A small-business guide

Wood Furniture

TR-106676-V14

Final Report, June 1997

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ORDERING INFORMATION

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REPORT SUMMARY

Many of the challenges faced by small business owners can be addressed through efficient use of electric technology. Each volume in the Small Business Guide describes the current state of a business type and details new or alternative electric equipment that can help it meet its characteristic problems.

Background

Members of the small-business community historically have had little contact with their energy providers. These guides were developed to facilitate communication between electric utilities and the small businesses in their communities.

Objective

To provide utility personnel and small business owners and operators with information on the key electrotechnologies that can help these businesses compete effectively.

Approach

The project team researched small business energy, productivity, and environmental concerns and the electrotechnologies that can meet these needs. Telephone surveys, published reports, directories, buyers guides, and technical journals provided information on technology availability, suppliers, information sources and trade associations.

Results

The Small-Business Guide series covers a range of industries:

Volume 1: Wholesale Bakeries

Volume 2: Auto Body Shops

Volume 3: Lodging

Volume 4: Medical Clinics

Volume 5: Drycleaners and Launderers

Volume 6: Metal Finishers

Volume 7: Shopping Centers

Volume 8: Convenience and Grocery Stores

Volume 9: Printers

Volume 10: Office Buildings

Volume 11: Electronic Components

Volume 12: Wood Preservers

Volume 13: Plastics Products

Volume 14: Wood Furniture

Each guide is based on extensive and ongoing research and contains the latest information available at the time of publication. The guides have been organized as a reference document for use on an as-needed basis. Section tabs are included to facilitate quick access to topics of interest; and each volume concludes with lists of equipment suppliers, EPRI information resources, and trade organizations.

EPRI Perspective

The EPRI Small Businesses target is dedicated to research, development, and dissemination of information on electrotechnologies that address the energy, productivity, and environmental concerns of small business owners and operators. Future volumes in the Small Business series will cover

- Apparel Manufacturers
- Photofinishers

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Interest Categories

Commercial building systems and analysis tools
Commercial appliances
Product and service design
Marketing

Key Words

Electrotechnologies
Load building
Marketing
Customer needs
Commercial buildings

ACKNOWLEDGMENTS

Electric Power Research Institute (EPRI) thanks the many utility and industry representatives and consultants who participated in the development and review of this guide. Specifically, we thank reviewers Larry Guenther, Northern States Power; Drew Killeen, Baltimore Gas & Electric Company; Mark Selverian, PECO Energy Company; Siraj Shaikh, Jersey Central Power & Light; Michael Thorpe, Orange and Rockland Utilities; and Mike Walsh, Consolidated Edison, for contributing a utility perspective.

Special thanks to the staff at Pacific Consulting Services: to Patrice Ignelzi and Dorothy Foster for their invaluable contributions to the contents and organization, and to Gretchen Keith for its design, graphics, and production of the *Guide*.

This guide was prepared by the Resource Dynamics Corporation of Vienna, Virginia.

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 furniture manufacturers in their communities.

The *Wood Furniture* guide is intended to familiarize readers with the business of wood furniture production by providing descriptions of basic processes and practices, and summaries of the issues and challenges faced by wood furniture manufacturers. It focuses on delineating how electric equipment can address the needs and interests of shop owners and managers.

This business guide is one of a series of publications produced by EPRI about small businesses. The *Wood Furniture* 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 furniture plays a major role in American culture, serving us literally from cradle to rocker; sometimes treasured heirloom furniture serves for generations. Wood furniture manufacturing is traditionally a small business in the United States. Of about 12,600 wood furniture manufacturing facilities currently operating in the United States, 88% employ fewer than 50 people, and more than 93% employ fewer than 100 people. Total receipts, however, are not small; they totaled over $34.5 billion in 1993 and are expected to rise through the 1990s, given the strong economy overall.

Historically, wood furniture companies have been highly specialized, typically producing furniture for just one of the industry's eight market segments and often in distinctive, name-brand styles. Among these segments, producers of wood household furniture and producers of wood fixtures, partitions, and shelving for stores are currently experiencing the strongest sales. However, given the discretionary nature of furniture purchases, all wood furniture manufacturers continually tread a fine line between maintaining adequate inventory to ensure prompt response to orders and avoiding the plight of overproduction that ties up vital capital and floor space. In addition to the long-standing challenge to meet the whims of consumers, wood furniture manufacturers today face increased foreign and domestic competition; constraints on and higher costs for wood supplies; and new environmental, health, and safety regulations. These pressures have given rise to a new interest in consolidation as some companies choose to pursue greater control of costs through economies of scale.

As a whole, U.S. wood furniture manufacturers are seeking tools and processes that will allow them to increase productivity, reduce material and operating costs, and/or respond cost-effectively to new mandates calling for control of hazardous emissions and wood dust. The accompanying table identifies electrotechnologies that can meet these business concerns. These electrotechnologies and other high-efficiency electric technologies are described in the *Wood Furniture* guide (EPRI TR-106676-V14), copies of which are available from the EPRI Distribution Center. To order this publication, or others in the series, call the Center at (510) 934-4212.

Table 1
Electrotechnologies for Wood Furniture Manufacturers

	Outdoor Lighting	**Computer Numerical-Controlled Machining**	**Radio-Frequency Wood Drying and Adhesive Curing**	**Electric Infrared Drying and Curing**	**Ultraviolet Curing**
Description	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.	Computer numerical-controlled (CNC) machines perform operations automatically, based on instructions provided by an operator or fed in from a data file.	Radio-frequency energy is a rapidly alternating electromagnetic field that causes polar molecules to vibrate and create heat; wood is not particularly reactive, whereas water and adhesives are polar and heat up.	Uses panel or stationary systems of quartz lamps and reflectors to direct infrared (IR) radiation at a cleaned or coated part; heat is generated within the part or coating so that it dries from the inside out.	Ultraviolet (UV) radiation lamps trigger a chemical reaction that transforms radiation-curable coatings from liquid to solid.
Wood Furniture Manufacturer Need	Good outdoor lighting is needed to improve the visibility and attractiveness of a facility, reduce the potential for crime, and increase employee safety.	Manufacturers need methods for shortening production time and/or for reducing production errors that interfere with scheduling and result in production of defective furniture components.	To control prices, manufacturers need methods for improving the yield of usable wood from a given quantity. To speed production, manufacturers need methods for accelerating glue/resin drying time.	Manufacturers need methods for using low-solvent and solvent-free finishes as alternatives to solvent-based finishes, which emit hazardous volatile organic compounds during the drying/curing process.	Manufacturers need low-solvent and solvent-free finishes as alternatives to solvent-based coatings, which emit hazardous volatile organic compounds during the drying/curing process.
Application	Lighting on signs on or near the facility; in parking lots, walkways, and delivery areas; on the building facade; and in the landscape or surrounding area.	CNC machines are used in many woodworking operations, including cutting, boring, routing, drilling, and/or sanding a panel or board.	Effective for rough wood drying, for redrying of hardwood veneers, and for curing adhesives to bond furniture components without excessive heat.	Some manufacturers are shifting to water-based low-solvent wood finishes; electric IR energy can cure these coatings quickly—before they have time to seep in and raise the wood grain.	Following coating, furniture components are exposed to UV light on a conveyor-driven process line for nearly instantaneous emission-free curing.

Table 1 (continued)

	Outdoor Lighting	Computer Numerical-Controlled Machining	Radio-Frequency Wood Drying and Adhesive Curing	Electric Infrared Drying and Curing	Ultraviolet Curing
Benefits	General and facade lighting can increase public perception of quality, goodwill, and success; area lighting can help reduce potential for accidents, injuries, and crime.	CNC machines perform many woodworking tasks more accurately and quickly than conventional equipment, improve the fit between parts, shorten the setup time between tasks, and reduce the lapse time from product design to market.	Radio-frequency drying can reduce rough wood drying time from a period of several weeks to just a few days; reduce the veneer drying damage rate from 60% to 20%; and significantly shorten the glue and/or resin curing time.	Provides consistently high-quality results in 50–80% less time than convective ovens, reduces floor space and ventilation requirements, and reduces labor requirements for drying.	Eliminates hazardous emissions, increases productivity through faster drying, requires minimal floor space, and provides a high-quality finish.
Cost	Systems are custom-designed to meet a facility's needs and budget.	Lower-end automatic cutters cost roughly $80,000; more advanced machines cost over $200,000.	Smaller radio-frequency systems (1–200 kW) cost $2500–$4000 per kW; larger systems (200–1000 kW) cost $1000–$2500 per kW. A 210-kW system costs about $570,000.	A small spot or panel heater costs $1000–$2500; a custom-designed oven, $10,000–$250,000.	A typical small system costs $1000–$5500 and consumes 120–600 W/in.; a fully automatic conveyor system costs $8000–$60,000 and consumes 200–800 W/in., depending on size and complexity.

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INTRODUCTION TO WOOD FURNITURE MANUFACTURING

Wood is a renewable resource that serves as a primary material for industries ranging from pulp and paper products to construction. Wood's aesthetic appeal, along with its strength, durability, and versatility, has given it long-standing dominance as the material of choice for furniture craft. The fabrication of wood furniture in manufacturing plants or factories began full-scale in the United States during the industrial revolution of the mid-1800s. In fact, the furniture manufacturing industry was among the first to incorporate the change to process line production.

Business Statistics

Hence, fastening techniques, equipment speed and accuracy, and material usage vastly improved in this century. However, the tradition of craftsmanship has remained an integral part of the industry, and many of the basic tools of construction used in 1900 are still found in today's manufacturing facilities.

In the wood furniture industry, the decision to embrace new technology is primarily driven by concerns about wood cost and availability. Cost-effective access to high-quality wood has been an issue for centuries. During the industrial age, the ability to locate, harvest, and ship lumber improved; however, poor forest management in the last half of the nineteenth century has resulted in rapid depletion of this resource and rising material costs. At the turn of the century, when wood supplies were plentiful, most furniture manufacturers relied on wood-fired steam engines fed wood shavings, sawdust, and scrap to power overhead drive shafts and provide motor drive. Rotary cutting equipment evolved at this time that could hold and spin logs (similar to the action of a lathe) as a cutting bit sheared off sheets of wood known as veneer. This process enabled woodworkers to obtain more useful wood from a given supply (with the result that there was less scrap to burn) and led to the development of plywood.

Electricity helped establish the dominance of motor-driven equipment during the first half of the twentieth century. At the turn of the century, overhead drive shaft and belt systems typically operated woodworking equipment. As small, alternating current (ac) motors became more weight-efficient, the industry began to equip saws and planers with motors, which allowed operators greater freedom. Further, once freed of the belts, production lines could shift from a linear conveyor system to workstations that gave operators better access to the wood surfaces. Today, electrically driven compressed-air hand tools are popular due to their low weight and small size.

Table 1-1
Industry Segments and Typical Products

Segment	Typical Products
Wood Kitchen Cabinets (SIC 2434)	Vanities, cabinets
Wood Household furniture (SIC 2511)	Beds, bookcases, chairs, desks, dining room furniture, tables
Wood Household Furniture, Upholstered (SIC 2512)	Chairs, couches, recliners, rockers (wood frames)
Wood Television and Radios Cabinets (SIC 2517)	Audio, sewing, and television cabinets
Wood Office Furniture (SIC 2521)	Bookcases, cabinets, chairs, desks, filing cabinets panel furniture systems, tables
Public Building and Related Furniture (SIC 2531)	Furniture for churches, libraries, schools, theaters, and other public buildings
Wood Office and Store Partitions and Fixtures (SIC 2541)	Counters, display cases, garment racks, shelving
Furniture and Fixtures Not Elsewhere Classified, (NEC) (SIC 2699)	Furniture specially designed for use in restaurants, cafeterias, bowling centers, and ships

Other technological advances in furniture construction include improvements in bonding techniques for attaching veneers to substrate materials and the development of glues and resins for creating particleboard and other composites. Particleboard is formed by pulverizing scrap wood and wood shavings into small particles then bonding the particles together, under pressure, with a resin. Bonding a veneer of high-quality wood to a particleboard core creates an inexpensive, attractive, craft-quality material. This combination of low-cost wood-based materials has allowed wood to cost-effectively compete with polymers (plastics), albeit plastics are increasingly substituted for wood in many applications.

Polymer products have competed with wood since the early 1950s; ironically, the same material technology responsible for the development of polymer resins also led to novel wood products such as particleboard, medium-density fiberboard, and other wood composites. In furniture applications, plastic veneers compete with wood veneers. Wood is a more attractive material but is typically more expensive in terms of raw material cost and treatment requirements. Since polymers can be treated to resemble a wood finish, plastic veneers can substitute for wood in many applications. Conversely, wood particles are increasingly being used in many plastic applications as filler; for example, in plastic park benches and picnic tables.

The wood furniture industry can be divided into eight segments on the basis of the Standard Industrial Classification (SIC) codes (see Table 1-1). All of these segments fall within SIC 25 (Furniture and Fixtures), with the exception of wood kitchen cabinets, which is classified as SIC 24.

Table 1-2
Profile of the Wood Furniture Industry (1993)

Segment	No. of Establishments	No. of Employees	Value of Shipments ($ million)
Wood Kitchen Cabinets (SIC 2434)	4473	66,100	5397
Wood Household Furniture (SIC 2511)	2827	123,896	9267
Wood Household Furniture, Upholstered (SIC 2512)	1157	81,744	6690
Wood Television and Radio Cabinets (SIC 2517)	103	4220	315
Wood Office Furniture (SIC 2521)	623	23,012	1929
Public Building and Related Furniture (SIC 2531)	507	32,400	5018
Wood Office and Store Partitions and fixtures (SIC 2541)	1877	37,682	3375
Furniture and Fixtures NEC (SIC 2599)	1082	28,300	2637
TOTAL	12,649	397,354	34,628

Source: Department of Commerce, Bureau of the Census, *County Business Patterns*, 1992 & 1993, (CD-CBP-92/93) and *1992 Economic Census CD-ROM*, (CD-EC92-1H),1996.

As illustrated in Table 1-2, household furniture (SIC 2511) is the largest of these segments in terms of the number of people employed and the value of shipments ($9.2 billion in 1993). Television and radio cabinets (SIC 2517) is the smallest, having only 103 establishments and $315 million in shipments in 1993.

Most wood furniture manufacturers are small businesses; that is, approximately 88% of these establishments employ fewer than 50 people, and over 93% employ fewer than 100 people. The industry is also highly specialized. Although the large firms that produce all types of furniture dominate the industry in terms of sales, most firms produce a narrow range of products (e.g., only wood household furniture). Large firms tend to be vertically integrated, operating their own lumber mills, shaping their own raw stock, and producing and finishing the furniture themselves. Bringing each facet of the business in-house assures control over quality and production efficiency. Some firms, such as Ethan Allen, are completely vertically integrated, operating their own retail stores in addition to lumber and furniture production facilities. This practice is expected to become more widespread.

Table 1-3
Distribution of Wood Furniture Manufacturers by Size (1993)

Subsegment	Number of Employees						
	Small (0-49)		Medium (50-99)		Large (100+)		
	No.	% of Total	No.	% of Total	No.	% of Total	Total
Wood Kitchen Cabinets (SIC 2434)	4245	95	119	3	109	2	4473
Wood Household Furniture (SIC 2511)	2414	85	150	5	263	9	2827
Wood Household Furniture, Upholstered (SIC 2512)	826	71	128	11	203	18	1157
Wood Television and Radio Cabinets (SIC 2517)	87	84	8	8	8	8	103
Wood Office Furniture (SIC 2521)	520	83	46	7	57	9	623
Public Building and Related Furniture (SIC 2531)	367	72	52	10	88	17	507
Wood Office and Store Partitions and Fixtures (SIC 2541)	1697	90	119	6	61	3	1877
Furniture and Fixtures NEC (SIC 2599)	959	89	73	7	50	5	1082
TOTAL	11,115	100	695	100	839	100	12,649

Source: U.S. Department of Commerce, Bureau of the Census, *County Business Patterns*, 1992 & 1993, (CD-CBP-92/93), 1996.

Roughly 15% of all wood furniture manufacturers (1929 establishments) are located in California (see Figure 1-1). Ranked behind California are Florida, North Carolina, New York, and Texas, each of which has fewer than half as many facilities as California. Rounding out the list of top 10 states are Pennsylvania, Illinois, Ohio, Georgia, and Tennessee. Wood furniture manufacturers tend to locate close to the source of lumber. This explains the proliferation of these establishments in the southeastern states and California.

The wood furniture industry is affected by the overall performance of the U.S. economy. Since furniture is often a discretionary purchase, consumer perception of the economy's health and direction has a significant impact on furniture sales. Consequently, the industry experienced declining demand during the economic recession in the late 1980s and early 1990s. Furniture also competes against other discretionary purchases such as consumer electronics. Growth in the consumer electronics market has two influences on furniture sales: Although it competes for a share of consumer disposable income, it also stimulates demand for specialized furniture appropriate for housing the electronic products.

States	Facilities
CA	1929
FL	831
NC	756
NY	705
TX	617
PA	525
IL	446
OH	419
GA	393
TN	356

Figure 1-1
Top 10 States for Wood Furniture Manufacturing (1993)

While 1993 and 1994 were years of healthy growth for the wood furniture industry overall, due to an increase in private housing starts, low mortgage rates, and a rise in personal disposable income, consumer confidence faltered somewhat in 1995, translating into declining sales. During this period, consumers focused on furnishing their dens and living rooms and postponed purchases of bedroom and dining room furniture. This resulted in more plant downtime and "bloated inventories" for many furniture manufacturers.

Throughout the remainder of the 1990s, household furniture shipments are predicted to increase 3–5% per year. Experts expect the number of items shipped to increase, as well as the average amount spent on each item. New houses being built are larger, and buyers will therefore need to spend more on furniture. According to industry experts, a 2000-squarefoot home requires the buyer to spend 3.5 times more on furniture than a 1000-squarefoot home. In addition, the offspring of baby boomers now in their 50s are graduating from college, freeing up disposable income for household purchases.

Foreign markets are becoming increasingly important to U.S. manufacturers of household furniture because of the opportunity for increased sales. Many in the industry were therefore in favor of the North American Free Trade Agreement (NAFTA), which was expected to benefit U.S. exporters of wood household furniture. As it turned out, however, while NAFTA had a positive effect on trade with Mexico, all gains were nullified when the peso was devalued. For example, NAFTA made some products 14% less expensive, but the later peso devaluation increased market prices 50%. While these recent events have not deterred the optimism of some furniture companies, others are now less optimistic. Overall, developing countries appear to be preparing to pursue aggressive and often destructive forest management and export policies to compete in this market.

Under the pressure of increased competition, the U.S. wood furniture industry recently experienced a wave of consolidation. Many furniture manufacturers see integration as a solution to the problem of increasing material costs, especially for softwoods, and increasing consumer price awareness. It is a common perception among manufacturers that retailers absorb a disproportionate share of profits while setting prices at high levels that inhibit sales. More manufacturers are vertically integrating to achieve greater control over the production-to-sales process. Others are merely taking over companies in an effort to improve their market share or diversify into other furniture markets. Amidst this industry trend, small manufacturers are seeking the relative security of niche markets, while also trying to improve the cost-effectiveness of their operations.

Another driver in the trend toward consolidation is price cutting. Price wars among manufacturers, while welcomed by consumers, drain manufacturers of financial resources. Larger companies seeking to get into niche markets often buy out the small companies already in the market.

The domestic markets for wood furniture manufacturers are kitchen cabinets (SIC 2434), household furniture (SIC 2511), and upholstered household furniture (SIC 2512), which represent nearly 62% of industry shipments (see Figure 1-2). Public building furniture (SIC 2531), wood fixtures and partitions (SIC 2541), and furniture not elsewhere classified (SIC 2599) (“Other” in Figure 1-2) together comprise a share of 32%, while office furniture (SIC 2521) and television and radio cabinets (SIC 2517) represent a relatively small share, less than 7%.

Household Furniture. Slow growth in new housing construction in the early 1990s dampened industry shipments. Housing starts and consumer confidence rebounded, however, in 1993 and 1994. Shipments of household furniture rose 5% in 1993 to $22.2 billion (inclusive of non-wood furniture, such as mattresses), due to increases in home sales, residential construction, disposable income, consumer expenditures, employment, average weekly hours worked, and overtime. The strength of the tie between housing starts and furniture purchases relates to consumers’ tendency to spend more on furniture within the first two years of buying a house than at any other time.

For manufacturers, the boon of higher furniture sales was offset by significant increases in the cost of wood. In 1993, the cost of softwoods and particleboard rose more than 30%. In an effort to sustain sales, manufacturers typically did not pass these cost increases on to the retail level. Rather, given consumer sensitivity to price and the fact of rising material costs, many furniture manufacturers searched for ways to lower their operating costs. Another challenge to traditional domestic sales is the increasing quality of ready-to-assemble furniture and the availability of low-cost products from foreign manufacturers.

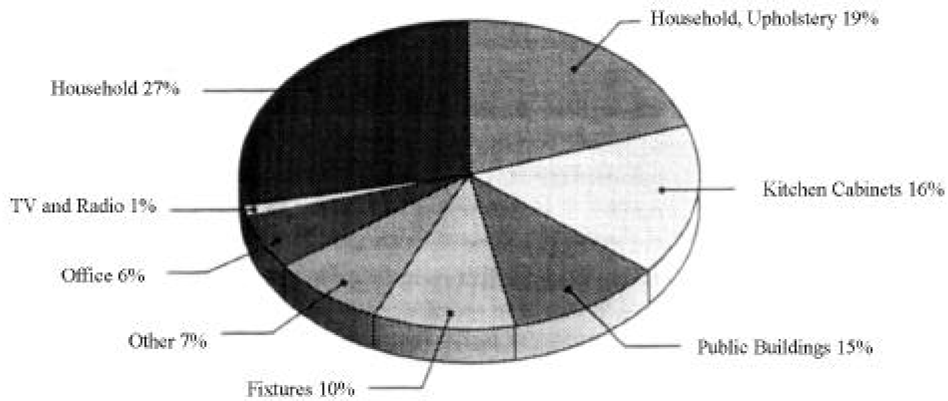

Figure 1-2
Relative Furniture Industry Market Shares (based on industry shipments)

On the export side, household furniture exports rose only 5% in 1993 (compared to a 17% increase in 1992) to $1.2 billion, associated with a continuing worldwide recession. Since 1989, however, exports of household furniture have risen nearly 87%. Canada and Mexico are the two largest destinations for U.S. exports. Imports of household furniture have risen more than 24%, to $3.4 billion, since 1989; Taiwan is the largest source of imports.

Kitchen Cabinets. This industry segment manufactures wood kitchen cabinets and bathroom vanities, typically for permanent installation. The prosperity of the kitchen cabinet industry is therefore tightly linked to new housing starts, which in turn depends primarily on the overall performance of the U.S. economy. Typically, more than 90% of cabinet shipments go toward new housing construction. As a result, this segment suffered during the 1990–1991 recession. Cabinet shipments have rebounded since then, increasing more than 30% between 1991 and 1993. Despite this improved performance, this industry segment is currently facing supply-side challenges. Plywood and board prices have increased significantly in recent years due to timber shortages in the Pacific Northwest. These raw material shortages have forced many manufacturers to turn increasingly to composite and engineered woods.

Public Building Furniture. This industry segment manufactures furniture and fixtures for public facilities (e.g., schools, libraries, theaters, and churches). Oddly, this segment also includes manufacturers of seating for public conveyances, such as automobiles, trains, and airplanes. It is one of the smaller wood furniture industry segments, accounting for 14% of total wood furniture industry sales. While at the beginning of the century most public furniture was made of wood, many of the products manufactured under this SIC code are now plastic and metal. In addition, the advent of automobile and airline travel has significantly increased industry shipments. As a result, much of the recent growth in industry shipments (shipments increased 43% between 1992 and 1993) is accounted for by non-wood products such as automobile and airline seating. This large increase in shipments was due in part to regulations issued in 1988 by the Federal Aviation Administration and the National Transportation Safety Board that required newly certified aircraft to be outfitted by 1995 with seats capable of withstanding greater gravitational force.

Office Furniture. Office furniture manufacturers produce wood benches, bookcases, cabinets, chairs, desks, tables, and modular furniture systems. In contrast to a period of strong growth in the 1980s, this segment of the industry is still plagued by the recession and experienced only slight growth in 1993. This is attributable to an oversupply of office space—the legacy of the commercial construction boom of the late 1980s—and office vacancy rates as high as 20% in some major cities. Furniture manufacturers find that small companies with limited budgets are their primary new customers. These companies are trying to stretch their money as far as it will go and hence create a strong demand for mid-range products. With no surge in demand expected in the U.S. market, manufacturers are looking to overseas markets for increased sales.

Wood Fixtures and Partitions. This industry segment manufactures fixtures, partitions, and shelving for the office and retail market. Manufacturers in this market are currently thriving due to increased demand for wood fixtures and shelving in retail stores. Merchandisers feel wood is attractive and lends a certain high-quality feel to their stores and products. In addition, laminated plastic coatings on wood products have helped the industry by increasing the durability of frequently used surfaces. This industry segment does, however, face competition from plastic imitation-wood products.

Wood TV/Radio Cabinets. This industry segment manufactures wood cabinets for televisions, radios, phonographs, and sewing machines; its primary customers are television and radio manufacturers. This market arose after World War II, when the demand for televisions soared, and remained healthy throughout the 1950s, 1960s, and into the 1970s. Foreign competition and plastics have led to a downturn in demand. Imports of consumer electronics surged in the 1980s, and domestic demand for radio and television cabinets plummeted. In addition, manufacturers here and abroad replaced wood cabinets with cheaper and more versatile plastic cabinets. Sales fell at a rate of 9% per year throughout the 1980s, and the workforce was reduced to 3000 employees. During the recession of the early 1990s, some companies exited the market. This market is currently stagnant, and most companies are expected to leave the market for other wood furniture segments.

Niche Markets. Three niche markets are currently experiencing significant growth: home entertainment systems, home office furniture, and ready-to-assemble (RTA) furniture.

- Home Entertainment Furniture**.** Home entertainment furniture is one of the most important growth areas in the wood household furniture industry. An entertainment center is a large cabinet for housing televisions, audio equipment, videotapes, audiotapes, and compact discs. Some manufacturers are teaming up with audio-video suppliers to offer integrated furniture/ equipment packages. The trend is toward larger televisions and more sophisticated entertainment centers.

- Home Office Furniture**.** As companies downsize, subcontract with part-time specialists, and adopt telecommuting and flextime strategies, more people are working out of their homes. These decentralized employees need home offices. Even those who work at a central location may need a home office to do work in the evenings and on weekends. A survey by Link Resources reported the existence of 9 million home offices in 1995 and predicts 13 million by 1998. Originally, home office furniture was sold primarily through office superstores, but home centers and furniture stores are now beginning to sell home office furniture as well. The high demand for home office furniture may replace some of the diminished demand for traditional household furnishings.

- Ready-to-Assemble Furniture**.** RTA furniture is now the fastest growing segment of the wood furniture market as a result of better design, higher quality and functionality, and greater variety and individuality among pieces. RTA furniture, no longer having merely “dorm room” status, includes such features as wood veneer finishes, rounded corners, and beveled glass doors. Pieces can usually be assembled in less than one hour and cost much less than factory-finished products. RTA furniture is also popular with mass merchandisers and warehouse clubs because it is easily stocked. As a result, manufacturers of wood panels (considered part of the lumber industry) are expected to experience high levels of growth.

The Wood Furniture Manufacturing Process

The wood furniture manufacturing process has five basic steps: preliminary handling, raw stock shaping, parts assembly, finishing, and packaging (see Figure 1-3).

Preliminary Handling. This process involves drying the lumber. Some plants, typically larger plants and those concerned with high quality, operate their own saw and planing mills, while others purchase lumber or wood products from manufacturers that produce hardwood veneer and plywood (SIC 2435), softwood plywood (SIC 2436), and reconstituted wood products such as particleboard and fiberboard (SIC 2493). At the saw and lumber mill operations, lumber is typically air dried in sheds for 90–120 days until the moisture content is about 30%. The lumber is then put into a kiln and dried 7–10 days to reduce the moisture content to 6–8%. After kiln drying, the boards are moved to the planing mill for rough milling.

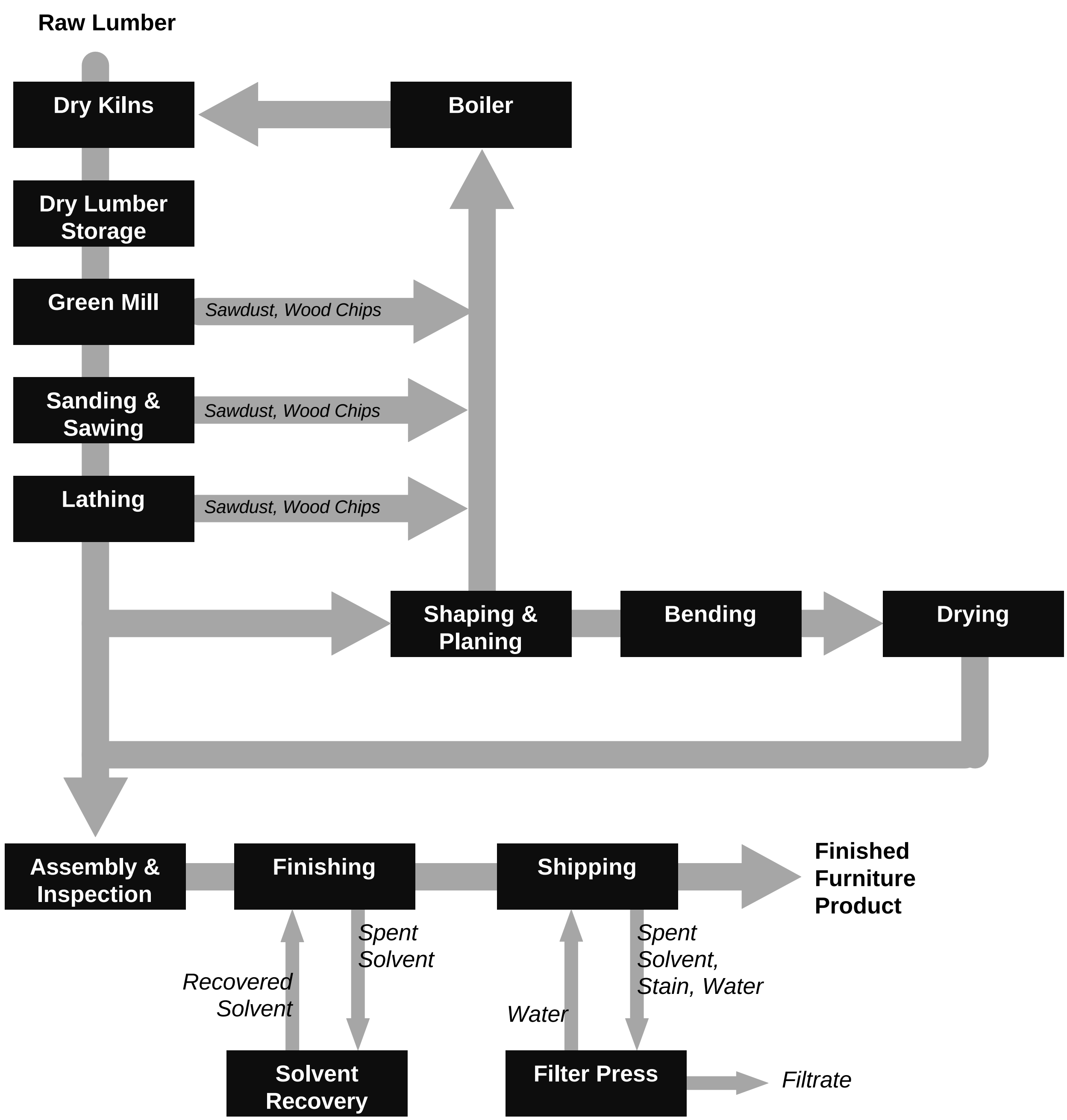
Raw Lumber
Dry Kilns
Boiler
Dry Lumber Storage
Green Mill
Sawdust, Wood Chips
Sanding & Sawing
Sawdust, Wood Chips
Lathing
Sawdust, Wood Chips
Shaping & Planing
Bending
Drying
Assembly & Inspection
Finishing
Shipping
Finished Furniture Product
Spent Solvent
Recovered Solvent
Water
Spent Solvent, Stain, Water
Solvent Recovery
Filter Press
Filtrate

Figure 1-3
The Wood Furniture Manufacturing Process

Raw Stock Shaping. This step involves sanding and sawing, lathing, shaping, planing, bending, and redrying the prepared wood. The waste products are predominantly wood dust, chips, and shavings that are typically burned in a boiler as a fuel supplement for process heating.

Once on the assembly line, the parts are machined. That is, solid wood planks are glued together into larger panels. Doors and frame faces are mortised and tenoned together and are then hand assembled. Intricate cuts are made using a router or machining center. Edges are banded with an edgebander. Moldings are produced on a molding machine. Holes are bored on a boring machine, and other parts are sized with a panel saw. If a high-quality finish is desired, parts are sanded by hand.

Parts Assembly. This step involves gluing, bolting, stapling, and otherwise fastening unfinished parts together. Although finishing operations are the largest source of solvent emissions, adhesives are also a source of volatile organic compounds (VOCs). The amount of adhesive used depends on the end product. For example, a facility that uses veneer in manufacturing products is more likely to have significant VOC emissions than a facility manufacturing RTA furniture. Solvents are also used to clean the adhesive application equipment.

Finishing. Finishing involves coating, drying, and sanding the assembled piece of furniture in a series of repeated steps until the desired finish is achieved. Finishing operations are the major sources of solvent wastes and VOC emissions. Solvents are used in wood stains, paints, and finishes, as well as in the inks used to print simulated wood grain onto plywood and particleboard. Solvents are also used in cleanup operations, specifically, when removing overspray from spray booths, rinsing solvent-based finishes from spray guns, and before color changes. Trace amounts of toxic heavy metals from paints and coatings, such as cadmium, chromium, mercury, and lead, are also present in the process wastewater of some wood furniture manufacturers.

Most wood furniture products go through a multistep finishing process involving, for example, staining, sealing, sanding, sealing, sanding, and topcoat application. Doors and other “hangable” parts are often finished while hanging on conveyors. Nonhangable parts are typically finished in spray booths. Flat pieces can be coated by machines using rollers. Drying is accomplished with ambient air, conventional gas-fired drying ovens, or innovative electrotechnologies such as infrared and ultraviolet light.

Energy Use

According to the U.S. Department of Energy, the furniture industry as a whole (SIC 25) consumed 68 trillion Btu in 1991. Natural gas and electricity comprise the bulk of the energy sources, representing 28% and 25%, respectively. The remainder of the energy is provided by other sources of fuel such as wood waste. For example, wood shavings and scrap are typically used to fire boilers that provide much of the process heat necessary for plant operation.

Electricity consumption for the industry in 1991 was 4915 million kWh, most of which went to motor drive (57%) end uses (see Figure 1-4). Electric motors are primarily used in manufacturing to operate materials processing and handling equipment: saws, planers, air compressors, and conveyor systems. Process heating (4%), lighting (14%), heating, ventilation, and air conditioning (HVAC) (12%), and other process uses make up the remainder of the electricity consumption.

Cogeneration is used relatively little in this industry. For example, the 33 million kWh of electricity generated on-site by furniture manufacturers in 1991 accounted for less than 1% of the industry's total electricity use.

Overall, furniture manufacturing is more labor-intensive than energy-intensive; consequently, electricity consumption is relatively low compared to other industries. The ratio of energy consumption per wood furniture employee is 159 million Btu / worker compared to 9400 million Btu / worker for a typical paper mill. Craftsmanship is essential to many furniture manufacturing operations and, despite advances in automating wood and lumber inspection, human evaluation of surface quality, joint fit-up, and overall furniture quality remains essential. Technological improvements are likely to increase the energy consumption ratio, but the labor-intensity of the industry is unlikely to change substantially.

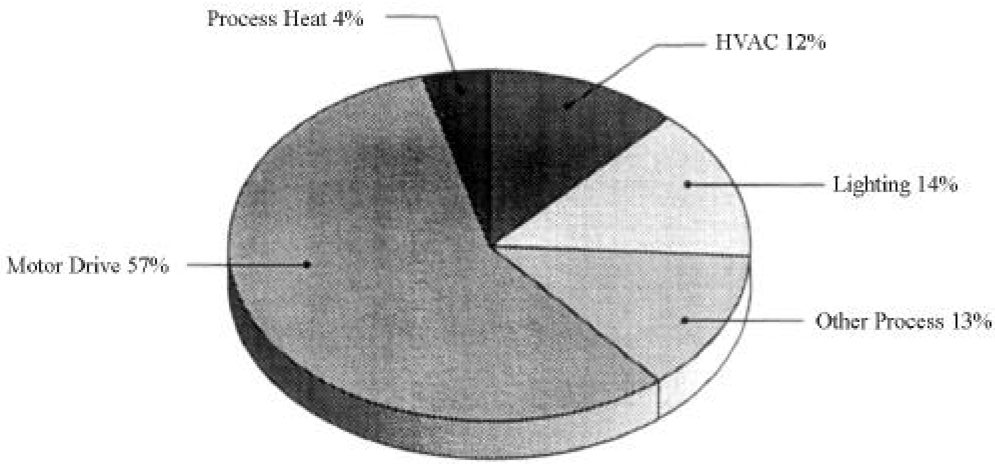

Figure 1-4
Typical Electricity Use in a Furniture Manufacturing Facility

2

BUSINESS CHALLENGES AND NEEDS

The wood furniture market is inextricably tied to trends in consumer buying power and preferences. The discretionary nature of furniture purchases forces manufacturers to respond quickly to social and economic changes that affect consumer purchase decisions. Concerns related to job security, economic recession, and personal debt exert a strong downward influence on the decision to purchase furniture.

Competition

Furniture manufacturers therefore need the ability to respond quickly to shifts in purchasing behavior to avoid the costly buildup of inventories. Ideally, furniture would be produced to order; manufacturers would then bear no cost of inventory, and there would be no guesswork about matching production and inventory to consumer purchasing behavior. However, since a long turnaround time between furniture selection and delivery to the customer often discourages sales, manufacturers must maintain sufficient inventories for timely shipment. Unfortunately, high inventory costs can dramatically degrade the financial strength of a manufacturer. As a result, bar-code-based “quick response” information technologies that automatically feed information back to the manufacturer, and “intelligent inventory management” technologies, are competitive advantages.

In addition to the need for flexibility in responding to changes in consumer purchase behavior, furniture manufacturers face a number of other important business challenges, including

- increased industry competition from both domestic and foreign manufacturers,
- wood supply constraints,
- environmental regulations on volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), and
- employee exposure to potentially hazardous compounds.

The labor-intensive nature of the industry provides competitive advantages to manufacturers in countries with lower labor costs. In addition, increases in wood prices in the United States have made less expensive imported products a presence in the U.S. market, resulting in a trade deficit of nearly $3.4 billion in 1993. Hourly wages in developing countries are much lower than in the United States, and an absence of restrictive health and safety regulations in many of these countries keeps total labor costs relatively low. The largest exporters of furniture to the United States are Taiwan, Canada, Mexico, Malaysia, and Italy. Although labor costs in Canada and Italy are not significantly lower than in the United States, Canada's proximity to the United States and Italy's reputation for and expertise in furniture design ensure that these two countries rank high on the list.

To remain competitive, both domestically and internationally, U.S. producers have been forced to increase productivity, reduce material and operating costs, and/or adjust to smaller profit margins. To meet these challenges, the industry has consolidated as larger companies have sought greater control of material costs, and has sought technologies that improve the flow of information from the retailer back to the manufacturer. Many smaller companies that have secured market niches are acquisition targets for larger companies looking to apply economies of scale over a broader range of market segments.

Need

Improve Productivity and Product Quality

Different market segments require different levels of manufacturing performance. With some types of furniture, customer purchase decisions are primarily driven by price; with other types of furniture, sound construction and high-quality craftsmanship are highly valued. Furniture manufacturers must therefore evaluate their investments according to their market needs. In markets where a manufacturer competes with low-price furniture manufactured in countries with low labor costs, U.S. manufacturers should focus on improving productivity, thereby reducing the portion of the product cost attributable to labor. In markets where high quality is valued more than low price, manufacturers should focus on technology investments that will improve product quality; although improvements in productivity can help any manufacturer compete more effectively.

Technology Solutions

A significant portion of a furniture manufacturer's ongoing overhead costs consist of work-in-process inventory. Consequently, decreasing production task times lowers inventory holding costs and the amount of work tying up floor space. Since furniture assembly typically requires a series of cutting, fitting, and gluing operations, technologies that improve the speed and quality of these processes can enhance a manufacturer's competitiveness.

Improved cutting methods include computer numerical-controlled cutting machines and, in some applications, laser cutting equipment. Computer numerical-controlled machines operate according to instructions provided manually by an operator or according to data generated by computer design software. These machines can follow a pattern more accurately and cut more quickly than a human. Additionally, their responsiveness to changes in work instructions and their characteristically low setup times offer major productivity advantages.

Similarly, improvements in gluing operations can increase productivity. Raising the temperature of an adhesive lowers the time required for it to cure. However, in many wood applications, excessive heat distorts a joint and causes wood fibers to weaken. Since wood is a poor thermal conductor, it is difficult to cure the middle of a joint without overheating the wood at the surface. Radio-frequency (RF) energy avoids this problem because wood is relatively non-polar and does not absorb heat as quickly as the glue. RF heating typically speeds up a gluing process and provides an opportunity to increase the production rate.

Automating processes such as cutting and gluing offers improvements beyond simply speeding up the tasks. By connecting these processes with an information system that schedules and monitors the production flow, a manufacturer can plan the work flow more accurately, which in turn enhances the use of labor and material resources. Knowing the status of upstream work can be useful in distributing labor among supporting downstream processes. Additionally, an intelligent manufacturing control system can quickly identify problems at a task station, thereby potentially minimizing the impact on the production schedule.

See pages 3-8, 3-9, 3-10, 3-15

Need

Reduce Operating and Material Costs

To address competition, wood furniture manufacturers are also striving to reduce material and operating costs. Reducing wood waste, for example, as well as labor and energy costs can contribute significantly toward cost-effective operations that ensure competitiveness in the global market.

Technology Solutions

Technologies that can reduce energy costs include energy-efficient electric motors and adjustable speed drives (ASDs). Since more than half of all electricity use in a typical wood furniture manufacturing facility is for motor-driven processes, reducing the electricity consumption of these processes can contribute significantly to reducing overall plant energy costs. Energy-efficient indoor and outdoor lighting and ventilation fans can also reduce a plant's overall electricity bill. Electrotechnologies such as electric infrared (IR) drying and curing and ultraviolet (UV) curing can improve product quality and the energy-efficiency of the wood furniture coating and finishing process when compared to conventional gas-fired drying processes. Electron beam curing, an emerging electrotechnology, also has the potential to significantly improve drying and curing energy efficiency if adopted by furniture manufacturers.

See pages 3-4, 3-5, 3-6, 3-18, 3-19

Wood Supply Constraints

A sustainable wood supply—based on sustainable forest management and wood use practices—is critical to maintaining a cost-competitive supply of lumber. Combined with consumer pressure to utilize wood in an environmentally responsible manner, furniture companies are facing the challenge to improve wood utilization.

Need

Improve Wood Utilization

Improving wood utilization, and thereby lowering material costs, is essential for many manufacturers. This can help to counteract increasing wood prices—the result of constrained domestic wood supplies—and can improve the environmental image of a company. The two principal methods of decreasing material costs are to improve the yield from a unit quantity of wood and to adopt less expensive substitute materials for existing applications.

Technology Solutions

Wood utilization efficiency has already improved dramatically in this century. Bark is used to fire boilers for process heat and is packaged and sold for non-furniture purposes such as animal bedding and garden mulch. Defect-ridden lumber and wood scraps are pulverized for use in particleboard and other wood composites.

Efforts to improve the yield from wood typically are more cost-effective for high-value hardwoods. Advanced techniques to ensure maximum use of hardwood begin at the log-processing stage and continue through veneer drying and panel assembly. During log processing, the cut patterns, or "flitches," are conventionally determined by the skilled eye of an experienced woodworker based on surface patterns and bark indications. However, advanced scanning techniques have been developed which, combined with computer imaging software, allow operators to maximize the wood obtained from a log based on its grain structure and the distribution of internal defects.

After peeling a log into veneers or cutting it into boards, the resulting lumber has a high moisture content and must be dried. The lumber drying processes are often damaging; damage rates are typically 60–70% due to uneven drying or imbalanced moisture profiles. Vacuum drying and RF heating technologies have been shown to bring this loss rate down to 20%. Although these drying processes are expensive, the material savings can provide a rapid payback for expensive hardwoods.

Additionally, in veneer drying, the need for a comparatively low moisture level in the final product often necessitates redrying veneers after they come out of the kiln. Unfortunately, the damage rate of redrying is higher than that of the initial drying. Using RF heating for redrying reduces this damage rate. The controllability and low thermal stress characteristics of RF heating are helpful in decreasing defect rates and material costs.

After drying, optical scanning of panel surfaces, used in combination with cut-optimization software, can offer additional material savings. An optical scan of the panel surface is analyzed by computer software that determines the best cuts using the constraints of minimal wood waste and the shapes of the products. This technology is similar to the log-use maximization technique that uses three-dimensional scanning and analysis.

Another material cost improvement relies on substituting materials that are less expensive yet have acceptable mechanical and physical properties. Engineered wood products (e.g., plywood and composite board) enable manufacturers to maximize the yield from logs and produce a secondary product that has dimensional stability, uniformity, and diversity. Although wood veneers have been used since ancient Egyptian times, plywood was the first large-scale commercial wood veneer development. Plywood is a series of laminated wood veneers glued together with alternating perpendicular grain patterns. It gained a place in the market as adhesive technologies advanced during the 1920s. Plywood greatly improves log-use efficiency.

Particleboard similarly affected the industry in the 1950s by providing a commercial use for wood scraps. Over the next decade, particleboard became the “workhorse of the wood industry” due to its relatively low cost, good strength, and acceptable surface qualities.

The use of wood composites such as particleboard, medium-density fiberboard, and oriented-strandboard, overlaid with hardwood veneers, provides a less expensive alternative to solid wood components. This practice is already commonplace in furniture manufacturing. For example, many high-quality headboards for use with bed frames are now simply hardwood veneers wrapped over a lower-grade substrate.

Improvements in adhesives and bonding techniques should allow manufacturers to find more opportunities to substitute low-value substrates covered with attractive wood overlays for solid wood.

See pages 3-8, 3-9, 3-14, 3-15

Environmental Regulations

The Clean Air Act Amendments (CAAA) of 1990 required the establishment of emissions standards for each industry considered a major contributor to health and environmental problems. The furniture industry uses large quantities of solvents in finishing tasks; the organic compounds that evaporate off constitute solvent emissions and present an environmental quality concern. In 1995, the U.S. Environmental Protection Agency (EPA) developed a National Emissions Standard for Hazardous Air Pollutants (NESHAP) for furniture manufacturers that use coatings or finishes; the EPA also issued restrictions on the solvent content of many finishes.

Title I Regulation of VOCs. To meet federal standards for ozone, states with ozone non-attainment areas were required by the CAAA to regulate major sources of VOCs in these areas. The EPA was required to develop control technology guidelines (CTGs) for sources of VOCs for states to use in developing reasonably achievable control technology (RACT) standards, although states are permitted to develop standards even more strict than those suggested in the CTG.

A draft CTG for the wood furniture industry was published in September 1995. It covers wood furniture manufacturers located in ozone nonattainment areas that have the potential to emit more than 25 tons of VOCs per year in their finishing operations (10 tons per year in Los Angeles). The EPA estimates that these regulations will affect 2200 of the 11,000 furniture manufacturers it surveyed. The CTG recommends that states limit the VOC content in finishing materials to certain levels (i.e., limit the pounds of VOC per gallon of finishing material). In general this will require affected furniture manufacturers to cut their VOC emissions 30–50%. This can be accomplished by switching to water-based or UV-curable finishes and/or using add-on emission-control devices. While the EPA's CTG focuses on material reformulation, some states also may allow the use of high-efficiency spray guns to reduce VOC emissions.

According to an industry study, the regulations could result in the closure of between 930 and 2015 furniture plants and the elimination of between 5787 and 62,774 jobs, depending on the required reduction in emissions. The low estimates represent a 10% emission reduction, while the high estimates represent an 80% emission reduction. Industry expenditures for compliance could total as little as $53 million or as much as $624 million annually, depending on the number of plants complying in a given year and their choice of compliance technology. This expense may cause a number of plants to close or consolidate with larger companies that can better afford the costs of compliance.

Title III Regulation of HAPs**.** In accordance with Title III of the CAAA, the EPA issued a NESHAP for the wood furniture industry in December 1995, targeting the emissions of 189 hazardous air pollutants (HAPs). Facilities with the potential to emit 10 tons of any one HAP or 25 tons of a combination of HAPs annually are designated “major sources.” The EPA estimates that the NESHAP will affect approximately 750 wood furniture manufacturing facilities nationwide and will reduce emissions by 60% from current levels.

Once a facility exceeds the 10-/25-ton threshold, it must meet an emission level stated in pounds of HAPs per pound of solids used. The emission standard is 1.0 pound of HAP per pound of solid for existing sources and 0.8 pound of HAP per pound of solid for new sources. Companies that emit 50 tons or more of HAPs in 1996 must be in compliance by November 1997; those emitting less than 50 tons in 1996 have until December 1998. To meet these standards, facilities must change the finishing materials they use, upgrade their finishing equipment, use emission-control equipment, and/or change their workplace practices. It is estimated that the rule will require the industry to invest $7 million initially and $15 million per year once all facilities are in compliance. Most (80%) of the emissions come from the finishing operation; 10% come from the gluing operation, and 10% from the cleanup operation.

Need

Reduce or Control VOC and HAP Emissions

Compliance with the emissions restrictions is a technical problem for which a range of solutions exist, from electric-based technologies to reformulated coatings. Unfortunately, documenting this compliance for auditing purposes presents an administrative problem for many smaller manufacturers. Each manufacturer typically uses a range of finishes, and each finish has a unique composition. The emissions from each of these finishes depend on the size of the application and the type of surface quality desired; consequently, tracking HAPs requires data on a range of manufacturing parameters. Although environmental software is commercially available to handle this information, manufacturers must have the appropriate employee and computer resources to perform daily emissions tracking.

To avoid the costs of compliance, some companies already have switched to water-based finishes. These finishes contain significantly less solvents, and their use can keep a manufacturer safely within the environmental standards. Manufacturers have been slow to adopt water-based finishes due to quality and durability concerns. However, advances in this technology enable current water-based finishes to provide equal or better quality than their solvent-based counterparts.

Technology Solutions

Manufacturers have several options for complying with stricter environmental standards. Selecting finishes that have lower solvent concentrations appears to be the least disruptive method of compliance. Switching to new finish formulations will require some process testing and adjustment; but this is on the whole less taxing than the process of tracking daily emissions. Future changes in standards may require repeated effort in the assessment and selection of a compliance method.

Fortunately, a range of alternative coating processes are available to manufacturers. Water-based finishes and UV-curable coatings can significantly reduce VOC emissions. While powder coatings are frequently used in other industries, such as metal finishing, they are not yet practical for use on wood because of the high temperature required for curing. At these elevated temperatures, wood tends to release air and moisture, which interferes with the surface quality of the finish.

Water-based finishes have improved immensely over the last several years. Motivated by increasing consumer environmental awareness and the threat of tighter emissions standards, the wood furniture industry has sought solutions to the problems initially encountered with water-based compounds. Wood tends to absorb moisture and, since its aesthetic appeal is among its greatest selling points, the complex (often damaging) interaction between wood and a water-based finish has inhibited widespread acceptance of these finishes. However, for many applications, water-based finishes now provide a surface quality that is appealing and durable.

UV-curable coatings are also useful in many applications. Chemically activated by exposure to UV light, UV-curable coatings provide an exceptionally tough surface. The primary drawback to this technology is the difficulty of ensuring uniform exposure of all the surfaces of a coated furniture part to UV light. Complex shapes, curves, and crevices are difficult to cure. UV light generally cures coatings rapidly, often within seconds. This cure time is much shorter than the hours required for most solvent-based finishes; consequently, UV-curable coatings can provide a sizable productivity improvement as well as lower the risk of surface contamination during the cure period. In Europe, the high demand for RTA furniture has prompted manufacturers to adopt UV coating systems that can treat furniture pieces while disassembled. The increasing U.S. consumer demand for RTA furniture may prompt similar adoption of UV technology here.

See page 3-19

Employee Health and Safety Concerns

In 1994, the International Agency for Research on Cancer (IARC) named wood dust as a human carcinogen after research showed that breathing wood dust causes a rare form of nasal cancer known as adenocarcinoma. Since then, the American Conference of

Governmental Industrial Hygienists (ACGIH) proposed classifying hardwood dust as a confirmed human carcinogen. This would put hardwood dust in the same category as asbestos. It recommended a threshold limiting value (TLV) for certain hardwood dust of 1 mg/m^3 and a TLV of 5 mg/m^3 for softwood dust. Although the ACGIH is merely a governmental advisory group that makes recommendations on health issues, states often adopt the group's TLVs in their regulations.

By contrast, the Occupational Safety and Health Act (OSHA) only requires that any facility producing wood dust post a cancer warning, although it may in the future move to create a new wood dust standard. OSHA initially set permissible exposure levels (PELs) for respirable wood dust in 1971, and these have been adopted by the majority of the states; however, at least 13 states enforce PELs that are lower than those set by OSHA. In 1989, OSHA made an attempt to tighten the standard below the 5 mg/m^3 exposure limit set in 1971, but its effort was overturned by an appellate court. OSHA's standard or PEL is currently set at 15 mg/m^3 for total dust and 5 mg/m^3 for respirable dust. This is a time-weighted average for a normal 8-hour work day, 40-hour work week.

Some in the U.S. wood industry are skeptical of the new rating set by the IARC because it is based on data gathered 10–30 years ago in Europe. They argue that manufacturing and dust-control methods have improved, and that the risk for American woodworkers has never been as high as the risk for European woodworkers. However, labor representatives for woodworkers, specifically The United Brotherhood of Carpenters and Joiners, propose there is sufficient health risk to warrant lower exposure limits. Both sides of the debate agree that manufacturers should maintain efficient dust-collection and ventilation systems.

Manufacturers expect that PELs will be tightened. In anticipation of such changes, some manufacturers already have adopted expensive bag-collection systems, and in some states, these systems are already mandated. Bag systems have problems, however, such as the potential for fire or dust explosion.

Need

Reduce Worker Exposure to Wood Dust

Wood dust comes from shattered wood cells created in the rough milling, component making, and assembly steps of manufacturing during which wood is sawed, milled, planed, chipped, sanded, routed, and shaped, and parts are tenoned, molded, and jointed. Hardwoods are a more serious concern than softwoods because the wood is denser and produces more dust. Cabinet making, which involves heavy sanding operations, was found to produce the highest average levels of wood dust—1.6 mg/m^3, compared to 1.3 for residential furniture and 0.8 for office furniture. In a recent study, more than half of the kitchen cabinet manufacturers surveyed had a respirable wood dust concentration exceeding 1 mg / m^3.

Technology Solutions

Worker exposure to dust can be minimized by ensuring proper work-area ventilation and / or by equipping tools with localized dust-collection devices. Since the presence of wood dust can also interfere with sanding operations, localized dust collection offers an opportunity to improve the pace and quality of work. Dust collection can be accomplished by attaching bags to the air discharge side of a sanding tool or a saw. The overall presence of wood dust in the work environment can be reduced by installing a vacuum draw beneath the process equipment.

Recently, antistatic abrasives have been suggested as an effective dust-control measure. The dust emitted during sanding tends to accept a slight charge, which explains why dust collects on metal enclosures. Antistatic abrasives on the sanding belt can increase the effectiveness of an existing dust-collection system.

In many industries, worker exposure to harmful substances is minimized by increasing the distance or shielding between a worker and the source of the substance and decreasing the time a worker spends near the source. Woodworking, however, requires workers to be in close contact with products. Automation provides a partial solution in that many sawing and rough sanding processes can be performed with computer-assisted machines; unfortunately, worker evaluation of the finish quality is necessary for most final processes. To protect these workers from the potentially harmful effects of wood dust, enhanced ventilation and filtration technologies provide reasonable, cost-effective options.

Backward-inclined airfoil fans are among the most energy-efficient air circulating equipment. Typically used in high airflow applications, these fans are well-suited for particulate removal in industrial environments. This type of fan does not generate high-velocity air streams that can create drafty and unsuitable woodworking conditions and is able to transfer large quantities of air through dust-collection filters. Consequently, backward-inclined airfoil fans are an excellent option for woodworking facilities concerned with worker exposure to wood dust.

See page 3-13

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 "efficiency technology." Electrotechnologies are selected new or alternative electric equipment options. In many wood furniture manufacturing facilities, the electrotechnologies can improve productivity; reduce operating and/or material costs; improve wood utilization; address environmental, health, and safety concerns; and may couple increased energy costs with an overall decrease in operating costs. Efficiency technologies offer opportunities to decrease energy use, but have little or no direct impact on production.

Also discussed are "emerging electrotechnologies," electrotechnologies that are not currently used in the industry but have the potential to meet business needs in the future. Each electrotechnology is more completely described in Section 4, Electrotechnology Profiles. Vendors of these 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 furniture industry electricity use. Table 3-1 summarizes the technology solutions.

Table 3-1
Technology Solutions to Wood Furniture Industry Needs

			Business Needs			
End Use	**Solution Type**	**Technology Type**	**Improve Productivity and Product Quality**	**Reduce Operating and Material Costs**	**Improve Wood Utilization**	**Address Environmental, Health, and Safety Concerns**
Motors and Drives	Efficiency Technology	Energy-Efficient Electric Motors	■	■		
Motors and Drives	Efficiency Technology	Adjustable Speed Drives	■	■		
Lighting	Efficiency Technology	Energy-Efficient Indoor Lighting	■	■		■
Lighting	Electrotechnology	Energy-Efficient Outdoor Lighting	■	■		■
Misc. Process	Emerging Electrotechnology	3-D Scanning (X-Ray) System	■	■	■	
Misc. Process	Emerging Electrotechnology	2-D Scanning (Optical and X-Ray) System	■	■	■	
Misc. Process	Emerging Electrotechnology	Laser Inspection	■	■	■	
Misc. Process	Electrotechnology	Computer Numerical-Controlled Machining	■	■	■	
Misc. Process	Emerging Electrotechnology	Laser Cutting	■	■	■	
Misc. Process	Emerging Electrotechnology	Vacuum Coating	■	■		
HVAC	Efficiency Technology	Backward-Inclined Airfoil Fan		■		■
Process Heating	Electrotechnology	Radio-Frequency Drying of Hardwood	■	■		
Process Heating	Electrotechnology	Radio-Frequency Veneer Redrying	■	■		
Process Heating	Electrotechnology	Radio-Frequency Curing of Adhesives	■	■	■	
Process Heating	Electrotechnology	Electric Infrared Drying and Curing	■	■		■
Process Heating	Electrotechnology	Ultraviolet Curing	■		■	■
Process Heating	Emerging Electrotechnology	Electron Beam Curing	■	■		■

Motors and Drives

Before electricity was commercially available, machine drive in most furniture manufacturing plants was provided by a central steam engine that powered overhead drive shafts. In the early 1900s, public power became available with the advent of steam boilers (turbines) to drive electric generators. Over the next few decades, woodworking plant operations evolved from dependence on belt-operated tools and conveyors to the convenience of equipment driven by individual motors. By 1991, more than half of all electricity used (57%) in the wood furniture industry went to drive machinery such as planers, saws, air compressors, and materials handling devices. Depending on plant needs, many shops use electric compressed-air hand tools; virtually all spray guns are air-driven.

Air compressors for woodworking plants vary widely in capacity. Small compressors used for spray guns are 5–30 horsepower (hp), while compressors used in large facilities can be up to 400 hp. Air-powered tools have some advantages over their motorized counterparts: they tend to be smaller and lighter for a given capacity because the turbines that drive the tools are less cumbersome than electric motors. The weight and maneuverability of a hand tool is critical to minimizing the onset of worker fatigue and cumulative trauma disorders such as carpal tunnel syndrome. However, compressed air transfers energy less efficiently than electricity.

Many woodworking tasks, such as sanding and routing, are speed sensitive. Scratching, oversanding, chipping, sanding unevenly, or sanding through a veneer can result from selection of inappropriate tool speed. For tasks that affect the final finish of a wood product, the tool drive should be adjustable to within a reasonable accuracy. The airflow to an air-powered tool can be manually adjusted to control tool speed; recent improvements in electric motors have increased their speed-control qualities as well.

Industry trends toward thinner veneers and increased use of water-based finishes make speed control during sanding critically important. Thinner veneers are becoming more popular as the cost of hardwood increases. A thinner veneer amplifies the potential of sanding through the veneer and irreparably damaging the piece. The costs of such an error extend beyond the material cost of the hardwood sheet itself to include all the production costs up to that point. Controlling the speed of a sander lessens this risk and allows the operator to apply a proper surface finish while guarding against excessive loss in the furniture's dimension.

The use of water-based finishes also heightens the need for exact sanding control. Water tends to swell wood grain, which causes it to stand out more; therefore, sanding a furniture surface after applying a water-based finish requires the operator to control the sanding speed to accommodate changes in the wood grain in accordance with its moisture content.

Efficiency Technology Solution
Energy-Efficient Electric Motors

Energy-efficient electric motors (also known as high- or premium-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 over 50 times the initial cost of the motor. As a result, energy-efficient motors are extremely cost-effective, with simple payback of less than 2 years when compared to a standard-efficiency motor. The payback is generally attractive unless electricity prices are very low, or a motor is operated infrequently.

Energy-efficient motors above 1 hp should be available for most woodworking applications. Since air-handling equipment in woodworking plants represents a significant part of overall electricity use, fans are a good application for higher-performance motors. Additionally, some air compressors are equipped with or can be retrofitted with energy-efficient motors. Because of the high usage rate of an air compressor, payback can be relatively short.

In certain applications, saws and belt sanders offer feasible opportunities for upgrades to energy-efficient motors because, as with most production machinery, minimal downtime for maintenance or repairs is a highly valued quality. Cutting and sanding often determine the speed of a production line. Energy-efficient motors are typically manufactured to closer tolerances, use better materials, and offer more robust construction than standard motors. High-quality motors also create less noise; therefore, the use of energy-efficient motors in labor-intensive work environments can increase employee comfort and, potentially, productivity by reducing fatigue due to high noise levels.

Efficiency Technology Solution
Adjustable Speed Drives

ASDs, also known as variable-speed drives, should be considered for large motors (5 hp or greater), particularly on large belt sanders and ventilation fans. Speed control is a key quality of many final sanding tasks. Cross-grain sanding requires high belt speeds to minimize scratching; sanding with the grain can be performed at lower speeds. ASDs utilize electronic control of the motor current frequency to raise and lower the speed of a motor in accordance with the demands of the load. Better speed control can result in improvements in productivity and product quality.

In addition, ASDs can lower operating costs through reduced energy consumption. Reducing the frequency of the current to a motor below 60 hertz slows the motor, thereby eliminating energy use that otherwise would be wasted. In conventional motors, the motor speed remains constant when the load decreases, causing power factor to drop and the motor or run inefficiently. A low power factor indicates a motor is performing comparatively little real work compared to its demand on the electrical system. ASDs tend to maintain high power factors since they ensure the motor speed and electrical demand correspond more closely to the immediate mechanical needs. Consequently, with less electrical losses, ASDs have been demonstrated to result in energy savings of 15–40% in many applications.

Lighting

Lighting represents 14% of industry electricity use and is critical to woodworkers' ability to observe and assess the fit and finish of wood furniture and cabinets. Customers typically appraise the quality of the finish on a piece of furniture as an indicator of overall quality. Hence, prior to finishing, products are often inspected with a white incandescent light to detect scuffs, scratches, or dents. The imperfections are then repaired before the product moves to the finishing department. The products are inspected again prior to packaging. Proper lighting is necessary to detect flaws in a finish.

While many woodworking plants are increasing the level of automation in their processes, a keen eye and experienced judgment is irreplaceable in ensuring the quality of a wood product. Often, the labor freed up by automating a certain production step is applied to inspection and quality-assurance efforts. Task lighting with lamps that provide the proper intensity of illumination and correct color rendering improves the reliability and speed of these quality checks.

Fluorescent lamps (also known as tubes or bulbs) with magnetic ballasts are used by the majority of facilities in the wood furniture manufacturing industry. Fluorescent lights typically appear as 4-foot-long tubes used in two-, three-, and four-tube fixtures; they are used in offices and sometimes in production and loading dock areas. They are more efficient and have longer operating lives than incandescent lamps. Larger facilities also sometimes use 8-foot-long tubes.

Another common lighting source is the incandescent light. These fixtures are relatively inexpensive and easy to install; however, they are the least efficient lighting source available. Typically, they are used in offices, hallways, and common areas. They are also used for signs, displays, and exit lighting.

Efficiency Technology Solution
Energy-Efficient Indoor Lighting

The most efficient form of fluorescent lighting available today is a 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 and $100, respectively.

Ceiling-mounted incandescent lamps can be successfully replaced with compact fluorescent lights when the ceiling height is less than 12 feet, such as in offices or hallways.

Another type of lighting system used in larger manufacturing facilities is high-intensity discharge (HID) lighting. The HID family of lamps includes mercury vapor, metal halide, and high-pressure sodium lamps. All of these lamps are more energy-efficient than fluorescent lamps and have significantly longer lives, but may not have as good a color rendition index (CRI). Although these lamps are most commonly used in parking lots and driveways, they can be used in large warehouse-style facilities. Mercury vapor is the least efficient HID lamp and can be replaced with either metal halide or high-pressure sodium lamps with a relatively short payback.

Electrotechnology Solution
Energy-Efficient Outdoor Lighting

Existing applications for outdoor lighting range from incandescent lights on facility signs to mercury vapor lights in parking lots and driveways. These lighting systems normally represent only a small portion of a facility's 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 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.

Miscellaneous Processes

Approximately 13% of total industry electricity use is consumed in miscellaneous processes such as inspection, cutting, and coating. These processes and technology solutions are discussed below.

Inspection

Inspection and quality control are essential in a wood furniture manufacturing operation. The availability of large-diameter, high-quality hardwoods is decreasing in the United States due to high consumption and efforts to preserve some forested areas. Consequently, there is pressure to improve yields at both sawmills and furniture plants.

After a log is processed into lumber, it is dried and processed into wood products. At this point, another inspection process offers additional material efficiency improvements. Optically scanning the surface of the lumber and using imaging software to identify defects can provide a cutting pattern that maximizes wood usage. If the sawing equipment is computer-operated, the pattern developed from the optical scanning can directly drive the cutting process.

An automated lumber processing system (ALPS) can significantly improve lumber-use efficiency. There are several components to an ALPS. Scanning a log with radiation (X rays) or a magnetic field (magnetic resonance imaging, MRI) and then developing a three-dimensional image helps identify defects. Next, depending on the intended uses of a log, a cutting or veneering pattern is developed. Finally, an operator manually guides the cutting operation, or a set of instructions is programmed into the machinery that then automatically processes the log into lumber. Although the ALPS was specifically developed for hardwoods, it is feasible for softwoods as well.

Computer tomography (CT) is essential in translating the data from a radiation or magnetic scan into a three-dimensional image. This process is complicated by density differences among species of wood and inconsistencies among trees of the same species; therefore, sophisticated computer software is required to make this technology practical.

A similar optical scanning inspection system is used to grade lumber. Lumber grade is a measure of board defects per unit length and determines the value of the lumber. Historically, lumber grading was performed manually by inspectors using visual inspection and judgment to identify the quality of a lumber sample. An automatic grading system offers a quicker way to perform this task. Combined with an automated materials-handling system, automated grading can save labor costs and reduce sorting time. Automatic lumber grading employs the same optical analysis methods used to minimize waste during lumber cutting; however, the software must track the defect rate, correlate this with the wood species, and assign the proper grade to the wood.

Emerging Electrotechnology Solution
3-D Scanning (X-Ray) System

Three-dimensional CT systems evaluate the images created by X-ray scanning of lumber. Computer software identifies the defects in a log based on density differences and uses an optimization routine to plan a pattern of cuts. This process generates less scrap wood than conventional cutting methods. Although the equipment can initially cost as much as $2 million, the high cost of many valuable hardwoods often justifies the investment. Expanding computer capabilities should bring the costs of these systems down and, combined with the trend of increasing prices for hardwoods, should reduce the payback time.

Emerging Electrotechnology Solution 2-D Scanning (Optical and X-Ray) System

Similar to three-dimensional CT systems, optical and X-ray sensors evaluate the surface of a veneer or a board for defects. Working in two-dimensional space, this system requires less-sophisticated and less-expensive software than a CT system. By identifying defects and measuring the distance between them, this system can be used to grade lumber. Additionally, by combining this system with cut-optimization software, manufacturers can maximize the yield from veneers or boards.

Two-dimensional scanning technology is useful in applications other than defect identification. Panel assembly often requires joining boards cut from different trees or from different parts of the same tree. Color matching is essential to forming boards that appear homogenous. While this has traditionally been a labor-intensive task, the accuracy of optical sensors has improved sufficiently to allow automation of this task. Color-imaging software with an optical scan system can group boards of sufficiently similar color and texture qualities. Automating this task saves labor costs and can speed the sorting process.

Emerging Electrotechnology Solution Laser Inspection

Another surface-evaluation technology uses laser technology to read the surface of a veneer or a board. The more penetrating, higher energy fields that characterize this method allow it to work on rough, dirty lumber. In some applications, the laser can also cut defects, such as knots, twisted grain, and mineral stains, out of the wood.

Cutting

The major improvements in saws over the last few decades have been in blade metallurgy and control systems for the cutting head. Saws are used at several different points in the woodworking process, including

- cutting lumber into boards and beams,
- cutting boards and veneers into component parts for panels,
- finger jointing boards and wood scraps into beams, and
- cutting furniture components out of panels and boards.

Different types of saws are appropriate for different applications. Circular saws are effective for high-speed, rough cutting; band saws are appropriate for following patterns to cut thick panels and beams; reciprocating cutting heads are effective for cutting intricate patterns in panels.

Similar to cutting, routing removes material from the edge of a piece of wood or excavates a pattern in a veneer. Routers use a cutting bit that spins at high speeds and travels along a perimeter or according to a programmed pattern. Routers are often mounted on a movable cutting head that travels over a work piece in two-dimensional space.

Technology improvements in control systems for the cutting head have decreased setup times and increased the control and accuracy of cuts. Automated cutting machines that have materials-handling capabilities offer significant improvements in the speed of task performance. Human experience is irreplaceable in evaluating the quality of a panel assembly, joint, or completed furniture piece. The use of automated cutting machines allows skilled workers to monitor machine setup and subsequently inspect the result rather than manually perform all tasks at a slower production pace.

Electrotechnology Solution
Computer Numerical-Controlled Machining

Computer numerical-controlled (CNC) machines automatically perform operations based on instructions that are input manually at the machine or transferred from a data file. In the woodworking industry, typical applications involve cutting, boring, routing, drilling, and/or sanding a panel or a board. There are several advantages to automating these processes, including

- greater accuracy in translation from design to production,
- shorter setup times,
- improved speed of design-flaw correction, and
- reduced time from product design to marketing.

Many cutting operations are intricate, especially for decorative furniture. Manual performance of these tasks introduces human variability and error into the process. One operator may cut along a pattern line slightly differently than another operator does, causing dimensional inconsistency among the component parts of an assembly. Poor fit often results when assembling parts cut by different operators; these discrepancies require added time to dress the joint or the bond line. Computer numerical-controlled (CNC) machines are much more consistent and thereby avoid these problems.

In addition to improved consistency in cutting parts, CNC machines are characterized by quick setup time. Since setup time is a significant factor in many production processes, decreasing the time required to reconfigure a machine for different items increases the productivity of the whole line.

Improved software capabilities now translate computer-assisted design (CAD) files into instructions that directly guide cutting machines. This connection eliminates the labor required to transfer a design concept into machine instructions and further reduces process variability. Linking design to production also provides a valuable competitive advantage by shortening the time required to modify products. Furniture manufacturers must react quickly to changes in consumer preferences; using design files to directly drive production machinery allows manufacturers to rapidly put new products on the market or modify existing ones to satisfy new trends.

Other key benefits to rapid communication between design and production are the quick correction of design errors. New designs are frequently flawed in some aspect, and often these flaws are not revealed until the assembly is completed. Speeding the design-to-product time reduces the number of defective components that are manufactured, thus lowering the cost of rework.

As furniture manufacturing becomes more competitive, productivity strategies such as just-in-time (JIT) manufacturing promise to become more common among domestic manufacturers. JIT production is quick, responsive, small-batch manufacturing in which demand for the product “pulls” the manufacturing process. CNC machinery is necessary for this business strategy because it shortens the time to complete an order.

CNC equipment is quickly becoming essential in furniture manufacturing. Plants that embrace it have a significantly higher chance of survival in an increasingly competitive market.

Emerging Electrotechnology Solution
Laser Cutting

Laser cutting combines lasers and CNC technology to cut highly intricate designs in veneer. Lasers with energy ratings of 0.08–2.0 kW are used and are practical for veneers up to $^{1}/_{8}$-inch thick. Laser cutting is also used to project guidelines onto wood for high-precision cutting. This technique improves yield by reducing production losses from miscuts.

Coating

Two important environmental issues facing woodworkers are solid-waste disposal and VOC emissions; both are related to the wood finishing process. The overspray from a coating operation must be cleared from the air and off of the surfaces in an application area. Since the coating overspray is typically unfit for reuse, it must be disposed of. Because many coatings contain heavy metal pigments, this overspray waste is considered hazardous, and plant operators are therefore required to have this waste collected and disposed of by specially licensed contractors. Additionally, overspray represents a direct drain on material cost. Depending on the specific application, some finish sprayers waste up to half of the total finish applied. Furniture makers can realize significant material purchase and disposal cost savings by improving the effectiveness of their spray processes.

High-volume, low-pressure (HVLP) spray equipment uses a low-velocity stream to coat a surface. This application method minimizes the amount of reflected, bounce-back particles and can save up to 60% in coating costs. In addition, the improved spray efficiency helps furniture makers meet environmental regulations in some areas.

VOC emissions result from the use of solvent-based paints and coatings. Coatings reformulated for lower solvent content and therefore less VOC emissions include high-solids and water-based coatings.

High-solids coatings are solvent based, but have a lower concentration of solvents than conventional coatings and require some modifications to the application process, specifically because they tend to be more viscous.

Adopting water-based low- or no-solvent coatings is more complicated because it requires equipment and process modifications. These coatings are more sensitive to contamination and therefore require corrosion-resistant piping. Typically, manufacturers install stainless steel lines to transport water-based coatings from storage to the application site. In addition, water-based finishes cause wood fibers to swell, which affects the appearance of the grain and complicates sanding. To compensate, a finer grit abrasive or a faster belt speed may be necessary. Additionally, the water-to-wood reaction is time sensitive; less time for water absorption means less damage to the wood surface. Accelerating the drying process with heat or infrared (IR) energy minimizes grain swelling by removing the moisture before the wood absorbs it.

Water’s effect on wood varies, depending on the species of wood. Oak is exceptionally sensitive to water and, until recently, medium-density fiberboard was unsuitable for many water-based coatings. The pressure on the industry to adopt environmentally responsible coatings has motivated a search to develop water-based coatings and coating procedures. Currently, properly applied water-based coatings provide equal or better finish quality than conventional solvent-based coatings.

Emerging Electrotechnology Solution
Vacuum Coating

Vacuum coating systems are available that provide 100% material transfer efficiency. These systems can be used to apply water-based paints or stains or UV-curable coatings. Typically self-contained and automated, vacuum coating systems also offer opportunities to speed the production rate and lower the labor costs associated with finishing tasks. One drawback is a limited range of applications. Vacuum coating systems are effective primarily on flat, two-dimensional surfaces and are not yet practical for coating complex parts with hidden surface features such as grooves and decorative reliefs.

Heating, Ventilation, and Air Conditioning

HVAC accounts for 12% of total furniture industry electricity use. The key function of an HVAC system in a woodworking facility is ventilation. The ventilation load in these facilities is large because of the need to control wood dust and to meet the makeup air requirements of the spray booths. The heating and cooling loads primarily depend on losses through the building envelope. Although people and machinery add heat and moisture, woodworking facilities do not have unusually high heating or cooling needs.

Wood Dust Control

Excessive wood dust in the air poses a fire and explosion hazard, and can cause respiratory difficulties for employees; it is also associated with a rare form of nasal cancer. As a result, wood dust control is an important part of a furniture manufacturing facility's operation.

Wood dust can be controlled by strongly ventilating the affected workshop areas. Typically these areas are equipped with filters that collect dust from the air and prevent it from entering the main return-air ducts. Many woodworking tools are also equipped with local dust-collection devices; retrofitting older tools with these features can be a low-cost, practical, dust-control measure. Additionally, antistatic abrasives have been developed that neutralize charged dust particles and improve dust collection. Since wood dust particles have the same charge, they repel each other, remain airborne longer, and are attracted to grounded metal surfaces. Antistatic abrasives (i.e., antistatic sandpaper or sanding cloth) lessen the development of a charge during sanding. The advantage is that dust with a weaker charge is less attracted to grounded electric tools, so there is less fouling of equipment. Use of antistatic abrasives can also improve the speed with which a finish is achieved and the effectiveness of the ventilation system, thereby providing a less expensive option to upgrading ventilation equipment capacity.

In addition, some manufacturers offer high-efficiency dust hoods that totally enclose the sanding head. This reduces a machine's ventilation requirements by 35%, as well as reduces downtime for maintenance because equipment bearings and windings have less damage due to wood dust. Manufacturers of portable tools are also making it possible to attach a central vacuum system directly to the tool. Some wood plants use down-draft benches to further maximize dust collection and limit employee exposure to wood dust.

Efficiency Technology Solution Backward-Inclined Airfoil Fan

Most wood furniture facilities use a heavy-duty radial fan for dust control. However, the efficiency of a ventilation system can be improved by prefiltering the air before it enters the ventilation system's filter and by using energy-efficient backward-inclined airfoil fans instead. These fans are 20–25% more energy-efficient than conventional fans. When using backward-inclined fans in these applications, the addition of a prefilter upstream of the fan lowers the mass density of the airflow, which improves the efficiency of the fans. Since ventilation fans operate continually during production, the energy-saving qualities of backward-inclined fans can provide significant cost savings.

Spray Booth Ventilation

The finish quality of a wood product is a critical determinant of its final value. Minimizing the amount of dust in the air in spray booths and finishing rooms is essential to avoid the introduction of airborne dust into production areas. As a result, these work areas are carefully isolated from production areas. Spray booths normally have filters on the makeup air supply ducts to keep contaminants from entering the area and settling on the finished wood surfaces.

Another major concern in furniture finishing areas is the exhausting of solvent vapors released from the finishing process. Although spray booths often have open fronts for improved access, they may be enclosed to ensure cleanliness and vapor containment. There are four common filtering systems for exhaust: electrostatic, dry-disposable, roll-type, and water-wash. Water-wash systems are typically associated with large spray booths.

Most facilities induct makeup air from the outside to replace the air removed by the exhaust fans. Makeup air units are equipped with high-efficiency filters to ensure that only clean air enters the booth area. During much of the year, the air brought in from outside must be heated or cooled, which can add considerably to a facility's energy costs. One option to reduce this cost, if the solvent concentration from the exhausted airstream is sufficiently low, is to add a heat recovery heat exchanger to condition the incoming makeup airstream. Heat recovery heat exchanger surfaces, however, are subject to damage by condensation of corrosive liquids. In combination with an adequate filtration or solvent capture system, these heat exchangers can significantly lower the energy costs of operating a finish booth.

Process Heating

Process heating accounts for 4% of the electricity used in the wood furniture manufacturing industry. In general, process heat is used by large furniture manufacturers for drying lumber, and by both small and large manufacturers for drying and curing adhesives (during parts assembly) and drying and curing coatings in the finishing process.

Wood Drying

Lumber drying is necessary to remove enough moisture from the wood so that it holds reasonably stable dimensions. While many furniture manufacturers purchase their lumber after it has been dried, large manufacturers who prefer a greater degree of quality control dry their own lumber.

Lumber delivered for manufacturing often has an initial moisture content near 30%; this has a significant impact on its density. Rough drying is usually performed outside under a shelter, and months are often required to bring the moisture content down to a level appropriate for kiln drying.

Since the drying process is time-consuming and kiln space is limited, woodworkers must balance the supply of dry wood with the costs and space requirements of storing it. The costs of simply holding wood in inventory are high because it ties up capital. Moreover, if the wood is removed from a kiln only to sit idle prior to use, then the risk of it getting wet again or damaged increases. Technologies that shorten the required drying time can help relieve this cash flow burden on the manufacturer.

Electrotechnology Solution
Radio-Frequency
Vacuum Drying of Hardwood

Radio-frequency (RF) vacuum drying can help reduce the time required to dry hardwood from 4–8 weeks to a few days. Current applications use a natural-gas-fired or waste-wood-fired boiler to heat the kiln air that dries the wood. Typically, a kiln is labor- and energy-intensive and has a yield of only 30–40% due to wood damage. Damage occurs because wood reacts to uneven moisture removal by warping and splitting. Since kiln space is limited, wood is normally tightly stacked; where the airflow is inadequate, the wood is either insufficiently or unevenly dried.

RF vacuum drying avoids this issue because it is performed in a depressurized enclosure. Under vacuum and when exposed to RF energy, water is quickly pulled from wood cells without excessive heat, thus reducing damage. Since space in this enclosure is more restrictive than in a kiln, wood is cut to the final dimensions first, thereby reducing the amount of wood to be dried.

RF energy is absorbed more readily by polar substances such as water. Consequently, the more moisture that wood holds, the more RF energy it absorbs. This leads to a self-limiting process that results in even drying and significantly less damage to the wood. The total yield in this process can be as high as 80%. Because operating costs are usually higher with this method, it is more cost-effective for use with high-value hardwoods. It may also be useful in cases where very thick lumber is being dried or when speedy drying is critical to production.

RF vacuum drying is currently being used by more than half a dozen manufacturers for drying hardwoods for specialty products. Typical power consumption for an 8000-board-foot kiln is 14,000 kWh per load.

RF energy can be used by wood furniture manufacturers to heat mats of composite wood, such as fiberboard, during the manufacture of engineered wood products. RF energy penetrates thick wood mats and, when used in conjunction with a primary heating source, helps apply an even distribution of curing energy. Applying RF energy thus speeds up the cure and produces a higher-quality board. With a more even temperature distribution, the wood mat surfaces do not need to be heated to as high a temperature. The use of RF energy also helps to prevent “precure”—a situation in which the outer fibers cure too rapidly.

Another application for RF is to preheat composite boards prior to entering the press. By preheating thick wood mats, the task time for completing the cure inside the press equipment can be significantly reduced. In these applications, RF heating equipment is characteristically space-efficient and can achieve cost savings by speeding production.

Electrotechnology Solution
Radio-Frequency Veneer Redrying

Veneers are used to assemble plywood boards and to cover low-cost substrates; in most cases they must be glued in place. To effectively bond veneers, the moisture content of the wood must be below a level dictated by the particular application; usually less than 5%. Conventional kiln drying of a batch of veneers results in uneven drying such that many veneers must be redried to achieve the desired moisture content. Up to 25% of the veneer exiting primary dryers is too wet for plywood manufacturing and must be redried. Damage caused by uneven drying also contributes to a high defect rate. Sending partially dried veneers back through the kiln drying process increases their chance of damage.

The use of RF energy for redrying results in a lower defect rate (thereby minimizing costs) and achieves the target moisture levels in a controlled manner. The RF waves dry the veneer evenly from the inside out, reducing material distortion and the risk of overdrying. Hot air circulating in the RF dryer removes the moisture evaporated by the RF energy so it does not condense and drop back on the veneers.

The RF redrying process also increases productivity by freeing up the primary dryers to begin drying a new load of veneer. Economic studies show that it is more efficient to cycle the veneer sheets through a natural-gas dryer quickly and then redry, in an RF dryer, those that are not completely dry than it is to dry sheets longer in a natural-gas primary dryer or send them through the primary dryer a second time. The additional production possible from the primary dryer increases plant productivity and can pay for the capital cost of the RF dryer in less than 2 years.

Manufacturing Engineered Wood Products

Engineered wood products—typically manufactured by companies classified as Reconstituted Wood Product manufacturers (SIC 2493)—consist of wood particles, fibers, or wafers that are combined with resins, adhesives, and fillers to create materials that have specific physical and/or mechanical properties such as high strength or flexibility. Engineered wood products use bonding agents and fillers to convert low-value wood scraps and wastes into valuable products. Particleboard is an early example of an engineered wood product; more recently, medium-density fiberboard and high-density fiberboard have become significant material sources for the furniture and construction industries.

The uses for engineered wood products range from the cores onto which hardwood veneers are bonded to furniture pieces that are treated and painted to hold simulated wood grain. Engineered woods used as cores for furniture components must have strength and dimensional stability. Engineered woods used alone as a furniture component must have strength, dimensional stability, machinability, and the ability to hold paints or finishes. Particleboard, for example, serves as an effective core material but does not hold a sufficiently smooth edge to be used in many furniture applications. Medium-density fiberboard, however, is machinable and can be used as a furniture surface.

Critical to the manufacture of engineered wood products are the resins that bond the wood particles and fibers together. Most of the resins used in engineered woods are thermosets such as urea formaldehyde, phenol formaldehyde, and methanol formaldehyde. Thermoset resins form irreversible chemical reactions at high temperatures, which means that these resins will not decompose when reheated. Heat is required to cure the resin and pressure to achieve an adequate composite density.

Adhesive Drying and Curing

Adhesives have a significant role in a range of woodworking applications, from panel assembly to furniture construction. Panels are manufactured by fitting together mating boards and gluing them along the joint line. Many furniture pieces, on the other hand, are held together by glue or a combination of mechanical fasteners and glue. Many beams are constructed by gluing the finger joints of wood pieces. Adhesives typically cure faster at higher temperatures, and, in many applications, properly heating the bond line enhances productivity.

RF energy is well-suited for curing adhesives. The polar qualities of glue absorb RF energy while the surrounding wood, which is less dielectrically sensitive, remains relatively cool. Depending on the application, heat, which is conductively or convectively transferred to a joint during conventional curing, may damage the wood or cause dimensional problems. Joint expansion and contraction during exposure to excessive heat can result in poor fit and a weak bond. RF heating avoids this problem by accurately applying energy to the adhesive.

Electrotechnology Solution
Radio-Frequency Curing of Adhesives

Most adhesives used in wood manufacturing and woodworking applications, once cured, will not unbond under heat. These adhesives require tight joint fit when used to bond two pieces of wood together. Low moisture content is important to ensure that the boards are flat and straight when glued. Pressure is used to hold the joints closely together during curing.

- Panel Assembly. Component pieces for panels are passed under a roller that applies adhesive to the edges. The pieces are then manually placed side by side to form a panel. The panel then enters the RF drying system, which combines heat and pressure to cure the glue lines.

- Edge Bonding. Smaller pieces of wood are glued side-to-side or end-to-end to create long, wide boards. Table and cabinet tops are often made by gluing edge-bonded veneers onto cores. The advantage of RF edge-bonded boards is that they are immediately ready to be sent to the next operation and will not be torn apart by subsequent machining. This rapid task time reduces work in process which, in turn, reduces storage space requirements and inventory costs.

- Furniture Assembly Gluing. Assembly gluing is an important application of RF heating. RF energy cures the glue quickly and significantly reduces task time. This application also increases productivity and reduces storage space and inventory costs.

Drying and Curing of Coatings

Furniture makers must respond to environmental regulatory trends that are decreasing the allowable emission levels of VOCs and increasing the cost of discharging solid wastes. Wood typically is stained to achieve a desired color and / or to highlight a grain texture. Wood also usually is sealed to prevent moisture exchange between the wood and the environment. Historically, stains and sealants have contained large amounts of solvents to keep the active compounds dispersed in solution and to facilitate application. After application, these solvents evaporate, leaving the stain and sealant to cure on the wood surface. Unfortunately, emissions from these solvents are harmful to the environment and, above certain concentrations, pose health risks for workers. Consequently, furniture manufacturers are among the industries targeted by the EPA for emissions restrictions.

In anticipation of more stringent regulations, many manufacturers are reconfiguring their processes to use water-based finishes. Although water-based finishes contain some solvents, the carrier is mostly water, and problems with emissions are minimized. Early experiences with water-based finishes showed they would leave a milky haze on the wood surface. Recent improvements in their composition, however, have resolved such problems.

Electrotechnology Solution
Electric Infrared Drying and Curing

Electric IR energy is particularly useful with water-based coatings because it dries the coatings before they seep into and raise the wood grain. In one application, products exposed to electric IR energy were dry enough to be stacked 6 seconds after a coating was applied. Additionally, preheating wood and keeping it warm throughout a sealing or priming process maximizes water evaporation and reduces production time. Small electric IR heaters are economical and effective in heating the wood surface and not the air.

Many wood finishers are shifting to water-based coatings to improve their bottom line as well as to improve their environmental performance. IR heaters can be placed just inches from coated stock, drying the materials in seconds. The increased drying speed dramatically improves productivity and reduces labor requirements. In one example, a wood products manufacturer was working two 12-hour shifts with 15 people per shift, six days per week. After switching to waterborne coatings and IR drying, the company doubled its output and operated only one 9-hour shift with 5 people, five days per week.

Electrotechnology Solution
Ultraviolet Curing

UV-curable coatings are compounds that cross-link almost instantly upon exposure to UV light. This technology is used heavily in both the printing and furniture industries to quickly cure strong, durable coatings. UV-curable polymers provide a durable, high-gloss, and scratch-resistant coating. In many applications, UV-curable coatings can be cured in 3–6 seconds, versus several minutes for conventional coatings in a natural-gas dryer, substantially improving the time it takes to finish a piece of furniture.

A key characteristic of UV-curable coatings is the absence of solvents. As manufacturers attempt to lower their VOC emissions to comply with regulations and consumer pressure, UV-curable coatings offer an attractive method of emissions reduction. The physical properties of UV-curable coatings are also favorable. Because they have relatively low viscosities, the coatings flow smoothly and evenly onto a surface. The footprint of the process equipment is exceptionally small, which allows a manufacturing facility to make better use of floor space. No special ventilation is required, and the speed of the process can minimize work-in-process inventory.

The principal drawback to UV-curable coatings is the need to evenly expose the coating to UV radiation. Flat surfaces are ideal. Complex surfaces with grooves and hidden features are generally not practical for UV coatings because of unequal exposure to the radiation.

Emerging Electrotechnology Solution
Electron Beam Curing

Electron beam radiation can be used to rapidly cure layers of adhesives or resins impregnated in the wood. Characterized by an ability to penetrate deeply, the focused nature of electron beam radiation allows it to cure coatings much more quickly than is achieved with conductive heat transfer. Also, electron beam curing can be applied relatively accurately: it can cure a thin bond line without affecting surrounding material. The best compounds for this application are acrylic resins, acrylated epoxies, or polyurethanes. The amount of electron beam radiation required for curing varies with the moisture content of the substrate. High moisture levels can impair or prevent the curing reaction. Currently, electron beam curing is used in comparatively specialized applications within the wood furniture industry and others. The technology is expected to become more cost-effective to purchase, operate, and maintain.

4

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 guide. For further information, turn to Section 5 for a list of equipment vendors that can provide further information as needed.

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.

Table 4-1
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.

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.

Table 4-2
Typical Lamp Characteristics for Outdoor Applications

Type of Lamp	typical Wattages	Initial Lumens/Watt	Avg. Rated Life (h)
Incandescent	60-1500	15-24	750-2500
Compact fluorescent	12-35	25-75	8000-12,000
Fluorescent	20-215	50-100	9000-20,000
Metal Halide	175-1500	69-115	10,000-20,000
High-Pressure Sodium	35-1000	51-140	7500-24,000
Mercury Vapor	40-1000	24-60	12,000-24,000

Note: Initial lumens / watt includes ballast losses.

Advantages

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

- Increased perception of comfort and friendliness
- Increased security for customers and employees
- Reduced number of 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.

Computer Numerical-Controlled Machining

Basic Principle

Computer numerical-controlled (CNC) machines perform operations based on digital instructions provided to the machine by an operator or fed into the machine from a data file. CNC equipment, available for many woodworking tasks, increases production flexibility and responsiveness. CNC technology can improve boring, routing, drilling, panel cutting, and sanding tasks through quicker process times and lower labor costs. However, the most significant benefit of CNC performance is the speed with which new tasks can be started.

In conventional woodworking operations, machine configurations must be changed manually; bit selection, machine speed, and cutting instructions are typically adjusted for each type of product. Since small manufacturers often work with small batch sizes and customized items, setup times can account for a large portion of the overall production time. CNC machines do not require lengthy setup times and provide a level of responsiveness that can help keep costs down while increasing production performance. Increasingly, CNC machines are a state-of-the-art necessity for furniture manufacturers.

CNC machines are more accurate and consistent than conventional equipment. Many CNC machines operate at tolerances below 0.005 inches at a high level of repeatability. This precision enhances product quality by improving the fit between mating parts. Production defects found on manufacturing lines that use CNC equipment are usually attributable to design problems rather than operator error; consequently, design flaws can be detected and corrected relatively early in the production process. This quality assurance benefit can prevent the production of multiple copies of ill-fitting parts.

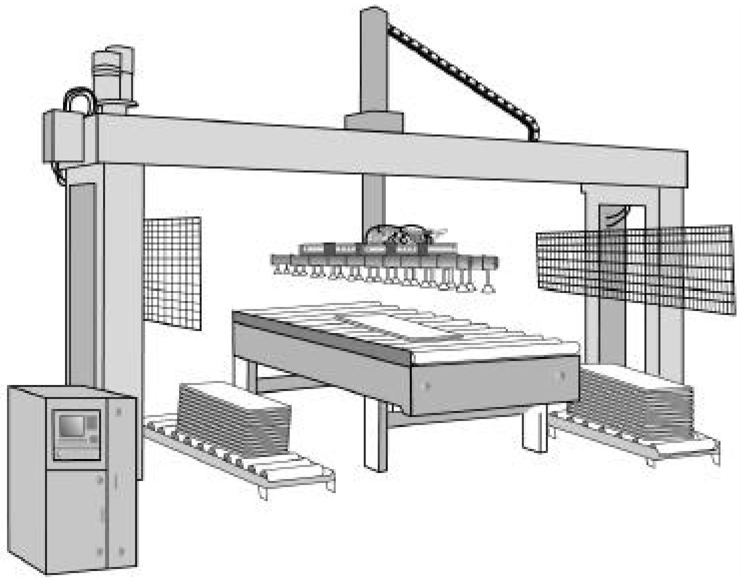

Figure 4-1
Computer Numerical-Controlled Machine

Courtesy of Biesse America

CNC machines provide an essential link to the labor-saving benefits of plant automation. Although human inspection of woodworking quality is indispensable, moving labor resources away from materials-handling tasks and toward the higher-skill areas of final assembly and quality assurance provides a more cost-effective application of labor.

Shifting materials-handling tasks to automated CNC equipment provides several advantages: Workers do not have to manually arrange the production blanks according to their particular needs. Instead, the production units are fed into the CNC equipment by an automated system of lifts, rollers, and conveyors. Automated equipment is typically quicker than manual materials handling, and the speed of material flow can be adjusted according to the needs of a specific production batch. The pace of the production line can be controlled with greater accuracy, which minimizes work-in-process inventory and decreases the amount of floor space necessary for storage. Worker health problems from cumulative trauma disorders and accidents are also reduced by automating materials-handling tasks.

CNC machines also tend to lower the labor costs associated with parts production. By lessening the labor requirements, CNC equipment brings unit production costs down such that shops with high production volume can realize relatively short payback periods. Manufacturers are currently facing pressure to adopt a “mass customization” level of performance. Mass customization is the term for producing customized work at mass-production costs. Custom work is characterized by small batch production and high unit costs. The responsiveness and speed of CNC equipment enables manufacturers to maintain high-speed production despite multiple batch reconfigurations. Since CNC equipment has characteristically low setup times, the production delays associated with preparing a production line for a different production item are less troublesome. Efficient mass customization is difficult to achieve without the use of CNC equipment.

A trend throughout all manufacturing industries is the adoption of just-in-time (JIT) practices. JIT mandates that the pace of production relate directly to downstream product demand; a unit of production is not started until a need for it exists. This concept translates broadly to production planning and specifically to adjacent machines on an assembly line. JIT manufacturing is characterized by a pull system in which an upstream task is performed only when a downstream task is ready to accept the unit.

The key benefits to JIT are low inventory costs and a responsive production system. Low inventory costs free up capital and lower the debt requirements for a manufacturer. A more responsive production line permits small batch sizes and quick changes in production tasks.

In addition to facilitating rapid production of a series of small batches of products, CNC machines overcome another industry problem: the shortage of skilled labor. CNC equipment allows manufacturers to make better use of available labor. CNC equipment itself requires a relatively high degree of skill; however, combining this technology with automated materials handling allows fewer workers to operate a production line.

System Description

CNC equipment is conventional woodworking equipment that is operated by computer. The computers translate the instructions of an operator or a data file into digital code that then directs machine operation. CNC capabilities have been developed for a number of woodworking tasks, including routing, boring, cutting, and sanding.

Advantages

- Increased throughput: With a CNC machine, it takes less time to perform a task, thereby increasing the production rate. Setup time is considerably quicker, which allows rapid changeover to a new task. Some machines combine previously separate machining operations.

- Improved quality: Improved accuracy (precision machining with fewer defects) and faster design layout.

- Faster design-to-manufacture process: CNC machines can be driven by information pulled directly from computer-aided design (CAD) data files. This connection allows designs and design changes to be quickly incorporated into the manufacturing process and improves the connection between order processing, design, and manufacturing.
- Lower labor costs per unit: By replacing a manual process, CNC machines reduce the labor requirement. Although CNC machine operation requires greater skill than operation of conventional equipment, the automated process has higher productivity.
- Enhanced production responsiveness: Brings a company one step closer to JIT manufacturing. Older CNC systems required programmers to manually type in code; newer machines automatically generate code when translating the CAD file to machine instructions for manufacturing.

Disadvantages

- High initial cost: CNC machines are expensive, typically costing $80,000–$200,000 or more.
- Increased worker skill level: CNC machine operation demands trained operators and maintenance personnel.
- Requires added maintenance: New software programs are constantly being developed to help facilitate the design of parts. Labor resources must be allocated toward keeping up with these changes.

Commercial Status

CNC machines were introduced on an experimental level in the early 1970s and are now a mature technology widely accepted in the industry. The computer’s role in wood furniture manufacturing is expected to expand dramatically in the future. The trend is to integrate CNC machines more tightly in the design-to-manufacture process. Production procedures in plants without CNC assistance may be too slow and inaccurate to allow a company to survive in today’s market-driven economy.

Cost and Electrical Requirements

The cost of CNC machines varies from $80,000–$200,000 (or more). The electricity consumption of the CNC portion of a woodworking machine is equivalent to the electricity needed to run a computer and monitor, which averages 280 kWh per year (for a typical office computer). The electricity consumption of an individual unit of CNC equipment depends on the size, type, and complexity of the equipment.

Table 4-3
Computer Numerical-Controlled Machining System Characteristics

Dimensions	Varies by type and size of equipment
Energy Consumption	Varies by type and size of equipment
Key Inputs	
Power	Electricity
Other	None
Key Outputs	
Solid Waste	None
Air Emissions	None
Water Effluent	None
Cost	
Purchase	$80,000 and up, depending on equipment type, size, and complexity
Installation	Varies depending on equipment type and size
Other Supplies	Varies depending on equipment type and size

Radio-Frequency Wood Drying & Adhesive Curing

Basic Principle

Radio-frequency (RF) energy is used to dry wood and to accelerate the curing of resins and adhesives. RF energy is a rapidly alternating electromagnetic field that causes polar molecules to vibrate and create heat. Wood is not particularly reactive to a changing dielectric field; however, water is exceptionally polar and responds strongly to RF energy.

Wood Drying. Lumber must be dried prior to use in any furniture application. RF heating is particularly effective for drying wood because wet wood absorbs more RF energy than dry wood. This quality prevents wood from overheating as it dries and helps even out the moisture profile. In conventional drying, although wood is stacked to allow airflow between pieces, the wood deep inside a stack retains more moisture. Moreover, uneven drying causes warping, cracking, and the loss of a significant percentage of each batch of wood. Vertically integrated cabinet and furniture manufacturers typically perform their own hardwood drying. The conventional drying process requires several weeks, which means a large amount of capital is tied up in inventory costs. By speeding the drying process, RF drying provides some furniture manufacturers an opportunity to lower their inventory costs.

The next drying step is kiln drying. In this step, wood that is suitable for furniture or construction material is selected and placed in a kiln for several weeks. The final moisture content of the wood is determined by its end-use application.

Veneer Redrying. RF drying is beneficial for veneer redrying for a different set of reasons. Wood is dried in kilns to achieve a particularly low moisture content. After kiln drying, much of the wood is often not sufficiently dry and must be sent back through the kiln. Plywood veneer is particularly sensitive to moisture. Since many adhesives do not bond well in the presence of moisture, plywood veneers must be dried to a 5% moisture content. Unfortunately, sending veneers back through a kiln for redrying results in an unusually high defect rate. The use of RF energy for veneer redrying offers a much lower defect rate, which can result in significant materials savings.

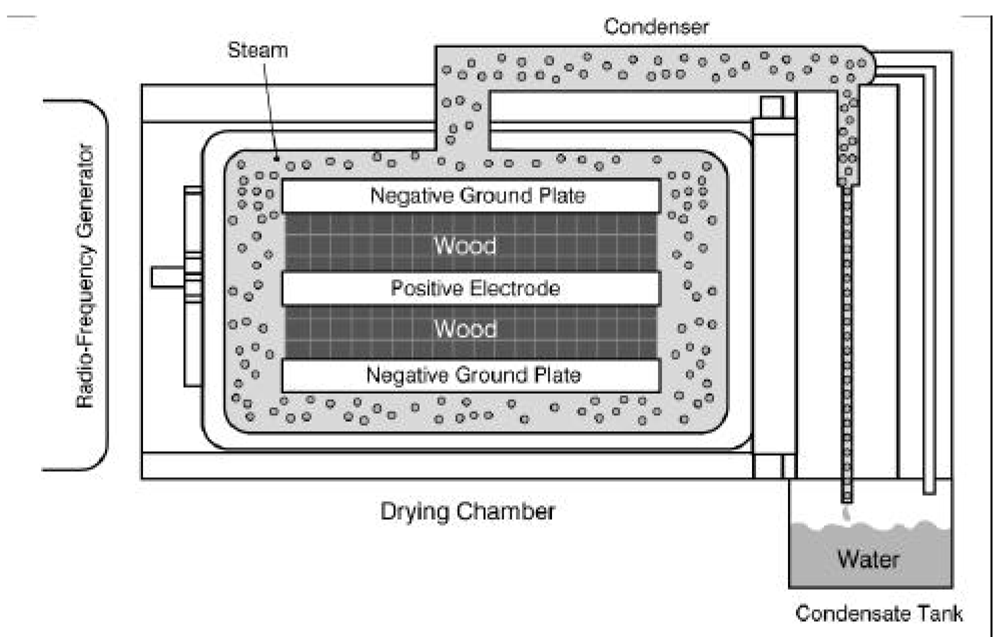

Figure 4-2
RF Drying Unit

The consistent moisture profiles produced by RF drying equipment offer added advantages. Consistent moisture distribution in wood panels increases the dimensional stability of the panels, making them less likely to warp. Also, assembling cabinets and furniture with low-moisture wood improves the bonding process, which can increase productivity and product quality.

Adhesive Curing. In most curing applications, higher temperatures accelerate the cross-linking reactions that allow glues to bond and resins to solidify. Since adhesives and resins contain water and other polar compounds, they heat up when exposed to RF energy. Wood, which burns or weakens under excessive heat, remains comparatively cool at the levels of RF energy used to cure glues and resins. Consequently, RF heating can accelerate the manufacture of many wood composites and the assembly of glued-wood parts.

Hastening glue and resin drying is advantageous because it can speed the overall rate of production, which in turn lowers the amount of work-in-process and inventory costs. Also, the quick curing time eliminates bottlenecks and provides a degree of freedom in sequencing tasks that can further reduce the production cycle time. For example, two parts can be bonded prior to a machining operation rather than machined first and glued later.

System Description

A typical RF heating unit consists of a power supply, an oscillator, and a set of electrodes. The power supply feeds the oscillator, which generates high-frequency energy (2–100 MHz). The electrodes convert the high-frequency energy to RF waves. This RF energy provides an alternating electric field that rapidly reverses the orientation of the polar molecules. This molecular motion manifests as heat within the product. Because the same frequencies are used for radio communication, the RF heaters must be shielded to avoid radio interference.

In an RF drying shed, wood is placed between plate electrodes of alternating polarity. The strength of the RF field is adjusted according to the dielectric properties of the wood, which varies by species and moisture content. In veneer redrying, the veneer moves through the RF oven horizontally. Because the moisture levels tend to be lower, and the risk of damaging the wood is higher, the RF field must be controlled with greater precision than in the RF drying shed.

In adhesive curing applications, RF equipment is typically configured to fit a production line. If each unit of production has the same dimensions and material characteristics, they all require the same RF exposure. This limits variation in the voltage settings and associated stress on the RF equipment; it also eliminates “ramp up” and “ramp down” variations that can slow production. The cost justification for RF adhesive curing is based primarily on the increases in productivity and production flexibility that accompany more rapid bonding of components.

Table 4-4
Radio-Frequency Drying/Heating System Characteristics

Dimensions	Length: 15-40' Height: 5-10' Width: 5-10'
Power Rating	1-1000 kW
Energy Consumption	52,000 kWh annually*
Key Inputs	
Power	Electricity
Other	Oscillator tube replacement
Key Outputs	
Solid Waste	None
Air Emissions	None
Waste Effluent	None
Cost	
Capital	$1000-$800,000
Operating and maintenance	$200-$10,000

*Assuming a 50-kW unit used 4 h / d, 5 d / wk, 52 wk / yr.

Advantages

Wood drying

- Rapid, uniform drying: RF drying offers superior performance in comparison to conventional drying methods by lowering drying times to a small fraction of their normal requirement.

- Decreased material costs: RF drying greatly reduces the defect rate when compared to conventional drying and, especially in hardwood applications, can provide significant savings in materials.

- Improved product quality: RF drying is effective in achieving a consistent moisture content among all pieces of wood in a batch. Reduced variability in moisture content improves control of moisture-sensitive tasks such as bonding.

Adhesive/resin curing

- Faster production rate: RF energy penetrates wood to heat adhesives and resins and thus accelerates their cure times and significantly improves production rates.
- Improved bond strength: RF energy improves the consistency of a cure by heating adhesives uniformly.
- Greater flexibility in production scheduling: Accelerating the cure time allows parts to be assembled prior to downstream machining. In many applications, this attribute can improve the fit and appearance of the final product.

Disadvantages

- High initial capital cost: RF equipment is expensive; however, improvements in throughput and product quality can provide payback periods of one to two years for high-volume applications.
- Must be shielded: RF heaters use the same frequencies that are used for radio communications, thus the unit must be shielded to avoid interference.

Commercial Status

RF technology has been used commercially in the United States for more than 50 years for heating and drying fabrics, glues, and wood. Continuous systems (conveyor-based) and batch systems (operator removes the product from the exposure area when the processing is complete) are available from a variety of vendors for numerous applications. Vendors usually specialize in specific applications, such as wood drying or adhesive curing.

Cost and Electrical Requirements

One of the major disadvantages of an RF system is the high initial capital cost. Capital costs are $1000–$4000 per kW of power output. Approximately 60% of the power input to an RF generator actually reaches the product. As a result, the power required is about 1.7 times the power reaching the product. Thus, a generator with an output of 210 kW would require about 350 kW of power input. Smaller systems (output of 1–200 kW) cost $2500–$4000 per kW; larger systems (output of 200–1000 kW) cost $1000–$2500 per kW.

Electric IR Drying & Curing

Basic Principle

Infrared (IR) is part of the electromagnetic spectrum, occurring between visible light and radio waves (0.75–1000 microns). Electric IR radiation is produced by heating an emitter of IR radiation. The radiation emitted is then absorbed by the substance at which it is directed, causing the molecules of the substance to vibrate and generate heat. The heat thus generated dries a coating from the inside out. IR systems require no special airflow for heat transfer because energy radiates directly to the coated surface without heating the air. By localizing the origin of the emissions, and allowing the use of reduced- or non-solvent paints, inks, and coatings, the technology enables facilities to significantly reduce or eliminate VOC emissions.

Figure 4-3
Panel IR Unit for Process Line Drying

IR wavelengths are separated into three ranges: short, medium, and long. Short-wave IR provides fast, intense bursts of energy and, depending on the material, can penetrate the deepest. Short-wave IR is most useful when short cycle times are required, such as in drying inks in the printing industry and curing powder coatings in the metal finishing industry. Medium-wave IR is less intense than short-wave, thus it is more useful for heat-sensitive materials such as textiles. Medium-wave IR is also more readily absorbed by plastics and glass, and is typically used to dry water-based inks, coatings, and adhesives. Long-wave IR has the shallowest penetration and therefore heats more by convection; it is well-suited to slower, more even heating, such as is required for drying paper products and film. Long-wave IR is also less sensitive to color differences, making it the wavelength of choice for drying or curing multicolored products.

Many factors must be considered in selecting the appropriate type of IR equipment (i.e., short-, medium-, or long-wave emitters) for a given application. These factors include the absorption factor and color of the product as well as the depth of penetration and processing speed required. The absorption factor is determined by the temperature, humidity, thickness, color, and surface condition of the material being dried or cured. Each material best absorbs energy of a specific wavelength. Peak efficiencies are typically achieved by matching the wavelength of the IR emitter to the absorption wavelength of the product. For example, water has a maximum absorption of 2.6–3.2 microns, making medium-wave IR best for drying water-based materials.

System Description

A typical electric IR system includes quartz lamps and reflectors. Systems are typically configured as a tunnel or bank of lamps on a process line; smaller applications use moveable arch or portable arm-mounted lamps. An IR system reaches full power in less than 1 second and can be accurately regulated with simple controls. Electric IR systems are also highly energy-efficient, especially in comparison to gas IR systems. In an electric IR system, more than 85–90% of the energy used is converted to radiation, and 50–70% of the energy used is absorbed by the substance that needs drying. A gas IR system transfers only 20–25% of the energy used to the drying substance and produces emissions of its own.

Table 4-5
Electric IR Drying & Curing System Characteristics

Dimensions	Length: 6-90” Width: 10-60” Height: 10-90”
Power Rating	8-15 kW per square foot
Energy Consumption	4160 kWh annually*
Key Inputs	
Power	Electricity
Other	None
Key Outputs	
Solid Waste	None
Air Emissions	None
Water Effluent	None
Cost	
Purchase	Panel: $1000-$2500 Custom oven: $10,000-$250,000
Installation	10-20% of purchase cost
Other Supplies	None

*Assuming an 8-kW unit 2 h/d, 5 d/wk, 52 wk/yr.

Advantages

- Quick, effective drying or curing. Reduces process time 50–80% in comparison to convective drying ovens. Curing takes place almost instantly.
- Markedly increases production potential.
- Quick startup and shutdown eliminates costly preheating, thereby increasing overall efficiency.
- Relatively insensitive to changing conditions (i.e., temperature, humidity).
- Modular design and small size of IR panels allow flexibility; they are easily incorporated into existing production lines and require minimal floor space.
- Reduced need for air circulation since IR heats products directly.
- Long lifespan, minimal routine maintenance.
- Relatively short payback period, depending on the application.

Disadvantages

- Initial capital cost can be high.
- Has difficulty uniformly heating geometrically complex shapes.

Commercial Status

Long- and medium-wave IR are well-known and have been used to dry materials and / or cure coatings since the 1930s. A variety of IR source systems are available from numerous vendors. Systems can be obtained with heating element temperatures of 600–4000°F, thereby producing radiation in the 1.0–6.0-micron wavelength. However, as the industry makes increased use of low- and non-solvent paints, inks, and coatings, short-wave technology (0.75–2.3-micron wavelength) is becoming more prevalent. As evidenced by the large number of IR equipment manufacturers active in this market, many manufacturing facilities are already using short-wave IR equipment.

Cost and Electrical Requirements

A basic electric IR spot heater or panel heater with two or three quartz emitters costs $1000–$2500. Custom-designed ovens or tunnels cost $10,000– $250,000.

Electric IR ovens typically cost 10–20% less than gas convection ovens for the same application and features. This is primarily because fewer control systems are required (e.g., air-handling equipment and gas-related safety features).

Ultraviolet Curing

Basic Principle

Ultraviolet (UV) radiation has a wavelength range of 4–400 nanometers. UV radiation can be used to cure inks or coatings containing polymers that cross-link when subjected to radiation. The cross-linking transforms the coating from a liquid to a solid. Radiation-curable coatings provide a clear or pigmented finish that protects, decorates, and provides other functional properties.

Curing differs from drying in that drying is accomplished by driving off a solvent, usually through evaporation, leaving the pigment or coating material on the surface of the product. Only solvent-containing inks or coatings can be dried. Curing, on the other hand, changes the molecular structure of the coating material to solidify it. Radiation-curable coatings, therefore, do not need to contain organic solvents and eliminate the problem of volatile organic compound (VOC) emissions.

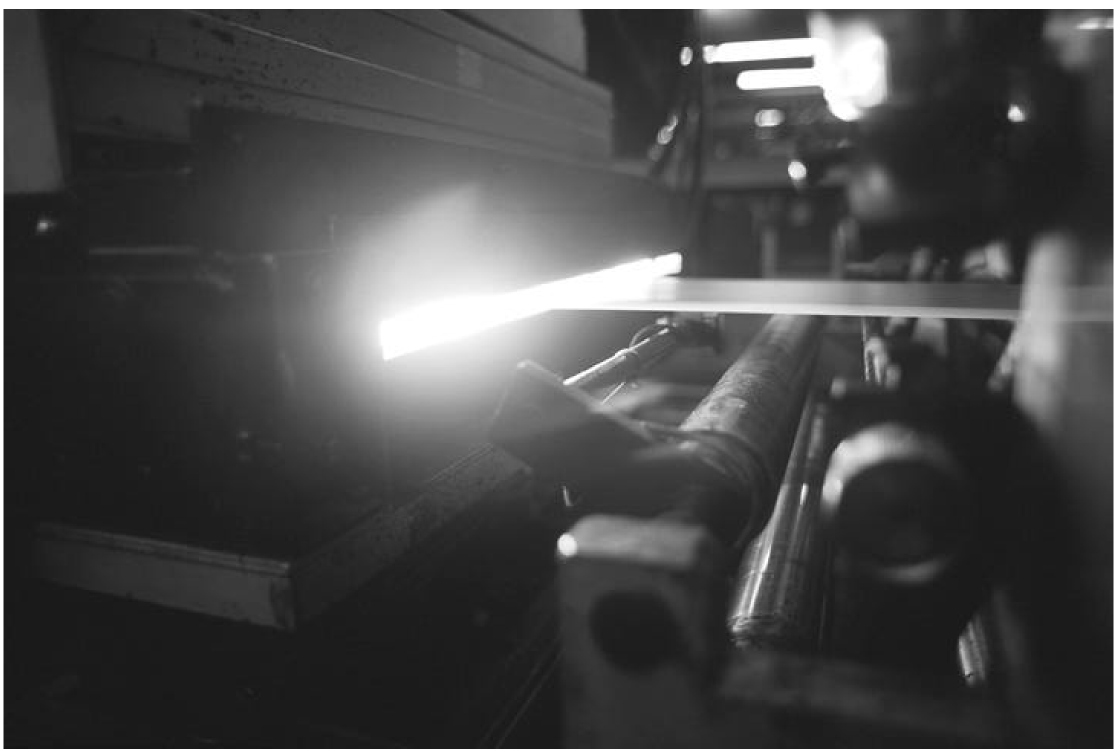

Figure 4-4
Ultraviolet Curing

System Description

Two basic types of lamps are commonly used to produce UV light: medium-pressure mercury vapor lamps (arc lamps) and medium-pressure mercury microwave-powered lamps (microwave-powered or electrodeless lamps). In both cases, the UV energy produced by the lamp bulb is focused by reflectors onto the coated materials as they move down a process line. The UV energy striking the materials causes a photoinitiator (a chemical in the coating) to trigger the cross-linking reaction, curing the coating. The UV light must be enclosed to prevent worker exposure.

Most UV systems are custom-made for use with conveyor-driven process lines. By using multiple lamps, the width of the treatment area can be extended as needed. Lamp length determines the number of lamps needed to achieve a specific treatment-area width. The system price varies with the type, number, and length of lamps; type of shielding; and cooling method. The capital cost of a conventional curing system such as a gas-fired curing oven can be nearly four times greater than that of an equivalent UV curing system. Also, although radiation-curable inks or coatings are twice as expensive per pound as conventional solvent-based coatings, less coating material is used per unit. The process is also easy to control; so there is less loss of product due to poor quality, and costs become comparable.

Advantages

- Radiation-curable inks and coatings dry quickly, thereby increasing the production rate.
- UV systems work with non-solvent coatings, thus eliminating VOC emission concerns.
- Since no VOC emissions occur, UV curing eliminates the need for VOC incinerators.
- UV curing equipment takes 10–50% less space than conventional fuel-fired curing ovens.
- Radiation-curable coatings are available in an array of colors and provide a high-gloss finish with improved wear- and scratch-resistance.

Disadvantages

- Ozone can form if the UV light reacts with available oxygen.
- Operating personnel must avoid the hazards of exposure to UV light.

Table 4-6
Ultraviolet Curing System Characteristics

Dimensions	Length: 11-86” Width: 9-55” Height: 18-86”
Power Rating	120-800 watts per inch
Energy Consumption	9600-64,000 kWh per year*
Key Inputs	
Power	Electricity
Other	None
Key Outputs	
Solid Waste	None
Air Emissions	Ozone
Water Effluent	None
Cost	
Purchase	$1000-$60,000
Installation	Minimal
Other Supplies	None

*Assuming a system with four 10-inch lamps operated 2000 h/yr.

Commercial Status

UV curing is currently used in a variety of industrial applications where a clean or very thin coating is required and where acceptable radiation-curable coatings are available. Examples include printing labels, decorating metal, hardening polymers on non-wax flooring materials, and coating printed circuit boards with protective insulation.

UV systems are readily available for a range of applications. Small systems with one or two lamps are frequently used in laboratories and in manufacturing plants for testing ink coatings and adhesives before application to film, foil, or paper substrates. Medium-sized systems with multiple lamps are used to cure finishes on metal, glass, and plastic products. Large multichambered ovens with rows of lamps are used to cure finishes on floor tiles and on textured coatings on large substrates such as paper, board, or glass. More complex UV systems are used in curing coatings on products that are not flat, such as wires, tubes, furniture, packaging, and electronic assemblies.

Cost and Electrical Requirements

The cost of UV curing systems varies significantly with size and system complexity. A single-lamp system may cost a few hundred dollars, while a complex multilamp system may cost hundreds of thousands of dollars. The majority of UV curing systems are custom-made multilamp systems; their price depends on the type and number of lamps, type of shielding, and cooling method.

An arm-mounted UV system for new installation or retrofit to an existing system usually costs $1000–$5500 and consumes 120–600 watts per inch, depending on the number of lamps and lamp length. A fully automatic UV lamp conveyor system costs $8000–$60,000 and consumes 200–800 watts per inch, depending on the complexity of controls and lamp lengths.

5

RESOURCES

This section contains three lists: 1) equipment suppliers for the electrotechnologies profiled in this guide, by equipment type; 2) EPRI information sources on efficiency technologies; and 3) wood furniture 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. This information was current at the time of publication and is expected to change over time.

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 Division of Holophane
515 McKinley Ave., Newark, OH 43055
(614) 349-4194, fax: (800) 346-5923

Computer Numerical-Controlled Machining

Equipment Suppliers

CNC Boring Equipment

Accu-Systems/Mountain View Machinery
1801 E. Creek Rd., Sandy, UT 84093
(801) 965-1900, fax: (801) 965-3999

Biesse America, Inc.
P.O. Box 19489, Charlotte, NC 28219-9489
(704) 357-3131, fax: (704) 357-3130

Dankaert Woodworking Machinery
891 Howell Mill Rd., Atlanta, GA 30318
(404) 873-6477, fax: (404) 874-4813

Holz-Her U.S., Inc.
5120 Westinghouse Blvd., Charlotte, NC 28273
(704) 587-3400, fax: (704) 587-3412

ICBT, Inc.
P.O. Box 18507, Greensboro, NC 27419-8507
(910) 668-9581, fax: (910) 668-4211

Servatek, Inc.
4180 44th St. S.E., Grand Rapids, MI 49512
(616) 698-6646, fax: (616) 698-6691

Wisconsin Automated Machinery Corp.
P.O. Box 1531, Hickory, NC 28603
(704) 327-3000, fax: (704) 327-4872

CNC Routing Equipment

ANA Machinery Corporation
3100 Pullmann Ave., Costa Mesa, CA 92626
(714) 540-2442, (800) 942-4270, fax: (714) 966-2400

Accu-Router, Inc.
634 Mountain View Industrial Dr., Morrison, TN 37357
(615) 668-7127, fax: (615) 668-9187

American Woodworking Equipment Distributor Corp.
110 W. Clarkstown Rd., New York, NY 10956
(914) 634-7964, fax: (914) 634-7446

Black & Decker (U.S.), Inc.
701 E. Joppa Rd., Towson, MD 21286
(410) 716-3900, fax: (410) 716-7051

Gerber Scientific Products, Inc.
151 Batson Dr., Manchester, CT 06040
(800) 222-7446, fax: (800) 227-6228

Stiles Machinery, Inc.
3965 44th St. S.E., Grand Rapids, MI 49512
(616) 698-7500, fax: (616) 698-9411

Thermwood Corp.
P.O. Box 436, Dale, IN 47523
(812) 937-4476, fax: (812) 937-2956

CNC Panel Saws

Altendorf America Division of Stiles Machinery
P.O. Box 316, Grand Rapids MI 49512
(616) 698-8456, fax: (616) 698-9411

Biesse America, Inc.
P.O. Box 19489, Charlotte, NC 28219-9489
(704) 357-3131, fax: (704) 357-3130

Force Machinery Co.
2271 Route 222, P.O. Box 3729 , Union, NJ 07083
(908) 686-0910, fax: (908) 686-6156

Holz-Her U.S., Inc.
5120 Westinghouse Blvd., Charlotte, NC 28273
(704) 587-3400, fax: (704) 587-3412

Peterson Panel Saws
30 Pamaron Way, Unit J, Novato, CA 94949
(415) 382-4337, fax: (415) 382-6760

Schelling America, Inc.
P.O. Box 80367, Raleigh, NC 27623
(919) 544-0430, fax: (919) 544-0920

Tekna Machinery
2475-A Satellite Blvd., Duluth, GA 30136
(770) 813-8820, fax: (770) 813-2188

Radio Frequency Wood Drying & Curing

Equipment Suppliers

Ameritherm, Inc.
P.O. Box 901, Scottsville, NY 14546
(716) 889-9000, fax: (716) 889-4030

Callanan Company
1844 Brummel Drive, Elk Grove, IL 60007
(847) 364-4242, fax: (847) 364-4373

IHS-INDUCTOHEAT
5009 Rondo Drive, Fort Worth, TX 76106
(817) 625-5577, fax: (817) 625-1872

Kaber Manufacturing Corporation
140 Schmitt Blvd., Farmingdale, NY 11735
(516) 694-6857, fax: (516) 694-6846

LaRose Radio Frequency Systems, Inc.
150 Dover Rd., Minis, MA 02054
(508) 376-0850, (617) 762-4900, fax: (617) 762-4952

Nemeth Engineering Associates, Inc.
5901 W Highway 22, Crestwood, KY 40014
(502) 241-1502, fax: (502) 241-5907

PSC
21761 Tungsten Rd., Cleveland, OH 44117
(216) 531-3375, fax: (216) 531-6751

Radio Frequency Co., Inc.
P.O. Box 158, 150 Dover Rd., Millis, MA 02054
(617) 762-4900, fax: (617) 762-4952

Thermex Thermatron
60 Spense Street, Bayshore, NY 11706
(516) 231-7800, fax: (516) 231-5399

Electric IR Drying & Curing

Equipment Suppliers

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

Americure, Inc.
2353 W. Lincoln St., Phoenix, AZ 85009
(602) 253-3130

Argus International
P.O. Box 38-M, Hopewell, NJ 08525
(609) 466-1677, fax: (609) 466-4111

BGK
4131 Pheasant Ridge Dr., N.E., Minneapolis, MN 55449
(612) 784-0466, fax: (612) 784-1362

Cleveland Process Corporation
127 S.W. Fifth Ave., Homestead, FL 33030
(800) 241-0412, fax: (305) 248-4371

Dry-Clime Corporation
P.O. Box 146, State Rd. 46 W., Greensburg, IN 47240
(812) 663-4141, fax: (812) 663-4202

Edwin Trisk Systems
670 New York Street, Memphis, TN 38104
(800) 261-7976, fax: (901) 274-8355

Eraser Company, Inc.
Olivia Drive, P.O. Box 4961, Syracuse, NY 13221
(315) 454-3237, fax: (315) 454-3090

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

Future Cure
29313 Clemins, Westlake, OH 44145
(800) 722-4664, fax: (216) 835-1578

Glenro, Inc.
39 McBride Ave., Paterson, NJ 07501
(800) 922-0106, fax: (201) 279-9103

Infratech Corporation
1634 Industrial Park St., Covina, CA 91722
(818) 331-9400

Infratrol Manufacturing Corporation
646 S. 29th St., Milwaukee, WI 53234
(414) 671-7140, fax: (414) 671-5088

IRT Systems
89 Connie Crescent, Concord, Ontario, L4K 1L3, Canada
(800) 387-3639, fax: (905) 669-1171

Prime Heat
1946 John Towers, El Cajon, CA 92020
(619) 449-6623, fax: (619) 449-9844

Process Thermal Dynamics
304 G 50th Ave., Alexandria, MN 56308
(612) 762-2077, fax: (612) 762-1319

Radiant Energy Systems
458 Hamburg Turnpike, Wayne, NJ 07470
(201) 942-7767, fax: (201) 942-5581

Solaronics
704 Woodward, Rochester, MI 48307
(810) 651-5333, fax: (810) 651-0357

Tech Systems
1030 N. Lincoln St., Greensburg, IN 47240
(812) 663-4720, fax: (812) 663-4799

Watlow Electric Manufacturing Company
12001 Lackland Rd., St. Louis, MO 63146
(314) 878-4600, fax: (314) 878-6814

Ultraviolet Curing

Equipment Suppliers

American Ultraviolet Company
562 Central Ave., Murray Hill, NJ 07974
(908) 665-2211, fax: (908) 665-9523

Argus International
424 Route 31 North, Irngoes, NJ 08551
(609) 466-1677, fax: (609) 466-4111

Canrad Hanovia, Inc.
100 Chestnut St., Newark, NJ 07105
(201) 589-4300, fax: (201) 589-4430

Fusion Systems Corporation
910 Clopper Rd., Gaithersburg, MD 20878
(301) 527-2660, fax: (301) 527-2661

Industrial Heating & Finishing Company
P.O. Box 129, Pelham, AL 35124
(205) 663-9595, fax: (205) 663-9608

UV III Systems, Inc.
21 Governor Ave., Bellingham, MA 02019
(800) 398-5456, (508) 883-4881, fax: (508) 376-4748

Werner Lemnermann
Specialty Coating Systems, 5707 West Minnesota St., Indianapolis, IN 46241
(800) 356-8260, fax: (317) 240-2073

XENON Corporation
20 Commerce Way, Woburn, MA 01801
(617) 938-3594, fax: (617) 933-8804

Information on Efficiency Technologies

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

Adjustable Speed Drives

Adjustable Speed Drives: Application Guide, TR-101140, February 1993.

Proceedings: Advanced Motors and Drives R&D Planning Forum, TR-101288, December 1992.

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

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

Energy-Efficient Lighting

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

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

Electronic Ballasts, BR-101886, May 1993.

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

Energy-Efficient Motors

Assessment of Electric Motor Technology: Present Status, Future Trends, and R&D Needs, TR-101264, February 1993.

Electric Motors, TR-100423, June 1992.

Trade Associations

American Furniture Manufacturers Association
P.O. Box HP-7, High Point, NC 27261
(919) 884-5000, fax: (919) 884-5303

Members are manufacturers of household and institutional furniture.

Business and Institutional Furniture Manufacturers Association
2680 Horizon Dr. S.E., Suite A-1, Grand Rapids, MI 49546-7500
(616) 285-3963, fax: (616) 285-3765

Members are manufacturers of business and institutional furniture.

National Association of Store Fixture Manufacturers
1776 N. Pine Island Road, Plantation, FL 33322-5233
(305) 424-1443, fax: (305) 473-8268

Members are manufacturers of store, bank, and office fixtures.

Summer and Casual Furniture Manufacturers Association
P.O. Box HP-7, High Point, NC 27261
(919) 884-5000, fax: (919) 884-5303

A division of the American Furniture Manufacturers Association.

Unfinished Furniture Association
36 S. State St., Suite 1212, Chicago, IL 60603-2607
(312) 782-5252, fax: (312) 236-1140

Members are companies that manufacture unfinished furniture.