature at an electronics plant resulted in energy and cost savings of 58,218 kWh/year and $2,390/year. The implementation cost was $200.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

CHILLED WATER SUPPLY TEMPERATURE RESET

■ DESCRIPTION

The efficiency of chillers increases as the chilled water temperature increases. This is because, in order to obtain lower temperature chilled water, the refrigerant must be compressed at a higher rate, which in turn increases the compressor power requirements and decreases the efficiency of the chiller. There is approximately a 1% increase in efficiency for each degree Fohrenheit increase in the chilled water setpoint temperoture. The efficiency increase tends to be higher near the lower temperatures in the setpoint range and decreases as the setpoint temperature increases. The amount of allowable increase must be determined by a detailed engineering analysis that evaluates the load requirements from the chiller, the design chilled water temperature, and other aspects of the system. It is not uncommon to find chilled water setpoints that are lower than is required from industrial chillers.

■ DEFINITIONS AND TERMS

EVAPORATOR The unit on the chiller in which heat is transferred to the refrigerant. Warm water flows over tubes containing a liquid refrigerant in a tube-and-shell heat exchanger. Heat is extracted from the water as the refrigerant vaporizes and the temperature of the water is reduced to the desired chilled water temperature.

CHILLED WATER Water in the evaporator that is cooled when heat is removed to vaporize the refrigerant.

■ APPLICABILITY

FACILITY TYPE Any focility that has a chiller.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

ASHRAE Handbook, 1988 Equipment, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlonto, GA, 1988, ch. 17.

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contoct the EADC Center nearest to your area.

Table I-4. Chilled Water Supply Temperature Reset: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Chilled Water Supply Temp. Reset	510	13,000	650	0.8	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. Systems ranged in size from approximately 20 tons to approximately 500 tons. The frequency of implementation for this measure was 80%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Resetting the chilled water supply water temperature at an electronics plant resulted in energy and cost savings of 9,493 kWh/year and $140/year. The implementation cost was $240.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

HOT-GAS DEFROST

DESCRIPTION

Frost builds up on air cooler unit (freezer) evaporator coils when the unit operates at less than 32°F. Frost is the result of moisture in the air freezing to the coil as the air posses over the coil. The performance of the coil is adversely affected by frost. Frost acts as on insulator and reduces the heat transfer copobility of the coil, and it restricts airflow through the coil. Frost buildup is unavoidable and must be removed periodically from the coil.

One method of frost removal is to use the hot refrigerant discharge gas leaving the compressor. During the defrost cycle, hot gas is circulated through the coil to melt the frost. Hot-gas defrost systems may be used for all cooling unit capacities and may be included in new or retrofit construction. For retrofit applications, hot-gas defrost systems most often replace electric resistance defrost systems. Using waste heat off the hot-gas side for defrost may result in savings on the order of 10% to 20% of the total system usage.

DEFINITIONS AND TERMS

HOT GAS The refrigerant vapor discharged by the compressor. This vapor is superheated; the temperature of the vapor has been raised above that which normally occurs at a particular pressure.

APPLICABILITY

FACILITY TYPE Any facility that has on air cooler (freezer). The measure is especially applicable to the food industry.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

ASHRAE Handbook, 1988 Equipment, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1988, p. 8.3.

Table I-5. Hot-Gas Defrost: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Hot-Gas Defrost	3,000	22,300	1,100	2.7	20	L

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 20%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing a hot-gas defrost system in a dairy resulted in energy and cost savings of 20,500 kWh/year and $1,070/year. The implementation cost was $2,500.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. L stands for low.

TWO-SPEED MOTORS ON COOLING TOWER FANS

DESCRIPTION

Cooling tower performance is affected by the outdoor wet-bulb temperature. Higher wet-bulb temperatures correspond to higher air saturation temperatures. As air loses the ability to extract heat from water droplets flowing through a cooling tower (increasing wet-bulb temperature), a higher air flow rate is required to remove the desired amount of heat and reduce the condenser water to the design temperature. The cooling tower fan motor is often sized to perform under design conditions (i.e., full water flow rate at maximum air flow rate and design wet-bulb temperature). During periods of lower outdoor wet-bulb temperature, the design amount of cooling can be obtained with lower air flow rates. As the air flow rate decreases, the fan speed and the motor power requirements also decrease. It may then be beneficial to install a two-speed motor for the cooling tower fan to reduce the fan motor power consumption. Two-speed motors may be part of new or retrofit construction. Savings for the addition of a two-speed fan motor are estimated based on the number of hours per year that the wet-bulb temperatures occur at various temperature ranges between design wet-bulb and minimum wet-bulb temperatures and the power requirements for various air flow rates. It should also be noted that variable speed drives for fan motors achieve cooling tower energy savings in the same manner as two-speed motors.

DEFINITIONS AND TERMS

WET-BULB TEMPERATURE The temperature indicated by a thermometer for which the bulb is covered by a film of water. As the film of water evaporates, the bulb is cooled. High wet-bulb temperatures correspond to higher air saturation conditions. For example, dry air has the ability to absorb more moisture than humid air, resulting in a lower wet-bulb temperature.

■ APPLICABILITY

FACILITY TYPE Any facility that has a cooling tower.

CLIMATE All. It is advantageous to install two-speed motors on cooling towers in both humid and dry climates; however, the benefits are greater in climates that experience a low wet-bulb temperature.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Motor Master, Washington State Energy Office, Olympia, WA, 1992.

Table I-6. Two-Speed Motors on Cooling Tower Fans: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Two-Speed Motors on Cooling Tower Fans	4,170	47,900	2,400	1.7	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 20%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing two-speed motors on the cooling towers at a plastic film extrusion plant resulted in energy and cost savings of 58,335 kWh/year and $2,680/year. The implementation cost was $3,900.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility when compared to one-speed motors.
4. H stands for high.

II. HEATING SYSTEMS

Space and process heating systems are often the primary consumers of energy in industry. Many existing industrial heating systems are outdated and inefficient. There are numerous energy conservation opportunities associated with heating systems in manufacturing operations. In addition to boilers (which are discussed elsewhere in this guidebook), energy use can be reduced in several space and process heating systems. This section includes briefs describing the following measures: destratification fans; comfort radiant heating systems; process radiant heating systems; and quartz radiant heating systems. Other space heating measures that may be applicable to industry are included in the HVAC section of the *DSM Pocket Guidebook, Volume 2: Commercial Technologies.* A summary of additional process heating systems is included in Table I-48 of this guidebook.

DESTRATIFICATION FANS

■ DESCRIPTION

Stratification usually occurs in spaces where there is insufficient air movement. If stratification is present, the heating requirements of the facility are increased because the temperature at the ceiling level is higher than the thermostat setpoint temperature, while the temperature at the working level is near the setpoint temperature. If the air is destratified, the temperature at the ceiling level would be nearly equal to the temperature at the floor level. This destratification process also reduces the heat loss due to ventilation and infiltration, again because the average temperature in the plant would be reduced to near the setpoint temperature. The destratification is achieved by mixing the warm air near the ceiling with the cool air near the floor. It is recommended that destratification fan systems be sized for flow rates of 5-10 cfm/ft^2 of floor area to ensure effective air mixing.

■ DEFINITIONS AND TERMS

STRATIFICATION The physical occurrence of an increasing air temperature gradient between the floor and the ceiling in an enclosed space. If air is undisturbed, hot air will rise, resulting in warmer air temperatures near the ceiling of a space and cooler air temperatures near the floor.

■ APPLICABILITY

FACILITY TYPE Any facility in which there is a heating requirement and in which there is, on average, a temperature gradient of at least 0.5°F/ft and a ceiling height of at least 20 ft.

CLIMATE All climates in which heating is used for several months per year.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Table I-7. Destratification Fans: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Destratification Fans	6,080	925.9	3,900	1.56	20	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 40%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing destratification fans in a warehouse to reduce the temperature difference between floor and ceiling during the heating season resulted in energy and cost savings of 144 MMBtu/yr and $670/year. The implementation cost was $1,600.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

COMFORT RADIANT HEATING SYSTEMS

■ DESCRIPTION

Comfort radiant heating systems warm people and other objects without warming the air. They operate similar to the sun's rays in that the infrared radiation emitted by the radiant heater is absorbed by the people that it strikes, thereby providing warmth. The same degree of comfort can be maintained at lower indoor temperatures with radiant heating systems as with conventional convection heating systems. Radiant heating systems are especially attractive for industrial space heating applications such as the heating of spaces with high ceilings where stratification is a problem or spot heating, such as near dock doors. A typical application would be in a loading dock area, where dock doors may be opened frequently. If the space near the dock door is heated by a convection heating system, this heated air will be cooled when the dock doors are opened. If radiant heating is used, the workers will keep warm even though the space air may be cold.

Radiant heating systems are usually gas-fired or electric. The type of radiant heating system is determined by the characteristics of the building in which the system is to be installed. For example, electric radiant heating systems may be installed in an area of the building where gas is unavailable. A radiant heating system is often a relatively easy retrofit measure but may also be integrated into new construction.

■ DEFINITIONS AND TERMS

INFRARED RADIATION Radiation at wavelengths longer than visible light.

CONVECTION HEATING Heating systems that deliver heated air to a space to maintain a desired space setpoint temperature.

STRATIFICATION The physical occurrence of an increasing air temperature gradient between the floor and the ceiling in an enclosed space. If air is undisturbed, hot air will rise, resulting in warmer air temperatures near the ceiling of a space and cooler air temperatures near the floor.

APPLICABILITY

FACILITY TYPE Any facility where space or spot heating is required. Particularly applicable to warehouse aisles, production lines, and dock areas.

CLIMATE All climates where heating is required.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

ASHRAE Handbook, 1987 HVAC Systems and Applications, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1988, ch. 16.

Table I-8. Comfort Radiant Heating Systems: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Comfort Radiant Htg. Systems	24,700	1,870	8,560	2.9	20	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. Systems ranged in size from approximately 100,000 to 150,000 Btu/hr. The frequency of implementation for this measure was 46%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing comfort radiant heating systems in an industrial plant resulted in energy and cost savings of 2,726 MMBtu/yr and $11,670/year. The implementation cost was $40,000.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

PROCESS RADIANT HEATING SYSTEMS

■ DESCRIPTION

Radiant heaters may be used for many process heating applications instead of conventional convection heating systems. With radiant heating, the object is heated directly, instead of indirectly, through heating of the air surrounding the object. Radiant heaters operate similar to the sun's rays in that the infrared radiation emitted by the radiant heater is absorbed by the solid object that it strikes, thereby warming the object. The short response time of radiant heaters when compared to convective heaters can also be advantageous to industry. Gas or electric radiant heaters may be designed and tailored for specific heating applications. Applications include cooking, broiling, drying, and deep fat frying of food; drying, melting, and curing of metals; drying inks and varnishes; curing cores and molds in foundries; web drying, preshrinking, and finishing of textiles; curing and drying of rubber and plastics; etc.

■ DEFINITIONS AND TERMS

CONVECTION HEATING Heating systems that deliver heated air to a space to maintain a desired space setpoint temperature.

INFRARED RADIATION Radiation at wavelengths longer than visible light.

RESPONSE TIME The time needed to reach a desired value.

■ APPLICABILITY

FACILITY TYPE Process radiant heating systems can be beneficial to almost all industry. An engineering analysis that evaluates the process is required to determine when radiant heating is applicable.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide, SIC 35, Non-Electrical Machinery Products Industry*, Washington, DC, 1987.

Table I-9. Process Radiant Heating Systems: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Demand Savings (kW)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Process Radiant Heating Systems	2,300	233.8	36	4,300	0.53	5	L

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. A majority of the systems recommended by EADC are gas-fired systems. The frequency of implementation for this measure was 46%.
2. Average implementation cost per system for this measure.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. L stands for low.

INDUSTRIAL BRIEF # 8

QUARTZ RADIANT HEATING SYSTEMS

■ DESCRIPTION

All materials have physical properties that lead to peak absorptivity of radiation at given wavelengths. There will be wavelengths at which a material absorbs quite well, and other wavelengths where the material is nearly transparent to the applied radiation. It can then be cost-effective to direct that radiation having the appropriate wavelength to heat an object. Quartz radiant heaters are used to control the wavelength directed at a material. Two important properties which characterizes quartz are: (1) quartz is essentially transparent to infrared radiation over most usable wavelengths and (2) quartz is a very poor conductor of heat. These characteristics allow the quartz envelope to act like an insulated window in that it does not absorb the infrared energy passing through it, and, consequently, there are very low convection losses. Quartz radiant heaters may be used in place of convective heaters, have a faster response time than convective heaters, and may be part of new or retrofit construction. The measure is very application specific and, as a result, has not been used extensively by industry.

■ DEFINITIONS AND TERMS

CONVECTION HEATING Heating systems that deliver heated air to a space to maintain a desired space setpoint temperature.

RESPONSE TIME The time needed to reach a desired value.

■ APPLICABILITY

FACILITY TYPE Facilities that have process heating systems. An engineering analysis that evaluates the process is required to determine when quartz radiant heating is applicable. Quartz radiant heating has been particularly applicable in the plastics industry.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide, SIC 30, Rubber and Plastics Products Industry*, Washington, DC, 1985.

Table I-10. Quartz Radiant Heating Systems: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Quartz Radiant Heating Systems	266,000	13,800	133,000	2	10	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) and the ACEC data base. The frequency of implementation for this measure was 10%.
2. Average implementation cost per system for this measure.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

III. BOILERS

There are four principal boiler categories: (1) natural draft, (2) forced draft, (3) hot water or steam, and (4) fire tube or water tube. In a natural draft boiler, the combustion air is drawn in by natural convection and there is no control of the air/fuel ratio. For forced draft boilers, the quantity of combustion air and the air/fuel mixture are controlled by a blower. Some boilers produce hot water, typically in the 160° to 190°F range, while others produce steam. Steam boilers may be low pressure (approximately 15 psi), medium pressure (15 to 150 psi), or high pressure (150 to 500 psi). Finally, boilers may be fire-tube or water-tube boilers. In a fire-tube boiler, the hot gases flow through tubes immersed in water, whereas in a water-tube boiler, the water flows through tubes heated by the hot combustion gases. There are also some very high temperature and super-heat boilers but these are seldom encountered in typical manufacturing operations. The typical boiler used in small to medium sized industrial operations is a forced draft steam boiler at 120 - 150 psi and approximately 150 hp. The following measures are also applicable to utility boilers. Other than the major differences of not being natural draft boilers and producing steam at greater than 150 psi, utility boilers are similar to boilers commonly used by industry.

This section includes demand-side management strategies for boiler systems. Combustion air blower variable frequency drives, air/fuel ratio reset, turbulators, high-pressure condensate return systems, steam trap repair, and steam leak repair are discussed in this section. Boiler efficiency tips are included in Appendix B of this volume.

INDUSTRIAL BRIEF # 9

COMBUSTION AIR BLOWER VARIABLE-FREQUENCY DRIVES

DESCRIPTION

The load on a boiler typically varies with time, and, consequently, the boiler varies between low and high fire. The amount of combustion air required changes accordingly. Common practice has been to control a damper or vary the positions of the inlet vanes in order to control the air flow; that is, when little air is required the damper is essentially closed and is opened as more air is required. This is an inefficient method of air flow control because air is drawn against a partially closed damper whenever the maximum amount of combustion air is not required. It is much more efficient to vary the speed of the blower by installing a variable-frequency drive on the blower motor. (Note that it is sometimes expensive to install a variable-frequency drive if inlet vanes exist.) Because the power required to move the air is approximately proportional to the cube of the air flow rate, decreasing the flow rate by a factor of two will result in a reduction of power by a factor of eight. This measure is particularly significant on boilers of 3.3 MMBtu/h or greater.

Combustion air blower variable-frequency drives are available from boiler manufacturers for new boiler installation. They also may be retrofitted to an existing boiler with few changes to the boiler.

DEFINITIONS AND TERMS

FIRING RATE As the load on a boiler varies, the amount of fuel supplied to the boiler varies in order to match the load.

APPLICABILITY

FACILITY TYPE Applicable to any facility that has a large, forced-draft boiler.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Witte, L.C., P.S. Schmidt, D.R. Brown, *Industrial Energy Management and Utilization*, Hemisphere Publishing Corp., Washington, D.C., 1988, pp. 530-532.

Table I-11. Combustion Air Blower Variable-Frequency Drives: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Combustion Air Blower Variable-Frequency Drives	47,000	236,400	11,800	4.0	20	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 34%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing variable speed drives and corresponding controls on two 250 hp combustion air fans at a food processing plant resulted in energy and cost savings of 483,445 kWh/yr and $23,000/yr. The implementation cost was $30,000.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

INDUSTRIAL BRIEF # 10

AIR/FUEL RATIO RESET

DESCRIPTION

For each fuel type, there is an optimum value for the air/fuel ratio. For natural gas boilers, this is 10% excess air, which corresponds to 2.2% oxygen in the flue gas. For coal-fired boilers, the values are 20% excess air and 4% oxygen. Because it is difficult to reach and maintain these values in most boilers, it is recommended that the boiler air/fuel ratio be adjusted to give a reading of 3% oxygen in the flue gas (about 15% excess air) for gas-fired boilers and 4.5% (25% excess air) for coal-fired boilers. Combustion analyzers are available that give readings of oxygen, carbon dioxide, temperature, combustibles, and efficiency, but these may cost as much as $5,000. Less expensive instruments that give only one or two readings are available for less than $1,000, and it is often recommended that these be purchased. For natural gas boilers, the efficiency as a function of excess/deficient air and stack temperature is shown in Figure I-1.

The curves for oil- and coal-fired boilers are similar. Because the efficiency decreases rapidly with deficient air, it is better to have a slight amount of excess air. Also shown is the effect of stack gas temperature on efficiency; the efficiency decreases as the stack gas temperature increases. As a rule of thumb, the stack temperature should be 50° to 100°F above the temperature of the heated fluid for maximum boiler efficiency and to prevent condensation from occurring in the stack gases. It is not uncommon that as loads on the boiler change and as the boiler ages, the air/fuel ratio will need readjusting. It is recommended that the air/fuel ratio be checked as often as monthly.

DEFINITIONS AND TERMS

STACK GASES The combustion gases that heat the water and are then exhausted out the stack (chimney).

AIR/FUEL RATIO The ratio of combustion air to fuel supplied to the burner.

■ APPLICABILITY

FACILITY TYPE Any facility that has a forced draft boiler.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Dyer, D.P., G. Maples, eds., *Boiler Efficiency Improvement*, Boiler Efficiency Institute, Auburn, AL, 1981, pp. 4-31.

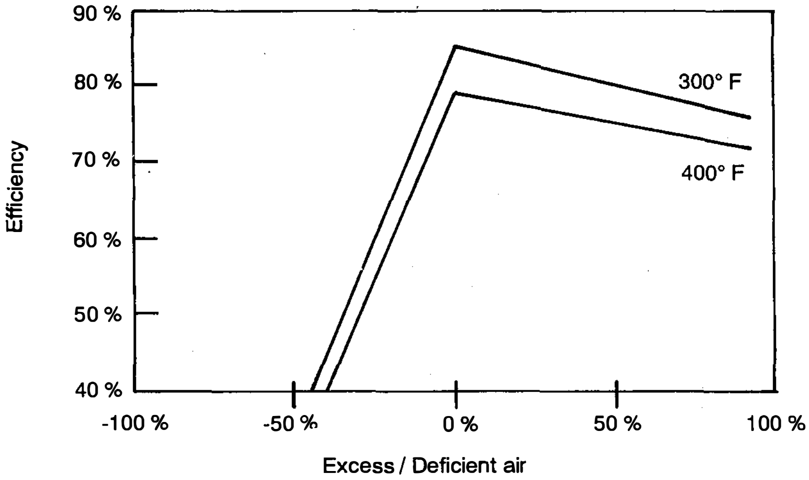

Figure I-1 Boiler efficiency as a Function of excess or deficient air and stack temperature

Source: ***Boiler Efficiency Improvement*, Dyer, Maple, Maxwell, Boiler Efficiency Institute, Auburn, AL, 1981**

Table I-12. Air/Fuel Ratio Reset: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Air/Fuel Ratio Reset	1,612	1,075.2	4,425	0.4	1	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 83%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Adjusting the air/fuel ratio on a 6.3 million Btu/h boiler at a concrete plant resulted in energy and cost savings of 1,314 MMBtu/yr and $4,760/yr. The implementation cost was $1,500, which was the cost for flue gas analysis equipment and labor.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

TURBULATORS

DESCRIPTION

The stack temperature of a boiler, as a rule of thumb, should be 50° to 100°F above the temperature of the heated fluid for maximum boiler efficiency and to avoid condensation accumulation in the stack. Temperatures higher than this can be an indication of fouling of the heat transfer surface inside the boiler by carbon buildup on the combustion side or scaling on the water side of the tubes. The higher temperatures can also be the result of combustion gases flowing too quickly through the tubes.

If the combustion gas temperature is too high, turbulators could be installed to slow the combustion gases flow rate. Turbulators are twisted strips of metal that are inserted into the tubes of fire-tube boilers to increase the heat transfer from the hot gases to the water. Studies have shown that a 10% to 30% reduction in stack temperature can be achieved by installing turbulators. This reduction gives an increase in operating efficiency of approximately 1% for each 40°F decrease in stack temperature.

DEFINITIONS AND TERMS

FIRE-TUBE BOILER A boiler in which the combustion gases pass through tubes surrounded by the water to be heated.

APPLICABILITY

FACILITY TYPE Any facility that has a fire-tube boiler.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Dyer, D.P., G. Maples, eds., *Boiler Efficiency Improvement*, Boiler Efficiency Institute, Auburn, AL, 1981, pp. 4-31.

American Consulting Engineers' Council, *Industrial Market and Energy Guide, SIC 20, Food and Kindred Products Industry*, Washington, DC, 1985, p. III-65.

Table I-13. Turbulators: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Turbulators	1,020	805.3	3,350	0.3	10	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 39%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing turbulators in the tubes of a 2.4 million Btu/h fire-tube boiler at a food manufacturing facility resulted in energy and cost savings of 465 million Btu/yr and $1,780/yr. The implementation cost was $1,200.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

HIGH-PRESSURE CONDENSATE RETURN SYSTEMS

DESCRIPTION

If pressurized condensate return is exposed to atmospheric pressure, flashing will occur. Flash tanks are often designed into a pressurized return system to allow flashing and to remove noncondensable gases from the steam. The resulting low-pressure steam in the flash tank can often be used as a heat source. A more efficient alternative is to return the pressurized condensate directly to the boiler through a high-pressure condensate return system. Heat losses due to flashing are significant, especially for high-pressure steam systems. Steam lost due to flashing must be replaced by water from the city mains (at approximately 55°F). This causes the feedwater mixture to the boiler to be significantly below its boiling point, resulting in higher fuel consumption by the boiler to increase the temperature of the feedwater to the boiling point. Water treatment costs are also greater with increased flash losses.

In a retrofit application, a closed, high-pressure condensate return system would prevent the flashing that occurs in the existing system by returning the condensate to the boiler at a higher pressure and temperature, thereby reducing boiler energy requirements and water treatment costs. Noncondensable gases (such as air and those formed from the decomposition of carbonates in the boiler feedwater treatment chemicals) can be removed from a closed condensate return system through the use of variable orifice discharge modules (VODMs). VODMs are similar to steam traps in that they return condensate but also can remove noncondensable gases. In a system that does not contain VODMs, these gases can remain in the steam coil of the equipment being heated and can form pockets of gas that have the effect of insulating the heat transfer surfaces, thus reducing heat transfer and decreasing boiler efficiency.

■ DEFINITIONS AND TERMS

CONDENSATE The hot water that is the steam after it has cooled and consequently condensed.

FLASHING Pressurized condensate will change phase into steam if the pressure is suddenly reduced.

■ APPLICABILITY

FACILITY TYPE All facilities that have a steam system with a high-pressure condensate return system.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

American Consulting Engineers' Council, *Industrial Market and Energy Guide, SIC 20, Food and Kindred Products Industry*, Washington, D.C., 1985, p. III-10.

Table I-14. High-Pressure Condensate Return Systems: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
High Pressure Condensate Return	31,341	2,850	12,791	2.4	20	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 78%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing of high-pressure condensate return system equipment at a food processing plant resulted in energy and cost savings of 4,727 MMBtu/yr and $14,100/yr. The implementation cost was $37,000.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

INDUSTRIAL BRIEF # 13

STEAM TRAP REPAIR

DESCRIPTION

A steam trap holds steam in the steam coil until the steam gives up its latent heat and condenses. In a flash tank system without a steam trap (or a malfunctioning trap), the steam in the process heating coil would have a shorter residence time and not completely condense. The uncondensed high-quality steam would be then lost out of the steam discharge pipe on the flash tank. Steam trap operation can be easily checked by comparing the temperature on each side of the trap. If the trap is working properly, there will be a large temperature difference between the two sides of the trap. A clear sign that a trap is not working is the presence of steam downstream of the trap. Nonworking steam traps allow steam to be wasted, resulting in a higher steam production requirement from the boiler to meet the system needs. It is not uncommon that, over time, steam traps wear and no longer function properly.

DEFINITIONS AND TERMS

CONDENSATE The hot water that is the steam after it has cooled and consequently condensed.

APPLICABILITY

FACILITY TYPE Any facility having a steam boiler.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Kennedy, W.J., W.C. Turner, *Energy Management*, Prentice-Hall, Englewood Cliffs, N.J., 1984.

Table I-15. Steam Trap Repair: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Steam Trap Repair	3,490	2,030	10,670	0.33	5	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 25%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Repairing one steam trap resulted in energy and cost savings of 105 MMBtu/yr and $483/yr on a 600 hp boiler at a rendering plant. The implementation cost was $220.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

INDUSTRIAL BRIEF # 14

STEAM LEAK REPAIR

DESCRIPTION

Significant savings can be realized by locating and repairing leaks in live steam lines and in condensate return lines. Leaks in the steam lines allow steam to be wasted, resulting in higher steam production requirements from the boiler to meet the system needs. Condensate return lines that are leaky return less condensate to the boiler, increasing the quantity of required make-up water. Because make-up water is cooler than condensate return water, more energy would be required to heat the boiler feedwater. Water treatment would also increase as the make-up water quantity increased. Leaks most often occur at the fittings in the steam and condensate pipe systems. Savings for this measure depend on the boiler efficiency, the annual hours during which the leaks occur, the boiler operating pressure, and the enthalpies of the steam and boiler feedwater.

DEFINITIONS AND TERMS

ENTHALPY A measure of the energy content of a substance.

APPLICABILITY

FACILITY TYPE Any facility having a steam boiler.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Table I-16. Steam Leak Repair: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Steam Leak Repair	512	13,000	6,568	0.1	5	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 96%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Repairing steam leaks on a 600 hp boiler system at a rendering plant resulted in energy and cost savings of 986 MMBtu/yr and $4,535/yr. The implementation cost was $350.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. M stands for medium.

IV. AIR COMPRESSORS

Air compressors in manufacturing facilities are often large consumers of electricity. There are two types of air compressors: reciprocating and screw compressors. Reciprocating compressors operate in a manner similar to that of an automobile engine. That is, a piston moves back and forth in a cylinder to compress the air. Screw compressors work by entraining the air between two rotating augers. The space between the augers becomes smaller as the air moves toward the outlet, thereby compressing the air. Screw compressors have fewer moving parts than reciprocating compressors have and are less prone to maintenance problems. However, especially for older types of screw compressors, screw compressors tend to use more energy than reciprocating compressors do, particularly if they are oversized for the load. This is because many screw compressors continue to rotate, whereas reciprocating compressors require no power during the unloaded state.

This section includes demand-side management measures for increasing outside air usage, reducing air leakage around valves and fittings in compressor air lines, recovering air compressor cooling water, recovering air compressor waste heat, pressure reduction, adding screw compressor controls, compressor replacement, and adding low-pressure blowers.

OUTSIDE AIR USAGE

DESCRIPTION

The amount of work done by an air compressor is proportional to the temperature of the intake air. Less energy is needed to compress cool air than to compress warm air. On average, outside air is cooler than air inside a compressor room. This is often the case even on very hot days. Piping can often be installed so that cooler outside air can be supplied to the intake on the compressor. This is particularly simple and cost-effective if the compressor is located adjacent to an exterior wall.

The energy and cost savings are dependent on the size of the compressor, the load factor, and the number of hours during which the compressor is used. The payback period is nearly always less than two years. The load factor is fairly constant for compressors that operate only when they are actually compressing air. Most reciprocating compressors are operated in this manner. When they are on, they operate with fairly constant power consumption, usually nearly equal to their rated power consumption; when they are cycled off, the power consumption is zero. Screw compressors are often operated in a different manner. When loaded (i.e., actually compressing air), they operate near their rated power, but when compressed air requirements are met, they are not cycled off but continue to rotate and are "unloaded." Older screw compressors may consume as much as 85% of their rated power during this unloaded state. Therefore, if a screw compressor is to be operated continuously, it should be matched closely to the compressed air load that it supplies. Often, plant personnel purchase compressors having several times the required power rating. This may be done for a variety of reasons, but often in anticipation of expansion of the facility and a commensurate increase in the compressed air requirements.

DEFINITIONS AND TERMS

RATED LOAD The power usage indicated by the air compressor manufacturer—usually shown on the nameplate.

LOAD FACTOR The average fraction of the rated load at which the compressor operates.

■ APPLICABILITY

FACILITY TYPE Any facility that uses compressed air in its operations. The savings increase as the size of the compressor and the hours of use increase for both types of compressors.

CLIMATE Any climate in which the average outdoor air temperature is less than the air temperature in the compressor room.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation and peak clipping.

■ FOR MORE INFORMATION

Witte, L.C., P.S. Schmidt, D.R. Braun, *Industrial Energy Management and Utilization*, Hemisphere Publishing Corp., Washington, D.C., 1988, pp. 433, 437.

Baumeister, T., L.S. Marks, eds., *Standard Handbook for Mechanical Engineers*, 7th Edition, McGraw-Hill Book Co., New York, NY, 1967, pp. 14.42-14.61.

Table I-17. Outside Air Usage: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Outside Air Usage	540	21,000	1015	0.5	0.5	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 63%.
2. Typical implementation cost for this measure is $1.50/ft of piping. One example from the EADC data base to further clarify the costs is as follows: Supplying outside air to the intakes of three air compressors (100 hp, 75 hp, and 50 hp) resulted in energy and cost savings of 10,050 kWh and $490/yr. The implementation cost was $780.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

LEAKAGE REDUCTION

DESCRIPTION

Air leaks around valves and fittings in compressor air lines may represent a significant energy cost in manufacturing facilities. Sometimes up to 20% of the work done by the compressor is to make up for air leaks. The energy loss as a function of hole diameter at an operating pressure of 100 psi is shown in Table I-18.

Table I-18. Air Leaks
Fuels and Air Losses Due to Compressed Air Leaks*

Hole Diameter, (in.)	Free Air Wasted (ft³/yr), by a Leak of Air at 100 psi	Energy Wasted Per Leak (kWh/h)
3/8	90,400,000	29.9
1/4	40,300,000	14.2
1.8	10,020,000	3.4
1/16	2,580,000	0.9
1/32	625,000	0.2

*Source: National Bureau of Standards (NBS) Handbook 115 Rule of Thumb—5%-10% of total energy consumed by a compressor is lost due to air leaks.

DEFINITIONS AND TERMS

GAGE PRESSURE The system pressure supplied by the compressor.

ABSOLUTE PRESSURE The sum of the gage pressure and the atmospheric pressure. The gage and absolute pressures are used in calculating the amount of air lost due to air leaks.

APPLICABILITY

FACILITY TYPE Any facility that has an air compressor.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation and peak clipping.

■ FOR MORE INFORMATION

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide*, SIC 32, Stone, Clay and Glass Products Industry, Washington, D.C., 1987, p. III-30.

Turner, et. al., *Energy Management Handbook*, John Wiley and Sons, New York, NY, 1982, pp. 424-425.

Table I-19. Leakage Reduction: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Leakage Reduction	335	34,600	2,070	0.2	1	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 89%.
2. One example from the EADC data base to further clarify the costs is as follows: Repairing air leaks in a compressed air system having air compressors of 150 hp, 60 hp, and 25 hp—all operating at 110 psig—resulted in energy savings of 35,750 kWh and cost savings of $2,760/yr. The implementation cost was $500.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

INDUSTRIAL BRIEF # 17

COOLING WATER HEAT RECOVERY

DESCRIPTION

Air compressors, 100 hp and larger, are often cooled by water from a cooling tower. The temperature of the water after leaving the cooling coils of the compressor may be sufficiently high that heat can be extracted from the water and used in a process. For example, boiler feedwater could be preheated by the water used to cool the compressor. Preheating the make-up water displaces boiler fuel that would ordinarily be used to heat the make-up water.

DEFINITIONS AND TERMS

COOLING COILS Finned tubes on a water-cooled compressor through which water flows and across which air flows.

APPLICABILITY

FACILITY TYPE Any manufacturing facility that has a large, water-cooled air compressor.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

Table I-20. Cooling Water Heat Recovery: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Waste water heat recovery	8,560	5,570	23,840	0.4	20	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 48%.
2. One example from the EADC data base to further clarify the costs is as follows: Sending compressor cooling water to a boiler feedwater tank resulted in energy savings of 37.2 MMBtu/yr, water savings of 229,000 gallons/yr (866,765 liters/yr) and a cost savings of $600/yr. The implementation cost was $1,000. The 3.8 MMBtu/h boiler produced steam at 150 psig. Larger savings would result if larger equipment were in use.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

INDUSTRIAL BRIEF # 18

WASTE HEAT RECOVERY

DESCRIPTION

For both screw and reciprocating compressors, approximately 60% to 90% of the energy of compression is available as heat, and only the remaining 10% to 40% is contained in the compressed air. This waste heat may be used to offset space heating requirements in the facility or to supply heat to a process. The heat energy recovered from the compressor can be used for space heating during the heating season. The amount of heat energy that can be recovered is dependent on the size of the compressor and the use factor. For this measure to be economically viable, the warm air should not have to be sent very far; that is, the compressor should be located near the heat that is to be used.

DEFINITIONS AND TERMS

USE FACTOR The fraction of the yearly hours that the compressor is used.

APPLICABILITY

FACILITY TYPE Any facility that uses an air compressor and has a use for the waste heat.

CLIMATE Wherever space heating is required for a significant portion of the year.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Vorigos Research, Inc., *Compressed Air Systems, A Guidebook on Energy and Cost Savings,* Timonium, MD, 1984.

Table I-21. Waste Heat Recovery: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Waste Heat Recovery	1,420	280.3	1,290	1.1	20	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 63%.
2. One example from the EADC data base to further clarify the costs is as follows: The waste heat from a 150 hp screw compressor was used to heat a space in a lumber mill. The energy savings were 121 MMBtu/yr, the cost savings were $2,730/yr, and the implementation cost was $670—giving a simple payback of three months.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

PRESSURE REDUCTION

DESCRIPTION

Demand and energy savings can be realized by reducing the air pressure control setting on an air compressor. In many cases, the air is compressed to a higher pressure than the air-driven process equipment actually requires. By determining the minimum required pressure, one may find that the pressure control setting on the compressor can be lowered. This is done by a simple adjustment of the pressure setting and applies to both screw and reciprocating compressors. The resulting demand and energy savings depend on the power rating of the compressor, the load factor, the use factor, the horsepower reduction factor, the current and proposed discharge pressures, the inlet pressure, and the type of compressor. This measure should only be considered when the operating pressure is greater than or equal to 10 psi higher than what is required for the equipment (with exception to situations with extremely long delivery lines or high line pressure drops).

DEFINITIONS AND TERMS

POWER RATING The power indicated by the air compressor manufacturer—usually shown on the nameplate.

POWER REDUCTION FACTOR The ratio of the proposed power consumption to the current power consumption, based on operating pressure.

INLET PRESSURE The air pressure at the air intake to the compressor, usually local atmospheric pressure.

APPLICABILITY

FACILITY TYPE Any facility that has an air compressor.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

National Technical Information Service, *Compressed Air Systems, A Guidebook on Energy and Cost Savings*, #DOE/CS/40520-T2, March 1984.

Table I-22. Pressure Reduction: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Pressure Reductions	1,120	22,150	1,100	1.0	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 55%.
2. One example from the EADC data base to further clarify the costs is as follows: Reducing the air pressure control setting on a 75 hp air compressor from 115 psig to 100 psig resulted in energy savings of 22,500 kWh and cost savings of $1,180/yr. The implementation cost was $270, resulting in a simple payback of three months.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

SCREW COMPRESSOR CONTROLS

DESCRIPTION

Screw compressors may consume up to 80% of their rated power output when they are running at less than full capacity. This is because many screw compressors are controlled by closing a valve; the inlet throttling valve on a typical throttled-inlet, screw-type compressor is partially closed in response to a reduced air system demand. The pressure rise across the compression portion of the unit does not decrease to zero, and thus power is still required by the unit. Accordingly, an older unit will continue to operate at 80% to 90% and a new unit at 40% to 60% of its full load capacity horsepower. When several screw-type air compressors are being used, it is more efficient to shut off the units based on decreasing load than to allow the units to idle, being careful not to exceed the maximum recommended starts/hour for the compressor. Modular systems that conserve energy by operating several small compressors that are brought on line as needed instead of operating one large compressor continuously are often found in retrofit and new installations.

DEFINITIONS AND TERMS

None.

APPLICABILITY

FACILITY TYPE Any facility that has screw-type air compressors.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

Table I-23. Screw Compressor Controls: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Screw Compressor Controls	2,300	75,100	3,750	0.6	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 50%.
2. One example from the EADC data base to further clarify the costs is as follows: Installing controls on a 100 hp compressor resulted in energy savings of 128,600 kWh and a cost savings of $6,750/year, at an implementation cost of $1,500.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

COMPRESSOR REPLACEMENT

DESCRIPTION

It is often advantageous to install a smaller compressor to more closely match the compressed air requirements normally met by oversized or large compressors, for processes that have periods of low compressed air usage. A smaller compressor will reduce energy usage and associated costs because the smaller compressor will operate at a better efficiency than the larger compressor when air requirements are low. Generally pre-1975 stationary screw-type compressors, if oversized for the load, will run unloaded much of the time when the load is low. They are unloaded by closing the inlet valve and hence are referred to as modulating inlet type compressors. Based on manufacturers' data, these compressors can consume as much as 85% of the full load horsepower when running unloaded. Some pre- and post-1975 compressor manufacturers have developed systems that close the inlet valve but also release the oil reservoir pressure and reduce oil flow to the compressor. Other strategies have also been developed but are not usually found on older (pre-1975) screw-type compressors. The unloaded horsepower for screw compressors operating with these types of systems typically ranges from 80% to 90% of the full load horsepower for older compressors and from 40% to 60% for newer compressors, depending on the particular design and conditions. In any event, if the compressed air requirements are reduced during particular periods (such as on a third shift), but are not eliminated entirely, then installing a smaller compressor to provide the air requirements during these periods can be cost-effective.

DEFINITIONS AND TERMS

None

APPLICABILITY

FACILITY TYPE Any facility that has a screw compressor and in which there are time periods during which the compressed air requirements are low.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

Table I-24. Compressor Replacement: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Compressor Replacement	3,446	57,800	2,890	1.2	15	H

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1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 62%.
2. One example from the EADC data base to further clarify the costs is as follows: A manufacturer of computer peripheral equipment replaced a 200 hp air compressor with a 75 hp air compressor. The energy savings were $61,850 kWh and the cost savings were $2,725/year. The implementation costs were $4,000.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

LOW-PRESSURE BLOWERS

■ DESCRIPTION

Compressed air is sometimes used to provide agitation of liquids, to control vibration units for material handling (as air lances), and for other low-pressure pneumatic mechanisms. For such purposes, it is more efficient to use a blower to provide the required low-pressure air stream. Use of low-pressure air from the blower would reduce energy consumption by eliminating the practice of compressing air and then expanding it back to low pressure for use.

■ DEFINITIONS AND TERMS

PLATING TANKS Tanks containing chemicals used in plating operations, such as chrome plating.

■ APPLICABILITY

FACILITY TYPE Any facility having plating tanks.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation and peak clipping.

Table I-25. Low-Pressure Blowers: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Low-Pressure Blowers	2,500	11,800	650	3.9	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 60%.
2. One example from the EADC data base to further clarify the costs is as follows: A plating facility added a low pressure blower. The energy savings were $41,000 kWh/yr and the cost savings were $3,200/year. The implementation cost was $5,000.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

V. INSULATION

There are several opportunities in the industrial sector to realize energy savings by installing insulation in manufacturing facilities. Good insulation design and installation are very important in terms of performance and energy efficiency. It is important to determine the most appropriate type and thickness of insulation for specific applications. The most cost-effective approaches involve insulating pipes and tanks. These opportunities are described in this section.

STEAM LINES AND HOT WATER PIPES

DESCRIPTION

Steam lines and hot water pipes should be insulated to prevent heat loss from the hot fluids. Recommended thickness for pipe insulation may be determined from the reference given below and from Table I-27 in this brief. The energy and cost savings depend on the size of the pipe (diameter and length of run), the temperatures of the fluids and the surroundings, the annual hours during which the pipes are heated, the efficiency of the heat supply, the heat transfer coefficient, and the fraction of the year during which heat loss from the pipes does not contribute to space heating.

DEFINITIONS AND TERMS

HEAT TRANSFER COEFFICIENT A parameter used in determining heat loss.

APPLICABILITY

FACILITY TYPE All facilities with uninsulated steam and hot water systems.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Kennedy, W. Jr., W.C. Turner, *Energy Management*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1984, pp. 204-221.

1989 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA, 1989.

Table I-26. Steam Lines and Hot Water Pipes: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Steam Lines and Hot Water Pipes	1,620	426.4	1,610	1.0	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 80%.
2. One example from the EADC data base to further clarify the costs is as follows: Insulating 500 ft of condensate return pipes located throughout a plant having a 300 MMBtu/hr (300 hp) steam boiler resulted in energy savings of 370 MMBtu/yr and a cost savings of $960/year. The implementation cost was $1,920.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

Table I-27. Recommended Thickness of Pipe and Equipment Insulation*

		Process Temperature (°F)									
Nominal Pipe Size (in)		150	250	350	450	550	650	750	850	950	1050
1	Thickness	1	1 1/2	2	2 1/2	3 1/2	4	4	4 1/2	5	5 1/2
	Heat loss	11	21	30	41	49	61	79	96	114	135
	Surface temperature	73	76	78	80	79	81	84	86	88	89
1 1/2	Thickness	1	2	2 1/2	3	4	4	4	5 1/2	5 1/2	6
	Heatloss	14	22	33	45	54	73	94	103	128	152
	Surface temperature	73	74	77	79	79	82	86	84	88	90
2	Thickness	1 1/2	2	3	3 1/2	4	4	4	5 1/2	6	6
	Heat loss	13	25	24	47	61	81	105	114	137	168
	Surface temperature	71	75	75	77	79	83	87	85	87	91
3	Thickness	1 1/2	2 1/2	3 1/2	4	4	4 1/2	4 1/2	6	6 1/2	7
	Heat loss	16	28	39	54	75	94	122	133	154	184
	Surface temperature	72	74	75	77	81	83	87	86	87	90

4	Thickness Heat loss Surface temperature	1 1/2 19 72	3 29 73	4 42 74	4 63 78	4 88 82	5 102 86	5 1/2 126 85	6 152 87	7 174 88	7 1/2 206 90
6	Thickness Heat loss Surface temperature	2 21 71	3 38 74	4 54 75	4 81 79	4 1/2 104 82	5 130 84	5 1/2 159 87	6 1/2 181 88	7 1/2 208 89	8 246 91
8	Thickness Heat loss Surface temperature	2 26 71	3 1/2 42 73	4 65 76	4 97 80	5 116 81	5 155 86	5 1/2 189 89	7 204 88	8 234 89	8 1/2 277 92

*Abstracted from *1989 ASHRAE Handbook of Fundamentals*, American Society of Heating, Refrigerating and Air Conditioning Engineers. The table is for mineral fiber insulation (fiberglass and rock wool). In each row the thickness is expressed in inches, the heat loss in Btu/hr-°F, and the surface temperature in °F.

CHILLED WATER PIPES

■ DESCRIPTION

Lines containing chilled water should be insulated to prevent condensation and frost buildup on the lines and to prevent heat gain. Condensation will occur whenever moist air comes into contact with a surface that is at a temperature lower than the dewpoint of the vapor. In addition, heat gained by uninsulated chilled water lines can adversely affect the efficiency of a cooling system.

■ DEFINITIONS AND TERMS

CHILLED WATER Water that is cooled by a chiller. It is usually used for process cooling in industrial applications.

■ APPLICABILITY

FACILITY TYPE Any facility having uninsulated chilled water lines.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC Center nearest to your area.

Table I-28. Chilled Water Pipes: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Chilled Water Pipes	970	16,400	850	1.1	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 52%.
2. One example from the EADC data base to further clarify the costs is as follows: Insulating 250 ft of cold pipe in a brewery resulted in energy savings of 3,500 kWh/year and a cost savings of $234/yr. The implementation cost was $1,200.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

HOT TANKS

■ DESCRIPTION

Often, tanks containing hot fluids in manufacturing operations lock adequate insulation. The tanks may be insulated with blanket type flexible fiberglass insulation (1 in. thick, 1.5 lb density) or rigid insulation, depending on the type of tonk. The savings would increase as the boiler efficiency decreases. The savings would also increase as the temperature in the tonk increases.

■ DEFINITIONS AND TERMS

CONDENSATE The hot water that is the steam after it has cooled and consequently condensed.

■ APPLICABILITY

FACILITY TYPE All.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

Table I-29. Hot Tanks

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Hot Tanks	3,230	465.4	1,750	1.84	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 54%.
2. The cost of insulation is typically around $0.50/ft². One example from the EADC data base to further clarify the costs is as follows: Insulating the manufacturing tanks in a food plant resulted in energy savings of 135 MMBtu/yr and cost savings of $470/yr. The implementation cost was $1,090. The tanks had a top area of 50 ft² and side areas of 175 ft² and contained fluids at temperatures between 150°F and 230°F. The tanks were located in a room at 70°F.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

COLD TANKS

DESCRIPTION

Uninsulated tanks containing cold fluids are occasionally found in applications, such as chilled water tanks that are located in areas where there can be considerable heat gain through the tank surfaces. If the air surrounding the tank is at a higher temperature than that of the tank, heat will be transferred to the contents of the tank. By insulating these tanks, the heat transfer will be reduced and the load on the refrigeration system can be reduced, resulting in significant energy savings.

DEFINITIONS AND TERMS

COEFFICIENT OF PERFORMANCE (COP) The ratio between thermal energy out of and electrical energy into the system.

APPLICABILITY

FACILITY TYPE Any facility having uninsulated cold tanks and significant operating hours.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

1989 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA. 1989, Ch. 22.

Table I-30. Cold Tanks: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Cold Tanks	460	10,500	520	0.7	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 54%.
2. One example from the EADC data base to further clarify the costs is as follows: The energy savings on a refrigeration system having a coefficient of performance of 2 and an uninsulated chilled water tank of 47 ft² at a temperature of 52°F in a room at 85°F would be over 2636 kWh/yr if the tank were insulated with 1 in. of fiberglass.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. H stands for high.

INJECTION MOLD BARRELS

■ DESCRIPTION

The barrels on injection molding machines are heated to a very high temperature so that the plastic will flow into the mold. The heat loss from the barrels contributes to the air conditioning load in the plant as well as increasing the energy required to keep the barrels hot. Rock wool blanket insulation is made specifically for this purpose and is easily removed if maintenance on the barrels is required. This measure is not recommended when Acryla Nitral Budadine (ABS) or Poly Vinyl Chloride (PVC) plastics are being molded because the shear forces generate so much heat that cooling is required.

■ DEFINITIONS AND TERMS

BARRELS The portion of an injection molding machine through which the molten plastic is forced by the piston.

■ APPLICABILITY

FACILITY TYPE Any injection molding facility.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

Table I-31. Injection Mold Barrels: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Injection Mold Barrels	4,033	54,900	2,700	1.5	5	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 30%.
2. One example from the EADC data base to further clarify the costs is as follows: Insulating the barrels on nine molding machines ranging in size from 25 tons to 716 tons resulted in energy savings of 15,000 kWh and a cost savings of $1,700/year. The implementation cost was $3,100.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. M stands for medium.

INDUSTRIAL BRIEF # 28

DOCK DOORS

DESCRIPTION

Uninsulated dock doors can be a source of significant heat loss in manufacturing facilities. The doors can often be insulated by installing styrofoam or fiberglass in the door panels. The savings depend on the size of the doors, the efficiency of the heating system, the R-values of the insulated and uninsulated doors, and the number of degree heating hours per year.

DEFINITIONS AND TERMS

DEGREE HEATING HOURS A measure relating ambient temperature to heating energy required. If the outside temperature is 1 degree below the base temperature in the plant for 1 hour then that represents 1 degree heating hour.

R-VALUE Measure of resistance to heat transfer h - ft^{2} - °F / Btu

APPLICABILITY

FACILITY TYPE All facilities with overhead doors.

CLIMATE Any climate in which heating is required.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

1989 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

Energy Analysis and Diagnostic Center (EADC). Refer to Appendix A for a complete list of presently operating EADCs. Contact the EADC center nearest to your area.

Table 1-32. Dock Doors: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (MMBtu/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Dock Doors	1,300	199.1	667	2	10	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 54%.
2. One example from the EADC data base to further clarify the costs is as follows: Placing 1 in. of polystyrene on an uninsulated dock door of approximately 150 ft² resulted in an energy savings of 4 MMBtu/year in the Denver, CO area. This assumes that the door is open 20% of the time. The cost for materials is about $0.50/ft² and $0.75/ft² for the installation.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. M stands for medium.

VI. INDUSTRIAL PROCESS HEAT RECOVERY

Industrial process heat is the thermal energy needed for the treatment and preparation of manufactured goods. Process heating applications require more than half of the total energy consumed by industry, yet an estimated 25% to 50% of this process heating energy is discharged as exhaust gases or waste liquids ranging in temperature from 100°F to 2,000°F. The otherwise wasted energy can be reused by way of waste heat recovery systems—systems that transfer heat from a high-temperature waste heat source to a lower temperature process supply source.

Combustion-equipment exhausts are the most plentiful source of waste heat in industry. Other typical heat sources include warm waste water from industrial processes and equipment cooling, return and exhaust air from ventilation systems, and waste steam and other hot waste process vapors. Heat recovery from these and other sources is typically used to preheat combustion air for boilers, furnaces, ovens, or kilns; to preheat boiler feedwater; to preheat ventilation air; or to use directly in the industrial process.

Waste heat recovery equipment is commercially available for both installation into existing industrial process systems and for installation during new construction. Implementation of such systems has helped industry to improve the efficiency of its process heating systems, reduce purchased energy costs, and decrease the life-cycle costs of its process heating equipment. In many cases, the initial cost of heat recovery systems varies only slightly from the initial cost of nonrecovery systems, especially in larger projects.

Industrial process heat recovery systems which are discussed in this section include waste heat recovery heat exchangers, waste heat recovery boilers, industrial process heat pumps, and cogeneration.

INDUSTRIAL PROCESS HEAT EXCHANGERS

DESCRIPTION

Heat exchangers transfer heat from a high-temperature fluid to a low-temperature fluid. Industrial heat exchangers usually serve two functions: to cool a hot waste stream and to heat a cool process stream. Heat exchanger systems are generally simple—with few components and almost no moving parts. Equipment for these systems is commercially available, both as packaged units and for custom-designed applications. Confidence in the technology results from its familiarity to industry and to designers and installers. Most importantly, heat exchangers reduce the amount of energy consumed for industrial heating processes. Process heat energy reduction of 20% is not uncommon after the installation of industrial heat exchanger equipment.

Heat exchangers are categorized into two groups: regenerative and recuperative heat exchangers. Regenerative heat exchangers alternately store and transfer heat between hot and cold air streams. The most common type of regenerative heat exchanger is the rotary or heat wheel heat exchanger. Recuperators directly transfer heat between two fluid streams separated by a heat transfer surface. Common recuperative heat exchangers are known as either tubular recuperators (such as the shell-in-tube or the finned-tube heat exchangers) or plate recuperators (such as the air-to-air plate heat exchanger or the liquid-to-liquid plate-and-frame heat exchanger).

Heat-pipe heat exchangers and economizers are also found in industry.

DEFINITIONS AND TERMS

ROTARY OR HEAT WHEEL HEAT EXCHANGERS Heat exchangers that transfer heat by continuously rotating a matrix (usually a closely knitted metal mesh or a desiccant-impregnated [drying agent] material used to temporarily store heat) through adjacent hot and cold fluid streams. As the matrix rotates, heat is removed from the hot stream, stored in the matrix, and then transferred to the cold stream.

SHELL-AND-TUBE HEAT EXCHANGERS Heat exchangers constructed of concentric tubes through which heat is transferred between a fluid flowing in the shell and a second fluid of a different temperature flowing through the tubes.

FINNED-TUBE HEAT EXCHANGERS A bundle of tubes with fins welded or otherwise attached to the outside of the tubes. The fins increase the heat exchange surface area, which increases the effectiveness of the heat exchanger. Finned-tube heat exchangers that tolerate corrosive liquids and gases are available.

PLATE HEAT EXCHANGERS Stacks of thin plates separated by plate-like fins that form exhaust and supply air flow passages. These heat exchangers are light-weight, simple, reliable, and durable.

PLATE-AND-FRAME HEAT EXCHANGERS Heat exchangers that transfer heat between two liquid streams. The plates are designed so that when they are stacked and gasketed together, channels are created for the counterflow of a hot waste heat stream and a cool process supply stream. This type of heat exchanger is attractive because it is compact, relatively easy to clean, and capable of handling a wide variety of industrial fluids.

HEAT-PIPE HEAT EXCHANGERS A bundle of sealed tubes containing a refrigerant installed between a hot and a cold air stream. As warm air passes over the tubes, heat is transferred to the refrigerant, and the refrigerant is vaporized. The vaporized refrigerant condenses back to a liquid and releases heat as cool air passes over the opposite end of the bundle. Limitations to heat-pipe heat recovery systems are that there are relatively few commercial suppliers, and the systems are generally more expensive than other heat recovery systems.

ECONOMIZER Economizers, usually a finned-tube heat exchanger, are typically installed into boiler exhaust streams whose temperatures are less than 800°F. Economizers are capable of increasing boiler efficiency up to 10%.

EFFECTIVENESS A measure of heat exchanger performance that is the ratio of the amount of heat transferred to the theoretical maximum amount of heat that could be transferred.

■ APPLICABILITY

PROCESS TYPE Applicable to processes that simultaneously deliver waste heat and demand a heat source at a constant rate (i.e., preheat boiler, furnace, or kiln air). The waste heat source must also be near the process in need of the heat.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation, peak clipping.

■ FOR MORE INFORMATION

Thanos, P., F.W. Payne, eds., "Waste Heat Recovery Applications," *Integration of Efficient Design Technologies*, The Association of Energy Engineers, The Fairmont Press, Inc., Liburn, GA, 1988.

Goldstick, R., A. Thumann, *Principles of Waste Heat Recovery*, The Fairmont Press, Inc., Atlanta, GA, 1986.

Table I-33. Heat Exchanger Comparison

Type of Heat Exchanger	Efficiency Range[1] (%)	Equipment Size Range[2]	Temperature Range (F)	Possible Applications
Rotary Wheel	50 to 80	50 to 70,000 cfm	-70 to +1,500	heating or cooling ventilation air when large air changes are required (i.e., 30 air changes per hour), process heat recovery in low and moderate temperature ranges such as for preheating air to drying ovens or boilers
Shell and Tube	50 to 90	0.5 to 50 gpm (through tube)	up to 1,000	transfer heat from condensates (i.e., refrigeration and air conditioning systems and process steam systems), transfer heat from coolants (i.e., engines, air compressors, machinery lubricants)
Finned Tube	50 to 90	0.5 to 50 gpm (through tube)	no maximum	heating boiler feedwater, process liquid heating, hot water space heating systems
Plate	50 to 80	25 to 10,000	no maximum	recovering heat from exhaust gases such as from ovens, furnaces, and incinerators to preheat process or combustion air to these and other equipment
Plate and Frame	60 to 90	up to 16,000 gpm	-300 to +400	recovering heat from exhaust gases such as from ovens, furnaces, and incinerators to preheat process or combustion air to these and other equipment

Heat Pipe	45 to 65	100 and up	-40 to +95	process or space air heating and cooling; extracting heat from boiler, oven, furnace, and kiln exhaust to preheat air to these and other process equipment
Economizer	50 to 90	0.5 to 50 gpm (through tube)	up to 800	transfer heat from a boiler exhaust stream to the boiler feedwater only

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1. Efficiency depends on heat exchanger size, rate of fluid passage, and the heat exchanger condition.
2. Equipment size in terms of airflow (cfm) or liquid flow (gpm).

WASTE HEAT RECOVERY BOILERS

■ DESCRIPTION

Waste heat recovery boilers use waste heat from industrial gases to produce steam, replacing some or all of the purchased combustion fuels normally consumed to fire boilers. The most common heat source for waste heat recovery boilers is from gas turbine exhaust. Other waste heat sources include furnace, kiln, reactor, and incinerator exhaust streams. Waste gas streams between 500° and 2,000°F and with flow rates of less than 1000 cfm up to nearly a million cfm are used by commercially available waste heat recovery boilers to generate steam. These boilers are capable of producing steam from as low as 1,000 lb/hr up to hundreds of thousands lb/hr, depending on the temperature and flow rate of the waste gases entering the boiler and on the boiler efficiency.

Waste heat recovery boilers are either fire-tube or water-tube type boilers. Hot exhaust gases circulate through tubes surrounded by water in fire-tube boilers. Heat is transferred through the tubes to heat the water or produce steam. Water-tube boilers consist of water circulating through tubes surrounded by hot exhaust gases. The water in the tubes is heated or converted into steam as heat is transferred from the hot exhaust gases to the water. Fire-tube boilers are commercially available for steam production capacities below 60,000 lb/h, and water-tube boilers are available for steam production capacities of up to 200,000 lb/h.

Waste heat recovery boilers are a common method of waste heat recovery in industry. The technology is familiar to industry, system designers, and equipment suppliers. Waste heat recovery boilers are also used by utilities to reuse the heat from turbine exhausts. Boilers used by utilities are most often custom designed water-tube boilers with steam generating capacities of up to 10,000,000 lb/h.

Three types of waste heat recovery boilers are commercially available: unfired heat recovery steam generators (HRSGs); supplementally fired

HRSGs; and fully fired HRSGs. These boilers are fire tube or water tube depending on the process steam requirements and the available waste heat. Waste heat recovery boilers in general may be beneficial to an industry or a utility for both retrofit and new construction applications.

DEFINITIONS AND TERMS

HRSG Heat Recovery Steam Generator

UNFIRED HRSG Unfired HRSGs use only the heat available from an exhaust stream to produce steam. These boilers are capable of recovering approximately 75% of the heat from an exhaust stream and are capable of producing steam between 50 psig at 212°F and 1000 psig at 900°F. The disadvantage of this boiler type is that it cannot easily respond to the changing process steam demands.

SUPPLEMENTALLY FIRED HRSG Supplementally fired HRSGs use a hot waste exhaust stream that is mixed with enough additional air to fire a conventional fuel (usually natural gas, oil, or coal). The high temperature of the waste stream increases the temperature of the combustion air, which in turn increases the efficiency of the HRSG. Fuel consumption is normally 10% to 20% less than that required by a non-waste heat recovery boiler under the same conditions. Commercially available supplementally fired HRSGs are capable of producing steam between 600 psig and 1,500 psig. Gas turbines are the principal waste heat source for this type of boiler in present industrial applications.

FULLY FIRED HRSG Fully fired HRSGs use only a hot exhaust stream to accommodate fuel combustion requirements of the boiler. The exhaust stream, usually from a gas turbine exhaust, must contain sufficient oxygen to allow for proper combustion of the fuel. Fully fired HRSGs can be six to seven times more efficient than the unfired HRSG described above. There are few applications of fully fired HRSGs in industry because when compared to the unfired or supplementally fired HRSGs, the initial cost of fully fired HRSGs is very high and the payback period is long.

APPLICABILITY

PROCESS TYPE Waste heat recovery boilers are most applicable to processes which are capable of supplying a constant waste heat stream of over 500°F and which are able to reuse the heat near to the waste heat source. It is also important that the waste heat is available at the same time that there is a demand for the heat.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation, peak clipping.

FOR MORE INFORMATION

Goldstick, R., A. Thumann, *Principles of Waste Heat Recovery*, The Fairmont Press, Inc., Atlanta, GA, 1986.

Gonopothy, V., "HRSG Features and Applications," *Heating/Piping/Air Conditioning*, Vol. 61, no. 1, January 1989.

Table I-34. Waste Heat Recovery Boilers: Costs and Benefits

Options[1]	Equipment Costs ($)	Natural Gas Energy Savings (MMBtu/yr)	Cast Savings ($/yr)[2]	Simple Payback (yr)	Life (yr)	Confidence[3]
HRSG	525,000	11,400	30,552	17.1	20	L

1. The costs and savings for waste heat recovery boiler installation is unique to each application. The example given in this table is based on an average cost of $7/1,000 lb capacity of a supplementally fired, water-tube steam boiler which has an annual fuel consumption savings of 15% when compared to a conventional steam boiler with similar characteristics. The waste heat recovery boiler is assumed to have a capacity of 75,000 lb/h for 150 psig saturated steam, operating 7,200 h/yr.
2. Based on $2.68/1,000 ft^3/hr of natural gas. Electrical requirements assumed to be similar between Heat Recovery Steam Generator (HRSG) and gas/oil fired steam boilers.
3. L stands for low.

INDUSTRIAL BRIEF # 31

COGENERATION

DESCRIPTION

Cogeneration is the use of one energy source to provide both heat and power simultaneously. Cogeneration systems rely on the energy source—typically natural gas, oil, or coal—to produce process steam or hot water and to produce electricity. Industrial cogeneration systems are usually large scale, capable of providing 2 MW or more of power.

To date, most cogeneration systems have been built in energy-intensive industries: pulp and paper, chemical, petroleum, food, and primary metals industries. The paper industry is the leading cogenerated power user in the United States, generating about one third of the nation's installed capacity. Potential cogeneration growth in the chemical and petroleum industries is high because of the high process temperature requirements of both industries. Food processing industries whose thermal needs are not seasonal can benefit from cogeneration, such as the distilled beverage industry. The primary limit for cogeneration systems in the food and kindred products industry is the seasonal steam demand of many processes, which results in a low thermal demand. Primary metals industries, such as the aluminum industry, will continue to depend on high thermal energy processes in the future, keeping the options open for new cogeneration systems.

The prime mover of a cogeneration system is the system component that consumes fuel or thermal energy (steam) to produce electricity and deliver waste heat to (or receive waste heat from) the industrial process. Typical prime movers of industrial cogeneration systems include the reciprocating engine, the combustion or gas turbine engine, and the steam generator. Reciprocating engines for industrial cogeneration systems are capable of meeting part load demands while continuing to operate at high efficiencies. Industrial cogeneration systems producing hot water (180°F) or low-pressure steam (15 psig) tend to use reciprocating engines as the prime mover. Higher pressure steam (up to 125 psig) can be produced if heat recovery from the engine exhaust is used.

The combustion or gas turbine is probably the most common prime mover for industrial cogeneration systems because of its high thermodynamic efficiency, high exhaust temperature (900°F to 1100°F), large range of capacities commercially available (0.5 MW to 150+ MW), and its relatively low capital cost. Due to the combustion or gas turbine engine's poor part load performance, it is most applicable to processes characterized by steady steam loads.

Cogeneration systems using steam turbines are typically used for large installations where the steam demand is constant. Steam produced in a boiler passes through a turbine generator to produce electricity. The lower temperature thermal energy is then consumed by the industrial process.

Industrial cogeneration systems fueled by biomass and fuel cells are beginning to be implemented in new systems. Information on these two fuel sources can be found in brief #2 and brief #12, respectively, of the *DSM Pocket Guidebook, Volume 5: Renewables for Utility Supply and Demand-Side Management*.

Cogeneration systems are classified as topping or bottoming cycles. Topping cycle systems produce electricity first, and the excess thermal energy (usually steam or hot water) is used in the industrial process. Most industrial cogeneration systems are topping cycles. Bottoming cycle systems produce thermal energy (usually steam) for a process heating application, such as for high-temperature furnaces or kilns, and after the process needs have been met, electricity is produced using the excess thermal energy.

Factors most affecting cogeneration development in the near future are the flexibility to meet part load requirements of the process, the ability to remain below the emission limits as determined by the Clean Air Act, the difference in conventional energy prices, and federal and state tax incentives to help industry justify the high initial costs of cogeneration systems. Utility support of cogeneration most often occurs when the utility is faced with increasing electrical demands which could eventually exceed its power generating capabilities.

■ DEFINITIONS AND TERMS

CAPACITY The maximum electrical and process heat loads that the cogeneration system is designed to meet.

TOTAL EFFICIENCY The ratio of the system electrical output plus thermal heat utilized, to the energy input.

■ APPLICABILITY

PROCESS TYPE Most applicable to industrial processes that require a steady steam or hot water load or that produce high-temperature waste heat.

CLIMATE All.

LOCATION Cogeneration systems are beneficial to industries in areas of high electric utility rates and low fuel costs, and are beneficial to utilities which are seeking opportunities to defer capacity expansion.

DEMAND-SIDE MANAGEMENT STRATEGY Peak clipping.

■ FOR MORE INFORMATION

Dickenson, R.L., S.A. Vajtasa, N. Korens, *Future Cogeneration Technologies*, Electric Power Research Institute report CU-6795, Palo Alto, CA, May 1990.

California Energy Commission, Appendix A Volume II: Detailed Electric Generation Technology Evaluations, *Energy Technology Status Report*, P500-90-003A, Sacramento, CA, June 1991.

Table I-35. Cogeneration: Costs and Benefits

Options[1]	System Cost ($)[2]	O&M Cost ($/yr)[3]	Thermal Energy Savings (kWh/yr)[4]	Electrical Energy Savings ($/yr)[5]	Cost Savings ($/yr)	Simple Payback (yr)	Life	Confidence[6]
Cogeneration	3,000,000	1,142,500	388,800	25,497,500	2,285,800	2.62	20	M

1. Cogeneration system costs and savings are extremely site specific. The numbers in this table represent a 2.8 MW, gas turbine, topping cycle cogeneration system. All costs are based on 1991 dollars. Source: Engineering Economics, Inc., Golden, CO.
2. Installed cost.
3. Annual operating and maintenance cost including cost of fuel.
4. Actual savings for the system described in footnote 1, when compared to the cost of buying power and generating steam prior to installing the cogeneration system.
5. Cost savings include both thermal and electrical energy savings. Thermal savings are based on $2.60/MMBtuh and the electrical savings are based on $0.05/kWh.
6. M stands for medium.

INDUSTRIAL PROCESS HEAT PUMPS

DESCRIPTION

Industrial process heat pumps extract heat from one source and deliver it to a second source, much the same as residential and commercial heat pumps (refer to Brief #9, "Residential Technologies", *DSM Pocket Guidebook, Volume 1: Residential Technologies*, and Brief #9, "Commercial Technologies", *DSM Pocket Guidebook, Volume 2: Commercial Technologies*). Industrial process heat pumps differ in that they ore nonreversible; they are capable of transferring heat in only one direction.

Industrial heat pumps "lift" heat from a low-temperature source, increase the temperature, and then deliver the heotto a process stream. For example, an industrial heat pump may be designed to extract heat from a 100°F waste heat source and deliver heat at 300°F to a process stream. The primary energy requirements for a process are reduced with the implementation of a heat pump, leading to lower process operating costs. The need for additional boiler capacity is also consequently reduced, as are combustion-gas emissions within the plant.

Industrial heat pumps are categorized into three groups; closed, open, or semi-open cycle. Closed cycle systems use a separate working fluid to transfer heat between process streams. The working fluid, typically steam or a refrigerant such as Freon or ammonia, extracts and releases heat as it alternates between a vapor and a liquid in the heat pump cycle. In most closed cycle systems, a compressor increases the pressure and temperature of the vapor before it releases the heat as it is condensed back into a liquid. Closed cycle systems are also sometimes used for industrial cooling applications. Heat is removed from a process as a working fluid in the liquid state absorbs heat and vaporizes. Closed cycle systems are normally needed when the waste and process streams must be isolated from one another or when either stream contains contaminants that would foul a heat pump system. These systems are also applicable to situations where the waste heat source and the process stream are not near to one another in the plant.

Open cycle systems compress waste process vapors to increase the temperature and then reuse the higher temperature vapors directly in the process. Steam or other process vapors may be used if the vapors are relatively clean and will not foul the heat pump components. Open cycle systems may be used to recover gaseous solvents contained in industrial vapors or to increase the quality of waste steam for reuse elsewhere in the process.

Semi-open cycle systems vaporize a process fluid using waste heat. The vapor is then compressed to elevate its temperature before it is returned to the process. Semi-open cycle systems isolate the waste heat source from the process stream, similar to the closed cycle systems. These systems are commonly used for recovering heat from contaminated waste streams.

Industrial process heat pumps are also categorized as mechanical or chemical and as electric or heat (steam) driven. Mechanical heat pumps depend on a compressor to increase the temperature and pressure of a vapor in order to "lift" heat from a waste stream. Chemical heat pumps do not have a compressor but instead condense vaporized refrigerant in a concentrated salt solution (heat is released) and then pressurize the solution to a vapor (heat is absorbed). Chemical heat pumps are most often used for industrial cooling applications.

Industrial heat pumps are often integrated into existing manufacturing processes. Because each industrial heat pump application is site specific, a detailed analysis of the process is necessary for all retrofit and new construction applications in order to determine the most efficient means of transferring heat. The high cost of this analysis, as well as the cost of the system design, often causes potential users to shy away from the technology, especially if the cost of energy is relatively low at the time.

■ DEFINITIONS AND TERMS

COEFFICIENT OF PERFORMANCE (COP) A measure of heat pump performance. It is the ratio of the useful energy out of the system to the required energy into the system. Industrial heat pump COPs range from four (for some closed cycle heat pump systems) to 30 (for some open cycle heat pump systems). High COPs are desired.

LIFT The difference in temperature that a heat pump is capable of delivering. For example, an industrial heat pump that can extract heat from a 100°F waste heat source and furnish heat at 300°F to process or boiler make-up water would have a lift of 200°F. Heat pumps found in today's industry typically have lifts of up to 300°F for closed cycle systems and 60°F for semi-open and open cycle systems.

APPLICABILITY

PROCESS TYPE Industrial process heat pumps are best suited for processes with a continuous waste heat source and process heat need.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Load shifting, valley filling.

FOR MORE INFORMATION

Heat Pumps for Industry, Take Another Look, Chapter 3, DOE/CH10093-114, National Renewable Energy Laboratory, Golden, CO, September 1991.

Pucciano, F.J., "The Utility's Role in the Industrial Application of Applied Heat Pumps," *ASHRAE Transactions, 1987*, Vol. 93, part 1, The American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA, 1987.

Table I-36. Industrial Process Heat Pumps: Costs and Benefits[1]

System[2]	Installed Cost ($)	Energy Savings (MMBtu/h)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Confidence[4]
1	1,376	45.2	500	2.8	M
2	2,230	98.5	1,300	1.7	M
3	1,084	63.5	1,300	0.8	M
4	1,638	72.3	1,000	1.6	M

1. Information for this table is referenced from *Heat Pumps for Industry, Take Another Look*, Chapter 3, National Renewable Energy Laboratory, Golden, CO, September 1991.
2. The systems represented in this table depict individual case studies. System descriptions are as follows:
   System 1: Two open cycle heat pumps were added to an existing petroleum refinery. The heat pumps eliminated the need for one gas-fired heater. Electricity consumption increased slightly (2.4%) and the net fuel consumption (primarily natural gas) decreased by 44%.
   System 2: Two open cycle heat pumps were added to an existing rubber plant process. One heat pump produced steam to be used directly by the process. The other heat pump compressed process vapors in order to heat boiler feedwater. Electricity consumption increased by less than 5% and the net fuel consumption (primarily coal) decreased by 59%.
   System 3: One open cycle heat pump was added to an existing pulp and paper process. Boiler feedwater is heated by steam produced from waste heat in the heat pump cycle. Electricity consumption increased by less than 1% and the net fuel consumption (primarily natural gas) decreased by 14%.
   System 4: One open cycle heat pump was added to an existing wet-corn-milling process. The new heat pump was added to aid in the evaporation process. The net fuel consumption (primarily coal and natural gas) decreased by 33%.
3. Cost savings were estimated based on the installed costs and the simple payback.
4. M stands for medium.

VII. SOLAR ENERGY

Almost all industry requires some form of process heat for the treatment and preparation of its manufactured goods. More than half of the total energy consumed by industry is for process heating applications. Approximately 90% of these process heating needs are met through the consumption of fossil fuels. Using present-day technology, one-third to one-half of the U.S. industry's process heating requirements could potentially be met by solar energy.

Solar energy industrial applications range from process water and air preheating to the direct use of solar-generated steam and contaminant removal from industrial process wastewater or groundwater contaminated by industrial processes. Solar energy may be used as it is collected during the day or stored to use during nighttime or cloudy periods. Because solar industrial process heat systems can be designed to match the temperature needs of the process and because industrial process loads often occur during the day and are constant throughout the year, solar industrial process heating systems can be viable alternatives to fossil fuel systems.

Solar energy systems reviewed in this section include solar industrial process heating systems, solar preheated ventilation and process air systems, and solar photocatalytic water detoxification systems. Passive solar building design for industrial buildings is very similar to commercial building design (refer to Brief #2, "Passive Solar Design," in the *DSM Pocket Guidebook, Volume 2: Commercial Technologies*).

SOLAR INDUSTRIAL PROCESS HEATING

■ DESCRIPTION

Currently, almost any industrial plant in a reasonably sunny area and requiring heated air or water can benefit from using solar heating systems to reduce its peak energy demand, reduce the quantity of fossil fuels required for process heating, and/or reduce air emissions. Industries that consume the majority of process heat are the food, textile, chemical, pulp and paper, petroleum, stone/glass, and primary metals industries.

Solar industrial process heat systems available today include flat plate collectors for low-temperature applicotians (less than 200°F) and parabolic trough collectors, evacuated tube, and combined parabolic concentrators for low-to-intermediate-temperature applications (up to 600°F). Refer to Figures I-2, I-3, I-4, I-5, and I-6 for schematic diagrams of these four collector types.

Parabolic trough, evacuated tube, or combined parabolic concentrator collectors are capable of producing the temperatures necessary for steam generation. There are three types of solar steam generation systems: flash steam, unfired boiler, and direct steam generation. Flash steam systems heat pressurized water passing through the collector field and then flash the hot fluid to steam as it passes through a throttling valve. Unfired boiler systems circulate a heat transfer fluid through the collector system and then through heat exchangers in order to transfer heat to water and produce steam. Direct steam generation systems allow water to boil in the collectors and then distribute the steam directly to the industrial process. The direct steam generation systems are new and have not yet been installed in an industrial process.

Solar industrial process heat systems are usually supplemented by a fossil fuel system or a process heat storage system to ensure an uninterrupted supply of process heat. Solid materials such as rock, sand, brick, cast iron, or magnesium oxide are used to store heat from an air collector system. Large volumes are required for this type of heat storage. Liquid storage media for temperatures above 212°F are most often organic oils, molten salts, or liquid metals. Water has the highest storage capacity, lowest cost, and is the medium of choice for storage temperatures below 212°F. Pressurized water tanks are required for water storage of temperatures above 212°F.

The simplest solar industrial process heat system is that in which the solar collector system provides preheated air, water, or steam to the process, and no storage is involved. This system allows the solar collector system to operate at its lowest possible temperature, which results in the highest possible efficiency.

■ DEFINITIONS AND TERMS

FLAT PLATE SOLAR COLLECTOR Flat plate solar collector systems are capable of collecting both direct and diffuse solar radiation, lack moving parts, and are suitable for roof mounting (Figure I-2). These systems are designed to operate with air or liquid as the working fluid. Solar heated air may be supplied directly to the process, such as for drying, or may be used as preheated air for a higher temperature process. A new type of flat plate solar collector for once-through air heating is beginning to be used for industrial space heating. These high efficiency collectors are discussed in brief #34 of this guidebook. Collectors that use a liquid as a working fluid are well suited for heating low-temperature process water, but antifreeze or other freeze protection is required in most climates. These collectors must also include a heat exchanger if the working fluid is not used directly by the process.

PARABOLIC TROUGH SOLAR COLLECTOR Parabolic trough solar collectors have an absorber pipe mounted at the focal point of a parabolic reflector (Figure I-3). A working fluid, usually water, is heated as it circulates through the pipe. Because the parabolic trough is capable of collecting only direct solar radiation (radiation that does not change direction as it passes through the earth's atmosphere), tracking of the sun is required.

EVACUATED TUBE AND COMBINED PARABOLIC CONCENTRATOR SOLAR COLLECTORS The term "evacuated tube" refers to concentric tubes between which a vacuum exists. A working fluid circulates through the inner tube and an absorbent surface coats either the outer or an inner tube (Figure I-6). A series of these tubes is usually mounted above a reflective flat surface (evacuated tube collector, Figure I-4) or above parabolic reflectors (Compound Parabolic Concentrator [CPC], Figure I-5). These collectors are often nontracking ond are significantly more efficient during periods of diffuse solar radiation than the flat plate or parabolic trough solar collector systems.

COLLECTOR EFFICIENCY A measurement of a solor collector's ability to convert solar radiation into useful heat.

CONCENTRATION RATIO (CR) The ratio of the collector aperture area to the collector absorber area. Typical CRs for the following collector types are: flat plate collectors, 1; evacuated tube collectors, generally between 1 ond 2; compound parabolic trough collectors, os high as 10; and parabolic trough collectors, up to 60.

SINGLE AXIS TRACKING A system capable of tracking the sun about one axis.

NONTRACKING Solar collectors that are stationary and do not follow the path of the sun across the sky throughout the day.

■ APPLICABILITY

PROCESS TYPE Low- or medium-temperature industrial process heat systems (less than 600°F) requiring hot air, hot water, or low-pressure steam have the greatest potential for benefit from solar industrial process heat systems.

CLIMATE All. Solar industrial process heat systems are more efficient in regions of high solar radiation. Systems designed to collect diffuse solar radiation, such as evacuated tube or combined parabolic concentrator collectors, are efficient in generally cloudy or hazy regions.

DEMAND-SIDE MANAGEMENT STRATEGY Peak clipping, strategic conservation.

■ FOR MORE INFORMATION

Garg, H.P., *Advances in Solar Energy Technology, Volume 2, Industrial Applications of Solar Energy*, D. Reidel Publishing Co., Dordrecht, Holland, 1987.

Solar Engineering, Proceedings of the American Society of Mechanical Engineers (ASME) International Solar Energy Conferences, ASME, New York, NY, 1982 to present.

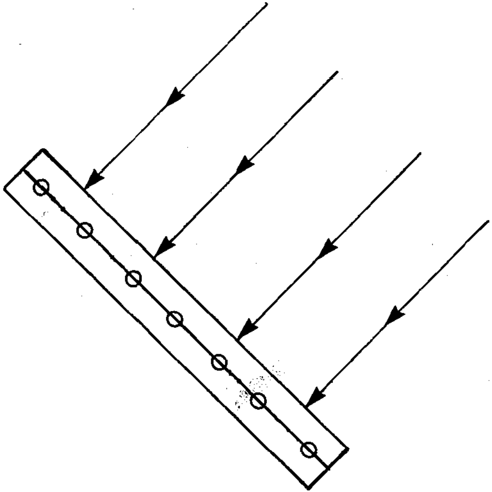

Figure I-2. Flat Plate Collector

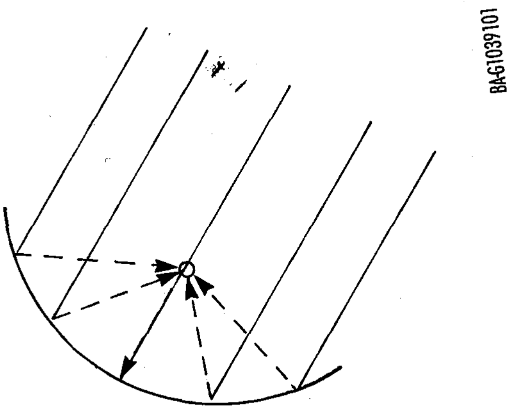

Figure I-3. Parabolic Trough Collector

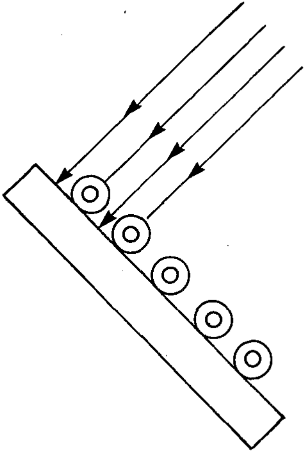

Figure I-4. Evacuated Tube Collector

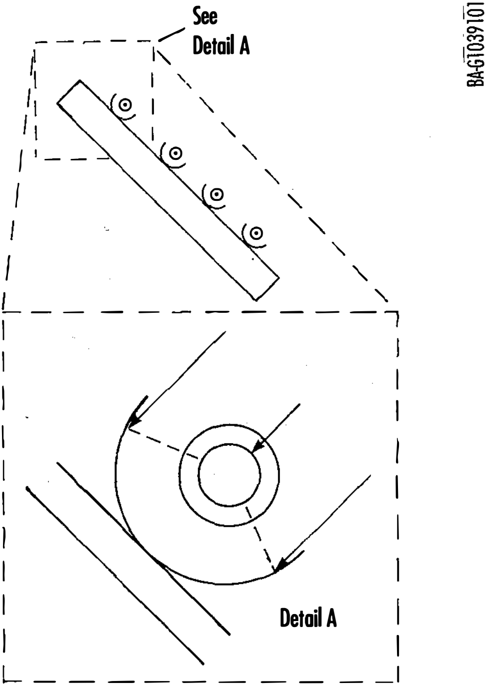

Figure I-5. Combined Parabolic Concentrator

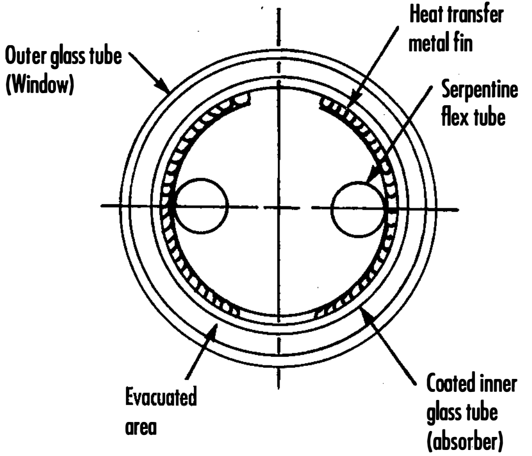

Figure I-6. Evacuated Tube

Source: *Engineering Principles and Concepts for Active Solar Systems,* **Solar Energy Research Institue, Hemisphere Publishing Corporation, 1978**

Table I-37. Solar Industrial Process Heating: Costs and Benefits

Options[1]	Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Flat Plate[5]	160,000	416,500	20,825	7.7	20-30	H
Flat Plate[6]	80,000	204,700	10,235	7.8	20-30	H
Parabolic Trough[7]	38,420	202,000	10,100	3.8	20-30	H
CPC[8]	92,000	144,700	7,235	12.7	20-30	H

1. All systems described here were supplied by U.S. manufacturers.
2. Solar system capital cost including installation for year that the system was installed (see system description notes 3-6).
3. Based on $0.05/kWh
4. H stands for high.
5. Process hot water heating system for poultry plant in Cairo, Egypt, installed in 1991: 4,000 sq.ft collector area, roof rock mounted and 7,000 gallons of water per day capacity,
6. Process hot water heating system for heating metal plating process water in Los Angeles, CA, installed in 1984: 1,920 sq.ft collector area, roof rock mounted.
7. Process hot water heating system for heating metal plating process water in Hayward, CA, installed in 1990: 2,260 sq.ft collector area, stretch membrane cover to parabolic troughs, and roof rock mounted.
8. Combined parabolic trough collectors for ice making system for use in fish storage and fish preservation in Maruata, Micoacon, Mexico, installed in 1992: 896 sq.ft collector area, ground and roof mounted.

ONCE-THROUGH SOLAR HEATED VENTILATION AND PROCESS AIR

■ DESCRIPTION

Once-through solar heated ventilation and process air systems are new to the market but have already demonstrated that they are low cost and can be very efficient. These systems heat outside air to be used directly as preheated ventilation air or as industrial and agricultural process drying air. Industrial buildings with high ventilation rates can especially benefit from once-through solar systems because a large part of the total building energy costs for space heating is often for heating outdoor air. Further energy savings may occur because there is virtually no heat loss through the wall on which the collector is installed.

When compared with other solar systems, as well as conventional air heating systems, once-through solar heating systems have many advantages. These systems are virtually maintenance free. Routine care of conventional air distribution system components (fan maintenance and repairing duct leaks) is practically all that is necessary. High collector efficiencies can be obtained from very simple, low cost, site built collectors. Retrofit of existing buildings is neither difficult nor expensive, and in some cases, part of the existing building's external surface can be incorporated into the collector design.

Drawbacks to once-through solar heated air systems are that large collectors are required to meet building or process loads, low cost naturol gas is typically used in manufacturing facilities, and at present there is only one company commercializing the technology.

There are two types of once-through solar heated air systems: unglazed transpired collectors and glazed wall collectors.

DEFINITIONS AND TERMS

UNGLAZED TRANSPIRED COLLECTORS Air is drawn through a dark colored, unglazed, perforated plate installed on a large, south-facing wall of a building. The air is heated as it passes through the perforations and is drawn into the building by fans. The air may then be distributed throughout the building by way of a conventional duct system and used as heated space ventilation air or used directly by an industrial process requiring heated air. These collectors do not require glazing because heat that may be lost to the wind for other collectors types is captured as the air is drawn through the perforations. The unglazed transpired collector is the most efficient collector on the market today. Efficiencies of 75% or more are obtainable with this collector type. The collectors are also low cost (installed costs are normally one-third less than installed costs for glazed collectors because of the lower material costs).

GLAZED WALL COLLECTOR Air is heated as it is drawn between a glazing spaced several inches from a dark wall. Outside air is drawn through a space located at the bottom of the wall and is heated as it is pulled up by fans located at the top of the wall. Expected efficiencies for this type of collector are approximately 45%. Maintenance costs for this collector type are higher than for the unglazed transpired collectors because of the glazing.

APPLICABILITY

BUILDING TYPE A large, unobstructed, south-facing wall is required on which to mount the solar collector system.

CLIMATE All. The solar collector systems described in this brief operate at lower but acceptable efficiencies in generally cloudy regions. Greater savings con be expected when these systems are used to preheat space ventilation air in sunny, colder climates.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

■ FOR MORE INFORMATION

Kutscher, C.F., C.B. Christensen, G.M. Barker, "Unglazed Transpired Solar Collectors: An Analytical Model and Test Results," (Arden, M.E. et al, editors), *Solar World Congress, 1991 Proceedings of the Biennial Congress of the International Solar Energy Society, Denver, CO, August 19-23, 1991*, vol.2, pp 1245-1250, Pergamon Press, 1991.

Carpenter, S.C., J.P. Kokko, "Performance of Solar Preheated Ventilation Air Systems," *Energy and the Environment... The Next Generation, Conference Proceedings for the 17th Annual Conference of the Solar Energy Society of Canada, Toronto, Ontario, June 21-26, 1991.*

Table I-38. Once-Through Solar Heated Air Collectors: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)[3]	Cost Savings ($/yr)[4]	Simple Payback (yr)[5]	Life (yr)[6]	Confidence[7]
Unglazed Transpired Wall Collector	72,000	1,472,000	35,000	2–10	20-35	L
Glazed Wall Collector	840,000	37,400,000	336,000	2–10	15-25	L

1. Characteristics of collector types: Unglazed transpired collector—4,680 ft², 44,000 cfm, ventilation air heating, new construction, Oshawa, Ontario, Canada; glazed wall collector—60,000 ft², 230,000 cfm, ventilation air heating, retrofit construction, Chicago, IL.
2. Installed costs include cost of collector, supply air fans, and associated ductwork and duct insulation per manufacturer's data.
3. Actual energy savings per manufacturer's data.
4. Actual cost savings per manufacturer's data.
5. Low payback approximations are based on manufacturer's estimates, which include savings from all solar and non-solar benefits of the wall. High payback approximations are based only on the solar energy collected with natural gas auxilliary. Paybacks vary depending on collector size, orientation, and location (which affects efficiency) of the system.
6. Anticipated life expectancy range.
7. L stands for low.

SOLAR PHOTOCATALYTIC WATER DETOXIFICATION

DESCRIPTION

Solar photocatalytic water detoxification is the removal of low-level hazardous organic compounds from contaminated water through the combined reaction of sunlight and a photocatalyst. Industrial process waste water or ground water contaminated by hazardous organic compounds in the parts per million range (such as benzene, toluene, trichloroethylene, and some heavy metals) can be effectively treated by a solar process. Sunlight and a photocatalyst react to degrade the hazardous organic compounds to carbon dioxide, water, and small amounts of mineral acids.

Main system components include a photoreactor, piping, pumps, and storage tanks. The same technology used to develop solar collectors is applied toward the design of photoreactors. A photoreactor differs from a solar collector in that it collects and uses the sun's energy simultaneously, whereas a solar collector collects the sun's energy to use elsewhere in the system (refer to brief #33 of this guidebook). The remaining system components are typical to conventional water detoxification systems and are familiar to industrial users and to system designers and installers.

The flow rate of contaminated water through the photoreactor is determined by the available sunlight and the type and amount of contamination. Periods of low light or darkness can be accounted for by using a large system volume and controlling (decreasing) the flow rates or by having storage capacity built into the system. Solar photocatalytic water detoxification systems may also be supplemented by a conventional detoxification system to accommodate large quantities of contamination or for nighttime operation.

When compared to conventional detoxification processes, solar photocatalytic water detoxification has several advantages. The contaminant can be completely destroyed—leaving only water, carbon dioxide, and dilute mineral acids—instead of being transferred from the water to another phase. Using solar energy also eliminates the need to consume fossil fuels, which reduces operating costs and the production of greenhouse gases.

At present, solar photocatalytic water detoxification systems have been installed only as experimental systems. However, it is expected that systems treating up to 100,000 gal/day of contaminated water will be commercially available as early as 1995.

DEFINITIONS AND TERMS

PHOTOCATALYST A substance that combines with radiant energy to accelerate a chemical reaction. The most effective photocatalyst for solar water detoxification is titanium dioxide (TiO^2).

PARTS PER MILLION (PPM) PPM concentration of contaminated water is the number of milligrams of contaminant per liter of water.

FLAT PLATE PHOTOREACTOR A closed photoreactor where contaminated water is spread over a flat surface covered with a transparent material such as a glass plate or Teflon film. The photocatalyst can be suspended in the water or attached to support material mounted in the reactor. Flat plate photoreactors are effective for use in typically cloudy regions.

TRANSPARENT PIPE PHOTOREACTOR Usually borosilicate (pyrex) pipes through which the contaminated water circulates. The transparent pipes may be mounted above a reflective surface, such as at the focal point of a reflective parabolic trough. The photocatalyst is either suspended in the water or fixed supports covered with the photocatalyst are mounted throughout the reactor. Parabolic trough photoreactors are not effective during periods of cloudy weather; however, other transparent pipe photoreactors are effective. Transparent pipe photoreactors are closed systems.

TANK OR POND PHOTOREACTOR This photoreactor is an open type because the contaminated water is not enclosed in a sealed environment. Tanks or shallow ponds containing contaminated water are continuously agitated to ensure that the suspended photocatalyst is evenly distributed. The contaminated water/photocatalyst mixture is exposed to the sun until the contamination concentration levels are in an acceptable range. Purchasing and operating costs of this type of photoreactor are much less than those of closed type systems, but considerable land areas may be required if large quantities of water are to be treated. Tank or pond photoreactors are effective for use in typically cloudy regions.

APPLICABILITY

PROCESS TYPE Photocatalytic techniques are effective in purifying contaminated process waste water and ground water containing a broad range of organic compounds including chlorinated solvents, aromatic compounds, pesticides, dyes, and fuel components. The technology is not effective in destroying contaminants such as carbon tetrachloride and some heavy metals such as copper, nickel, and cadmium. Nonvolatile contaminants (contaminants that do not easily vaporize) can be treated in open reactors such as tanks or ponds. Volatile contaminants (contaminants that readily vaporize at a relatively low temperature) require a closed reactor such as a flat plate or transparent pipe photoreactor.

CLIMATE All. Photoreactors can be designed to utilize scattered light. A backup system using lamps to provide near ultraviolet light may be advantageous in some areas.

DEMAND-SIDE MANAGEMENT STRATEGY Strategic conservation.

FOR MORE INFORMATION

Turchi, C.S., H.F. Link, "Relative Cost of Photons from Solar or Electric Sources for Photocatalytic Water Detoxification," *1991 Solar World Congress*, International Solar Energy Society, Denver, CO, August 17-24, 1991.

Mehos, M., C. Turchi, J. Pacheco, A.J. Boegel, T. Merrill, R. Stanley, "Pilot-Scale Study of the Solar Detoxification of VOC-Contaminated Groundwater," Presented at the American Institute of Chemical Engineers 1992 Summer Annual Meeting, Minneapolis, MN, August 9-12, 1992.

Turchi, C.S., M.S. Mehos, H.F. Link, "Design and Cost of Solar Photocatalytic Systems for Groundwater Remediation," Prepared for publication in *Remediation: The Journal of Environmental Cleanup Costs, Technologies and Techniques*, May 1992.

Table I-39. Solar Photocatalytic Water Detoxification: Costs and Benefits

Options[1]	Installed Capital Costs ($)	Energy Use (kWh/yr)	Treatment Cost ($/gal)	Energy Savings (kWh/yr)[2]	Cost Savings ($/yr)[2,3]	Simple Payback (yr)	Life (yr)	Pollutant Destroyed On-Site	Confidence[4]
Adsorption[5] Carbon	440,000	14,300	6.20	—	—	—	20	No	H
UV-Lamp/Hydrogen Peroxide[5]	350,000	530,000	4.40	—	—	—	20	Yes	H
Solar Detoxification (TiO_2 Photo-Catalyst)[6]	450,000-700,000	14,300-85,700	5.00-6.00	440,000-515,000	22,000-26,000	4-13	20	Yes	H

1. Installed and treatment costs were estimated based on a 100,000 gal/day unit treating trichlorethylene contaminated ground water at Livermore, CA. Contractor fees and design costs are included. 1992 dollar values were used.
2. When compared to the conventional UV-Lamp/Hydrogen Peroxide System.
3. Based on $0.05/kWh.

Footnotes continued on next page

4. H stands for high.
5. Conventional water detoxification system.
6. Cost, energy use, and payback ranges were based on experimentally developed systems with the same assumptions as are described in footnote 1. Because photoreactors ar similar to solar heating systems currently used by industry, and other systems components are typical to conventional water detoxification systems, costs for the systems shou be approximately those indicated in the table after solar detoxification systems become commercially available.

VIII. ELECTRICAL USAGE SHIFTING AND CONTROLS

A high demand charge can result from a high rate of energy use for short periods during production hours. The measures presented in this section provide options to shift or control demand. This section increases demand-side management measures for demand controls, interruptible and curtailable service and power factor corrections.

DEMAND CONTROLS

DESCRIPTION

Demand controls provide planned load scheduling, cycling and shedding to reduce energy consumption and peak demand. They operate in several ways. This problem may have one or more approaches. One way may be to distribute the facility's electrical usage over alternate shifts. Thus, if a high peak demand occurs during the day, a production line where heavy electrical usage occurs may be moved to a shift where the total demand will be less. An alternate solution may be to interlock specific pieces of equipment, thereby preventing them from all consuming power at their peak rates during any one particular demand interval. This is not always feasible when the natural operating interval of the equipment is much shorter than the demand interval, or when the machines must be in continuous operation to maximize production. Sometimes it is possible to reduce the peak demand by controlling electrical resistance heaters and other heating and ventilating equipment during periods when process requirements are peaking. This is sometimes referred to as duty cycling or load shedding. This concept is feasible if the building does not change temperature rapidly, or if slight temperature changes can be tolerated.

Another possibility is to schedule the operation of high consumption electrical machinery during lunch or break times. This is only feasible if the operation of the machinery is not required during other times.

DEFINITIONS AND TERMS

PEAK DEMAND The highest average load reached over all demand intervals during any billing period.

DEMAND INTERVAL A time period established by the utility, usually 15 minutes.

APPLICABILITY

FACILITY TYPE All.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Peak clipping, valley filling, and load shifting.

■ FOR MORE INFORMATION

Demand controls are also applied to storage systems. Refer to Brief #6 on Cool Storage Systems in *DSM Pocket Guidebook, Volume 2: Commercial Technologies*.

Table I-40. Demand Controls: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings	Cost Savings ($)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Demand Controls	3170	7,700 kWh/yr 47.9 kW/yr	5,603	0.5	10	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 48%.
2. One example from the EADC data base t a further clarify the costs is as follows: By shedding the electrical load associated with ice making during the on-peak hours and producing ice during the off-peak hours in a food plant, cost savings of $8,350 were realized. The implementation cost was $4,200, resulting in a simple payback of 6 months.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. M stands for medium.

INTERRUPTIBLE AND CURTAILABLE SERVICE

DESCRIPTION

Most utilities offer lower rates to customers who are willing to have their service discontinued during periods when the demand on the distribution system is greatest. This allows the electric and gas utilities to provide service with less capital cost, since the transmission and distribution equipment must be sized for the maximum load on the distribution system. The utility provides advance notice of service interruption; this notice can vary from 30 minutes to several hours.

Facilities with interruptible gas service have a back-up fuel source—either oil, propane, or a small natural gas meter—to meet the facility requirements during the curtailment of service, or at least, to provide enough space heating to prevent freezing of pipes.

Facilities on interruptible electric service can have a natural gas or diesel generator which provides power for those periods during which utility power is not available. Another strategy is to shut down the process during a power interruption, but to have a small electrical meter on a noninterruptible rate that provides power for computers, controls, HVAC equipment, emergency lighting, and burglar alarms.

DEFINITIONS AND TERMS

UNINTERRUPTIBLE POWER SYSTEM (UPS) A generator and/or set of batteries designed to prevent a loss of electrical power during a power outage.

APPLICABILITY

FACILITY TYPE This measure is most suitable for facilities with large energy requirements, or those that already own a UPS.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Flexible load shape, peak clipping.

Table I-41. Interruptible and Curtailable Service: Costs and Benefits

Options[1]	Installed Costs ($)	Energy Savings (kWh/yr)	Cost Savings ($/yr)[2]	Simple Payback (yr)	Life (yr)	Confidence[3]
Adding Second Gas Line or Back-up Generator	10,700	N/A	18,810	0.6	20	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 60%.
2. The energy cost savings are based on actual costs as reported to the EADC from the facility.
3. H stands for high.

INDUSTRIAL BRIEF # 38

POWER FACTOR

DESCRIPTION

The total power requirement of a load is made up of two components: the resistive component and the reactive component. The resistive component, measured in kilowatts (kW), does the useful work and is the quantity recorded by a watt meter. The reactive component, measured in reactive kilovolt-amperes (kVAR), represents the current needed to produce the magnetic field for the operation of a motor or other inductive device. This component does no useful work and is not registered on a power meter, but contributes to the heating of generators, transformers, and transmission lines. Thus it constitutes an energy loss for the electric utility.

Analysis of the reactive load versus the resistive load will yield a value known as the power factor. The power factor gives an indication of the portion of the total load that is resistive (real). To reduce reactive losses, the power factor should be increased to a value as close to unity (1.0) as possible.

For example, assume that a manufacturing plant has an average annual power factor (PF) of 0.78. Power factor of 0.78 means that for every 78 kW of usable power that the plant requires, the utility must supply 78 kW/PF or 100 kVA. If the plant's power factor is changed from 0.78 to 0.95, then for every 78 kW demanded by the plant, the utility need only supply 78 kW/0.95 or 82 kVA.

Capacitors can be installed to decrease the reactive power (kVAR) and thus the apparent power. Capacitors draw current which leads the voltage, while inductive loads draw current that lags the voltage. The net result of installing capacitors on circuits with inductive loads is that the current in the supply line is brought more closely in phase with the supply voltage. A power factor of 1.0 indicates that the current and the voltage are exactly in phase.

Capacitors can be installed at any point in the electrical system and will improve the power factor between the point of application and the power source. Capacitors can be added at each piece of equipment, ahead of groups of small motors, or at main services. The advantages and disadvantages of each type of installation are highlighted in Table I-42.

Table I-42.
Advantages and Disadvantages

Type of Capacitor Installation	Advantages	Disadvantages
Individual equipment	Increased load capabilities of distribution system Better voltage regulation	Smaller capacitors cost more per kVAR than larger units
Grouped equipment	Increased load capabilities of the service	Switching means may be required to control the amount of capacitance used

DEFINITIONS AND TERMS

INDUCTIVE DEVICE Any device, such as a motor or fluorescent lamp, for which the voltage changes in proportion to the time rate of change of current.

APPLICABILITY

FACILITY TYPE Any facility that has a power factor less than 0.90 or has large pieces of equipment having power factors below 0.90.

CLIMATE All.

DEMAND-SIDE MANAGEMENT STRATEGY Peak clipping.

FOR MORE INFORMATION

Ottaviano, V.B., *Energy Management*, Fairmont Press Inc., Atlanta, GA, 1985.

Table I-43. Power Factor: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Power Factor	6,690	NA	6,690	1.0	15	M

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 57%.
2. The cost represents the cost to install capacitors. One example from the EADC data base to further clarify the costs is as follows: By installing capacitors to correct a power factor from an average of 0.72 to 0.95, a plant having a demand of 300 kW was able to realize a demand cost savings of $4,750/yr. The implementation cost was $6,480, resulting in a simple payback of 1.25 yr.
3. The energy cost savings are based on actual costs as reported to the EADC from the facility.
4. M stands for medium.

MOTORS—UPDATE TO MOTORS BRIEFS IN *DSM Pocket Guidebook, Volume 2: Commercial Technologies*

Electricity needed to operate motors accounts for more than half of all the electricity consumed by U.S. industry. Motors are used to operate pumps, compressors, machine tools, and many other pieces of process equipment. The highest motor efficiency is achieved when the motor is matched to the load required from the equipment it serves. However, older industrial motors are often oversized and less efficient than new motors, or serve equipment having intermittent loads. These are all factors that adversely affect the efficiency of the motor, which, in turn, increases the motor electrical requirements and operating costs.

Industrial motors are often oversized for two reasons: (1) to ensure that the motor capacity will not, under any circumstance, be less than the required load; and (2) to allow for future increases in load demand. Depending on the motor loading, the efficiency of the motor operation can be significantly affected if the motor is oversized. If a motor serves both on-shift and off-shift loads, it may be beneficial to add a smaller motor matched to the lower load to operate during off-shift periods.

Energy-efficient motors (EEMs) that are commercially available are, on the average, 3% to 8% more efficient than older motors. Because of the high cost of EEMs, these motors are normally purchased only when existing motors need replacing. Table I-44 shows the costs and benefits of EEMs. This table is similar to Table C-27 in the commercial technologies guidebook but includes larger motors that may be found in industry.

Adjustable-speed drives (ASDs) maximize motor performance and energy efficiency by properly matching motor speed to the changing requirements. Energy savings are possible by reducing the power consumption of the motor as system requirements decrease. Variable-speed devices such as multispeed motors, adjustable belts and gears, and eddy current and hydraulic drives can improve the efficiency of the motor by up to 50%. Table I-45 summarizes the costs and benefits of variable-speed controls.

For detailed descriptions of motors, refer to the motors section of the *DSM Pocket Guidebook, Volume 2: Commercial Technologies.* That section includes a number of efficiency improvements that address the motor, as well as transmission of the energy to the load (e.g., gears) and the power supply. Because not all efficiency measures are applicable to all motor types, the first technology brief (#19) in the motors section of the commercial technologies guidebook presents an overview of the more common motors and their uses. Terms pertaining to motor efficiency measures are also defined.

FOR MORE INFORMATION

Keinz, J.R., R.L. Houlton, "NEMA/Nominal Efficiency: What is it and why?", IEEE Conference Record CH1459-5, Paper No. PC1-80-8 1980.

Lovins, A.B., et al., "State of the Art: Drivepower," Rocky Mountain Institute, Snowmass, CO, April 1989.

Ebosco Services, Inc., *Adjustable Speed Drive Applications Guidebook*, prepared for the Bonneville Power Administration, January 1990.

NEMA Standards Publication No. MG 10, *Energy Management Guide for Selection and Use of Polyphase Motors*, National ELectrical Manufacturers Association, Washington, D.C., 1989.

Nadel, S., et al., *Energy-Efficient Motor Systems: A Handbook on Technology, Programs, and Policy Opportunities*, American Council for an Energy Efficient Economy, 1991.

Table I-44. Variable-Speed Controls on Motors: Costs and Benefits

Options[1]	Installed Costs ($)[2]	Energy Savings (kWh/yr)	Cost Savings ($/yr)[3]	Simple Payback (yr)	Life (yr)	Confidence[4]
Variable-Speed Controls	46,100	331,000	16,600	2.8	10	H

1. These data were taken from the Energy Analysis and Diagnostic Center (EADC) data base. The frequency of implementation for this measure was 34%.
2. Average implementation cost per system for this measure. One example from the EADC data base to further clarify the costs is as follows: Installing a variable-speed controller on a 50 hp motor resulted in energy and cost savings of 33,700 kWh and $2,740/yr. The implementation cost was $6,570.
3. The energy cost savings are based on actual dollar savings as reported to EADC from the facility.
4. H stands for high.

Table I-45. Energy-Efficient Motors (EEMs): Costs and Benefits

Size (hp)	Std. Effic[1] (90)	EEM Effic[1] (90)	Annual Energy Savings[2] (kWh/yr)	Annual Cost Savings[3] ($/yr)	Cost Premium[4] ($)	Simple Payback (yr)
1	0.740	0.817	285	14.25	50	3.5
1.5	0.750	0.828	422	21.10	50	2.4
2	0.800	0.839	260	13.00	60	4.6
3	0.810	0.878	642	32.10	60	1.9
5	0.830	0.885	838	41.90	80	1.9
7.5	0.840	0.902	1,373	68.65	100	1.5
10	0.850	0.909	1,709	85.45	150	1.8
15	0.860	0.915	2,346	117.30	200	1.7
20	0.870	0.922	2,608	130.40	250	1.9
25	0.880	0.929	3,353	167.65	300	1.8
30	0.890	0.930	3,245	162.25	400	2.5
40	0.900	0.934	3,621	181.05	500	2.8
50	0.905	0.937	4,223	211.15	700	3.3
60	0.910	0.939	4,557	227.85	800	3.5
75	0.915	0.942	5,258	262.90	900	3.4

100	0.920	0.946	6,686	334.80	1,500	4.5
125	0.925	0.947	7,026	351.30	2,500	7.1
150	0.930	0.949	7,227	361.35	3,000	8.3
200	0.935	0.955	10,025	501.25	4,000	8.0
225	0.950	0.956	3,327	166.35	4,500	27.1
250	0.960	0.962	1,212	60.60	5,000	82.5
300	0.960	0.965	3,624	181.20	6,000	33.1
350	0.960	0.970	8,412	420.60	6,000	14.3
400	0.960	0.970	9,613	480.65	7,000	14.6
500	0.960	0.970	12,017	600.85	8,000	13.3

1. Average of TEFC (totally enclosed fan cooled) and ODP (open drip proof) types.
2. Assumes 75% full-load operation and 4,000 h/yr operation.
3. Assumes $0.05/kWh.
4. Additional cost of EEM over standard motor.

LIGHTING—UPDATE TO LIGHTING BRIEFS IN *DSM Pocket Guidebook, Volume 2: Commercial Technologies*

Lighting measures are addressed in the *DSM Pocket Guidebook, Volume 2: Commercial Technologies*, beginning on page 49. Those briefs, numbered 11 through 15, apply to industrial buildings as well as commercial buildings. This section provides an update to the information presented in the commercial technologies guidebook.

In the industrial sector, 10% of electric energy is used for lighting. (The industrial sector includes manufacturing, mining, and agriculture.) In the manufacturing industries, lighting accounts for 8.8% of total energy use. Lighting is one of the few end uses common to all industrial customers for which no practical nonelectric alternatives exist.

Lighting quality requirements vary with different industrial applications. In applications requiring good color rendering, high color rendering fluorescent lamps [Color Rendering Index (CRI) = 85] should be used. More energy savings can be realized by using metal halide lamps. The CRI of metal halide lamps is significantly lower (CRI = 65). Higher energy savings can be realized by using high-pressure sodium (HPS) lamps. It is cautioned that the use of HPS lamps can be limited to areas where color rendering is of little importance. The CRI of HPS lamps is 25. In some applications, the highest quality and most energy-efficient lighting scheme may be to create moderate background lighting levels and optimize work station illumination with the use of task lighting. As discussed in the commercial technologies volume, occupancy sensors and centralized lighting controllers used with fluorescent lighting can yield major energy and power savings.

■ FLUORESCENT LIGHTING

Brief #11 in the commercial technologies volume covers fluorescent lighting and includes costs for various energy savings options for fixtures with four 4-ft lamps. Since many of the industrial facilities are illuminated with fixtures containing two 8-ft lamps, Table I-46 provides cost and benefit information for energy-efficiency options for 8-ft lamps.

■ HIGH-INTENSITY-DISCHARGE (HID) LAMPS

High-intensity-discharge (HID) lamps are addressed in brief #13 in the commercial technologies volume. When evaluating industrial HID lamps, ceiling height and the task being performed should be considered. In some cases, HID lamps on a low ceiling may produce unacceptable glare at the work surface. HID ballasts use a significant portion of the total fixture power and should always be included when calculating lamp power.

FOR MORE INFORMATION

Kaufman, J.E., J.F. Christensen, eds., *IES Lighting Handbook, Reference Volume*, Illuminating Engineering Society, March 1990.

Kaufman, J.E., J.F. Christensen, eds., *IES Lighting Handbook, Application Volume*, Illuminating Engineering Society, February 1989.

Murdoch, J.B., *Illumination Engineering from Edison's Lamp to the Laser*, MacMillan Publishing Company, New York, 1985.

U.S. Department of Energy, *1992 Advanced Lighting Technologies Application Guidelines*, U.S. DOE, October 1992.

Table I-46. Lighting: Costs and Benefits (on a per fixture basis)

Option[1]	Retrofit Cost ($) (Installed)[2]	Power (W/fixture)[3]	Cost Savings ($/fixture/yr)[4]	Simple Payback (yr)	Relative Light Output (%)[5]	Life (h)
One standard ballast/two standard lamps	37	176	-	-	100	20,000 (lamps)
Replace two lamps with high efficiency lamps (standard ballast)	11	138	7.14	0.1[6]	95	20,000
Replace standard ballast with an electronic ballast (standard lamps)	55	123	9.94	5.5	100	45,000 (ballast)
Replace standard lamps and ballast with electronic ballast and high efficiency (T-8) lamps	77	112	11.98	6.42	110	20,000 45,000

Remove one standard lamp, reposition sockets, add a reflector	58	88	16.54	3.5	65-75	132,000 (reflector)

1. The base case is an 8-ft fixture with two standard (75-W lamps) and one ballast. The first option involves replacing the standard lamps with 60-W lamps. The third option involves replacing the lamps with more efficient 8-ft T-8 lamps at 50 W/lamp. The T-8 in 8-ft length lamps are just entering the marketplace (Aug. 1992) and are only available from some lighting suppliers. Removing one lamp and adding a reflector in a two-lamp fixture involves repositioning the socket to center the remaining lamp in the fixture. It will also involve rewiring the two-lamp ballast in tandem with an adjoining fixture, so that every other fixture has a two-lamp ballast.
2. The power per fixture is based on measured data provided by Financial Energy Management, Inc. in Denver, CO.
3. The cost is installed cost. An 8-ft. standard lamp is $5.00; a high-efficiency lamp is $5.50; a T-8 lamp is $11.00; a standard ballast is $27.00; an electronic ballast is $55.00.
4. Cost savings per fixture were calculated assuming that lamps are used 3744 h/yr (12 h/d x 6 d/w x 52 w/yr) at an average cost of $0.05/kWh. The base case cost is 176 w/fixture x 3744 h/yr/1000 x $0.05 = $32.94. Savings in cooling load costs are not included.
5. This is relative fixture light output.
6. Payback in this case only is based on the incremental cost of $1.00 ($11.00 - $10.00) for the high-efficiency lamps (assuming that the retrofit will be performed when the lamps need replacing). In all other cases, the payback is based on full replacement costs.

SECTION 2—DSM OPPORTUNITIES IN EACH TWO-DIGIT STANDARD INDUSTRIAL CLASSIFICATION

Industries have been categorized in a series of Standard Industrial Classification (SIC) codes according to their end product. The industrial sector is defined by 20 two-digit SIC groups, which are further subdivided into three- and four-digit SIC codes to describe specific industries. Opportunities exist for DSM strategies in all 20 groups. Many industries have begun to implement energy-use strategy programs because of rising energy costs and because of incentives provided by utilities.

Alternative industrial processes known as electrotechnologies provide opportunities for improved efficiency, controlability, and flexibility; reduction in equipment space requirements; significantly reduced process equipment pollutants; and increased productivity. Electrotechnologies also provide cost-effective options for creating energy usage patterns that benefit both the utility and the industry.

This section of the guidebook provides a summary of industrial DSM technology alternatives (Table I-47) followed by a matrix indicating electrotechnologies applicable to each industrial SIC group (Table I-48). Also included is a description of and sources for more information on demand-side management applications for each of the 20 SIC codes.

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES

SIC 20 Food and Kindred Products
SIC 21 Tobacco Products
SIC 22 Textile Mill Products
SIC 23 Apparel and Other Textile Products
SIC 24 Lumber and Wood Products
SIC 25 Furniture and Fixtures
SIC 26 Paper and Allied Products
SIC 27 Printing and Publishing
SIC 28 Chemicals and Allied Products
SIC 29 Petroleum and Coal Products
SIC 30 Rubber and Miscellaneous Plastics Products
SIC 31 Leather and Leather Products
SIC 32 Stone, Clay, and Glass Products
SIC 33 Primary Metals
SIC 34 Fabricated Metal Products
SIC 35 Non-electrical Machinery and Computer Equipment
SIC 36 Electric and Electronic Equipment
SIC 37 Transportation Equipment
SIC 38 Instruments and Related Products
SIC 39 Miscellaneous Manufacturing

Table I-47. Summary of Industrial DSM Technology Alternatives

DSM Industrial Technology Alternative	Definition and Application	Technology Features
Process Related		
Cogeneration	Cogeneration is the joint production of thermal and mechanical energy that can be used to generate electricity. Cogeneration is widely applied in industries with significant hot water or steam requirements (e.g., chemical, petroleum refining, pulp and paper, and steel) or in industries with waste streams that can be recovered for fuel (e.g., pulp and paper).	Installed costs generally range from $400 to $900 per kW. Cogeneration systems can operate at higher (65% to 90%) overall system efficiencies than conventional systems providing electricity or thermal energy separately.
Electrolytic Separation and Electrochemical Synthesis	Electrochemical synthesis involves the use of electrodes immersed in an electrolyte containing process reactants in ionic form. Electrolytic separation is similar, but it results in the dissolution of a single compound into two components. These processes, which operate at lower temperatures and pressures than conventional chemical reactors, give high efficiencies, high material yield, and are environmentally clean.	Electrochemical production of chlorine and caustic soda is a major electricity consumer. Adripanitrile, an organic compound used for nylon production, is also synthesized electrochemically.

Process Heat Recovery	A variety of waste recovery devices are available that use air-to-air and air-to-liquid heat exchange; each type operates differently, but all transfer heat from an exhaust stream to a cooler supply stream. Waste recovery systems are primarily associated with process industries.	Ventilation, process, and combustion-equipment exhausts are the major sources of recoverable energy. Rotary heat exchangers can recover 70% to 80% of the waste heat. Use of recuperators limits waste recovery rates to 50%, but are generally trouble free.
Industrial Process Heat Pumps	Heat pumps absorb heat and, using compression, elevates the temperature of this heat for subsequent use. Closed-cycle heat pumps are utilized in industries using large quantities of hot water and/or low-pressure steam (e.g., food processing, electroplating, and aqueous electrolytic separation processes), while open cycles are finding application in industries where large quantities of water vapor are produced in evaporation and drying (e.g., food, chemicals, paper, etc.).	Heat pump evaporators are now routinely selected over conventional multi-effect evaporators for several important applications.
Microwave Heating	Electromagnetic waves with a frequency range of 300 to 3,000 megahertz are transmitted to the workpiece by a wave guide that terminates in an applicator. Applications are found in the food and chemical industries where materials are heat sensitive and processing time considerations are involved.	Typical cost of equipment ranges from $2,000 to $4,000 per kW. Microwave heating can be easily integrated into existing production lines and is compatible with various automation concepts.

Table I-47. Summary of Industrial DSM Technology Alternatives (continued)

DSM Industrial Technology Alternative	Definition and Application	Technology Features
Metals Production Related Direct-Arc Melting	In this, the most commonly used method of electric melting in the steel industry today, scrap steel or direct-reduced iron is melted by a direct arc in which the current passes from one electrode through an arc to the metal charge, through the charge, and then from the charge through an arc to another electrode.	Cost is approximately $100 per annual ton capacity as compared to $450 per annual ton capacity for alternatives such as blast furnaces/basic oxygen furnaces. Plants can be built in the 200,000 to 400,000 ton per year capacity range as compared to the 2 million ton per year and larger capacity range for blast furnaces.
Direct Resistance Melting	Electric current is passed either directly through the material to be melted or through a resistance heating element that transfers heat to the material by radiation and convection. Direct resistance melting is commonly used in the glass industry, but metals and other materials of low electric resistance cannot be melted economically with this process. Present metal applications primarily involve steel, which is a relatively poor conductor.	Electric resistance furnaces range in capacity from 4 to 120 tons per day in volume production. Electricity consumption ranges from 750 to 1,500 kW per ton.
Electroslag Processing	This process is used to chemically purify molten metal for the production of high-purity, structurally homogenous	Manufacturing costs associated with electroslag casting range from $300-500/ton. Installed electroslag process-

	metal shapes. Electroslag remelting ingot production is widely used for the refinement of nickel- and cobalt-based alloys for aerospace applications.	ing capacity is estimated at 150 MW.
Induction Melting	A metal is placed inside a copper coil through which an AC current is passed, consequently inducing eddy currents in the metal. The resulting heat buildup melts the metal. The two principal types of induction furnaces are coreless, which is used for remelting, and channel, which is used for molding.	Growth of electricity demand attributable to induction melting is estimated to be 400 to 600 MW per year in the 1980s.
Plasma Processing	Plasmas, which are produced by exposing a gas to a high-intensity electric arc, can achieve temperatures in excess of 10,000°F. Plasma processing is currently used for direct reduction of iron ore to produce sponge iron and for smelting reduction of iron ore and scrap.	Energy consumption averages around 500 kWh/ton; annual capital costs are about $70/ton.
Materials Fabrication Electrical Discharge Machining (EDM) and Electrochemical Machining (ECM)	To erode a metal surface to any desired shape, EDM uses a high-voltage, pulsing direct current while ECM uses a low-voltage, non-pulsing source. EDM is used to produce complex shapes, dies, and carbide tools; EMC is used to produce high-temperature alloy forgings, turbine wheels, and jet engine blades.	Both systems maintain a high degree of precision tolerance and produce finishes of high quality. Cutting speed does not depend on material hardness.

Table I-47. Summary of Industrial DSM Technology Alternatives (continued)

DSM Industrial Technology Alternative	Definition and Application	Technology Features
Electron Beam Heating	Materials are heated when a directed beam of electrons under vacuum conditions is focused against the work surface. This process is used largely in the automotive industry for thick-section welding applications where deep heat penetration is needed.	While initial cost is typically 3 to 10 times those of conventional systems, savings in the case of heavy sections can reach 80%.
Flexible Manufacturing Systems (FMS) and Robotics	FMS are basically assemblies of one or more machine tools that include a control unit that monitors the performance of the equipment and implements corrective actions as required. Robots are reprogrammable, multi-functional manipulators designed to move materials, parts, tools, or specialized devices through variable programs to accomplish a variety of tasks.	Implementation of FMS in industry has been slow, with only about 40 installation to date. Robotic installations already number in the thousands, but market penetration cannot accelerate further without overcoming several application barriers.

Induction Heating	Induction heating generates heat within the material by placing the metal piece inside of a coil with alternating current passing through it. Inducting heating is used by ferrous and non-ferrous metals industries in a broad range of metal working processes including forging, forming, heat treating, and pining.	Growth of electricity demand attributable to induction heating is estimated to be 500 to 1,000 MW per year in the 1980s.
Infrared Drying and Curing	A filament, typically tungsten, is used to produce infrared radiation which, when absorbed, heats and dries textiles, paper, paints, and other coatings. The temperatures produced range from 600° to 4,000°F.	Provides uniform drying unlike conventional drying which sometimes causes blistering of a surface through effusion of vapor.

Table I-48. Recommended DSM Alternatives Per SIC

DSM Technology	SIC																			
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Cogeneration	X	X	X		X		X		X	X				X						
Electrolytic separation/electrochemical synthesis	X						X		X					X						
Process heat recovery	X	X	X		X		X		X	X			X							
Industrial process heat pumps	X		X		X		X		X	X										
Microwave heating	X	X	X	X	X	X	X	X	X		X	X	X	X						
Direct-arc melting														X						
Direct resistance melting													X	X	X	X	X			
Electroslag processing														X	X			X		
Induction melting														X						

Plasma processing									X					X	X	X				
Electrical discharge and electrochemical machining															X	X				
Electron beam heating											X					X	X	X		
Flexible manufacturing systems and robotics		X	X	X	X					X		X	X	X	X	X	X	X	X	
Induction heating														X	X		X	X		
Infrared dying and curing	X	X	X	X	X	X	X	X	X		X	X	X		X		X	X		
Laser processing			X	X	X	X						X	X		X		X		X	X
Resistance heating	X					X			X		X			X	X	X		X	X	
Ultraviolet and electron beam curing					X	X		X			X				X	X	X	X	X	
Battery storage							X		X				X							
Efficient electric motors and drives	X	X		X	X	X		X	X	X	X	X	X		X	X	X		X	X
Pumping systems							X			X										

SIC TITLE:
Food and Kindred Products

PREVALENCE IN WESTERN TERRITORY

High. Meat and grain production are prevalent in the Midwest and West, and fruit and vegetable production is heavy in the Southwest. Dairy production is not as prevalent in the western territory.

DESCRIPTION

In the last decade, electricity consumption in the food and beverage industry has increased because of a shift to more electricity-intensive processes. Four process categories consume the bulk of the energy in the food and beverage industry. These processes are cooking, drying, liquid heating, and refrigeration. Electrotechnology growth potential is the greatest for the cooking, drying, and liquid heating operations in order to replace the fossil fuels traditionally used for these processes. Refrigeration processes depend heavily on motor-driven equipment such as compressors and pumps, which would benefit from the use of energy-efficient electric motors and drives. Electricity accounted for approximately 17% of the energy consumed by the industry in 1988 or about 50,206 million kWh.

FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers Council, *Industrial Market and Energy Guide, SIC 20, Food and Kindred Products Industry*, Washington, DC, 1985.

Resource Dynamics Corporation, *Food Industry Scoping Study*, Electric Power Research Institute, CU-6755, March 1990.

PERIODICALS/DATA BASES:

Food Technology, Institute of Food Technologists, Chicago, IL.

Journal of Food Science, Institute of Food Technologists, Chicago, IL.

Food Science and Technology Abstracts—data base; producer: International Food Information Services, Reading and Bershire, England.

TRADE ASSOCIATIONS:

Institute of Food Technologists
221 N. LaSalle St.
Chicago, IL 60601
(312) 782-8424

Promotes application of science and engineering to the evaluation, production, processing, packaging, distribution, preparation, and utilization of foods.

National Food Processors Association
Western Research Laboratory
6363 Clark Ave.
Dublin, CA 94568-3097
(415) 828-2070

Contact: Walter W. Rose, Associate Director, Engineering/Environmental Division. Scientific and trade association for the food industry. Researches new processing techniques, new food technologies, and other topics.

SIC NUMBER: 21

SIC TITLE: Tobacco Products

PREVALENCE IN WESTERN TERRITORY

Low. The tobacco products industry is concentrated in the southeastern portion of the United States.

DESCRIPTION

The tobacco industry is one of the lowest energy-intensive industries of all the industrial categories and is the least electricity-intensive industry. This leads to limited demand-side management (DSM) opportunities. Drying and curing processes have the greatest potential of benefitting from electrotechnologies. Other DSM opportunities which benefit the tobacco industry are energy-efficient motors and drives, improved lighting, and off-peak electricity usage. Electricity accounted for approximately 12% of the energy consumed by the industry in 1988 or about 864 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management, Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS/DATA BASES:

Biological Abstracts, BIOSIS Previews—data base; producer: BIOSIS, Philadelphia, PA.

TRADE ASSOCIATIONS:

Tobacco Merchants Association of the United States, Inc.
P.O. Box 8019
231 Clarksville Rd.
Princeton, NJ 08543-8019
(609) 275-4900

Manufacturers of tobacco products and others related to the tobacco industry.

SIC NUMBER: 22

SIC TITLE: Textile Mill Products

PREVALENCE IN WESTERN TERRITORY

Low. Eighty percent of the total U.S. textile shipments are manufactured in the southeastern region of the United States, primarily in North and South Carolina and Georgia.

DESCRIPTION

Electricity is the largest energy source for the textile industry—representing about one-third of the industry's total energy requirement. Motors and drives account for approximately 80% of the electricity consumed, indicating that there is excellent demand-side management potential for energy-efficient motors and drives. Traditional drying, dyeing, and finishing processes that rely on fossil fuels may profit from electrification. Cogeneration and industrial process heat pumps are also applicable to the textile industry because of the presence of waste products and waste heat. Because of the importance of environmental conditions to the textile manufacturing processes, heating, ventilating, and air conditioning systems have the greatest potential for load management. Electricity accounted for approximately 37% of the energy consumed by the industry in 1988 or about 29,738 million kWh.

FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers Council, *Industrial Market and Energy Management Guide, SIC 22, Textile Mill Products Industry*, Washington, DC, 1985.

Resource Dynamics Corp. and Battelle-Columbus Div., *Textile Industry: Profile and DSM Options*, Electric Power Research Institute, CU-6789, July, 1990.

PERIODICALS:

Textile World, MacLean Hunter Publishing Co., Atlanta, GA.

TRADE ASSOCIATIONS:

American Association of Textile Chemists and Colorists
P.O. Box 12215
Research Triangle Park, NC 27709-2215
(919) 549-8141

Contact: Technical Director. Technical and scientific society of textile chemists and colorists in textile and related industries. Conducts textile research and disseminates scientific information.

Textile Research Institute (TRI/Princeton)
P.O. Box 625
Princeton, NJ 08542
(609) 924-3150

Conducts nonproprietary scientific research in support of the textile and allied industries. Disseminates research information and maintains a technical library.

SIC TITLE: Apparel and Other Textile Products

PREVALENCE IN WESTERN TERRITORY

Medium. Apparel and other textile products manufacturers are located throughout the United States but are concentrated in the southeastern and northeastern states.

DESCRIPTION

The two largest industries in the apparel and other textile products SIC category—men's and boys' clothing and women's and misses' clothing—consume more than half of the total electricity consumed by SIC 23. Technological advancements for these two industries have concentrated on more efficient methods of meeting the constantly changing consumer preferences in the marketplace. Most of the technological development has been in computer-aided manufacturing for cutting, stitching, pressing, automatic assembly, and many other applications. Other electrotechnologies that industries in the sector may find beneficial include laser cutting and infrared, microwave, and radio frequency heating and drying. Demand-side management programs (such as shifting the time of day for peak electrical use) are not attractive to the industry because of the industrywide need to maintain high production rates for economic competitiveness. Cogeneration is also not an economically attractive option because of the industry's small need for thermal energy and the lack of cheap byproducts that could be used as fuel for cogeneration systems. Electricity accounted for approximately 42% of the energy consumed by the industry in 1988 or about 6,659 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management, Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS:

Bobbin, Bobbin International, Inc., Columbia, SC

TRADE/RESEARCH ASSOCIATIONS:

Textile/Clothing Technology Corporation
706 Hillsborough St.
Raleigh, NC 27603
(919) 829-9071

Contact: Joe Off. Research and development for oll aspects of apparel manufacturing. Assists apparel manufacturers in the justification for and implementation of advanced process techniques.

Clemson Apparel Research Center
500 Lebanon Rd.
Pendleton, SC 29670
(803) 646-8454

The center's objectives include assistance to apparel manufacturers in the purchase justification of advanced manufacturing technology and conducting research to develop new manufacturing technologies.

SIC TITLE: Lumber and Wood Products

PREVALENCE IN WESTERN TERRITORY

Low. Lumber and wood products industries are located primarily in the Pacific Northwest and the Southeast. Other manufacturers are generally located near the wood sources throughout the United States.

DESCRIPTION

The lumber and wood products industry is dominated by the sawmills, planing mills, fabricated millworks, and plywood manufacturers. These industries will most likely lead the SIC sector in electrotechnology development, especially in automated technologies. Automation includes the use of lasers for cutting; electron beam processing, ultraviolet, and infrared for curing coatings, glues, and paints or varnishes; and infrared, microwave, and radio frequency for heating and drying raw wood and wood products. Less sophisticated demand-side management opportunities that could especially benefit the small manufacturers are high-speed fans to shorten drying times in steam kilns, variable-speed fans and motors to reduce electricity requirements for drying and other processes, and various vacuum drying technologies to increase the efficiency of drying processes. Because of the availability of wood byproducts, cogeneration and alternative fuels are common to this industry. Electricity accounted for approximately 14% of the energy consumed by the industry in 1988 or about 16,431 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Electrotechnologies for the Wood Processing Industry*, EPRI report, CMF Report No. 90-4, 1990.

Electric Power Research Institute Center for Materials Fabrication, *Electrotechnology Advances in Wood Processing*, CMF TechCommentary, Vol. 6, no. 1, 1990.

PERIODICALS:

Forest Products Journal, Forest Products Research Society, Madison, WI.

TRADE ASSOCIATIONS:

Forest Products Research Society
2801 Marshall Ct.
Madison, WI 53705
(608) 231-1361

Information-gathering organization for wood industry research, development, production, utilization, and distribution—from logging operations through finished products and utilization of residues os byproducts.

Notional Forest Products Association
1250 Connecticut Ave. NW, Ste. 200
Washington, DC 20036
(202) 436-2700

Represents the forest industries on national issues, including the manufacture, distribution, and use of wood products. May refer callers to the American Wood Council (same address and telephone).

SIC NUMBER: 25

SIC TITLE: Furniture and Fixtures

PREVALENCE IN WESTERN TERRITORY

Low. Most of the furniture and fixture production in the United States is in the southern states; North Carolina is the principal furniture-producing state.

DESCRIPTION

Opportunities for demand-side management do exist in the low-energy and low-electricity-intensive furniture and fixture industry. Processes common to the sector include lumber drying; cutting of wood, fabric, and other materials; assembly processes such as stapling and bolting of furniture parts; and final finishing such as staining, painting, and drying. Infrared drying and curing, radio frequency heating and drying, indirect resistance heating, ultraviolet beam processing, and electron beam processing are all electrotechnologies applicable to wood, adhesive, and finishing coatings, drying, and curing. Laser technologies are beginning to be introduced for wood, glass, metal, and fabric cutting. Automation of assembly processes could also benefit the industry. Lower cost retrofit measures to the industry's processes include installing high-speed fans in steam kilns to decrease drying time; replacing drying fans with variable-speed fans to better match fan speeds with drying air velocity requirements; and using various vacuum drying techniques to decrease energy consumption and increase product quality. Electricity accounted for approximately 30% of the energy consumed by the industry in 1988 or about 5,651 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute Center for Materials Fabrication, *Electrotechnology Advances in Wood Processing*, CMF Tech Commentary, Vol. 6, No. 1, 1990.

PERIODICALS:

Wood and Wood Products, Vance Publishing Corp., Lincolnshire, IL.

TRADE ASSOCIATIONS:
Wood Machinery Manufacturers of America (WMMA)
1900 Arch St.
Philadelphia, PA 19103
(215) 564-3484

Contact: WMMA. Manufacturers of heavy woodworking machinery and cutting tools for industrial use. Seeks to develop better high-speed, high-precision production equipment and assist the user in its selection.

SIC NUMBER: 26

SIC TITLE: Paper and Allied Products

■ PREVALENCE IN WESTERN TERRITORY

Medium. Approximately half of the U.S. pulp and paper products are produced in the southeastern region of the United States, with the remaining half divided evenly among the Northeast, North Central and West.

■ DESCRIPTION

When compared to other industrial classifications, the pulp and paper industry consumes the third largest amount of electricity. About one-third of the total energy used in the chemical pulping and paper process is used for pressing and drying the paper products. Two types of paper processing are used by the industry: mechanical and chemical processing. The mechanical process is much more energy intensive and is now used by significantly fewer manufacturers. An estimated 50% more electrical energy is needed for the mechanical process than for the chemical process. Mechanical processing, however, produces much higher yields and does not have the environmental impact of the chemical processes. For this reason, mechanical processing is expected to grow, compared to chemical processing. Self-generation satisfies roughly half of the industry's electrical needs. The industry will most likely increase the usage of cogeneration and other self-generated fuels. Electricity accounted for approximately 8% of the energy consumed by the industry in 1988 or about 55,517 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

Elaohi, A., H.E. Lowitt, *The Pulp and Paper Industry: An Energy Perspective*, DOE/RL/01830-T57, Energetics, Inc., Columbia, MD, April 1988.

Herzog, J.J., J.W. Tester, "Energy Management and Conservation in the Pulp and Paper Industry," *Energy and the Environment in the 21st Century*, proceedings of the conference held at the Massachusetts Institute of Technology, Cambridge, MA, March 26-28, 1990, pp. 437-447.

PERIODICALS:
TAPPI Journal, Technical Association of the Pulp and Paper Industry, Atlanta, GA.

TRADE ASSOCIATIONS:
American Paper Institute
260 Madison Ave.
New York, NY 10016
(212) 340-0600

Contact: Energy and Technology Department. U.S. manufacturers of pulp, paper, and paperboard. Gathers, compiles, and disseminates information and conducts research on scientific and technical problems.

Technical Association of the Pulp and Paper Industry (TAPPI)
Technology Park/Atlanta
P.O. Box 105113
Atlanta, GA 30348
(404) 446-1400

Contact: Information Resources Center. Engineers, research scientists, and others in the pulp, packaging, converting, paper, nonwovens and allied industries. Research and development in pulp manufacturing, paper and board manufacturing, process and product quality, and other areas.

SIC TITLE: Printing and Publishing

PREVALENCE IN WESTERN TERRITORY

High. Printing and publishing industries are found throughout the United States. Most industries are small, employing fewer than 100 people.

DESCRIPTION

The printing and publishing industry is a low energy-intensive industry ranking 13th in electricity usage in 1988. Motors and drives for press work and binding is the most electricity-intensive segment of the industry. Process developments that have resulted in increased electrical demand in the past decade have occurred with the increased use of automation, lasers, and microprocessors—mostly for press operations and finishing (cutting, binding, etc.) processes. Development of robotics (primarily for binding processes and materials handling) is expected to continue rapidly in the near future. More efficient process drying electrotechnologies such as radiation-, microwave-, infrared-, and radio frequency-drying and curing will become attractive to the industry as the trend toward slower drying (but less environmentally harmful) vegetable-based inks increases. Electricity accounted for approximately 50% of the energy consumed by the industry in 1988 or about 17,052 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS:

GATFWORLD, Graphic Arts Technical Foundation, Pittsburgh, PA.

TRADE ASSOCIATIONS:

Graphic Arts Technical Foundation
4615 Forbes Ave.
Pittsburgh, PA 15213
(412) 621-6941

Contact: Jim White—Membership Manager. Scientific, technical, and educational organization whose membership represents every facet of the printing and publishing industry. Conducts research in all graphic processes and their commercial applications.

SIC NUMBER: 28

SIC TITLE: Chemicals and Allied Products

PREVALENCE IN WESTERN TERRITORY

High. Most chemical manufacturers are located near a raw material source and/or in areas of relatively inexpensive energy.

DESCRIPTION

The energy-intensive chemicals and allied products industry ranks second in both total energy and electricity consumed when compared to the other SIC categories. The three largest electricity-consuming industries are the industrial inorganic chemicals, the industrial organic chemicals, and the plastics materials and synthetics industries. Because the electrical usage is very diverse for the sector, demand-side management (DSM) strategies must be evaluated on a site- and industry-specific basis. DSM opportunities that may be applicable to some chemical industries include scheduling energy-intensive processes for off-peak periods or better utilizing unused off-peak production capacity. Electricity consumption may increase for some chemical industries with the introduction of plasma processes for the production of high-purity silicon, titanium dioxide, and silicon carbide, and with the introduction of electric arc processing for converting coal to acetylene. The larger consumers of electricity are reducing their consumption of purchased electricity by relying more heavily on cogenerated electricity or by implementing more efficient processes. For example, the chlor-alkali industry is replacing the diaphragm cell process with the more efficient membrane cell process and reducing electricity consumption by 20%-35%. Electricity accounted for approximately 9.5% of the energy consumed by the industry in 1988 or about 121,854 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS:

Chemical Engineering, McGraw Hill Inc., New York, NY.

SIC NUMBER: 29

SIC TITLE: Petroleum and Coal Products

PREVALENCE IN WESTERN TERRITORY

Medium. The states with the largest petroleum refining capacities in the western territory are Texas and California. Other petroleum and coal product industries are located throughout the territory.

DESCRIPTION

The petroleum and coal products industry ranks first in total energy consumption but tenth in electricity consumption. This sector is dominated by the energy-intensive petroleum-refining industry. The petroleum-refining industry, which primarily produces gasoline, kerosene, fuel oils, lubricants, and other products from crude petroleum, requires more than 95% of both the total energy and electricity consumed by the sector. The high-temperature process heat requirements of the refining process characterizes this industry. Demand-side management opportunities for the industry include cogeneration, industrial process heat pumps, and process heat recovery because of the high process heat loads. As older steam-driven turbines wear out, the industry has been replacing these turbines with electrically driven motors. Electricity accounted for approximately 3.4% of the energy consumed by the industry in 1988 or about 6,225 million kWh.

FOR MORE INFORMATION

REFERENCES:

Robertson, J.L., "Energy Efficiency in Petroleum Refining-Accomplishments, Applications, and Environmental Interfaces," *Energy and the Environment in the 21st Century*, proceedings of the conference held at the Massachusetts Institute of Technology, Cambridge, MA, March 26-28, 1990.

PERIODICALS:

Results (Houston), Exxon Co., Houston, TX.

Petroleum Engineer International, Edgell Communications, Cleveland, OH.

TRADE ASSOCIATIONS:

American Petroleum Institute
1220 L St. NW
Washington, DC, 20005
(202) 682-8000

Contact: Library. Represents corporations in the petroleum and allied products industries that encourage the study of the arts and sciences connected with the petroleum industry. Publishes several hundred manuals, booklets, and other materials on production, refining, research, and other areas related to the industry.

SIC NUMBER: 30

SIC TITLE: Rubber and Miscellaneous Plastic Products

■ PREVALENCE IN WESTERN TERRITORY

Medium. Rubber and plastic products manufacturers are evenly distributed in most of the states located in the western territory.

■ DESCRIPTION

The rubber and miscellaneous plastics products industrial sector comprises two industries, each with a unique manufacturing process. The rubber industry depends on a six step process: drying, baking, calendering, extrusion, varnishing, and vulcanizing. The vulcanization process offers the most opportunity for DSM strategies. Vulcanizing chamber exhaust can provide waste heat to use for preheating air or boiler feedwater. Microwave heating is also replacing the traditional steam or electric heated vulcanizing chambers. The plastics industry is characterized by three methods of processing thermoplastic or thermosetting resins: extrusion, molding, and thermoforming. These processes require drying, curing, heating, and cooling of the plastic. Electrotechnologies such as radio-frequency heating and drying, infrared drying and curing, and electron beam processing could improve the efficiency of the processes and reduce the quantity of waste heat. Finally, reusing waste rubber and waste plastic as a secondary fuel is a viable DSM strategy for both industries. Electricity accounted for approximately 42% of the energy consumed by the industry in 1988 or about 31,299 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide, SIC 30, Rubber and Plastics Products Industry*, Washington, DC, 1985.

PERIODICALS:

Plastics Engineering, The Society of Plastics Engineers, Brookfield Center, CT.

Rubber and Plastic News, Crain Communications Inc., Akron, OH.

TRADE ASSOCIATIONS:

Rubber Manufacturers Association
1400 K St. NW
Washington, DC 20005
(202) 682-4800

Manufacturers of tires, tubes, mechanical and industrial products, roofing, sporting goods, and other rubber products. Publishes handbooks, standards, and specifications.

Society of the Plastics Industry
1275 K St. NW, Ste. 400
Washington, DC 20005
(202) 371-5200

Contact: Information Department. Manufacturers and processors of molded, extruded, fabricated, laminated, calendered, and reinforced plastics, as well as manufacturers of raw materials, machinery, tools, dies, and molds.

SIC NUMBER: 31

SIC TITLE: Leather and Leather Products

PREVALENCE IN WESTERN TERRITORY

Medium. Manufacturing establishments within the western territory are concentrated in the southwestern states. Leather and leather products industries are also concentrated in the northeastern and north central regions of the United States.

DESCRIPTION

The leather and leather products industry is one of the least electricity-intensive industrial SIC sectors. The nonrubber footwear industry is the dominating industry of the group. Most of the development for electrotechnology application has been for this industry. Automation for materials handling, cutting, and stitching is receiving the most attention. Specific electrotechnologies being developed are laser cutting, infrared drying, and microwave and radio frequency heating and drying technologies. The leather and leather products industry is generally eager to implement new technologies into its manufacturing processes in order to become more competitive with imported goods; however, the high cost of new technology is often prohibitive to smaller manufacturers. Electricity accounted for approximately 30% of the energy consumed by the industry in 1988 or about 1,391 million kWh.

FOR MORE INFORMATION

REFERENCES:

Hides and Skins, published by the U.S. Hide, Skin and Leather Association.

PERIODICALS:

Leather Manufacturer, Shoe Trades Publishing Co., Cambridge, MA.

World Footwear, Shoe Trades Publishing Co., Cambridge, MA.

TRADE ASSOCIATIONS:

U.S. Hide, Skin and Leather Association
1700 N. Moore St., Ste. 1600
Arlington, VA 22209
(703) 841-5485

Membership includes producers, processors, and others who handle raw hides and skins.

Leather Industries of America
1000 Thomas Jefferson St. NW, Ste. 515
Washington, DC 20007
(202) 342-8086

Represents firms engaged in leather tanning. Works for the promotion and advancement of the leather industry through the collection and dissemination of technical research and other areas.

SIC NUMBER: 32

SIC TITLE: Stone, Clay, and Glass Products

PREVALENCE IN WESTERN TERRITORY

Medium. Stone, clay, and glass industries in the Western territory are concentrated in California and Texas, with other plants distributed throughout the territory. The industry is more heavily concentrated in the eastern third of the United States.

DESCRIPTION

The stone, clay, and glass industry is ranked sixth for electricity use. The cement and glass industries consume approximately 70% of the total electrical power consumed by SIC 32. Most of the electricity used by the cement industry is for grinding the raw materials. Grinding efficiencies are usually very low, leading to demand-side management (DSM) opportunities for energy-efficient motors and drives. A majority of the electrical usage by the glass industry is for heating and melting of raw materials, annealing the formed glass, and operating mechanical equipment drives. Kilns used by the cement industry and furnaces in the glass industry (most often fired by fossil fuels) lose tremendous amounts of heat through the walls of the kiln or furnace and in exhaust gases. Process heat recovery and the addition of supplemental electric resistance heating (glass industry) are possible DSM opportunities to counteract these losses. Electricity accounted for approximately 12% of the energy consumed by the industry in 1988 or about 33,793 million kWh.

FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers Council, *Industrial Market and Energy Management Guide, SIC 32, Stone, Clay, Glass Products Industry*, Washington, DC, 1987.

Mellon Institute, *Glass Industry Scoping Study*, Science Applications International Corp., Electric Power Research Institute, July 1988, EM-5912.

PERIODICALS:

Stone Review, National Stone Association, Washington, DC.

Glass Magazine, National Glass Association, McLean, VA.

TRADE ASSOCIATIONS:

National Stone Association
1415 Elliot Pl. NW
Washington, DC 20007
(202) 342-1100

Contact: Public Affairs Director. Producers and processors of crushed stone; manufacturers of machinery, equipment, and supplies used in the production of crushed stone.

National Glass Association
8200 Greensboro Dr., Ste. 302
McLean, VA 22102
(703) 442-4890

Manufacturers and fabricators of flat, architectural, automotive, and specialty glass. Provides educational and technical services.

SIC TITLE: Primary Metals

■ PREVALENCE IN WESTERN TERRITORY

Medium. Most primary metals production locations are east of the Mississippi River. Manufacturers in the western territory are usually in areas of low electric power rates.

■ DESCRIPTION

The primary metals industry is the largest industrial user of electricity, consuming 21% of the total electricity consumed by industry in 1988. A primary metals manufacturer is often the single largest customer for a utility. SIC 33 is dominated by the primary iron and primary aluminum producers. Electric arc furnaces are replacing the traditional methods of steel production, especially as conventional steel-making facilities wear out. Minimills, which use only scrap steel as the base material, use electric furnaces exclusively for melting scrap, continuous casting, and rolling and finishing processes. Process heat recovery from the exhaust gases of the blast furnaces in conventional steel-manufacturing plants may be utilized for preheating various process steps or for electric power generation. In the aluminum industry, approximately 70% of the energy required is in the form of electricity. Electricity accounted for approximately 18% of the energy consumed by the industry in 1988 or about 149,202 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

Arthur D. Little, Inc., *Aluminum Industry Scoping Study*, Electric Power Research Institute, Center for Metals Production, CMP 86-2, August 1986.

Mellon Institute, *Technoeconomic Assessment of Electric Steelmaking Through 2000*, Electric Power Research Institute, Center for Metals Production, EM-5445, October 1987.

PERIODICALS/DATA BASES:

World Aluminum Industry Abstracts—data base; producer: ASM International, Metals Park, OH.

Iron and Steel Engineer, Association of Iron and Steel Engineers, Pittsburgh, PA.

TRADE ASSOCIATIONS:

Aluminum Association
900 19th St. NW, Ste. 300
Washington, DC 20006
(202) 862-5100

Contact: Technical Information Department. Producers of aluminum and manufacturers of semifabricated aluminum products. Free catalog listing all publications, reprints, and audiovisual material.

American Iron and Steel Institute
1133 15th St. NW
Washington, DC 20005
(202) 452-7100

Contact: Department of Manufacturing and Technology. Basic manufacturers and individuals in the steel industry. Conducts extensive research programs on manufacturing technology, energy, fuel consumption, and other areas.

SIC NUMBER: 34

SIC TITLE: Fabricated Metal Products

PREVALENCE IN WESTERN TERRITORY

Medium. Manufacturers of fabricated metal products are located in every state of the western territory; however, the industry is more heavily concentrated in the eastern third of the United States.

DESCRIPTION

Approximately one-quarter of the total energy used by the fabricated metal products industry is purchased electricity. This industry has more potential for electrotechnology applications than most industrial sectors. Because of the process heat requirements of this industry, applications such as process heat recovery for space heating; preheating boiler make-up water; preheating oven, furnace, and incinerator air; and other applications could be beneficial to almost every fabricated metal products manufacturer. Induction and infrared heating and curing offer efficient alternatives to the traditional fossil-fuel-fired systems used by most manufacturers. Industrial process heat pumps utilized to recover vaporized solvents that would otherwise have been incinerated is another demand-side management option applicable to the industry. Electricity accounted for approximately 30% of the energy consumed by the industry in 1988 or about 30,952 million kWh.

FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide, SIC 34, Fabricated Metal Products Industry*, Washington, DC, 1987.

PERIODICALS:

The Fabricator, Fabricators and Manufacturers Association, Rockford, IL.

Stamping Quarterly, Fabricators and Manufacturers Association, Rockford, IL.

The Tube and Pipe Quarterly, Fabricators and Manufacturers Association, Rockford, IL.

TRADE ASSOCIATIONS:

Fabricators and Manufacturers Association, International (FMA)
833 Featherstone Rd.
Rockford, IL 61107
(815) 399-8700

Contact: Technical Information Center. A technical educational association whose members include those interested in the metal forming and fabricating industry. Periodicals published by FMA are free to interested individuals.

National Machine Tool Builder's Association—
Association for Manufacturing Technology
7901 Westpark Dr.
McLean, VA 22102
(703) 893-2900
toll-free number (800) 544-3597

Contact: Information Resource Center. Makers of power-driven machines used in the process of transforming man-made materials into durable goods. Promotes research and development in the industry. Maintains a computerized data base on machine tool technology.

SIC NUMBER: 35

SIC TITLE: Non-Electrical Machinery and Computer Equipment

PREVALENCE IN WESTERN TERRITORY

Medium. Manufacturers of nonelectric machinery products are located in every state of the western territory; however, the industry is more heavily concentrated in the eastern third of the United States.

DESCRIPTION

The nonelectrical machinery and computer equipment industry manufactures industrial, construction and farm machinery and equipment, machine tools, computers and office equipment, and heating, ventilating, and air-conditioning equipment. Because of the diversity of manufacturing processes in this sector, demand-side management improvements must be evaluated on a per process basis. However, there are numerous electrotechnology opportunities that are applicable. Most of the manufacturers in this sector have some sort of painting operation in their process which may benefit from microwave or infrared heating. Welding processes (also common to SIC 35) may benefit from plasma arc welding, laser welding, or electron beam welding electrotechnologies. Process heat recovery opportunities for boiler make-up water preheat, industrial heat pumps, or cogeneration systems exist for most processes of this sector. Electricity accounted for approximately 41% of the energy consumed by the industry in 1988 or about 33,480 million kWh.

FOR MORE INFORMATION

REFERENCES:

American Consulting Engineers' Council, *Industrial Market and Energy Management Guide, SIC 35, Non-Electrical Machinery Products Industry*, Washington, DC, 1987.

PERIODICALS:

The Fabricator, Fabricators and Manufacturers Association, Rockford, IL

Stamping Quarterly, Fabricators and Manufacturers Association, Rockford, IL.

The Tube and Pipe Quarterly, Fabricators and Manufacturers Association, Rockford, IL.

Wood and Wood Products, Vance Publishing Corp., Lincolnshire, IL.

TRADE ASSOCIATIONS:

Fabricators and Manufacturers Association, International (FMA)
833 Featherstone Rd.
Rockford, IL 61107
(815) 399-8700

Contact: Technical Information Center. A technical educational association whose members include those interested in the metal fanning and fabricating industry. Periodicals published by FMA are free to interested individuals.

National Machine Tool Builder's Association—
Association for Manufacturing Technology
7901 Westpark Dr.
McLean, VA 22102
(703) 893-2900
toll-free number (800) 544-3597

Contact: Information Resource Center. Makers of power-driven machines used in the process of transforming man-made materials into durable goods. Promotes research and development in the industry. Maintains a computerized data base on machine tool technology.

Wood Machinery Manufacturers of America (WMMA)
1900 Arch St.
Philadelphia, PA 19103
(215) 564-3484

Contact: WMMA. Manufacturers of heavy woodworking machinery and cutting tools for industrial use. Seeks to develop better high-speed, high-precision production equipment and assist the user in its selection.

SIC TITLE: Electric and Electronic Equipment

■ PREVALENCE IN WESTERN TERRITORY

High. Electric and electronic equipment manufacturers are located throughout the United States.

■ DESCRIPTION

The electric and electronic equipment industry is ranked eighth for electricity consumption. Industries in the sector produce a wide range of products including electric distributing equipment, household appliances, communication equipment, and electronic components and accessories. More efficient motors and drives for materials-handling equipment and heating, ventilating, and air conditioning equipment is a demand-side management opportunity common to the sector as a whole. Induction heating, infrared heating, laser processing, and automation are anticipated to be more widely used by SIC 36 in the 1990s. Electricity accounted for approximately 48% of the energy consumed by the industry in 1988 or about 31,852 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS:

Electronic Engineering Times, CMP Publishing Co., Manhasset, NY.

Electronic Packaging and Production, Cahners Publishing Co., Des Plaines, IL.

TRADE ASSOCIATIONS:

National Electrical Manufacturers Association
2101 L St. NW
Washington, DC 20037
(202) 457-8400

Membership consists of companies that manufacture equipment used for the generation, transmission, distribution, control, and utilization of electric power. Objectives include maintaining and improving quality and reliability of products, energy conservation, and efficiency.

SIC TITLE: Transportation Equipment

■ PREVALENCE IN WESTERN TERRITORY

Medium. Approximately 9,500 transportation and equipment manufactures are distributed throughout the United States.

■ DESCRIPTION

The transportation equipment industrial sector is ranked eighth and fifth, respectively, for energy and electricity consumption. The sector, which manufactures products from bicycles and automobiles to guided missiles and space vehicles, is dominated by the motor vehicles equipment industry. This industry consumes more than half of the total electricity consumed by SIC 37. The conversion from fossil fuels to electricity for heat-intensive manufacturing processes provides an opportunity for increased electrical use for all industries in the sector. More efficient electrical processes may include infrared heating and curing of point coatings, induction and resistance heating for preheating and heat treatment of metal parts as well as heating metal for forming and forging, and electron-beam heating operations for surface hardening of high-wear metal parts. Electron beam welding and increased flexible manufacturing applications may also be beneficial to the sector. Electricity accounted for approximately 36% of the energy consumed by the industry in 1988 or about 37,283 million kWh.

■ FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management Volume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

PERIODICALS:

Intermodal Reporter, K-III Press, Inc., New York, NY.

TRADE ASSOCIATIONS:

Motor Vehicle Manufacturers Association of the United States
7430 2nd Ave., Ste. 300
Detroit, MI 48202
(313) 872-4311

Manufacturers of passenger and commercial cars, trucks, and buses.

SIC NUMBER: 38

SIC TITLE: Instruments and Related Products

PREVALENCE IN WESTERN TERRITORY

Medium. Instruments and related products manufacturers are found in all states of the western territory.

DESCRIPTION

The instruments and related products industry is a low energy- and electricity-intensive industry relative to the other industrial SIC categories. The measuring and control devices, medical instruments and supplies, and photographic equipment industries combined consume approximately three-quarters of the total electricity consumed by the sector. The majority of the sector's energy consumption is for process and space heating and for motors and drives. Energy use in these areas could be favorably affected by demand-side management technologies such as resistance heating, laser processing, and energy-efficient motors and drives. Automation also has potential for growth in the sector. However, the complex and highly customized process operations and the rapidly changing product technology limits possible automation applications. Electricity accounted for approximately 43% of the energy consumed by the industry in 1988 or about 14,344 million kWh.

FOR MORE INFORMATION

REFERENCES:

IECON: International Conference on Industrial Electronics, Control and Instrumentation Proceedings, IEEE Industrial Electronics Society Conference, Institute of Electrical and Electronic Engineers, Inc., New York, NY.

PERIODICALS:

MP Letter, Washington Business Information, Arlington, VA.

Medical Device and Diagnostic Industry, Canon Communications, Inc., Santa Monica, CA.

TRADE ASSOCIATIONS:
Instrument Society of America
P.O. Box 12277
67 Alexander Dr.
Research Triangle Park, NC 27709
(919) 549-8411

Educational organization dedicated to advancing knowledge and practice related to the theory, design, manufacture, and use of instruments and controls in science and industry.

SIC TITLE: Miscellaneous Manufacturing

PREVALENCE IN WESTERN TERRITORY

High. The miscellaneous manufacturing industries sector is represented throughout the United States.

DESCRIPTION

The miscellaneous manufacturing industries sector is one of the lowest energy- and electricity-intensive industrial sectors. The unrelated industries that comprise this sector have such varied processing operations that demand-side management opportunities must be evaluated on a site- and process-specific basis. Motors and drives applications for materials handling, heat treating, mixing, molding, and space ventilation equipment account for nearly all of the electricity consumed by the sector. Energy-efficient motors and drives provide the most potential for energy conservation. Electricity consumption for space and process heating application tend to be low for the sector. Heating electrotechnologies may benefit some industries and increase the amount of electricity consumed for heating applications. Electricity accounted for approximately 10% of the energy consumed by the industry in 1988 or about 4,183 million kWh.

FOR MORE INFORMATION

REFERENCES:

Electric Power Research Institute, *Demand-Side Management Valume 5: Industrial Markets and Programs*, EPRI EA/EM-3597, March 1988.

APPENDIX A

DIRECTORY OF ENERGY ANALYSIS AND DIAGNOSTIC CENTERS

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APPENDIX B

BOILER EFFICIENCY TIPS

1. Conduct flue gas analysis on the boiler every 2 months. Optimal percentages of O_2, CO_2, and excess air in the exhaust gases are given by:

Table B-1.

Fuel	O_2 (%)	CO_2 (%)	Excess Air (%)
Natural gas	2.2	10.5	10
Liquid petroleum fuel	4.0	12.5	20
Coal	4.5	14.5	25
Wood	5.0	15.5	30

The air-fuel ratio should be adjusted to the recommended optimum values if possible; however, a boiler with a wide operating range may require a control system to constantly adjust the air-fuel ratio.

2. A high flue-gas temperature often reflects the existence of deposits and fouling on the fire and/or water side(s) of the boiler. The resulting loss in boiler efficiency can be closely estimated on the basis that a 1% efficiency loss occurs with every 40°F increase in stack temperature. The stack-gas temperature should be recorded immediately after boiler servicing (including tube cleaning) and this value should be used as the optimum reading. Stack-gas temperature readings should be taken on a regular basis and compared with the established optimum reading at the same firing rate. A major variation in the stack-gas temperature indicates a drop in efficiency and the need for either air-fuel ratio adjustment or boiler-tube cleaning. In the absence of any reference temperature, it is normally expected that the stack temperature will be less than 100°F above the saturated steam temperature at a high firing rate in a saturated steam boiler (this doesn't apply to boilers with economizers and air preheaters).

3. After an overhaul of the boiler, run the boiler and re-examine the tubes for cleanliness after 30 days of operation. The accumulated amount of soot will establish the criterion as to the necessary frequency of boiler-tube cleaning.

4. Check the burner head and orifice once a week and clean if necessary.

5. Check all controls frequently and keep them clean and dry.

6. For water-tube boilers burning coal or oil, blow the soot out once a day. The National Bureau of Standards indicates that 8 days of operation can result in an efficiency reduction of as much as 8%, caused solely by sooting of the boiler tubes.

7. The frequency and amount of blowdown depend on the amount and condition of the feedwater. Check the operation of the blowdown system and make sure that excessive blowdown does not occur. Normally, blowdown should be no more than 1% to 3% of steam output.

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