

Lumber Kiln Technology and Training Needs in the Northeastern United States

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Abstract

This study surveyed dry kiln operations in the northeastern and north-central United States to understand current technology use and training needs. The research aimed to establish a better understanding of dry kiln production characteristics, prevailing tools and technology, and training requirements in the hardwood lumber drying industry to help providers better design training opportunities for the industry. Several different hardwood species were being dried by a majority of firms, while eastern white pine was the only softwood species dried by a majority of respondents. Key findings revealed a significant operational divide between small and large firms. For example, fewer than half of small facilities ($\leq 1,000$ board feet production) plan to invest in new drying equipment in the next 3 years. Smaller facilities also are significantly less likely to adopt crucial quality-control tools such as kiln samples and end coatings and show a greater reluctance to invest in new equipment or upgrades compared to medium and large firms. This directly correlates with their higher number of reported problems in achieving uniform final moisture content and mitigating warping. In contrast, larger firms, often with integrated postdrying processes like sorting and grading, prioritize advanced quality control but face challenges such as discoloration. The results underscore the need for tailored training programs and strategic modernization investments to address the unique challenges of different operational scales, ultimately enhancing product quality and fostering sustainable regional practices.

The Great Lakes Kiln Drying Association (GLKDA) and its agency partners have been training lumber industry dry kiln operators for nearly 50 years. Its week-long industry short course, along with its spring and fall meetings, are essential venues for technology transfer in the drying industry. The GLKDA short course started at the US Department of Agriculture (USDA) Forest Products Laboratory, moved to the University of Minnesota, and now resides at Northcentral Technical College in Antigo, Wisconsin. Wood technologists from Northcentral Technical College, University of Wisconsin, University of Minnesota, Wisconsin Department of Natural Resources, and the USDA Forest Service have trained generations of kiln operators since the inception of the short course. The primary goals of these dry kiln training opportunities are to improve the quality, consistency, and profitability of kiln-dried lumber. Ultimately, quality production supports local sawmill and dry kiln industries and rural communities and improves the sustainable management of private and public forests.

To stay current with today's industry challenges and ensure that training programs are relevant to industry needs, we surveyed kiln operations in 14 northeastern and north-central states with a focus on drying hardwood lumber. A

multistate study of the dry kiln industry has not been conducted in more than 30 years (Rice et al. 1994). More recently, researchers conducted a kiln study of the Canadian industry, to benchmark dry kiln practices and issues there (Alexiadis et al. 2007). Data from our current assessment will be used to update the GLKDA annual short course targeted at industrial-sized kiln operations. The results also will be shared with the industry through GLKDA annual meetings and publications.

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The hardwood lumber industry in the northeastern and north-central regions of the United States (NE/NC region¹) is a vital component of the national wood products sector. In 2008, the region's total annual hardwood lumber production was 4.7 billion board feet (BBF), with Pennsylvania, West Virginia, and Missouri being key producing states (Luppold and Bumgardner 2017). In comparison, hardwood lumber production for the eastern United States overall was 9.4 BBF, so the study region accounted for approximately 50 percent of the total. Hardwood lumber serves as a foundational raw material for a diverse array of value-added products, including flooring, pallets, furniture, cabinets, and molding (Denig et al. 2000).

Within the hardwood lumber manufacturing process, drying is a critical, often time-consuming, and relatively expensive step (Denig et al. 2000). It is essential for enhancing wood properties, increasing value, and expanding suitability for various applications. Effective drying is paramount for mitigating degradation, a substantial source of economic loss and waste (Denig et al. 2000). Furthermore, kiln drying offers significant logistical and financial advantages by reducing shipping weight, lowering inventory carrying costs, and enabling faster order fulfillment (Tiemann 1926). Issues from inadequate drying cascade into increased waste and rework in secondary manufacturing, underscoring the need for advanced technology and comprehensive operator training.

This study had two main objectives, which were to develop a better understanding of the: (1) dry kiln production characteristics of the NE/NC US hardwood lumber industry and the prevailing dry kiln technology and tools being used in the region; and (2) dry kiln training needs for operators and other stakeholders. This knowledge is crucial for optimizing operational efficiency, elevating product quality, and fostering sustainable utilization of hardwood resources. A key outcome is a better understanding of the training needs of kiln operators at different operational scales. Other studies have shown that smaller wood products firms differ from larger firms in many respects (Buehlmann et al. 2013), with smaller firms generally scoring lower in terms of investing in employee training and seeking information from different sources.

Literature Review

Dry kiln production in the northeastern United States

The NE/NC region is a significant contributor to the national hardwood lumber supply, with 53 percent of all hardwood sawlog roundwood received by mills located in this region (USDA Forest Service, Forest Inventory and Analysis, Timber Product Output 2025). Nationally, approximately 5.0 BBF of hardwood lumber was kiln dried annually between 1992 and 1993, compared to 24.0 BBF of softwood (Rice et al. 1994). In the North region of that study (very similar to the NE/NC region for this

study), 3.4 BBF of lumber (hardwood and softwood) was kiln dried annually, representing 79.1 percent of total (green) regional lumber production (Rice et al. 1994).

The species composition in the NE/NC region is diverse. Based on average annual harvest removals of sawlog wood volume, the leading harvest species in the NE/NC region currently are red oak (19.1%), hard maple (13.1%), soft maple (13.0%), white oak (10.8%), aspen (9.8%), ash (7.3%), cherry (5.9%), and yellow-poplar (5.8%) (USDA Forest Service, Forest Inventory and Analysis Program 2025). Comparing this data set to a 20-mill study of the region by Bergman and Bowe (2008), red oak and yellow-poplar have lost share while soft maple has gained share. This change highlights in part the influence of market demand on processed species.

Dry kiln characteristics and challenges in the northeastern United States

The North region's dry kiln infrastructure in 1992 to 1993 included over 2,800 dry kilns with a collective holding capacity of 130.5 million board feet (MMBF). Steam-heated kilns were predominant (2,503 units), followed by dehumidifier (273 units) and direct-fired kilns (49 units). Predryers (129 units, 60.4 MMBF capacity) and fan-shed dryers (21 units, 4.9 MMBF capacity) were also used for initial moisture reduction (Rice et al. 1994).

There is a persistent need for upgrading or overhauling existing old and inefficient dry kiln facilities and a demand for better precision and accuracy in maintaining kiln temperatures and fan speeds (Bergman and Bowe 2008). Other studies also have found that kiln corrosion and structure deterioration were significant problems for kiln operations (Little and Moschler 1993). This suggests that aging equipment potentially results in below-optimal kiln efficiency.

Kiln operations face challenges such as inadequate heating, humidification, and air circulation in older kilns, hindering effective drying of green hardwoods. In addition, insufficient venting can lead to slow drying and stain (Denig et al. 2000). Common operational problems include airflow issues, maintenance needs, and challenges in optimizing schedules (Alexiadis et al. 2007). Even minor deviations can profoundly affect drying quality; a few degrees difference in dry-bulb temperature can significantly change relative humidity and equilibrium moisture content (Denig et al. 2000).

Wood-drying technology has advanced, with modern kilns incorporating computer controls for precise regulation (Denig et al. 2000). Innovations include heat recovery ventilation systems for reduced fuel consumption and new retrofittable control systems with advanced features like mobile phone/Web-based controls (Elustondo et al. 2023). Artificial intelligence is also being explored for timber drying modeling and control to mitigate defects and enhance productivity (Uwizeyimana et al. 2020, Nyle Dry Kilns innovates 2023). Small dehumidification kilns (e.g., around 800 board feet of capacity with cost as low as \$3,000) offer economical solutions for portable sawmill owners (Bennett 2013). Despite these advancements, adoption of new technology in the forest products industry can be slow, influenced by economic factors and raw material heterogeneity (Rosenberg et al. 1990). Smaller wood products firms, which comprise a significant portion of the industry, also have been shown to face unique challenges in seeking information and making business investments (Buehlmann et al. 2013).

¹ According to Luppold and Bumgardner (2017), this region is comprised of the following 24 states: Connecticut, Delaware, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, West Virginia, and Wisconsin. This region corresponds closely with the states included in the current study.

Stakeholder knowledge and training opportunities

Proper operator training is fundamentally important for achieving high-quality drying and preventing costly defects. A proficient kiln operator must understand basic drying concepts, select and monitor kiln samples, operate and maintain equipment, and adhere to schedules, all of which directly impact product quality and profitability (Denig et al. 2000). Even with automation, modern drying systems rely on human operators for proper setup, calibration, and data interpretation; drying quality ultimately depends on operating procedures, not solely equipment. Automated moisture control systems still require daily visual inspection for defects and malfunctions, especially for high-moisture content (MC) and check-prone species (Denig et al. 2000). Issues from inadequate drying cascade into increased waste and rework in secondary manufacturing, underscoring the need for advanced technology and comprehensive operator training.

The previously mentioned Canadian study, while not a US-focused study, indicated that kiln operators were perceived as the most knowledgeable group regarding kiln drying issues, followed by equipment suppliers, distributors, sales personnel, and customers (Alexiadis et al. 2007). However, those authors also noted that “dried product quality problems were only considered to be moderately serious issues,” (Alexiadis et al. 2007, page 192) possibly due to the Canadian industry’s focus on primary wood products and volume maximization and less concerned about product quality. This suggests a training need to emphasize the business case for quality drying across all stakeholders.

University extension services and continuing education courses offer training programs to impart practical and scientific knowledge about lumber drying (North Carolina [NC] State University 2025). Examples include the aforementioned GLKDA short course and the NC State *Dry Kiln Operator’s Short Course*. These courses benefit new and experienced operators, as well as supervisors, sales personnel, and marketing personnel, often combining classroom learning with hands-on exercises.

Methodology

This study employed a paper questionnaire mailed to lumber dry kiln facilities in the NE/NC region of the United States. State resource specialists from the Northeast Utilization and Marketing Council were invited to participate in the study. Those interested in participating provided industry contact lists for lumber dry kiln facilities in their respective states. These states included Connecticut, Illinois, Indiana, Iowa, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New York, Ohio, Pennsylvania, Vermont, and Wisconsin. Experts from the Northcentral Technical College, University of Wisconsin, Wisconsin Department of Natural Resources, GLKDA, and USDA Forest Service developed the study questions.

The University of Wisconsin Survey Center managed the survey formatting, deployment, and data compilation. The questionnaire was limited to eight letter-sized pages. This allowed for a folded booklet to be produced from two 11 by 17-inch pages. Question format included yes/no, multiple choice, fill-in number values, scale, and some open-ended questions. Questions used to derive information for potential training needs related to the drying process, kiln control, and

product quality closely followed those used by Alexiadis et al. (2007).

Questionnaires were first mailed in spring 2024, with survey administration beginning on May 29, 2024, and ending on August 9, 2024. The study employed Dillman’s tailored design method for survey administration (Dillman et al. 2014) and involved two waves. The first wave included a cover letter, a prepaid business reply envelope, a \$5 bill pre-incentive, and the eight-page questionnaire. A total of 796 mailings went out in the first wave. The second wave mirrored the first wave without the \$5 incentive. In total, 512 mailings went out in the second wave.

For analysis, firm size categories were developed to help control for potential differences in the results. Upon inspection of the data, there were two apparent modal breaks in the data for drying production volume in 2023. One peak occurred for firms with 2023 annual dried lumber production of <50 thousand board feet (MBF) and another occurred in the 1,000 to 5,000 MBF category. Therefore, three categories were analyzed, a “small” firm category with production ≤ 1 MMBF ($n = 94$), a “medium” category for firms with 1 to 5 MMBF of production ($n = 46$), and a “large” firm category for production > 5 MMBF ($n = 57$). Chi-square tests ($\alpha = 0.10$) were used to determine differences among the firm size categories in their responses using SAS Enterprise Guide version 8.4.

Results and Discussion

Response rate

In total, 202 usable questionnaires were returned. After accounting for undeliverable mailings ($n = 52$) and responding firms without kilns ($n = 143$), the adjusted response rate was 33.6 percent, which was similar to the average response rate reported in other published forest products survey research (Bumgardner et al. 2017). As a check for nonresponse bias (Armstrong and Overton 1977), earlier respondents (wave 1, $n = 156$) were compared to later respondents (wave 2 responding after the second mailing, $n = 43$) using 2 by 2 chi-square tests for two variables regarding firm size and type. No differences were found based on whether firms had fewer than 20 employees or 20+ employees ($p = 0.49$), or whether their drying operations were integrated with other processes ($p = 0.65$). Therefore, nonresponse bias was not considered to be a significant problem with the study.

Trained data entry operators entered the responses into a CASES software-programmed data entry instrument. The data entry instrument included the questions as they appeared in the survey instrument and automatically checked that numeric codes were valid and implemented any skip patterns in the instrument. Comments that respondents made on the paper instruments were entered and delivered to the researchers.

Characteristics of the NE/NC drying industry

Series of questions were included in the study to determine which lumber species, volume percentage, and thickness percentage were being dried. Respondents were asked to indicate if they dried each species in 2023, along with categories for the percentage that was 4/4 thickness (~ 1 inch). Overall, 85.4 percent of respondents dried hardwood lumber and 46.7 percent of respondents dried softwood lumber. As shown in Table 1, red oak was being dried by 89 percent of

Table 1.—What lumber species and products does your facility dry?

Lumber species and product	Percent of firms drying
Hardwood lumber species	
Red oak	89.4
Soft maple	83.2
White oak	82.7
Cherry	82.7
Hard maple	80.3
Ash	67.8
Walnut	67.1
Hickory	60.6
Basswood	49.6
Yellow-poplar	46.9
Birch	42.3
Aspen	27.2
Softwood lumber species and product	
White pine boards	86.5
White pine dimension lumber (2 by 4, 2 by 6, etc.)	33.3
Red pine boards	29.2
Spruce dimension lumber (2 by 4, 2 by 6, etc.)	17.7
Red pine dimension lumber (2 by 4, 2 by 6, etc.)	15.6
Fir dimension lumber (2 by 4, 2 by 6, etc.)	11.5

the respondents that dried hardwoods. Red oak was followed by soft maple, white oak, cherry, and hard maple, respectively, with each representing more than 80.0 percent of respondents. These results are generally consistent with the harvest removal data discussed previously. For softwoods, white pine boards were by far the most common species and product dried.

We were interested in the percentage of 4/4 thickness lumber produced across the study area. Table 2 shows the percentage of responding firms with all their drying volume consisting of 4/4 thickness lumber along with other categories for each species. Overall, these numbers were somewhat lower than expected for the higher percentages and might indicate that dryers are being asked to process more customized orders. Additionally, we expected that small firms would tend to dry more 4/4 lumber as a percentage of their total drying. However, no significant differences were found across firm sizes for any of the major species dried.

Table 2.—Percentage of firms drying 100 percent, 75 to 99 percent, 50 to 74 percent, and less than 50 percent 4/4 thickness (1 inch) hardwood lumber, by species.

Hardwood lumber species	Percentage of firms with 100% volume in 4/4	Percentage of firms with 75% to 99% volume in 4/4	Percentage of firms with 50% to 74% volume in 4/4	Percentage of firms with less than 50% volume in 4/4
Birch	48.2	11.7	6.7	33.3
Hickory	40.6	14.0	10.5	34.9
Aspen	37.9	18.9	10.8	32.4
Soft maple	25.8	21.8	13.7	38.7
Cherry	25.0	23.4	8.1	43.5
Basswood	24.6	20.3	15.9	39.1
Yellow-poplar	23.5	19.1	22.1	35.3
Ash	23.3	24.2	15.1	37.4
White oak	23.2	18.6	17.1	41.1
Hard maple	22.2	27.0	16.4	34.4
Red oak	21.6	27.1	19.4	31.9
Walnut	15.0	15.0	31.0	39.0

Table 3.—Does your facility use the following tools/processes when kiln drying?

Tool/process	Volume dried ^a			Chi-square (p) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% yes			
Kiln samples	37.4	91.1	87.7	56.8 (<0.01)
End coating	44.1	60.9	63.2	6.46 (0.04)
Steam kilns	13.8	75.0	92.9	101.3 (<0.01)
Purchase green lumber	36.2	63.0	68.4	17.8 (<0.01)
Manufacture own stickers	66.3	30.4	33.3	22.9 (<0.01)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each variable (3 by 2 table for each). Approximate sample size for each test was 93 for small firms, 45 for medium firms, and 57 for large firms.

Technology and tools used and investments planned

Several drying tools and processes were examined for their frequency of use (Table 3). Smaller facilities were less likely than midsize and large facilities to use kiln samples, apply end coatings, use steam kilns, and purchase green lumber to dry. Less than half of small facilities used any of these tools/processes (Table 3). The gap between smaller and large facilities was especially large for steam kilns, with only 14 percent of smaller firms using them. This is not surprising given the boiler requirement needed to use steam. Overall, 49.2 percent of responding firms were operating steam kilns. Other nonsteam drying systems are available with lower costs to entry; qualitatively, respondents reported dehumidification kilns as a common alternative, and a few were using vacuum and solar kilns. Finally, smaller facilities were more likely to manufacture their own stickers. This data result is useful for our dry kiln operators' short course. For example, there is a need to stress the use of kiln samples, end coatings, and proper sticker manufacturing to improve quality in the final dried lumber product.

There are a variety of sticker types available in the commercial lumber drying market. Stickers are designed to improve lumber quality by increasing airflow. Advancements in sticker technology include reducing surface area contact with boards and extending sticker life by using high-specific-gravity species. As shown in Table 4, small firms were significantly

Table 4.—What types of stickers does your facility use?

Sticker type	Volume dried ^a			Chi-square (<i>p</i>) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% yes (<i>N</i> total)			
Fluted	37.5 (56)	64.3 (28)	63.2 (38)	8.3 (0.02)
Grooved	22.4 (49)	60.9 (23)	48.4 (31)	11.4 (<0.01)
Breeze Dried™	53.6 (56)	82.4 (34)	65.9 (44)	7.7 (0.02)
Tropical	10.3 (39)	23.5 (17)	35.3 (34)	6.6 (0.04)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each variable (3 by 2 table for each).

different from medium and large firms in their use of these “specialty” stickers. This is not surprising, since commercially available specialty stickers are significantly more costly than homemade stickers. Future industry training could seek to help smaller firms improve their sticker use.

Custom drying for small-scale use has been a key fee for service offered by small firms for many years and is clearly shown in the results (Table 5). Nearly 80 percent of the respondents in the smallest production category custom dry for small-scale use. On the other hand, less than half of respondents in all size classes custom dry for commercial use, suggesting that commercial users are looking for larger production runs. Still, the fact that nearly half of respondents are also custom drying for commercial users also shows the importance of customization in the hardwood industry.

Future investments

Respondents were asked about their investment plans for new drying equipment over the next 3 years. Significant differences were found among firm sizes for the “no investments planned” option, with more smaller firms in agreement. For those respondents that planned to invest in the next 3 years, 52.0 percent planned to invest \$100,000 or less, and 48.0 percent planned to invest more than \$100,000 (Table 6).

Similarly, respondents were asked about investment plans for kiln upgrades or repairs, such as controls, coils, vents, or structural panels. Again, significant differences were found among firm sizes for the “no investments planned” option, with more smaller firms in agreement. For those respondents that planned to invest in upgrades or repairs in the next 3 years, 79.5 percent planned to invest \$100,000 or

Table 5.—Does your facility custom dry lumber for the following markets?

Market	Volume dried ^a			Chi-square (<i>p</i>) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% yes			
Custom dry for commercial use	47.6	44.4	47.3	0.12 (0.94)
Custom dry for individual/ small-scale operation	79.8	22.5	24.0	57.1 (<0.01)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each market variable (3 by 2 table for each). Approximate sample size for each test was 86 for small firms, 43 for medium firms, and 53 for large firms.

Table 6.—Over the next 3 years, what are your investment plans for new drying equipment?

Plan	Volume dried ^a			Chi-square (<i>p</i>) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	%			
No investments planned	55.4	35.6	19.3	28.4 (<0.01)
Plan to invest a set amount ^c	35.9	37.8	40.4	
Not sure about amount yet	8.7	26.7	40.4	

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts. Sample size was 92 for small firms, 45 for medium firms, and 57 for large firms.

^c 52.0 percent planned to invest \$100,000 or less, and 48.0 percent planned to invest more than \$100,000.

less, and 20.5 percent planned to invest more than \$100,000 (Table 7).

Integrated processes with drying

We were interested in process integration and asked a series of questions about integrated production in addition to dry kiln facilities. It was expected that drying firms would be providing additional services, given the increased focus on customization in the industry, especially related to sorting lumber products and special grading (Espinoza et al. 2011). Overall, 85.3 percent of respondents indicated they had some form of integrated production at their facility. Differences by firm size are shown in Table 8. Small firms were more likely to have a sawmill, although most respondents in all size categories had a sawmill. Larger facilities provided more sorting and grading services than smaller facilities. For example, over 96 percent of larger facilities provided width sorting, while only 50 percent of smaller firms provided width sorting. Only 27 percent of smaller facilities provided color sorting, while 71 percent of larger firms provided this service. Most facilities across sizes provided width ripping and planing services (especially planing). About half of all facilities also produced dimension components, regardless of size (Table 8).

Training needs and priorities

Study questions examined issues related to drying processes, kiln control, and quality control to help identify training needs for the industry. Related to drying processes, there were clear

Table 7.—Over the next 3 years, what are your investment plans for kiln upgrades or repairs, such as controls, coils, vents, or structural panels?

Plan	Volume dried ^a			Chi-square (<i>p</i>) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	%			
No investments planned	38.0	19.6	1.8	27.0 (<0.01)
Plan to invest a set amount ^c	43.5	63.0	69.6	
Not sure about amount yet	18.5	17.4	28.6	

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts. Sample size was 92 for small firms, 46 for medium firms, and 56 for large firms.

^c 79.5 percent planned to invest \$100,000 or less, and 20.5 percent planned to invest more than \$100,000.

Table 8.—Which of the following integrated processes does your facility have?

Integrated process	Volume dried group ^a			Chi-square (p) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% yes			
Sawmill	92.5	87.5	74.0	7.98 (0.02)
Width sorting	50.0	71.9	96.2	28.5 (<0.01)
Length sorting	58.8	87.1	94.3	21.4 (<0.01)
Color sorting	27.1	65.5	71.4	21.5 (<0.01)
Special grading	45.8	76.7	86.3	20.0 (<0.01)
Width ripping	71.4	69.2	66.0	0.36 (0.83)
Planing	92.4	91.9	96.2	n.a. ^c
Dimension components	48.8	50.0	45.2	0.17 (0.92)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each process variable (3 by 2 table for each). Approximate sample size for each test was 54 for small firms, 30 for medium firms, and 50 for large firms.

^c Chi-square test was not used given small expected counts (<5) in the “no” categories.

differences by firm size in the importance of several processes (Table 9). In general, small firms were less likely to see the drying process issues as important (respondents were placed into a combined very/extremely important category for analysis), likely as a function of the smaller and less intensive nature of their facilities relative to larger firms. This was especially true for maintenance and repairs and use of optimized schedules. Energy consumption and kiln layout selection were areas where small firms responded similarly to larger firms. For small firms, airflow was rated as the most important drying process issue.

A similar pattern was observed with the perceived importance of kiln control issues, with small firms generally rating them as less important than larger firms (Table 10). However, kiln control issues were rated relatively highly by small firms as well (a majority rated each one as very or extremely important), suggesting training on control issues would appeal to all firm size categories.

Lastly, defect issues (i.e., quality control) in lumber drying were examined. Small firms struggled most with MC and warping issues relative to larger firms, with over 40 percent of small

Table 9.—How important are the following drying process issues to you?

Drying process issue	Volume dried ^a			Chi-square (p) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% rating very/extremely ^c			
Airflow	66.3	93.3	80.4	12.7 (<0.01)
Maintenance and repairs	48.2	81.8	89.5	31.6 (<0.01)
Use of optimized schedules	37.8	61.4	68.4	14.3 (<0.01)
Energy consumption	51.8	57.8	54.4	0.43 (0.81)
Corrosion	28.4	44.2	50.0	7.2 (0.03)
Selection of kiln layout	34.6	39.5	39.3	0.44 (0.80)
Spraying system	18.1	41.9	39.3	10.6 (0.01)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each drying process variable (3 by 2 table for each). Approximate sample size for each test was 83 for small firms, 44 for medium firms, and 56 for large firms.

^c Based on two combined categories from five, including not at all, a little, somewhat, very, and extremely.

Table 10.—How important are the following kiln control issues to you?

Kiln control issue	Volume dried ^a			Chi-square (p) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% rating very/extremely ^c			
Quality control during drying	78.3	95.6	93.0	10.8 (0.01)
Quality control after drying	61.5	77.8	82.5	8.7 (0.01)
Quality control before drying	64.4	86.7	89.5	15.4 (<0.01)
Ability to monitor moisture content	72.2	91.1	87.7	9.3 (0.01)
Operation of kiln control unit (e.g., simplicity)	73.0	84.1	79.0	2.17 (0.34)
Maintenance of monitoring equipment	57.8	81.8	87.5	17.8 (<0.01)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each kiln control variable (3 by 2 table for each). Approximate sample size for each test was 90 for small firms, 45 for medium firms, and 57 for large firms.

^c Based on two combined categories from five, including not at all, a little, somewhat, very, and extremely.

firms rating these issues as very or extremely problematic (Table 11). Small firms also were more likely to indicate that end checking, case hardening, sticker stain, and setting pitch were problematic relative to larger firms. As noted earlier, small firms tended to make their own stickers and often did not take advantage of advanced sticker designs. Across most other issues, ratings were similar regardless of firm size. For large firms, discoloration or staining (e.g., sap stain) was rated as very or extremely problematic by 33.3 percent of respondents, which was the highest rated issue for large firms.

Table 11.—How problematic are the following kiln-dried lumber quality issues to you?

Quality issue	Volume dried ^a			Chi-square (p) ^b
	≤1 MBF	1–5 MBF	>5 MBF	
	% rating very/extremely ^c			
Uniform final moisture content, or wide variation	43.0	20.9	22.8	9.5 (0.01)
Achieving target moisture content	42.4	20.5	22.8	9.2 (0.01)
Warping	42.5	22.2	21.1	9.6 (0.01)
moisture content internal gradients, such as shell or core	32.9	20.5	19.3	4.2 (0.12)
End checking	32.6	18.2	17.5	5.4 (0.07)
Surface checking	31.4	25.0	15.8	4.4 (0.11)
Shake	22.5	14.0	12.3	2.9 (0.24)
Case hardening, or internal stresses	33.7	22.7	17.5	5.0 (0.08)
Internal checking, such as honeycomb	30.6	22.2	16.1	4.0 (0.14)
Discoloration or staining, or sap stain	26.7	24.4	33.3	1.1 (0.56)
Collapse	24.4	15.9	14.0	2.8 (0.25)
Discoloration from high temperature	17.4	15.6	15.8	0.1 (0.95)
Sticker stain	34.1	24.4	17.5	4.9 (0.08)
Setting pitch	28.9	13.6	14.6	6.0 (0.05)

^a MBF = thousand board feet.

^b Chi-square tests based on frequency counts for each quality issue variable (3 by 2 table for each). Approximate sample size for each test was 85 for small firms, 44 for medium firms, and 57 for large firms.

^c Based on two combined categories from five, including not at all, a little, somewhat, very, and extremely.

Conclusions

This 2024 kiln survey provides an understanding of the current practices, technology use, and perceptions of kiln operators in the northeastern and north-central region of the United States. The region's kiln technology blends traditional steam-heated kilns with advanced, often automated, systems, as well as many smaller, nonsteam facilities that target small-scale custom drying needs. The study revealed a pronounced operational dichotomy between firm sizes. Other studies have shown that smaller wood products firms face challenges in seeking information and making business investments (Buehlmann et al. 2013). This study obtained similar results, as smaller facilities exhibited significantly lower rates of adopting critical quality-control tools, such as kiln samples and end coatings, and demonstrated a reluctance to invest in new equipment or essential upgrades. This translates directly into their higher reported struggles with achieving uniform final moisture content and mitigating warping. In contrast, larger firms, often benefiting from more integrated postdrying processes, prioritize advanced quality control and face distinct challenges like discoloration. This two-tiered landscape underscores the need for tailored training. Future industry advancement necessitates strategic investments in modernization and customized educational programs that address the unique challenges and opportunities inherent to each operational scale, ultimately fostering enhanced product quality and sustainable regional practices. Going forward, it also will be important for kiln operators to identify opportunities to integrate value-added processes such as sorting and customized orders to meet changing market needs. Future research could explore ways to increase small firm interest in training opportunities specific to their needs and internal resources. Researchers could also look for ways to conduct more frequent tracking studies to allow for more frequent updates of training needs across the country.

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