A small-business guide

Wood Preservers

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Wayne Krill manages the Small Businesses Target at EPRI and directed development of this *Guide.*

ABOUT THIS GUIDE

Members of the small-business community historically have had little contact with their energy providers. This guide was developed to facilitate communication between electric utilities and the wood preserving businesses in their communities.

The *Wood Preservers* guide is intended to familiarize readers with the business of owning and/or operating a wood preserving company by providing descriptions of basic processes and practices, and summaries of the issues and challenges faced by wood preserving facility owners and managers.

This business guide is one of a series of publications produced by EPRI about small businesses. The *Wood Preservers* guide is based on extensive and ongoing research and contains the latest information available at the time of publication. Nevertheless, it is a work in progress rather than a definitive and final document. The information and resources presented offer the reader a solid perspective from which to develop electricity-based solutions to energy and business needs.

This guide is organized as a reference document for use on an as-needed basis. Section tabs are included to facilitate quick access to topics of interest; icons representing energy end uses are also provided to help with locating complete information on electrotechnology solutions.

Wood is a favored construction material for everything from cabinets to bridges. It is also relatively fragile. Much of the wood intended for outdoor use or contact with the ground or water is treated with chemical preservatives and/or fire retardants to protect it from physical insults, such as decay or fire.

The U.S. wood preserving industry is small and highly regionalized, consisting of fewer than 500 plants located mainly in the southeastern part of the country. The companies are also typically small (88% have fewer than 50 employees) and customized; most operate one plant and specialize in one type of process. Under the influence of a shaky construction market, mounting competition, and rigorous new environmental regulations, the industry slumped in the early 1990s. By 1993 there was evidence of a rebound and new trends toward larger plants and increased emphasis on production for export. The industry is now expected to continue to grow, given a favorable economy in the United States and the development of overseas markets.

Predicting the health of individual companies is more problematic. Treated wood is a commodity product: a utility pole treated with creosote at one plant is no different from one treated at another plant. Wood preserving businesses are therefore forced to compete on the basis of price alone. Clashing with operators' desire to minimize operating costs, however, are new environmental regulations that affect routine processes as well as spill cleanup (more than 10% of existing facilities are designated Superfund hazardous waste sites).

To succeed in this increasingly competitive and cost-conscious market, wood preserving company owners and operators are seeking tools and procedures that will allow them to reduce operating costs, improve productivity, and comply with environmental regulations. The accompanying table identifies electrotechnologies that address these wood preserving business concerns. These electrotechnologies and other high-efficiency electric technologies are described in the *Wood Preservers* guide (EPRI TR-106676-V12), copies of which are available from the EPRI Distribution Center. To order this publication, or other guides in the series, call the Center at (510) 934-4212.

Electrotechnologies for Wood Preservers

	Ozonation of Wastewater	Membrane Filtration	Ultraviolet Oxidation	Outdoor Lighting	Electric Infrared Space Heating
Description	Ozone and caustic acid are injected into separator wastewater from the oilborne preservative treatment process to destroy phenols and produce a wastewater suitable for sewer discharge.	Electric pumps force wastewater through a permeable barrier that filters contaminants; three types of membranes (microfiltration, ultrafiltration, and reverse osmosis) are available to filter particles of different sizes.	Ozone and/or hydrogen peroxide is dispersed in wastewater, which is then irradiated by ultraviolet (UV) lamps to create highly reactive compounds that break down hazardous organics.	Six types of lighting technologies are available. Each offers different characteristics in wattage, brightness, light tone, efficiency, and life span; they can be combined to meet site-specific needs.	Uses ceiling-mounted infrared (electromagnetic radiation) fixtures to heat people and objects in a space, rather than the air around them.
Wood Preserver Need	Low-cost, quick, and highly effective methods are needed for treating wastewater from oilborne wood treatment.	Wood preservers need to reduce operating costs, including those related to the purchase of chemicals and water and the disposal of wastewater.	Wood preserving plants need effective methods of remediating contaminated groundwater.	Good outdoor lighting is needed to improve the visibility and attractiveness of a facility, reduce the potential for crime, and increase employee safety.	To cost-effectively provide warmth and comfort for workers during cold weather while also allowing for high ventilation rates.
Application	Used to decontaminate the separator wastewater left from cleaning the pressurized treatment cylinder in oilborne processing.	Used in some plants to treat the separator wastewater from oilborne processing to reduce contaminant volume; in others, to filter waterborne preservatives prior to reuse.	To treat oilborne process wastes contaminated with pentachlorophenols and other chlorinated solvents.	Lighting on signs on or near a facility; in parking lots, walkways, and delivery areas; on the building facade; and in the landscape or surrounding area.	Can be used in cold weather to heat treatment and/or storage areas that require high ventilation rates and that may be exposed to the outdoors.
Benefits	Removes hazardous organic compounds such as creosote and hydrocarbons from wastewater without producing harmful by-products.	Treats cleanup water from oilborne treatment to produce wastewater suitable for sewer discharge, and recovers waterborne preservatives to allow their reuse.	Destroys almost 100% of hazardous substances in contaminated water, works in the original media, forms no by-products.	General and facade lighting can increase the public perception of quality, goodwill, and success; area lighting can help reduce accidents, injuries, and crime.	Relatively inexpensive and easy to install; ensures worker comfort while allowing a background temperature of 50–60°F, thereby reducing energy use as compared to conventional systems.
Cost	The capital cost of a small wastewater ozonation system (generating 1–10 lb of ozone per day) is $8000–$25,000; the capital cost of a large system (20–50 lb of ozone per day) is $75,000–$200,000.	For systems processing 0.1–10.0 gallons per minute, the purchase cost is $5000–$100,000; the operating cost is $0.05–$0.40 per 100 gallons.	System capital costs are $25,000–$400,000; the capital cost of a UV oxidation system with a reactor volume of 725 gallons and a maximum feed rate of 50 gallons per minute is about $50,000.	Systems are custom-designed to meet a facility's needs and budget.	A small, four-fixture unit costs under $2000; a large, industrial-size system with specialized controls costs over $100,000.

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INTRODUCTION TO THE WOOD PRESERVING INDUSTRY

Wood has many advantages over other structural materials: it is strong, durable, light, easy to work with, and is a renewable resource. It also has two important disadvantages: it is flammable and can be easily decayed by insects and microorganisms. As a result, wood must be treated with chemical preservatives and fire retardants prior to use as a building material.

Business Statistics

The widespread use of wood preservatives began in the nineteenth century. The wood preserving industry developed rapidly in the 1880s as the expansion of the railroad system created a demand for durable wooden railroad ties. The industry's second growth spurt began in 1925 as electric utility companies increased their orders for wood utility poles. Demand for building materials that could survive in marine environments provided the impetus for a third expansion of the industry in the 1930s, when research yielded a preservative effective against infestation by the marine borer.

The wood preserving industry is relatively small and regional; there are fewer than 500 plants, concentrated mostly in the southeastern states (see Table 1). Wood preservers are typically small businesses located in rural areas, primarily because the preservation process does not require advanced technology and is most economically performed near timber cutting operations. The most significant challenges facing wood preservers today are a competitive commodity-type market and stringent environmental regulations.

Table 1
Profile of the Wood Preserving Industry

Year	No. of Establishments	No. of Employees	Value of shipments ($ billions)
1987	540	11,800	2.2
1988	522	11,700	2.2
1989	505	12,100	2.4
1990	494	13,000	2.5
1991	496	11,700	2.5
1992	486	10,800	2.6
1993	481	11,147	3.1

Source: U.S. Department of Commerce and Bureau of the Census, *Census of Manufacturers, Annual Survey of Manufacturers*, and *County Business Patterns—United States*, various years.

Businesses in the wood preserving industry (Standard Industrial Classification [SIC] code 2491) use chemicals to treat sawed or planed wood, poles, parts, and pilings. Treated wood is used whenever construction plans dictate that wood building components will be in contact with the ground or water. These preservatives protect the wood against decay, insects, and fire, assuring structural soundness and long life. The principal products of the industry are treated utility poles, railroad ties, and construction materials.

The industry itself is characterized by a large number of small, privately owned plants and a few large, integrated corporations. Most firms operate only one plant and specialize in one type of preservative and one treatment process. As a result, no single facility or process can be considered "typical." In 1993, there were an estimated 481 plants, 88% of which had fewer than 50 employees and 98% of which had fewer than 100 employees (see Table 2).

Table 2
Distribution of Wood Preserving Plants by Size (1993)

Year	No. of Establishments	Percent of Total
Small (0-49 employees)	424	88
Medium (50-99 employees)	47	10
Large (100+employees)	10	2
TOTAL	481	100

Source: U.S. Department of Commerce and Bureau of the Census, *County Business Patterns 1993,* CBP-93-1,1995.

The number of people employed in the industry increased during the late 1980s, peaking at 13,000 in 1990, but fell in the early 1990s primarily due to stagnant sales and increasing productivity. The value of industry shipments remained stable at $2.5 billion through 1990 and 1991, reflecting a slow down in the construction market due to the economic recession. Strict new environmental regulations were also introduced in the early 1990s. The U.S. Environmental Protection Agency (EPA) identified wood preserving process by-products as hazardous wastes in 1990 and began regulating the industry in 1991. By 1993, the overall economy and the industry had recovered from the recession: industry shipments rose to $3.1 billion, and industry new capital expenditures rose from $42 million in 1991 to $52.8 million in 1993. Although the number of establishments is steadily declining, the number of people employed rose in 1993 to more than 11,000. The industry is expected to continue to grow through the 1990s due to further economic recovery and the increased export of treated wood to the Caribbean, Mexico, and Canada.

There are four major types of wood preservatives:

Creosote. Creosote is a translucent brown-black oil used to improve the weathering characteristics of wood, protect it from damage by insects and/or fungi, and promote its insolubility in water. Polyaromatic hydrocarbons (PAH) are insoluble in water and difficult to degrade; they are the main component of creosote. Creosote is applied either full-strength or diluted with petroleum oil or coal tar. Because of its disadvantages—dark color, oiliness, tendency to bleed, and resistance to being covered up with paint—creosote is primarily used in treating railroad ties, utility poles, and timber for highway bridges and guardrails.

Oilborne. Pentachlorophenol (PCP), the most common organic wood preservative, is a crystalline compound dissolved in a light petroleum oil. Products treated with PCP are resistant to both insects and fungi and provide a surface receptive to paint. PCP is widely used to treat utility poles and piling and timber for freshwater bridges.

Waterborne. Waterborne wood preservatives contain inorganic salts such as copper, chromium, and arsenic. The most common waterborne preservatives are chromated copper arsenate (CCA) and ammoniacal copper-zinc-arsenate (ACZA). Wood treated with inorganic compounds is clean, odorless, and easy to paint. As a result, wood treated with waterborne preservatives is preferred for decks, playground equipment, and agricultural stakes. Waterborne preservatives are also widely used for utility poles and marina construction. A primary disadvantage is that the wood must be dried thoroughly before treatment.

Fire Retardants. Fire retardants, such as borates, phosphates, and ammonia compounds, are also waterborne but can contain hazardous chemicals such as zinc chloride and titanium dioxide. Wood products treated with fire retardants have advantageous characteristics including slow ignition, low flame spread, and reduced smoke.

Creosote was first used in the 1870s; because of its aesthetic limitations, high level of toxicity, and inability to stand up to marine environments, researchers immediately initiated development of alternative preservatives. This research resulted in the formulation of PCP, CCA, and ACZA in the 1930s. Today, 75% of all treated wood is treated with waterborne inorganic preservatives (primarily CCA). Of the remainder, 15% is treated with creosote, 8% with PCP, and 2% with fire retardants.

While essential to the use of wood as a structural material, all four major classes of preservatives are toxic. Creosote is a known carcinogen. PCP is lethal to many living organisms and can break down into chlorinated dioxins—potentially carcinogenic compounds currently under investigation by the EPA. CCA is a major chemical pesticide; and in addition to being poisonous, arsenic is also mutagenic and carcinogenic. Despite the toxicity of the widely used preservatives, the EPA has determined that the benefits of wood treatment outweigh the potential health and environmental risks. The preservatives are, however, classified as "restricted-use" chemicals and can be sold to and used by certified professionals only.

Utility poles currently represent the largest market for the wood preserving industry, accounting for approximately 25% of all sales. Most utility poles are treated with oilborne preservatives; some are treated with creosote. Other treated wood products include pilings, lumber, plywood, timbers, posts, and railroad ties.

To avoid transportation expenses, wood preservers tend to be located close to timber cutting operations. As a result, the largest concentration of wood preserving plants is found in the southeastern United States, where much of the country's wood is harvested. In 1993, the leading states, in terms of the number of establishments, included North Carolina, Alabama, and California. Other states with significant numbers of wood preserving businesses include Georgia, Virginia, Texas, Pennsylvania, Mississippi, Florida, and South Carolina (see Figure 1).

States	Facilities
NC	31
AL	29
CA	25
GA	23
VA	23
TX	22
PA	19
MS	19
FL	18
SC	17

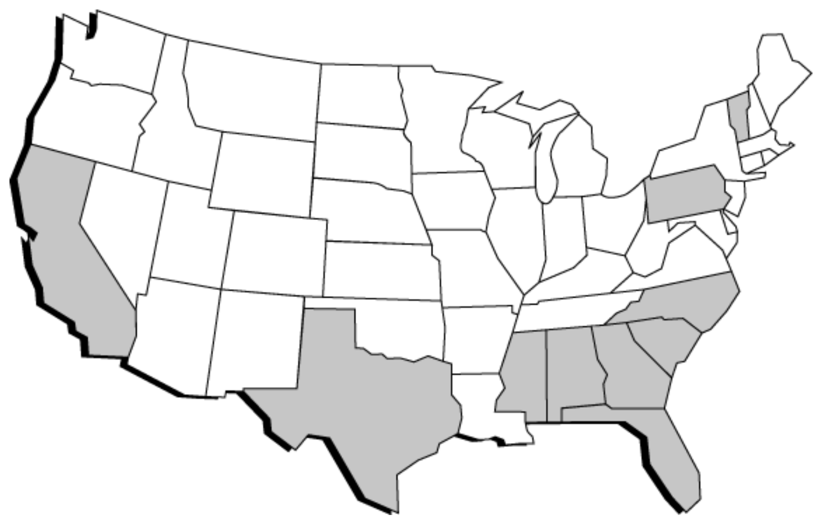


Figure 1
Top 10 Wood Preserving States

The Wood Preserving Process

It is difficult to characterize a "typical" wood preserving process since each plant's operation depends on the type of product it treats, the type of preservative it uses, and the type of treatment process it employs. In general, however, wood preservation is a two-stage process that involves pretreating or conditioning wood (to reduce moisture content) and preserving it with chemicals, using one of two treatment procedures.

Pretreatment/Conditioning. The lumber typically arrives by truck. The wood may go through an initial wash to remove road dust and grime. It is then stored until processing. Most wood is conditioned using ambient air drying, kiln drying, or steaming to remove excess moisture. Open air drying is typically used before treatment with organic (oilborne) preservatives, although steaming, heating, and vapor drying are other options. Kiln drying is typically used prior to treatment with waterborne (inorganic) preservatives.

Treatment. There are two methods of treating wood: pressure treating and thermal (or vacuum) treating. The process is generally determined by the wood species, the preservative used, and the end product. Approximately 97% of the plants in the United States preserve wood using a pressure treatment process; the remaining 3% use thermal treatment. Treatment conditions are usually controlled by computer to achieve proper chemical retention and minimal drippage.

- Pressure Treatment. In the pressure treatment process, lumber is loaded into a large cylinder. After the cylinder is sealed, a vacuum is created to remove air from the cylinder, and then a solution of water and preservative (organic or inorganic) is pumped into the cylinder at a pressure of 100–150 pounds per square inch (psi). The pressure is maintained 7–10 minutes to accelerate preservative absorption and eliminate excessive dripping. The preservative solution is then pumped out, filtered, and returned to a storage tank for reuse. A vacuum is maintained for 90 minutes in order to remove any residual preservative. The wood is then removed from the cylinder. Most treated wood is dried on a "drip pad" for at least 72 hours to allow any excess preservative to drip out of the wood. The "drippage" is collected, filtered, and returned to the storage tank for reuse. Wood treated with fire retardants is cured in a kiln to "fix" the preservative in the wood, making it virtually insoluble. Figure 2 illustrates the pressure treatment process using waterborne preservatives.

- Thermal or Vacuum Treatment. Although far less common, some wood is treated with a non-pressure, thermal process. In thermal treatment, wood is loaded into a tank of preservative and heated for several hours. It is then quickly submerged in a cold solution of preservative for several more hours. Heating causes air in the wood to expand, forcing it out of the cells. Any air remaining in the cells contracts during the cooling period, thereby forming a vacuum that forces preservative into the wood cells. Only a small percentage of all wood preserving facilities in the United States use this process because it is generally considered less effective.

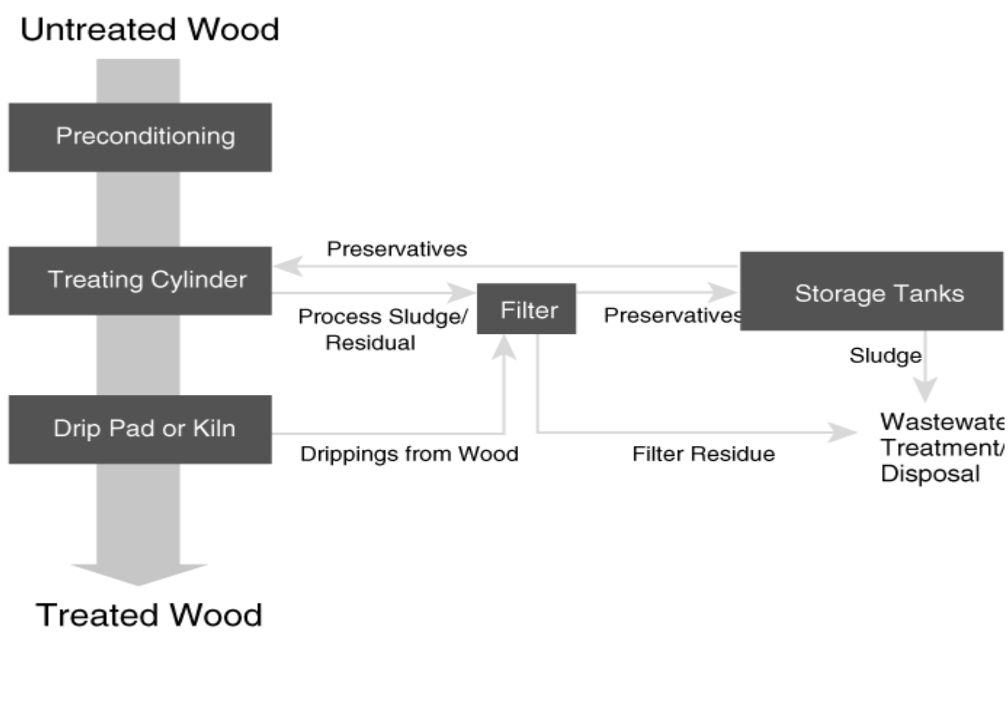


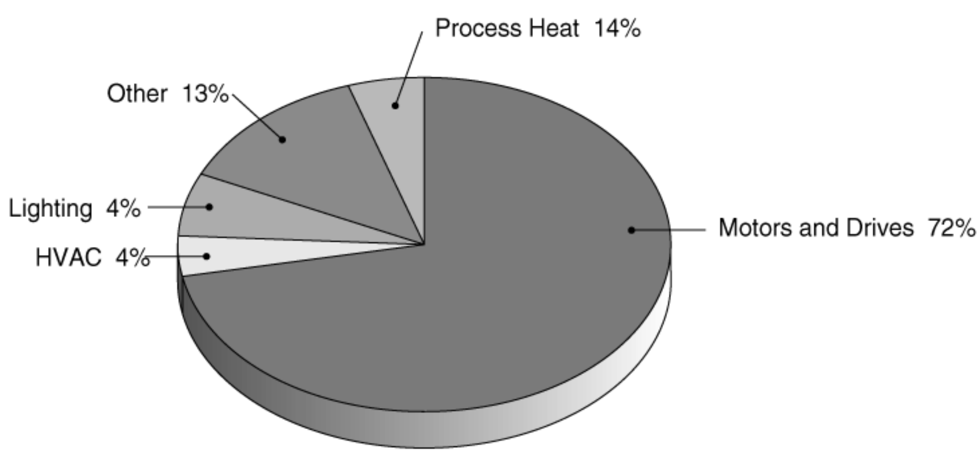
Figure 2
The Pressure Treatment Process Using Waterbome Preservatives

After either process, the treated lumber remains on a conveyor system, suspended over drip pads, for one to two days or until dripping stops. The preserved wood is then brought by forklifts to drying sheds, storage areas in the plant, or to an open yard.

Energy Use

Estimates of energy use by the wood preserving industry alone (SIC 2491) are not available from the U.S. Department of Energy (DOE). However, DOE data on the lumber and wood products industry as a whole (SIC 24, which includes 16 additional categories) indicate a total energy consumption of 423 trillion Btu in 1991. Less than 25% of this energy was electricity (14%) or natural gas (10%). The majority of the energy was provided by nontraditional fuels such as wood waste.

According to the DOE, 17.9 billion kWh of electricity was consumed by the wood products industry in 1991; approximately 77% of this electricity was used for process end uses—72% for driving machinery and 5% for process heating. The non-process uses of electricity included lighting (6%) and heating, ventilation, and air conditioning (HVAC) (4%). Other miscellaneous end uses accounted for nearly 13% of total electricity use (see Figure 3); these include the equipment used for wastewater treatment and/or site remediation and cleanup. Separately, the U.S. Bureau of Census *Annual Survey of Manufactures* reports the cost of electricity for SIC 2491 was $17.3 million in 1991.



Source: U.S. Department of Energy, Energy Information Administration, *Manufacturing Consumption of Energy, 1991*, DOE/EIA-0512(91), December 1994.

Figure 3
Primary Electricity Use in Wood Preserving Facilities

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BUSINESS CHALLENGES AND NEEDS

The major factors governing any wood preserving company's sales are competition within the industry, the U.S. economic climate, and the relative cost of alternative building products such as concrete, steel, and plastic. Since there is little difference between wood treated with waterborne preservatives by one company and similarly treated wood from another plant, companies must keep prices low in order to compete effectively in the market. As a result, improving productivity and reducing operating costs are key business needs.

Competition

In addition, because the wood treatment process employs a number of toxic chemicals, and past carelessness has contaminated the soil and groundwater at many plant sites, the wood preserving industry is now subject to strict environmental regulations. The cost to comply with environmental regulations has forced some older wood preserving facilities to shut down and is a continuing challenge to those still in business.

Preserved wood is largely a commodity market, which forces wood preservers to compete almost purely on the basis of price. The one key differentiating cost factor is transportation. Keeping prices low is a matter of keeping operating costs low and increasing productivity.

Need

Reduce Operating Costs

Since the 1970s, the wood preserving industry has experienced significant increases in the cost of raw materials—primarily chemicals and wood. Although wood preservers have raised their retail prices somewhat to counteract this fact, they compete on the basis of price within the industry and against alternative construction products within the United States and overseas. Increasing the energy efficiency of process, lighting, or HVAC equipment; improving productivity and thereby reducing labor costs; and reducing hazardous waste disposal costs are options that have the potential to reduce a facility's total operating costs.

The wood preserving industry itself is not electricity-intensive. For example, in 1991, electricity purchases of $17.3 million represented less than 1% of the total cost of materials, which was $1.9 billion. Wood products and chemicals account for the majority of the materials cost. Therefore, a facility owner is unlikely to invest in equipment to improve energy efficiency and achieve electricity cost savings—unless the improvements also help the plant become more productive, operate more cost-effectively, or comply with environmental regulations. Typically, small companies (fewer than 20 employees) require paybacks of 1–2 years; larger companies may accept paybacks of 3–5 years. Some wood preserving companies are willing to make significant investments (implying longer paybacks) to ensure they are on the cutting edge of technology developments and environmental protection; they view these investments as insurance against potential competitive disadvantage or future environmental liabilities.

Technology Solutions

Technologies such as energy-efficient motors, adjustable speed drives (ASDs), and energy-efficient indoor and outdoor lighting can trim a plant's operating costs by reducing its electricity consumption. Electric infrared (IR) space heating can also potentially reduce operating costs by allowing a facility to heat only the people and objects in a warehouse, rather than the full volume of air inside the warehouse. Membrane filtration of wood preserving chemicals can reduce operating costs by allowing chemical reuse, limiting wastewater treatment costs or charges from the publicly owned treatment works (POTW), and minimizing chemical purchases.

See pages 3-3, 3-4, 3-7, 3-9

Need

Increase Productivity

The typical measure of a wood preserving facility's productivity is board feet of wood treated—per day, week, or year. Productivity stems from a variety of factors including the type of treatment, product mix, and plant design. Stringent environmental regulations and the drive for increased productivity have prompted many wood preservers with older facilities to rethink their entire production process and layout. The increasing use of integrated facility design principles in the retrofitting of older facilities and the development of new facilities has led to improvements in productivity and environmental safety (see Text Box).

Integrated Facility Design

Since the implementation of environmental regulations, it has become increasingly common in the wood preserving industry to meet EPA requirements by building an entirely new plant rather than retrofitting an older plant. Owners often decide against upgrading when they determine that an existing facility is poorly designed for efficient materials handling, and when compliance with new environmental regulations by retrofitting would cost more than building a new treatment plant.

The design of new wood preserving plants is typically based on the environmental safety concept of "containing, capturing, recycling, and preventing"; many new plants include safety features not yet required by law. For example, most new facilities incorporate pollution prevention technologies. As a result, the industry as a whole has achieved a large reduction in the amount of hazardous waste it produces.

A well-designed treatment plant typically has the following features:

- **Enclosed Treatment Buildings.** Enclosed treatment buildings protect chemicals, treatment facilities, freshly treated wood, and drip pads from direct exposure to ambient weather conditions, thereby reducing the possibility of chemical contamination of the environment.

- **Covered Drip Pads and Drip Pads with Liners.** Drip pads intercept chemicals dripping from cylinder doors and freshly treated lumber. Covered drip pads and drip pads with liners significantly reduce the chances of contamination of surrounding areas.

- **Automatic Lumber Handling Systems and Power Rollers.** Automatic lumber handling systems and power rollers for lumber loading, unloading, and cylinder transfer reduce the potential for direct contact between employees and/or equipment (e.g., forklifts) and preservatives. These automated systems increase productivity and employee safety.

- **Centralized Tank Farms with Spill Containment.** Plants can be designed so that chemical tanks are located in a separate area, and so that these areas are adequately contained to ensure that the preservatives are retained in the event of a spill or tank rupture. Enclosed, computer-controlled mixing systems and remote monitoring can also limit worker time in the "tank farm," decreasing worker exposure to chemicals and reducing the possibility of transferring chemicals outside of the mixing area through employee contact/contamination.

Advances in closed production processes and handling systems have already allowed wood preservers to increase their operating efficiency, maximize recycling and reuse of preservatives, and minimize the generation of hazardous wastes on a case-by-case basis.

Through integrated facility design and improvement in process interaction, significant opportunities exist for even greater efficiency gains and pollution prevention in the wood preserving industry.

Technology Solutions

In addition to integrated design practices, a number of individual technologies have the potential to increase productivity. For example, ASDs can improve process control as well as reduce electricity consumption. Improved indoor lighting levels—for example, better brightness or reduced glare—can enable employees to see better and more comfortably. Added outdoor lighting can indirectly improve productivity by contributing to safety in the workplace and thereby helping to prevent accidents and time off the job. Finally, electric IR space heating can provide employees comfort during cold weather, thereby also potentially improving productivity.

See pages 3-3, 3-8, 3-9

Environmental Regulations

The wood preserving process generates both hazardous wastewater and hazardous solid waste. Process wastewater, surface water runoff, and sludge are all potential sources of contamination. Process wastewater includes water from preconditioning, kiln drying, washing treated wood, and residue from drip pads. Surface water runoff flows from non-process areas such as treated wood storage yards. Sludge typically consists of oil-water emulsions, water-and-debris mixtures, and wood debris.

The more common waterborne treatment processes produce little or no wastewater because the preservative that accumulates on drip pads, the rainwater collected in process areas, and the water used to clean drip pads are reused in the treatment process. As a result, no contaminated water is discharged to the sewer. Instead, the process is managed so that the filter sludge, which is collected in drums and sent off-site for treatment and disposal by licensed handlers, is the only hazardous waste generated.

Plants that treat wood with oilborne preservatives, on the other hand, produce large quantities of wastewater. In this case, the wastewater is sent through a water separator where the oilborne preservative is recovered. The preservative is then returned to the process; the residual wastewater is then treated and sent to the sewer.

Wood treatment wastewater, process residuals, preservative drippings, and spent preservatives from PCP, creosote, and CCA processes are all considered hazardous waste by the EPA. Wastewater filter sludge from creosote and/or PCP (oilborne) processes is also listed by the EPA as hazardous waste. The sludge, dirt, and solid waste collected from drip pads, cylinder door pits, and pump screens is typically stored in 55-

gallon drums for disposal at a hazardous waste landfill. Many wood preserving businesses are licensees of the chemical company that supplies the oilborne or waterborne preservatives used in their treatment process. In this case, when the chemical company delivers new preservatives, it picks up the drums of filter sludge and disposes of them. Other wood preservers buy their preservatives on the open market and are responsible for hiring a licensed handler to treat and/or dispose of their hazardous waste. A wood preserving facility treating 50 million board feet of wood each year might fill as few as two and as many as five 55-gallon drums of hazardous waste per year, depending on variations in housekeeping and filtering practices.

If these hazardous wastes are not properly managed, they can contaminate the soil as well as groundwater and surface water. As a result, the industry is regulated by both the Resource Conservation and Recovery Act (RCRA) and the Clean Water Act (CWA). RCRA regulates solid and hazardous waste handling, transportation, and disposal. The CWA protects the nation's waterways from further environmental degradation. In addition, some wood preserving plants are subject to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) also known as Superfund. In the past, due to faulty or absent waste management practices, some wood preserving operations seriously contaminated the soil, groundwater, and surface water at their sites. In fact, wood preserving facilities represent the largest single category of sites listed under Superfund. At least 54 wood preserving facilities have been designated as Superfund hazardous waste sites, and an additional 85 sites are currently undergoing Superfund evaluation. The cost of cleanup has severely strained the financial resources of the affected wood preserving businesses, causing several to shut down completely.

While wood preservers have a history of polluting, new practices in production, handling, and integrated design have helped maximize the recycling and reuse of preservatives and minimize the generation of hazardous waste. This has significantly reduced the potential for future contamination.

Today, hazardous waste generated by wood preservers is almost always sent off-site for treatment. According to the American Wood Preservers Institute, wood preserving facilities do not consider on-site waste treatment feasible due to the environmental regulatory complications that would ensue.

Need

Comply with Environmental Regulations

In November 1990, the EPA designated certain wood preserving process wastes as hazardous under RCRA Subtitle C. These wastes include wastewater, process residuals, preservative drippings, and spent preservatives from creosote, PCP, and CCA treatment processes. Wood preservers have had great difficulty in meeting RCRA requirements. The expenses include not only new costs for waste disposal, but the capital costs associated with purchasing the waste-minimizing technologies required under RCRA.

In 1992, the EPA promulgated “drip pad” management practices and technical requirements to prevent further contamination from drippage. Wood preservers are now required to hold treated wood on a drip pad adjacent to the treating cylinder until all dripping stops. The drip pads also must be coated with an impermeable sealer or equipped with a liner and a leak detection system. Depending on the age of its existing drip pad(s), a facility can have up to 15 years to upgrade. Existing and new drip pads must also meet a permeability standard. The Congressional Budget Office estimates that the wood preserving industry’s annual expenditure for RCRA compliance, including the 1992 stipulations, may be as high as $66 million, or roughly 2% of the value of shipments.

Wood preserving companies using oilborne preservatives and discharging treated wastewater to a local wastewater treatment plant or POTW also may be subject to discharge restrictions under the CWA. Most POTWs restrict the level of fats, oils, and grease (FOG) as well as the level of toxic organics that a facility can discharge to them. Separately, wood preservers are required, under the CWA, to control storm water or the runoff from rain to protect areas surrounding their facilities. Potential solutions include constructing roofs or wastewater collection systems for storage yards to eliminate the risk of contamination due to runoff. Compliance costs for this requirement alone could reach $200,000 per facility, even for relatively small operations.

Technology Solutions

A number of electrotechnologies are available to help wood preservers treat their hazardous wastewater and maximize recycling and reuse of preservatives. Ozone can be used to treat the separator wastewater generated in the oilborne preservation process. Ozone destroys the hazardous organic components of the wastewater, such that the treated water can be disposed of in the sewer. Membrane filtration can be used to filter the residual preservative, thereby minimizing the volume of hazardous waste requiring safe disposal and maximizing reuse of the preservative. Electrotechnologies are also available and under development to help with spill cleanup and site remediation. These technologies include ultraviolet (UV) oxidation, biological oxidation, and super-critical water oxidation; the latter two technologies are still in the commercialization phase.

See pages 3-4, 3-6

3

TECHNOLOGY SOLUTIONS

This section describes each of the technology solutions identified in the previous section. Each technology is summarized, linked by end-use application to a business need, and categorized as an "electrotechnology" or an "efficiency technology." Electrotechnologies are selected new or alternative electric equipment options. In many wood preserving applications, the electrotechnologies can reduce operating costs, increase productivity, and/or help control pollution, and may combine increased energy costs with an overall decrease in operating costs. Efficiency technologies, in contrast, offer opportunities to decrease energy use, but typically have little or no direct impact on production.

Also discussed are "emerging electrotechnologies," electrotechnologies not currently in use in the industry that have the potential to meet a business need in the future. Each electrotechnology is more completely described in Section 4, Electrotechnology Profiles. Vendors of the electrotechnologies, sources of information on efficiency technologies, and trade associations are listed in Section 5, Resources.

In this section, technologies are grouped and discussed by end use, beginning with "Motors and Drives," the end use that represents the greatest percentage of total wood preserving industry electricity use. Table 3 summarizes the technology solutions.

Table 3
Technology Solutions to Wood Preserving Industry Needs

			Business Needs		
End Use	**Solution Type**	**Technology Type**	**Reduce Operating Costs**	**Increase Productivity**	**Comply with Environmental Regulations**
Motors and Drives	Efficiency Technology	Energy-Efficient Electric Motors	■		
Motors and Drives	Efficiency Technology	Adjustable Speed Drives	■	■	
Process Equipment	Electrotechnology	Ozone Treatment of Separator Water			■
Process Equipment	Electrotechnology	Membrane Filtration	■		■
Process Equipment	Electrotechnology	Ultravoilet Oxidation			■
Process Equipment	Emerging Electrotechnology	Biological Oxidation			■
Process Equipment	Emerging Electrotechnology	Supercritical Water Oxidation			■
Lighting	Efficiency Technology	Energy-Efficient Indoor Lighting	■	■	
Lighting	Electrotechnology	Energy-Efficient Outdoor Lighting	■	■	
HVAC	Electrotechnology	Electric Infrared Space Heating	■	■	

Motors and Drives

Electric motors and drives consume more than 72% of the electricity used in the lumber and wood products industry, SIC 24, of which wood preserving is a part. In a wood preserving plant, this electricity is used to drive pumps, fans, and compressors throughout the preconditioning and treatment process, and to drive conveyor systems that transport the wood from storage, through the treatment process, and back to storage.

The primary electricity consumers are the vacuum and pressure pumps. Vacuum pumps, high-pressure pumps, and air compressors are all used in the treatment process. A vacuum pump creates a vacuum in the pressure treatment cylinder, removing the air to increase penetration of chemicals into the wood. A high-pressure pump then pumps in a preserving solution at pressures of 50–2000 psi. The pressure is held 5–15 minutes, depending on the species of wood and its size. After release of the pressure, a vacuum is again pulled in the cylinder to remove excess preservative from the lumber.

Opportunities to increase the efficiency of electric motor-driven systems at wood preserving plants include using energy-efficient electric motors and ASDs.

Efficiency Technology Solution
Energy-Efficient Electric Motors

Energy-efficient electric motors (also known as premium- or high-efficiency motors) are typically 2–6% more efficient than their standard counterparts and cost 15–30% more than standard motors. Over a typical 10-year operating life, a motor can consume electricity valued at more than 50 times the initial cost of the motor. As a result, energy-efficient motors are usually extremely cost-effective, having a simple payback of less than 2 years when compared to the purchase of a standard-efficiency motor. The payback is typically attractive unless electricity prices are very low or a motor is operated very infrequently. Energy-efficient motors are also manufactured to closer tolerances, use better materials, and offer more robust construction when compared to standard motors. This translates into improved reliability and reduced maintenance requirements.

Efficiency Technology Solution
Adjustable Speed Drives

ASDs, also known as variable-speed drives, should be considered for motors over 5 horsepower, particularly those on vacuum and pressure pumps and exhaust fans. Most motor systems are designed to meet maximum demand. In many cases, however, actual demand varies such that a system frequently operates at less than design capacity. Traditionally, these conditions are mediated by throttling valves or outlet dampers that reduce system output; however, the amount of energy they use does not always decrease in proportion to their reduced output. ASDs use solid-state electronics to vary the frequency of electricity applied to a motor. By reducing the frequency below the nominal 60 hertz, ASDs can efficiently reduce the speed or output of a motor, thereby allowing precise adjustments to the speed of a motor to match load requirements.

In addition to saving energy, ASDs can increase process control, thereby potentially improving overall productivity and product quality. ASDs can also increase the service life and decrease the maintenance costs of motors because they are automated to adjust the power draw to coincide with the system's resistance. This eliminates costly human error from the control process. ASDs are also less noisy than valves and can significantly reduce the noise level in a plant.

Process Equipment

The second largest electricity user in the lumber and wood products industry is non-motor-driven process equipment. In the wood preserving industry, the miscellaneous end uses in this category include equipment used for wastewater treatment and, in some cases, technologies for site remediation/spill cleanup.

Wastewater Treatment Technologies

Plants that treat wood with waterborne preservatives produce wastewater that can be recycled and reused; plants that treat wood with oilborne preservatives produce large quantities of hazardous wastewater. The hazardous wastewater is generated during the cleaning portion of the process. Specifically, after an oilborne preservative is drained from the treatment cylinder, the cylinder is typically flooded with steam to clean excess preservative and oil from the surface of the wood. The steam is then condensed and drained to a blowdown tank where the preservative is separated from the condensate and held for reuse. This wastewater may still contain some oilborne preservative and is typically treated before being discharged to a POTW.

Electrotechnology Solution
Ozonation of Wastewater

Ozone (O_3) is a very powerful oxidant—more than 150% more powerful than chlorine-based chemicals—that destroys organic substances. Ozone is produced by passing dry air or oxygen through an electric discharge corona, causing O_2 to form O_3. In separator water treatment, ozone is generated and injected (along with caustic soda) into the steam condensate to destroy phenols prior to wastewater discharge to the sewer. At one creosote wood preserving facility, 720,000 gallons of wastewater (annual volume) were treated with ozone for approximately $4000. By using ozone to treat separator water prior to disposal, an oilborne treatment plant operator can reduce hazardous waste disposal costs as well as the company's potential liability for improper disposal. Ozone can also be used to treat drinking water, cooling tower water, swimming pool water, laundry water, and dishwashing water.

Electrotechnology Solution
Membrane Filtration

Membrane filtration has several applications in the wood preserving industry. It can be used to treat separator water from oilborne processing to reduce the volume of hazardous contaminants, and it can be used to filter waterborne preservatives prior to their reuse. In a membrane filtration system, wastewater is circulated under pressure in contact with a specially constructed polymeric film. The type of membrane (microfiltration, ultrafiltration, or reverse osmosis) determines the amount of dissolved and/or particulate matter that is allowed to pass through.

The energy cost of a membrane filtration system is relatively low; electricity is required for the pump only. Other advantages (in comparison to conventional oilborne wastewater treatment and waterborne filtration processes) include low maintenance, because the system contains no moving parts; absence of air emissions; and nearly room temperature operation. Systems are modular and relatively compact; each module is a self-contained pressure vessel housing the membranes and fluid distribution system. The disadvantages of a membrane system are the generation of a residual sludge that must be properly disposed of as a hazardous waste, and the need for periodic replacement of the membrane.

Site Remediation/Spill Cleanup Technologies

Several electrotechnologies are available for site remediation and/or cleanup of wood preserving waste under Superfund (which governs past or abandoned spill sites) and/or RCRA (which covers current spills). These include UV oxidation, biological oxidation, and supercritical oxidation. All three technologies potentially can be used to treat groundwater contaminated by past or new spills. Likewise, all three technologies are theoretically applicable to on-site treatment of hazardous waste at wood preserving plants. At present, however, third-party disposal is the most cost-effective option.

Electrotechnology Solution
Ultraviolet Oxidation

UV oxidation uses a combination of UV radiation and chemical oxidation to destroy some hazardous organic compounds, including wastes contaminated with pentachlorophenols and other chlorinated solvents used in oilborne processing. Ozone is commonly used to treat (oxidize) drinking water, municipal wastewater, and industrial waste. When UV radiation is combined with ozone, however, the radiation acts as a stimulant for the oxidation reactions, resulting in a more thorough destruction of organic contaminants. The UV oxidation process, combining UV radiation and ozone, is also known as an "advanced oxidation process."

UV radiation enhances oxidation by reacting with the ozone to generate a large concentration of hydroxyl (OH-) radicals. The hydroxyl radicals break down toxic organic wood preserving waste into carbon dioxide, water, and chloride ions. The UV radiation is then absorbed by these compounds, making them more susceptible to subsequent oxidation. The process can achieve 99% destruction of oilborne wood preserving wastes such as pentachlorophenols.

While the capital cost and electricity requirements of UV oxidation may be higher than those of other remediation options, the technology has the advantage of destroying hazardous compounds in their original media and avoiding the formation of by-products that require further treatment and/or disposal. UV oxidation is currently being used in a few U.S. wood preserving facilities to remediate groundwater. Future applications are expected to include wastewater treatment.

Emerging Electrotechnology Solution
Biological Oxidation

Biological treatment can be used to destroy nonvolatile organics such as creosote and pentachlorophenol in wastewater from oilborne treatment plants. In this process, microorganisms biodegrade the organics into gases and other inert matter. The process can be aerobic (oxygen-dependent) or anaerobic. Aerobic treatment is more common because it results in a higher-quality effluent.

Aerobic treatment uses activated sludge systems (i.e., sludge containing microorganisms) to clean wastewater by converting organics into carbon dioxide and water. In this type of system, biomass and wastewater are mixed together in an aeration tank and then passed on to a clarifier. The recycled activated sludge is returned to the aeration tank where the sludge is removed and clean effluent is discharged. Aerobic systems can reach removal efficiencies of 98%.

In anaerobic treatment, bacteria convert organics into methane and carbon dioxide in the absence of oxygen. This process is best suited to higher concentrations of organics. The methane gas generated is either collected or flared. Removal efficiencies for anaerobic treatment can reach 80%. At least one wood preserving facility has claimed success in using bioremediation for its creosote-contaminated groundwater.

Emerging Electrotechnology Solution
Supercritical Water Oxidation

Supercritical water oxidation (SCWO) is an emerging technology for treating industrial process wastes and is potentially applicable to treating groundwater contaminated with wood preserving chemicals. In this process, electricity is used to raise water to its supercritical state: a temperature of 700°F and pressure of 218.3 atm. The water is then used to destroy hazardous organics through oxidation. SCWO can effectively destroy organic wastes such as dioxins, polychlorinated biphenyls (PCBs), and wood preserving chemicals and pesticides. The process can achieve removal efficiencies of nearly 99.9%.

A pilot SCWO unit capable of processing 40 gallons per minute was constructed by the University of Texas at Austin and a private company under a joint research grant. SCWO is also in commercial use at one industrial facility. Unlike incineration, the SCWO reactor is a closed system with no emissions, and its low operating temperature guarantees no production of NO_X. The manufacturer believes that all technical difficulties with SCWO have been overcome, but there is no known commercial release date for the technology.

Lighting

High productivity is one of the keys to maintaining low product prices. Proper indoor and outdoor lighting levels help to provide employees with a comfortable, safe, and productive working atmosphere. Energy-efficient lighting can also help reduce operating costs by lowering electricity consumption.

Three types of lighting systems are used in wood preserving plants; fluorescent tubes with magnetic ballasts are the most common. A typical plant lights the majority of its warehouse-style facility with this type of system. Fluorescent fixtures come in a variety of shapes and sizes, including 8-foot-long tubes and 4-foot-long tubes used in two-, three-, or four-tube fixtures. The basic components of the fluorescent lighting system are fixture, reflector, switch, tubes, ballast, and lens. Compact fluorescent lamps are used by a small percentage of plants.

The second most common lighting source used in wood preserving plants is incandescent lighting. Incandescent fixtures are relatively inexpensive and easy to install. However, incandescent lighting is the least efficient lighting source available and, as a result, is used to light only a small percentage of total floor space. Incandescent fixtures are typically used in offices, hallways, and common areas, but not in treatment or storage areas. They are also used in signs and exit lighting.

The third type of lighting used is high-intensity discharge (HID) lamps. Although these lamps are most commonly used in parking lots and driveways, they also can be used in the large warehouse-style facilities common to wood preserving plants. The HID family of lamps includes mercury vapor, metal halide, and high-pressure sodium lamps. Although HID lamps have higher initial costs, they are more energy-efficient than fluorescent lamps and have longer lives.

Efficiency Technology Solution
Energy-Efficient Indoor Lighting

The most efficient form of fluorescent lighting available today is the T-8 fluorescent lamp with an electronic ballast. Conversion from a magnetic (T-12, 40-watt) ballast to an electronic (T-8, 32-watt) ballast can be accomplished by either retrofitting an existing fixture or installing a new fixture designed for T-8 lamps, at a cost of roughly $40 or $100, respectively. Ceiling-mounted incandescent lamps can be successfully replaced with compact fluorescent lamps when the ceiling height is less than 12 feet, such as in offices or hallways. Mercury vapor lamps can be replaced with either metal halide or high-pressure sodium lamps with relatively short payback.

Electrotechnology Solution
Energy-Efficient Outdoor Lighting

Outdoor lighting is also part of a wood preserving plant's energy bill. Existing applications range from incandescent lights on building signs to mercury vapor lights in loading dock and storage areas. These lighting systems normally represent only a small portion of the energy bill because they are on for limited periods of time and because they seldom contribute to a facility's peak electrical demand. This means there may be relatively small savings potential from energy conservation projects. More significant benefits may accrue through increasing outdoor lighting to reduce the potential for crime and increase employee safety.

Process Heating

Process heating accounts for 5% of electricity use at a typical wood preserving facility. Heating is primarily used in the preconditioning process to remove moisture from wood before it is treated. The method of preconditioning used depends on the type of wood being treated and the treatment process itself, and can include ambient air drying, kiln drying, or steaming. In addition, it is common to heat preservatives during fluid handling to ensure favorable viscosities since oil-based compounds do not flow well at low temperatures. Electric immersion heaters are usually installed in storage tanks to perform this function and facilitate fluid transfer.

In thermal, non-pressure wood treatment, the preservative is heated to promote its reaction with acids formed from wood sugars. Process heat is applied to the preservative using either electric heaters immersed in storage tanks or in boilers. Boilers, which can be powered by fossil-fuel sources or by electricity, are required to generate steam for wood treatment or preservative removal. No electrotechnology or efficiency technology solutions are currently available for this end use.

Heating, Ventilation, and Air Conditioning

In general, there is little use of non-process heating and air conditioning in the wood preserving industry. As a result, HVAC represents only 4% of the industry's total electricity use. Most HVAC electricity is used for ventilation (to ensure employee comfort, health, and safety) and for space heating (to ensure employee comfort in colder climates). Some plants also use fans in drying sheds to circulate air and speed the drying process. In other plants, the wood-conditioning building is heated in the winter by gas-fired makeup air heaters/blowers; in the summer, the blower is used to circulate air, augmented by electric fans installed on the side walls.

Electrotechnology Solution
Electric Infrared Space Heating

For wood preserving plants that need to heat warehouse-style facilities during cooler weather, electric IR space heating is an innovative technology that can help reduce heating costs and increase employee comfort. IR space heaters can be used to heat both treatment and storage areas—areas that require high ventilation rates and may be exposed to the outdoors.

IR space heating is accomplished through electromagnetic radiation. In addition to electricity, natural gas and propane can be used to fuel the heaters. Although they are referred to as "space heaters" they actually heat the objects (e.g., people) in the space. The heaters and their radiation are typically directed at the people in the space, but will also heat other objects such as floors, walls, and equipment. These objects will, in turn, retransmit the heat they receive.

Electric IR heaters are relatively inexpensive to purchase and easy to install and operate compared to conventional space heating systems. They reduce overall energy requirements by keeping employees warm while allowing the background temperature to be maintained at 50–60°F. Their primary disadvantage is that if used to maintain temperatures of 70°F, their overall efficiency is no better than conventional resistance heating. In addition, for people to feel comfortable, they need to be radiated from both sides, requiring installation of the heaters in a crisscross pattern. The technology is mature, and units are available from several manufacturers.

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ELECTROTECHNOLOGY PROFILES

This section provides profiles of the electrotechnologies identified in Sections 2 and 3. Each profile explains the technology, its advantages and disadvantages, commercial status, and costs. The profiles have been designed as stand-alone descriptions so they can be utilized separately from this guidebook. Turn to Section 5 for a list of equipment vendors that can provide further information as needed.

Ozonation of Wastewater

Basic Principle

Wood preserving facilities use oilborne preservatives, such as pentachlorophenol (PCP) and creosote, to treat railroad ties, utility poles, timber for highway bridges and guardrails, and other wood products. These preservatives help the wood to resist decay, weathering, and destruction by insects or fire. All oilborne preservatives used by wood preservers are classified as hazardous substances by the U.S. Environmental Protection Agency (EPA). As a result, process wastewater, surface runoff water, and sludge containing these substances or certain derivatives are subject to environmental regulation. For this reason, wood preserving facilities using oilborne preservatives are exploring new options for wastewater treatment.

One viable option is ozonation. Ozone has an extremely high oxidation potential; its reactivity is surpassed only by fluorine (F_2) and the hydroxyl radical (OH-). In water and wastewater treatment, ozone is typically the strongest oxidant used. Ozone also readily attacks and breaks down exposed carbon bonds; it leaves no residue and disintegrates into harmless oxygen.

Courtesy of Ozonia North America

Ozone Generator

System Description

Ozone (O_3), a highly reactive oxidant, has been used for years to purify, disinfect, and deodorize water and wastewater. The high oxidizing potential of ozone is the result of a high number of free radicals that act rapidly to break down substances in their presence. To treat hazardous wastewater generated during the oilborne wood preserving process, ozone and caustic acid are injected into the steam condensate left from cleaning the pressurized treatment cylinder. The chemicals destroy the hazardous organic components, such as PCP and creosote, before the separator water is discharged to the sewer. By using ozone to treat separator water, instead of disposing of the wastewater as a hazardous waste, a wood preserving plant operator can reduce hazardous waste disposal costs as well as potential liability for improper disposal.

Ozone can be generated commercially by ultraviolet (UV) excitation or corona discharge. In ultraviolet excitation, ozone is produced by exposing air or pure oxygen to ultraviolet radiation. Ultraviolet excitation produces relatively small quantities of ozone; about 44 kWh are required to produce 2.2 pounds of ozone. Most commercial ozone generators use the corona discharge method. In this method, ambient air or pure oxygen is passed between two electrodes separated by dielectric material. High voltage electrical discharges, known as corona or silent discharges, convert the oxygen into ozone.

Advantages

- Low operating cost: Low requirements for maintenance, materials, energy, water treatment, and hazardous waste disposal in some cases result in a lower total cost when compared to off-site disposal.
- Oxidation of organics and hydrocarbons: Oxidizes phenols, benzene, and other aromatic hydrocarbons, including creosote and PCP.
- No harmful by-products or residues: Ozone decomposes hazardous organic substances into water, carbon dioxide, and simple, nonhazardous organic compounds. In addition, unreacted ozone decomposes into oxygen.

Disadvantages

- Hazards from ozone: Although the end products of wastewater ozonation are largely harmless, ozone itself is highly toxic and hazardous. Care must be taken to minimize the potential for worker exposure.
- High first cost: On its own, leasing or purchasing an ozone generator might appear expensive. When reduced chemical consumption and labor costs are taken into consideration, the technology can be economically feasible.
- Requires purification of feed gas: The air or oxygen supplied to the generator must be free of contaminants larger than 0.3 microns in diameter, as well as free of aerosols, moisture, and hydrocarbons. Purified oxygen can be purchased; systems using ambient air require a filtration system.

Commercial Status

The production of ozone by corona discharge and treatment of water with ozone is practiced by a variety of industries; the technology is mature and widely available. Wood preserving plants and sewage treatment facilities use ozonation to treat wastewater. Other applications include the treatment of cooling tower water, disinfection of hot tubs and swimming pools, purification of drinking water, and use as a cleaning agent in commercial laundering.

Cost and Electrical Requirements

The capital and operating costs of a wastewater ozonation system depend on the wastewater volume, composition, and concentration, as well as the feed gas utilized (air or oxygen). The approximate capital cost of a small ozonation system generating 1–10 lb of ozone per day is $8000–$25,000. The cost of a large system generating 25–50 lb per day is $75,000–$200,000.

Wastewater Ozonation System*Characteristics

Dimensions	Height: 18-82″ Width: 12-64″ Depth: 18-82″
Capacity	1-50 lb ozone/d
Energy Consumption	6-15 kWh/lb of ozone
Key Inputs Power Other	 Electricity Dry air or oxygen
Key Outputs Solid Waste Air Emissions Water Effluent	 None None None
Cost Purchase Installation Other Supplies	 $8000-$200,000 Minimal Oxygen 2-3 cents/lb

*Corona discharge ozonation system.

The operating cost of an ozonation system primarily reflects the system energy cost. (Ozonation systems using oxygen as the feed gas, however, have additional costs of 2–3 cents per lb of oxygen.) Energy requirements for ozone generators range from 6 kWh per lb of ozone using the corona discharge method, to 20 kWh per lb using the UV excitation method with air. The first figure is representative of the energy requirements when generating large volumes of ozone (100 lb per day) with corona discharge. Since the UV excitation method requires greater energy input, its commercial application has been limited.

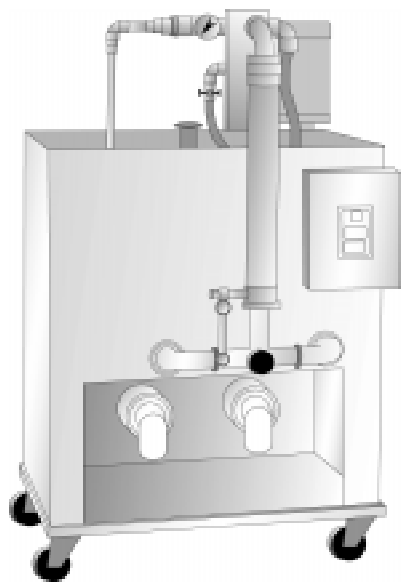
Most industrial applications require an ozone dosage level of 5–12 milligrams per liter of wastewater. For example, a typical wood preserving facility generating 720,000 gallons of phenol-contaminated wastewater per year would require 300–720 lb of ozone per year. Assuming use of a corona discharge system requiring 10 kWh per lb of ozone, the annual energy cost would be $3000–$7200.

Membrane Filtration

Basic Principle

Membrane filtration is used by various industries to recover materials and reduce hazardous wastes and contaminants in discharge water. In this process, electrically driven pumps force wastewater through a permeable barrier that filters out selected pollutant components, depending on their particle size.

Membrane separation processes include microfiltration, ultrafiltration, and reverse osmosis, and are distinguishable on the basis of the particle size filtered. Microfiltration systems have the largest pore size and capture particles from 1000–10,000 angstroms (i.e., suspended solids). Ultrafiltration systems capture particles larger than 10 angstroms—with greatest efficiency up to 1000 angstroms—which includes emulsified oil and grease, detergents, and precipitated metal hydroxides. The smallest membrane filtration systems are reverse osmosis systems, which act as a barrier to everything larger than 5–20 angstroms, including heavy metals and salts. As membrane pore size decreases, additional pressure is needed to force the wastewater through.



Courtesy of Koch Membrane Systems, Inc.

Ultrafiltration Unit

System Description

In membrane filtration systems, wastewater is circulated under pressure in contact with a specially constructed membrane. Water and some dissolved matter (depending on the type of membrane) passes through, while other contaminants do not. The systems are generally modular, designed as self-contained pressure vessels; microfiltration typically operates at pressures of 1–25 psi; ultrafiltration, at 10–100 psi; and reverse osmosis, at 400–800 psi. Continuous pressure is maintained by an electrically driven pump.

Advantages

- Pollution control: Membrane filtration systems decrease the waste load, thereby reducing the amount of treatment required prior to discharge.
- Low energy requirements: Membrane filtration systems require less energy than conventional phase-change processes.
- Limited maintenance requirements: There are no moving parts, reducing the need for maintenance.
- Limited water use: Membrane filtration systems allow for recycling and reuse of the permeate by removing suspended solids.
- Modular, compact systems: The systems require less space than either evaporation or distillation processes and can be added to an existing wastewater treatment process.
- Cost savings: In general, membrane filtration systems cost a fraction of phase-change systems.
- Labor savings: Fewer person-hours are required due to reductions in materials handling and process control requirements (compared to chemical precipitation).

Disadvantages

- Membrane filtration systems are susceptible to damage by a variety of inorganic and organic compounds.
- Fouling can/occur when particles collect on membrane surfaces.

Membrane Filtration System Characteristics

	Microfiltration	Ultrafiltration	Reverse Osmosis
Energy Consumption	1.0-3.0 kWh/100 gal of permeate	1.0-6.0 kWh/100 gal of permeate	1.0-7.0 kWh/100 gal of permeate
Capacity	0.1-10.0 gal/min	0.1-10.0 gal/min	0.1-10.0 gal/min
Key Inputs			
Power	Electricity	Electricity	Electricity
Other	Membrane	Membrane	Membrane
Key Outputs			
Solid Waste	Organics, metals	Oil, grease, solids	Heavy metal, salts
Air Emissions	None	None	None
Water Effluent	None	None	None
Cost			
Capital	\$5000-\$100,000	\$5000-\$100,000	\$10,000-\$130,000
Installation	10-30% of purchase price	10-30% of purchase price	10-30% of purchase price
Operating	\$0.05-\$0.40/100 gal	\$0.05-\$0.30/100 gal	\$0.10-\$0.30/100 gal

Commercial Status

Membranes have been used for over a decade to remove toxic metals and organics from wastewater. Membrane separation processes are currently used in such industries as wood preserving, electroplating, metal finishing, food processing, chemical processing, printing, and pulp and paper processing. Membrane filtration units are available from a large number of vendors nationwide; unit capacities range from 0.1 to more than 500 gallons per minute.

Cost and Electrical Requirements

Capital and operating costs depend primarily on the type of membrane and its specific application. The purchase cost for either an ultrafiltration system or a microfiltration system for a plant processing 5 gallons per minute is about $34,000, and the operating cost is about $0.004 per gallon. A reverse osmosis system processing the same amount would cost $30,000–$35,000, and have an operating cost of about $0.003 per gallon.

Electrical requirements depend on the type of application, unit size, membrane type (pore size), waste stream temperature, pressure, and flow rate. Electricity is required for pumping water through the system. Units for small operations range in size from 0.1–10.0 gallons per minute and require 4–10 kilowatts of electricity, respectively. In this range, the electricity usage of an ultrafiltration unit is 1.0–6.0 kWh per 100 gallons of filtered water (permeate), the usage of a microfiltration unit is 1.0–3.0 kWh per 100 gallons of permeate, and the usage of a reverse osmosis unit is 1.0–7.0 kWh per 100 gallons of permeate.

Ultraviolet Oxidation

Basic Principle

Ultraviolet (UV) oxidation combines UV radiation and chemical oxidation. The process can be used in the wood preserving industry to destroy hazardous wastewater contaminants such as pentachlorophenol and other chlorinated solvents that have contaminated the groundwater or are currently being generated in the oilborne preservation process. UV radiation alone cannot decompose toxic compounds; but in the presence of ozone or hydrogen peroxide, it can produce highly reactive hydroxyl radicals (OH-) that have a powerful detoxification potential.

Ozone and hydrogen peroxide have been used for years to purify, disinfect, and deodorize wastewater. The high oxidizing potentials of these substances allow them to rapidly destroy a variety of wastes. When UV radiation is combined with either ozone or hydrogen peroxide, the radiation stimulates the oxidation reactions that decompose hazardous compounds. UV oxidation has been used to destroy hazardous organic compounds such as phenols, chlorinated volatile organics, pesticides, and polychlorinated biphenols.

Courtesy of SOLOX, A Division of Solar Kinetics, Inc.

UV Oxidation System

System Description

In a typical UV oxidation system, small quantities of hydrogen peroxide and/or ozone are pumped into the wastewater stream or mixed with contaminated groundwater. The contaminated water then flows sequentially through one or more UV reactors. The exposure to UV light results in the formation of highly reactive hydroxyl radicals. These radicals react with the hazardous organic compounds, breaking them down into nontoxic compounds such as carbon dioxide, water, and chloride ions. Such a system can achieve 99% destruction of wood preserving wastes such as pentachlorophenol.

Depending on the feed agent, either low-pressure or medium-pressure UV lamps can be used. Low-pressure lamps operate at a wavelength of 254 nm and are applicable to the production of hydroxyl radicals from ozone or from ozone combined with hydrogen peroxide. Although these lamps have a lower energy rating (65 watts) and a longer life (1–1.5 years), more lamps are needed (up to 72 lamps) for effectiveness. The medium-pressure lamps are used to produce hydroxyl radicals from hydrogen peroxide because of the higher UV energy required in that process. Medium-pressure lamps have an energy rating of 1–30 kW and last 3–4 months, but fewer lamps are needed for equivalent effectiveness. With either type of lamp, a number of parameters must be taken into account to determine the number of lamps needed; these factors include wastewater pH, temperature, and flow rate; concentration and type of contaminant, other contaminants present in the wastewater; and desired reduction in concentration.

Note that if ozone is the preferred feed agent, it must be generated on-site, as needed. Ozone can be generated by either corona discharge or UV excitation. The corona discharge method is less energy intensive and is therefore more commercially available in liquid form and is typically stored on-site in a feed tank.

Ultraviolate Oxidation System Characteristics

Dimensions	Length: 40-50″ Width: 20-30″ Height: 40-50″
Capacity	1-400 gal/min
Power Rating	10-250 kW
Energy Consumption	0.2-1.5 kWh/100 gal of wastewater
Key Inputs Power Other	 Electricity Hydrogen peroxide and /or ozone
Key Outputs Solid Waste Air Emissions Water Effluent	 None None Water discharged to POTW
Cost Purchase Installation Other Supplies	 $25,000-$300,000 10% of cost Hydrogen peroxide: $0.005-$0.008/1000 gal@ 1 ppm concentration Oxygen: $0.02—$0.03/lb

Advantages

- Virtually complete destruction of organics: The technology destroys up to 99% of the hazardous substances in wastewater. No further treatment of the wastewater is required.
- Pollutants are destroyed in their original media: By destroying the hazardous constituents of the wastewater or contaminated groundwater in their original media, a plant or site owner can avoid disposal costs. In addition, the process requires no air permit to operate, as an incinerator might.
- No by-products are formed and no secondary disposal is required: Alternatives such as incineration generate potentially harmful air emissions, requiring further treatment and disposal.

Disadvantages

- Cannot treat cloudy or opaque solutions: UV light cannot penetrate cloudy or opaque solutions to destroy contaminants.

- High cost: The capital cost of a UV oxidation system is greater than that of activated carbon and other alternative technologies.

Commercial Status

UV oxidation units are currently used by chemical manufacturers, pharmaceutical companies, and wood preservers to oxidize phenols, chlorinated volatile organic compounds, benzene, toluene, xylene, and pesticides. Auto body coating operations also use UV oxidation to destroy VOC emissions from their processes.

Cost and Electrical Requirements

Capital costs are relatively high and depend on the system size, flow rate, and types of contaminants in the wastewater. Capital costs are usually $25,000–$300,000 for small systems and can cost millions for large industrial wastewater treatment systems. A UV oxidation reactor unit with a volume of 725 gallons and a maximum feed rate of 50 gallons per minute, for example, would cost $40,000–$60,000. Such a system would require a maximum of 15 kW.

Outdoor Lighting

Basic Principle

Many small businesses benefit from enhanced outdoor lighting through reduced potential for crime, increased employee safety, and improved visibility and attractiveness of the facility.

These benefits are obtained for a relatively small operating cost because, in most cases, outdoor lighting does not contribute to a facility’s peak electrical demand. This means that the average energy cost for outdoor lighting (in terms of cents/kWh) is typically less than the energy cost of other improvements.

Typical Outdoor Lighting Applications

Type of Light	Exterior Signage	Parking Garages	Parking Lots/ Driveways	Walkways	Facade and Landscaping
Incandescent	■			■	■
Compact Fluorescent		■		■	■
Fluorescent	■	■		■	■
Metal Halide		■	■	■	■
High-Pressure Sodium			■		
Mercury Vapor			■		

Note: Additional applications are possible for each of the lighting types, but the chart identifies the most efficient applications for each of the light sources. Low-pressure sodium lamps are not normally used in small businesses because of their poor color quality.

There are three principal methods for using outdoor lighting in small businesses:

1. Signage on the exterior of the building or illuminated signs near the building to generate attention for the building or the small business

2. General lighting in parking lots, driveways, parking garages, and walkways

3. Facade lighting to increase the visibility of the structure and surrounding architectural features and landscaping

Different lighting technologies are typically used for different applications. Existing lighting systems can often be retrofitted or replaced by energy-efficient lighting systems. In addition, existing lighting systems can be supplemented with new lighting systems to increase safety, security, visibility, and name recognition.

System Description

Mercury vapor, high-pressure sodium (HPS), and metal halide lamps are referred to as high-intensity discharge (HID) lamps. Metal halide lamps and HPS lamps provide approximately 100 and 140 lumens per watt, respectively, while mercury vapor lamps provide up to 60 lumens per watt. Mercury vapor lamps emit a blue-green light, while HPS lamps emit a yellow-orange light. Metal halide lamps emit a predominately white light. Most HID lamps require a spacing-to-mounting height ratio of 1.0–1.9, which means that the spacing is roughly one to two times the pole height.

Each HID lamp requires a specific ballast to drive the lamp; however, some manufacturers offer metal halide and HPS lamps that can be operated by a mercury vapor lamp ballast. This allows easier conversion from inefficient mercury vapor lamps to higher-efficiency metal halide and HPS lamps. HID lamps are available in a variety of wattages from 35–1500. The HID ballast adds approximately 8–15% to the wattage of the lamp.

Fluorescent lamps are also used as outdoor lighting sources for small businesses. Conventional 4-foot and 8-foot tubes are used in many parking garages and covered walkways. Compact fluorescent lamps are also becoming popular as replacements to incandescent lamps in stairways. Newer T-8 lamps and electronic ballasts are approximately 30% more energy-efficient than older 40-watt T-12 lamps with magnetic ballasts.

Typical Lamp Characteristics for Outdoor Applications

Type of Lamp	Typical Wattages	Initial Lumens/Watt	Avg Rated Life(h)
Incandescent	60-1,500	15-24	750-2,500
Compact Fluorescent	12-35	25-75	8,000-12,000
Fluorescent	20-215	50-100	9,000-20,000
Metal Halide	175-1,500	69-115	10,000-20,000
High-Pressure Sodium	35-1,000	51-140	7,500-24,000
Mercury Vapor	40-1,000	24-60	12,000-24,000

Note: Initial lumens/watt includes ballast losses.

Incandescent lamps are the least efficient form of outdoor lighting. However, incandescent lamps are still used as spotlights on signs and as floodlights on building facades and landscaping. The short lifetime of incandescent lamps often has a bigger impact on operating costs than does the additional energy use.

Common controls used for outdoor lighting systems include time clocks, photocells, and programmable controllers.

Advantages

Well-designed outdoor lighting systems can offer the following advantages:

- Increased perception of comfort and friendliness
- Increased security for customers and employees
- Reduced accidents in driveways, parking areas, and walkways
- Increased visibility for the facility and the small business

Disadvantages

Other than installation and operating costs, there are no overall disadvantages of outdoor lighting. However, specific lamps do have weaknesses:

- HID lamps require 2–7 minutes to warm up before reaching full output.
- Metal halide lamps require up to 15 minutes to cool before restrike.
- Special low-temperature fluorescent lamps are required in cold climates to maintain a relatively constant lumen output when temperatures are below freezing.

Commercial Status

All of the lamps described above are readily available from a variety of manufacturers. However, mercury vapor and older T-12 fluorescent lamps are being phased out of production.

Gradual improvements have been made in the efficiency of outdoor lighting systems. In addition, color-corrected HPS lamps are available, as well as improved metal halide lamps that contain incandescent or fluorescent lamps that come on if the power is interrupted.

EPRI Information

Additional information on lighting technologies is available from the EPRI Lighting Information Office, (800) 525-8555.

Electric Infrared Space Heating

Basic Principle

Heat is transferred in three ways: convection, conduction, and radiation. In most space heating systems, convection and conduction are the principle heat transfer mechanisms. Infrared (IR) space heating is accomplished through electromagnetic radiation. Natural gas, propane, and electricity are the fuels commonly used by IR heaters. Although these heaters are referred to as “space heaters,” they do not directly heat the space; they heat the people and objects in the space; these in turn eventually heat the space. The term “infrared space heating” is used to distinguish comfort heating applications from IR process heating.

Electric IR heaters have two basic components: an IR heating element and a reflector. The IR heating element is composed of a resistor material (or radiator) that gives off electromagnetic energy in the IR portion of the spectrum when excited by an electric current. The resistor material is partially enclosed in the reflector, a fixture that reflects the radiation toward the people to be heated. Resistor materials include tungsten wire in a quartz tube, nickel chromium alloy in a quartz tube, tungsten wire in a reflector lamp, and nickel chromium alloy in a metal rod. In space heating applications, the IR radiation is normally directed toward the people in the area. However, the radiation also strikes objects, such as the floors, walls, equipment, and furnishings. These objects then retransmit the heat they receive, through secondary convection, conduction, and radiation. In this way, IR heaters can be used to warm the air in a room to a set temperature, much like a conventional heating system.

Tungsten wires in quartz lamps and reflector lamps operate at filament temperatures of about 4050°F and radiate energy in the “near-infrared” portion of the spectrum. These lamps have the added advantage of providing visible light of approximately 8 lumens per watt. This light can help illuminate work areas. The potential downside is that when heating is not needed, the extra light is not provided. Other lamp elements, such as metal sheath, open wire, and ribbon elements, operate between 1200°F and 1800°F and emit in the “far-infrared” portion of the spectrum.

Applications

IR heaters are used in a variety of applications, including golf driving ranges, storage rooms, fire station garages, loading docks, covered walkways, warehouses, commercial/industrial plants and shops, outdoor restaurants, hotels and motels, shopping centers, and store entrances. The most cost-effective applications are in areas exposed to the outdoors and/or areas that require high ventilation rates.

An IR system can be designed to maintain an air temperature of over 70°F in an enclosed room. In this case, the overall efficiency of the system approaches 100%, but as little as 50% of the radiated energy actually reaches the people or objects. The ideal application is an area maintained at 50°F in which IR heaters are used only to warm people. An example is a large warehouse watched over by a stock person near the main door. IR heaters could be installed where the stock person spends the most time, providing the stock person heating comfort irrespective of the overall warehouse temperature.

System Description

IR lamps and fixtures are available in a variety of shapes and sizes. They are normally hung from or attached directly to the ceiling, in a manner similar to a lighting system, with careful attention to the maximum height of forklifts, trucks, cranes, etc., that operate in the area. The IR-system designer determines the desired energy levels for the different parts of the facility and then estimates the equipment wattage required to produce the desired energy levels. The fixtures are typically available in 120-, 240-, 277-, and 480-volt systems. Simple switches, time clocks, timers, and thermostats are used to control fixture output.

The lamp efficiency depends on the material of the resistor or radiator. Clear quartz lamps have an efficiency of about 96%. Tungsten wire and quartz tubes have efficiencies of 60–80%. Metal rods have lamp efficiencies as low as 50%. The overall efficiency of the IR system depends on the type of IR element in the lamp, the absorptivity of the people and the objects near the lamp, and the efficiency of the fixture (including the reflectivity of the reflector and the directional efficiency of the fixture). Other factors to consider in selecting an IR element include amount of visible light output, time required to develop full output, vibration resistance, and color of light. The life expectancy of any IR lamp is about 5000 or more hours.

Advantages

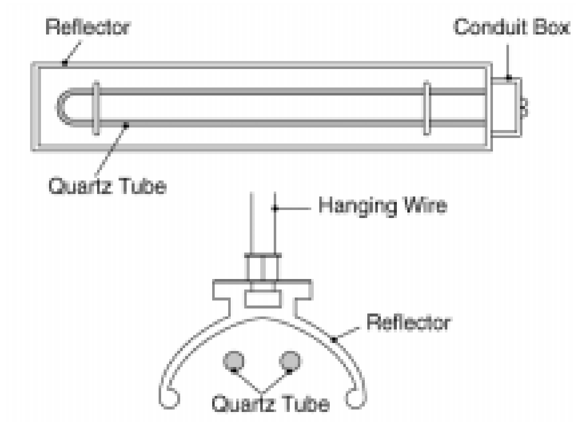
- Relatively inexpensive and easy to install compared to conventional HVAC systems
- Keeps people comfortable in relatively open areas such as bus stops, covered breezeways, loading docks, outdoor restaurants, and garages
- Reduces the overall energy required to heat an area by allowing a background temperature of 50–60°F
- Simple to lay out, control, and maintain
- Can be used to heat “trouble spots” such as lobby areas, hallways, and entrances
- Less complicated than gas heating because neither gas piping nor ventilation of combustion by-products is necessary

Disadvantages

- If systems are used to maintain space temperatures of 68–70°F, the overall efficiency is no better than conventional resistance heating.
- If mounted at ceiling heights of over 30 feet, IR lamps cannot keep people warm.
- People need to be radiated from both sides to feel comfortable. That is, enough lamps must be installed to produce a criss-cross pattern.

Commercial Status

Electric IR space heaters are available from several manufacturers in a variety of shapes, sizes, voltages, and radiant output. They come in both conventional fixtures and radiant wall and ceiling panels. A manufacturer’s sales representative normally assists in estimating the required energy output and in planning unit locations. Sales representatives can also assist in performing a simple heat-loss calculation facility or area to be heated.



Electric Infrared Space Heating

Cost and Electrical Requirements

The cost for electric IR systems varies significantly depending on the complexity of the unit and the number of fixtures used. For example, a simple loading dock application with four fixtures and an on/off switch costs under $2000. However, a large industrial application with specialized controls and fixtures can cost over $100,000.

The electrical requirements are very straightforward. Once the supply voltage is decided, the individual wattages of the lamps required to produce the desired results can be estimated. The total electrical requirements are simply the total wattage of the lamps installed on a particular electrical circuit in the facility. For example, a facility using four fixtures at 7 kW (total) for 8h/d (2000 h/yr) would require 56 kWh/d (14,000 kWh/yr) of electricity.

Electric Infrared Heating Fixture Characteristics

Dimensions	Length: 15-58″ Width: 8—32″ Height: 4—13″ Weight: 9—55 lb
Power Rating	0.5–13.5 kW
Mounting Height	Minimum: 10—14 ft Maximum: 30 ft
Key Inputs Power Other	 Electricity Infrared lamp replacements
Key Outputs Solid Waste Air Emissions Water Effluent	 None None None
Cost Purchase Installation Other Supplies	 Small: $100–$3000 Large: $2000–$100, 000 Minimal $40–$160 per 1–3 years

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RESOURCES

This section contains three lists: 1) equipment suppliers for the electrotechnologies profiled in this guide, by equipment type;
2) EPRI information resources on efficiency technologies; and
3) wood preserver trade associations. Information used to compile these lists was based on a combination of a telephone survey, published reports, directories, buyer's guides, and technical journals. The information was current at the time of publication and is expected to change over time.

Ozonation of Wastewater

Equipment Suppliers

Aqua-Flo, Inc.
6244 Frankford Ave., Dept. T-93, Baltimore, MD 21206
(410) 485-7600, fax: (410) 488-2030

Ozonia North America
P.O. Box 330, Lodi, New Jersey 07644
(201) 778-2131, fax: (201) 778-2357

PCI Ozone & Control Systems, Inc.
One Fairfield Crescent, West Caldwell, NJ 07006
(201) 575-7052, fax: (201) 575-8941

Quality Oxidation Systems, Inc.
25 Alondra, Irvine, CA 92620
(714) 838-7671, fax: (714) 838-7671

Membrane Filtration

Equipment Suppliers

Applied Membranes, Inc.
110 Bosstick Blvd., San Marcos, CA 92069
(619) 727-3711, fax: (619) 727-4427

EPOC
3065 North Sunnyside, Fresno, CA 93727
(209) 291-8144, fax: (209) 291-4926

Infinitex
P.O. Box 409, Clarence Center, NY 14032
(716) 741-8381, fax: (716) 741-9649

Koch Membrane Systems, Inc.
10 State Ave., Suite 205, St. Charles, IL 60174
(708) 513-0550, fax: (708) 513-0551

544 E. Eisenhower, Parkway, Suite 150, Ann Arbor, MI 48108
(313) 761-3836, fax: (313) 761-3844

Komline-Sanderson
12 Holland Ave., Petack, NJ 07977
(908) 234-1000, fax: (908) 234-9487

LCI Corporation
P.O. Box 16348, Charlotte, NC 28297
(704) 394-8341, fax: (704) 392-8507

Membrex, Inc.
155 Route 46 West, Fairfield, NJ 07004
(201) 575-8388, fax: (201) 575-7011

Memtek Corporation
28 Cook St., Billerica, MA 01821
(508) 667-2828, fax: (508) 667-1731

Osmonics, Inc.
59951 Clearwater Dr., Minetonka, MN 55343
(612) 933-2277, fax: (612) 933-0141

Prosys Corporation
187 Billerica Rd., Chelmsford, MA 01824
(508) 250-4940, fax: (508) 250-4977

Sanborn
9 Industrial Park Rd., Midway, MA 02053
(508) 533-8800, fax: (508) 533-1440

U.S. Filter
181 Thorn Hill Rd., Warrendale, PA 15086
(412) 772-0044, fax: (412) 772-1360

4669 Shepard Trail, Rockford, IL 61105
(815) 877-3041, fax: (815) 877-0946

Ultraviolet Oxidation

Equipment Suppliers

Peroxidation Systems, Inc.
5151 East Broadway, Suite 600, Tucson, AZ 85711
(520) 790-8383, fax: (520) 790-8008

Solox
10635 King William Dr., Dallas, TX 75220
(214) 556-2376, fax: (214) 869-4158

Terra-Aqua Enviro Systems
700 East Alosta, Unit 19, Glendora, CA 91740
(818) 969-7531, fax: (818) 969-4827

Ultrox International Division of Zimpro Environmental, Inc.
7755 Center Ave., Huntington Beach, CA 92647
(714) 545-5557, fax: (714) 372-4964

Outdoor Lighting

Equipment Suppliers

Bairnco Corp.
2251 Lucien Way, No. 300, Maitland, FL 32751
(407) 875-2222, fax: (407) 875-3398

Bieber Lighting Corp.
970 W. Manchester Blvd., Inglewood, CA 90301
(213) 776-4744, fax: (310) 216-0333

Bulbtronic, Inc.
45 Banfi Plaza, Farmingdale, NY 11735
(800) 647-2852, (516) 249-2272, fax: (516) 249-6066

Carlon (Lanson & Sessions Co.)
25701 Science Park Dr., Cleveland, OH 44122
(216) 831-4000, fax: (216) 831-5579

Cooper Lighting Group
400 Busse Rd., Elk Grove Village, IL 60007-2195
(847) 956-8400, fax: (847) 956-1475

Crouse-Hinds Co.
Lighting Production Div., P.O. Box 4999, Syracuse, NY 13221
(315) 477-8185

Doane, L.C., Co.
55 Plains Rd., P.O. Box 975, Essex, CT 06428
(203) 767-8295, fax: (203) 767-1397

Duro-Test Corp.
9 Law Dr., Fairfield, NJ 07004
(201) 808-1800, fax: (201) 808-6622

Federal APD, Inc., Federal Signal Corp.
24700 Crestview Ct., Farmington Hills, MI 48335
(800) 521-9330, (810) 477-2700, fax: (810) 477-0742

Gardco Lighting
2661 Alvarado St., San Leandro, CA 94577
(510) 357-6900, fax: (510) 357-3088

G.E. Company
3135 Easton Turnpike, Fairfield, CT 06431
(800) 626-2004, fax: (518) 869-2828

Hapco Division of Kearney-National, Inc.
P.O. Box 547-KN, Abingdon, VA 24210
(540) 628-7171, fax: (540) 628-7707

Litetronics International
4101 W. 123rd St., Alsip, IL 60658, (708) 389-8000 ext 195
fax: (708) 371-0627

Mason, L.E., Co.
98 Business St., Boston, MA 02136
(617) 361-1710, fax: (617) 361-6876

Philips Lighting Co.
200 Franklin Sq. Dr., Somerset, NJ 08875
(908) 563-3000, (800) 631-1259, fax: (908) 563-3975

Rig-A-Light
P.O. Box 12942, Houston, TX 77217
(713) 943-0340, fax: (713) 943-8354

Sterner Lighting Systems
351 Lewis Ave., Winisted, MN 55395
(320) 485-2141, fax: (320) 485-2899

Thomas and Betts
Corporate Headquarters, Memphis, TN 38119
(800) 888-0211, fax: (800) 888-1366

Unique Solution/Manville
515 McKinley Ave., Newark, OH 43055
(614) 349-4194, fax: (800) 346-5923

Electric Infrared Space Heating

Equipment Suppliers

Aitken Products, Inc.
P.O. Box 151, 566 North Eagle St., Geneva, OH 44041
(216) 466-5711, fax: (216) 466-5716

Chromalox Industrial Heating Products
641 Alpha Dr., Pittsburgh, PA 15238
(412) 967-3800, fax: (412) 967-5148

Fostoria Industries, Inc.
1200 N. Main St., P.O. Box 986, Fostoria, OH 44830
(419) 435-9201, fax: (419) 435-0842

Heatrex, Inc.
P.O.Box 515, Meadville, PA 16335
(814) 724-1800, fax: (814) 333-6580

InfraTech Corp.
1684 Industrial Park St., Covina, CA 91722
(800) 421-9455, (818) 331-9400, fax: (818) 858-1951

Information on Efficiency Technologies

This list provides EPRI resources on efficiency technologies identified in the guide. Copies of these publications can be ordered through the EPRI Distribution Center, (510) 934-4212.

Adjustable Speed Drives

Medium-Voltage Adjustable Speed Drives: A Basic Specification Guide, BR-104420, May 1995.

Adjustable Speed Drives: Application Guide, TR-101140, December 1992.

Adjustable Speed Drive Directory, Third Edition, CU-7544, January 1992.

Environmental Benefits of Adjustable Speed Drive Applications, TR-100200, July 1992.

Energy-Efficient Lighting

Proceedings—Efficient Lighting 1993: A Lighting Symposium for Electric Utility Lighting and DSM Professionals, TR-105963, January 1996.

Advanced Lighting Technologies Application Guidelines: 1990, TR-101022-R1, May 1993.

High-Intensity Discharge Lighting, BR-101739, May 1993.

Electronic Ballasts, BR-101886, May 1993.

Lighting Fundamentals Handbook, TR-101710, March 1993.

Commercial Lighting Efficiency Resource Book, CU-7427, September 1991.

Additional information on lighting can be obtained from the EPRI Lighting Information Office, (800) 525-8555.

Trade Associations

American Wood Preservers' Association
P.O. Box 849, Stevensville, MD 21666
(301) 643-4163

Members are individuals involved in the wood preserving industry.

American Wood Preservers Institute
2750 Prosperity Ave., Suite 550, Fairfax, VA 22031-4312
(703) 204-0500, fax: (703) 204-4610

This institute is the government relations and environmental affairs arm of the wood preserving industry. Members are companies that treat wood, manufacturers and formulators of wood preserving chemicals, and related industry suppliers and manufacturers.