

Marketing Strategy Recommendations for the U.S. Thermally Modified Wood Industry

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EXECUTIVE SUMMARY

Thermal modification of wood is a chemical-free treatment that results in enhanced resistance to decay and improved dimensional stability. Thermally Modified Wood (TMW) has multiple applications and offers an opportunity for high value-added uses for timber resources that are underutilized or affected by invasive species, which can improve forest health and create economic opportunities in rural communities. TMW is in the early stages of adoption in the United States. Insufficient marketing efforts have kept consumer awareness of TMW low. However, there is opportunity for TMW to capture a share of the market for products such as exterior decking and siding, where interest in thermal modification treatment is growing among wood products companies and environmentally-conscious consumers. The potential market space of TMW is close to that of tropical hardwoods, naturally durable wood, and wood-plastic composites (WPCs).

The main objective of this project was to identify the challenges and opportunities for TMW industry expansion in the U.S. market related to professional, intermediate consumers, and formulate actions to support the growth of the TMW industry. To achieve this objective, the priorities and perceptions of potential professional adopters of TMW products were identified by comparing TMW to competing wood-based products. With this information, a marketing strategy was developed to help the U.S. TMW industry better meet customer needs.

According to the study's results, professional users currently perceive TMW to have good *Durability*, *Aesthetics*, and *Environmental Performance*. However, they also perceive TMW to be an expensive material and not easily available. The main differentiation of TMW relative to other wood-based materials may be its strong *Environmental Performance*, which has become increasingly important, especially among end users. Currently, TMW is priced as a high-end product, in the range of tropical hardwoods and WPCs.

The TMW industry needs to increase awareness of their product, while positioning it as a chemical-free, solid wood alternative that can utilize sustainable domestic timber species. TMW should be promoted as a high-quality, high-performing material. The industry needs to establish relationships with design professionals and wholesalers, as effective distribution channels. There is a need for widely recognized U.S. performance standards or grades for TMW, to ensure product quality and consistency, assure users about performance and safety, facilitate market access and trade, and build consumer confidence. The TMW industry could benefit greatly from working together, through the formation of an industry association to achieve the aforementioned goals.

INTRODUCTION

The forest products industry is vital to maintaining many rural economies in the United States. However, the industry has faced significant challenges during the last two decades. Increased low-cost imports have taken market share away from domestic producers, with subsectors such as household furniture, flooring, and millwork particularly affected. Substitute materials are also threatening the market position of products such as siding, decking, and pallets. The economic downturn that started in 2007 and the slow recovery of the housing market has caused great job losses. This decreased activity in the forest products sector has resulted in timber harvest volumes remaining well below sustainable levels. Lack of harvest can lead to poor forest management by negatively impacting tree species diversity, making forests more susceptible to attack by pests and invasive species, and can lead to increased wildfire risk.

Thermal modification technology has the potential to create and expand forest products markets, particularly for traditionally underutilized and low-value species. This emerging, chemical-free technology produces sustainable, value-added wood products with improved dimensional stability, resistance to biodegradation and weathering, extended service-life, and reduced environmental impacts. Despite shifts in consumer preferences for more environmentally-friendly products, this fledgling technology has not taken hold in the U.S. on a substantial scale due to insufficient marketing efforts.

Thermally Modified Wood (TMW) can be utilized to create a variety of products, but it is particularly suited for exterior decking, due to its high performance in outdoor applications and aesthetic qualities. The U.S. decking industry is substantial, and there is potential for TMW to capture a niche of that market, particularly for environmentally conscious consumers with less price sensitivity than the general market.

This report contains marketing strategy recommendations for the U.S. TMW industry. Recommendations are based on research carried out in 2015 and 2016 at the University of Minnesota. The marketing strategy focuses on the TMW decking products industry, including manufacturers and distributors; however, the recommendations presented are broad in scope and are useful for the TMW industry in general. This document starts with a summary of results from the research conducted, followed by a description of the current state of the TMW industry and its marketing practices, and lastly marketing strategy suggestions for the TMW industry are listed. The appendices contain lists of thermal modification equipment manufacturers and TMW producers worldwide, as well as a list of U.S. trade shows and resources.

PROFESSIONAL USER RESEARCH SUMMARY

To achieve the objectives of this research, information on professional consumer perceptions of Thermally Modified Wood (TMW) was gathered, to better understand the challenges and opportunities for its market growth. The data generated was the major input to develop this strategic marketing plan for the U.S. TMW industry. Each step of the research process is explained in detail in this chapter.

Methods

This study was carried out by administering in-person and online surveys to professional users of decking products. The questionnaire contained demographic, perceptions, and conjoint analysis questions. Data collection was conducted at a trade show called the “Deck Expo” [1] in Baltimore, Maryland in the Fall of 2016, and online through a link posted on *Professional Deck Builder* magazine’s website [2]. After analyzing differences between the responses from these two surveys, the datasets were combined and results are presented in this report. When significant differences exist between the two data sets, it is noted in the discussion. The product selected for this project was decking, because of the large market size and growth potential for TMW, as well as decking being a suitable application of TMW. The questionnaire used was created through an iterative process, in which feedback was received from members of the academic community and industry. In addition, a testing event was held, where industry representatives were invited to participate and provide feedback on the questionnaire as well as the overall survey experience. Five wood and wood composite deck samples were manufactured for participants to examine in-person at the trade show event. Materials for the deck samples included: naturally durable softwood (western red cedar), wood-plastic composite (WPC), pressure treated lumber, tropical hardwood (ipe), and thermally-treated ash and aspen (Figure 1).



Figure 1. Decking samples of thermally modified aspen (left) and Western red cedar (right). Photo credit: Maria Fernanda Laguarda Mallo.

In addition to the research data collected, TMW industry members were consulted to contribute to the contents of this marketing plan and to better understand the goals of the industry. This was done through semi-structured phone interviews of six TMW companies in July of 2017. After the phone interviews, industry members were also sent an online survey on the strengths and weaknesses of the industry, as well as its opportunities and threats.

Results

Demographics

The survey started with several demographic information questions. In the first question, participants were asked to indicate the main activity of their companies, by selecting from a list. Multiple selections were possible. Respondents reported “Remodeling” (32%) and “Deck Specialist” (31%) to be their top two areas of work (Table 1).

The largest area of company business was in “Repair & Remodeling,” where 82% of respondents reported at least some percentage of their company’s business in this area. “Single-family New Construction” followed, with 66% of respondents reporting at least some percentage of their company’s business in this area. In addition, Deck Expo respondents reported a statistically significant larger percent of their company’s business in commercial projects, at 42%, compared to 31% of Online respondents (35% combined) (Table 1).

When asked to describe the size of their company, the largest percentage of respondents indicated working for companies with 1-4 employees (46%), followed by 20-49 employees (17%) (Table 1). Respondents to the online survey reported significantly smaller companies compared to respondents to the in-person survey, with two-thirds of the online participants in companies with 1-4 employees, and less than one-third of respondents in that category.

Participants were asked to indicate in which region(s) of the U.S. their company operated. Responses suggest an over-representation of companies operating in the Northeast, with 50% of overall respondents reporting having business in this region. This may be a result of the location of the Deck Expo event (Baltimore, MD). Online respondents reported a more even distribution of business operations, which can likely be explained by the nationwide reach of the online magazine where the survey was advertised.

Respondents were also asked to specify how often each of the decking materials were used for their company’s projects over the past year. In general, respondents seem to use a wide range of decking materials but the top two materials used were WPCs, followed by pressure treated lumber. TMW was reported to be used for at least some percentage of company projects by 5% of respondents (Table 1).

Table 1. Respondent demographic information. N=103. Responses marked with an asterisk* denote questions where multiple responses were allowed.

Demographic	Percentage
Company Description*	
Repair & Remodeling	32%
Deck Specialist	31%
Manufacturing	16%
New Construction	14%
Other	12%
Wholesale, Retail, Distribution	11%
Architect/Design	8%
Type of Projects*	
Remodeling	82%
Single-family New Construction	66%
Commercial	35%
Multi-family New Construction	30%
Institutional	15%
Other	13%
Company Size	
4 or fewer Employees	46%
5-9 Employees	10%
10-24 Employees	11%
25-49 Employees	17%
50-99 Employees	7%
100 or more Employees	11%
Company Location*	
Northeast	50%
Midwest	39%
South	32%
West	25%
Other	11%
Materials Used*	
WPCs	77%
Pressure Treated Lumber	54%
Naturally Durable Softwoods	42%
Tropical Hardwoods	40%
Plastic	29%
TMW	5%
Other	5%

When asked about their familiarity with TMW, over half of respondents (63%) (Figure 2) indicated that they are “Very familiar” or “Somewhat familiar” with TMW. However, more than one-third of respondents also reported little or no familiarity with TMW (37%) (Figure 2), which suggests an opportunity for educating and informing this audience on TMW.

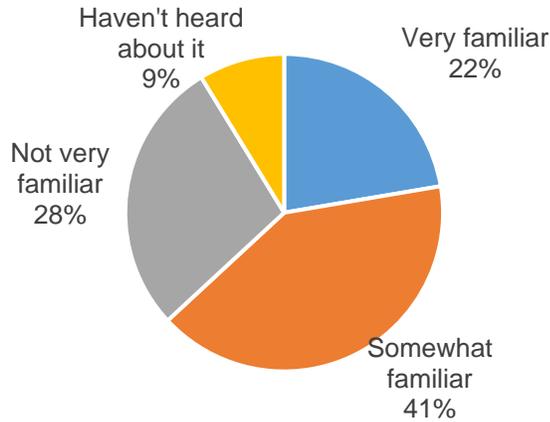


Figure 2. Respondent reported level of familiarity with TMW.

Material Preferences

The next section of the questionnaire asked respondents about their two top-choices of decking material for projects in three price ranges: low-end, medium-range, and high-end. Results indicated respondents prefer to use pressure-treated lumber for low-end projects, with 41% and 27% of respondents selecting this material as first and second choice, respectively (Figure 3). For medium-range projects, respondents prefer to use WPCs. Tropical hardwoods were overwhelmingly preferred for high-end projects, followed by WPCs. TMW was the second choice for 17% and 14% of respondents, in medium-range and high-end projects, respectively. Interestingly, WPCs have relatively high responses in all price ranges, perhaps reflecting the effective job by the WPC industry in segmenting the market and offering differentiated solutions for projects in all price segments.

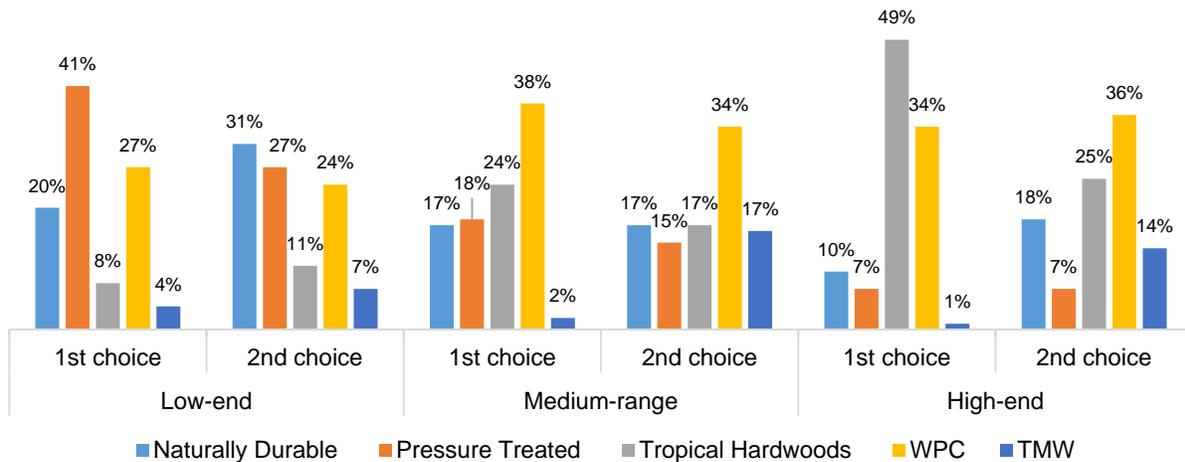


Figure 3. Percent of respondents selecting top two ranked choices for low-end, medium-range, and high-end decking projects.

Attribute Importance

Respondents were asked to rate the importance of six attributes when making decisions about decking materials. Answers to this question were given by selecting from a six-point Likert scale, ranging from “Not at all important” to “Extremely important.” Figure 4 summarizes responses to this question; where the scale was modified to simplify analysis by changing the six-point Likert scale to “Low importance,” “Medium importance,” and “High importance.” Overall, the most important material attributes when designing, constructing, or remodeling a deck were *Durability* and *Aesthetics*, with 82% and 80% of respondents rating these attributes as very or extremely important, respectively (Figure 4). *Need for Maintenance* was also among the top attributes, with 68% of respondents considering it very or extremely important. Only a little over one-third of respondents reported that *Environmental Performance* had “High Importance” when making decisions about decking materials.

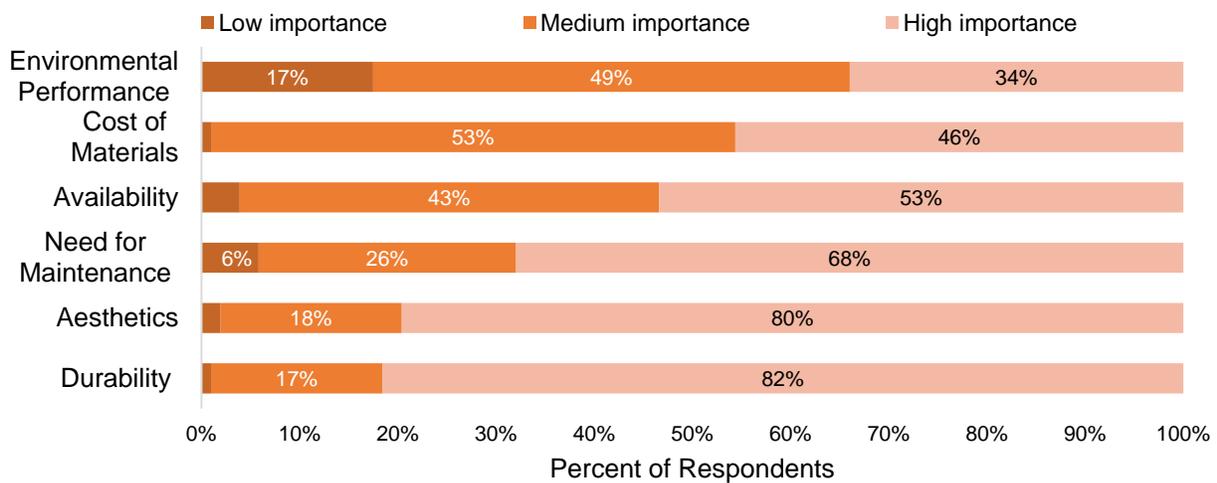


Figure 4. Perceived attribute importance among respondents when designing, constructing, or remodeling a deck.

Perceptions about Decking Material Performance

The next question asked respondents about their perceptions on the performance of five wood and wood composite decking materials (naturally durable softwoods, pressure treated lumber, tropical hardwoods, WPCs, and TMW). Six attributes were included: *Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance* (Figure 5). The scale for these questions included five choices, from low performance to high performance, and a “Do not know” option if respondents were unfamiliar with any of the materials. To make the analysis and interpretation of the perceptions question simpler, a “perception index” was calculated, as a weighted average of the ratings selected (1 to 5) and the frequencies of responses. Thus, a perception index was calculated for each material, reflecting the respondents’ perception of that material on the six attributes being evaluated; with values between 1 (for the lowest perceived performance) and 5 (highest performance). The perception indexes are summarized in Figure 5.

Respondents viewed TMW's *Availability* as the lowest among all materials and therefore perceived it as the most difficult to find (2.5 out of 5.0). For *Cost of Materials*, however, TMW was perceived as more affordable when compared with tropical hardwoods and WPCs. Except for *Cost of Materials*, WPCs were rated first or second for all attributes, and rated considerably higher for *Need for Maintenance*. Not surprisingly, pressure treated lumber had the highest rating for *Cost of Materials* and *Availability*.

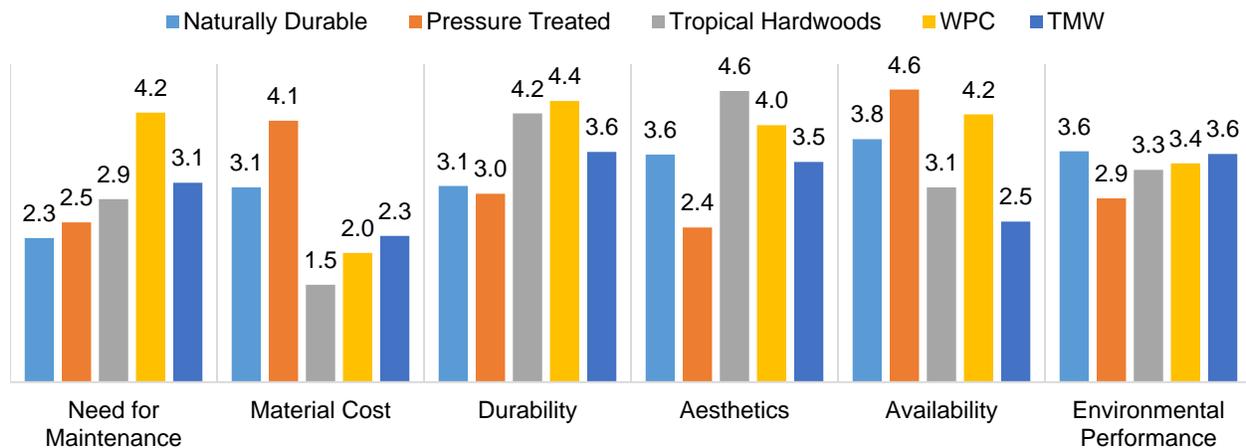


Figure 5. Comparison of perceived material performance among respondents for *Need for Maintenance*, *Material Cost*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*. Indexes were calculated as a weighted average of responses given on a 5-point scale from “very low” to “very high” performance.

Conjoint Analysis

Conjoint analysis is a marketing technique that identifies the relative importance consumers place on various product attributes. Including a conjoint analysis component in this survey allowed for a better understanding of the trade-offs professional consumers make among different product attributes, especially those that are influential to TMW’s marketability. Conjoint analysis questions collect information by presenting participants with a series of product alternatives, and then prompts them to select the product they would purchase if those were their only options. A “None” option is usually provided for participants who would not select any of the product alternatives available.

Overall attribute importance may be calculated from conjoint analysis data and indicates the relative importance consumers place on an individual attribute compared to other attributes included in the study. Respondents placed the highest importance on *Durability* (31%) and *Material* (28%) and placed the lowest importance on *Need for Maintenance* (9%), followed by *Environmental Certification* (10%) (Figure 6). A marked difference was noticed with how respondents rated *Need for Maintenance* in the Attribute Importance question (Figure 4), where this attribute was the third most important. Potential explanations are that respondents assume that maintenance needs are inherent to the materials, thus linking their perception of the *Need for Maintenance* attribute to the *Material* attribute. In addition, since respondents were intermediate consumers, and not directly in charge of the maintenance of the product, it is

possible that they did not place the same importance on maintenance that a homeowner would do.

Further analysis of the results from the conjoint analysis data revealed WPCs had the highest “utility,” a measure of preference, followed by tropical hardwoods. Pressure treated lumber was the least preferred material overall. TMW had a positive utility among Deck Expo respondents and a negative utility among Online respondents.

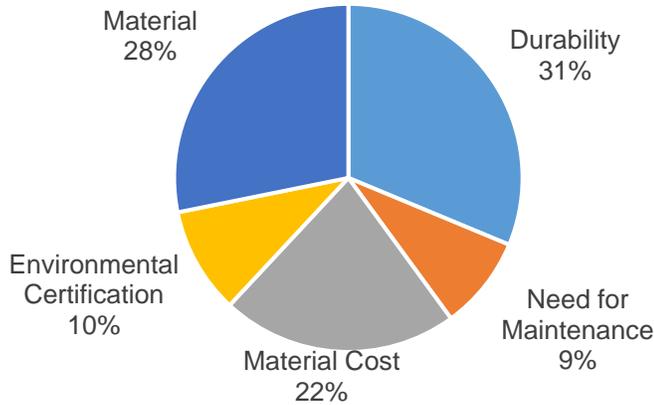


Figure 6. Overall attribute importance using conjoint analysis data.

CURRENT STATE OF THE TMW INDUSTRY

This section contains information about the current state of the TMW industry, including market development, standards, associations, regulations, technology, and awareness and perceptions. It also contains an analysis of the decking industry market and its major competing materials.

Macroenvironment

State of Market Development

During the last two decades, TMW has achieved technical maturity and commercial success in Europe. Part of this success was due to increasing consumer concerns about the use of toxic chemicals for wood durability enhancement [3]. However, TMW has not yet achieved the same level of commercial development in the United States. As of 2013, there were 118 producers of TMW in Europe and Russia [4] and the 2015 estimated annual production capacity of TMW was 400,000 m³ [5]. In comparison, there are currently only around 13 producers and distributors of TMW in the U.S. [5] with a 2012 North American TMW production capacity of around 100,000 m³ [6]. However, the U.S. production capacity is likely to rise, as many companies are considering opening thermal treatment plants. A list of TMW producers worldwide can be found in Appendix 1.

Standards

There were no widely recognized standards or grades for the manufacturing or testing of TMW in the U.S. as of 2016. The development and recognition of standards is important to ensure product quality and consistency, assure users about performance and safety, facilitate market access and trade, and build consumer confidence in the TMW industry. The only effort to date to address the need for standards in the U.S. resulted in a report titled “AWPA/ANSI Guidance Document for Listing Thermally Modified Wood in AWPA Standards” [7]. This document lists the performance requirements for getting a TMW product approved by the American Wood Protection Association (AWPA), an ANSI-accredited standard-developing organization. It also contains information on the need for standards, who is responsible for driving the development of standards, and the data requirements to create TMW standards.

By contrast, Europe currently has three published standards for TMW. “DS/CEN/TS 15679 Thermally Modified Timber – Definitions and Characteristics,” was published in 2007 and approved in 2013 [8]. This standard provides definitions and characteristics for TMW products; it requires manufacturers to document production data and mark products with the following information: manufacturer’s name, production plant and internal production control, assortment or specification, reference to the CEN/TS standard, wood species, end use class, and scope of application [9]. Another European standard is a certification program for TMW called “Quality Mark TMT,” published in 2007 in Germany and updated in 2015 [10]. It outlines specific procedures, quality requirements, and properties for TMW certification, as well as all trademarks and producer requirements. The third European standard “DIN 68800 Wood Preservation,” was published in multiple sections between October 2011 and February 2012 [11]. Information on TMW and thermal or chemical modification for the preservation of wood can be found in the

Annex A to Part 1 of the DIN 68800 standard [9]. This standard also contains information on general prerequisites for wood protection against biodegradation and an overview of the available measures for wood protection and natural durability. Finally, a related European standard is “EN 350:2016,” which provides guidance on methods for determining and classifying the durability of wood and wood-based materials against biodegradation (Table 2) [12].

Table 2. European durability classes of wood and wood-based materials to attack by decay fungi, wood-boring beetles, termites, and marine organisms. Durability classes refer only to the heartwood. Sapwood is considered not durable (DC 5) [12].

Durability Class	Description
Decay Fungi	
DC 1	Very durable
DC 2	Durable
DC 3	Moderately durable
DC 4	Slightly durable
DC 5	Not durable
Wood-Boring Beetles	
DC D	Durable
DC S	Not durable
Termites	
DC D	Durable
DC M	Moderately durable
DC S	Not durable
Marine Organisms	
DC D	Durable
DC M	Moderately durable
DC S	Not durable

Industry Associations

Currently, there are no U.S. associations representing the companies that manufacture or distribute TMW exclusively. Associations can play an important role in supporting and growing an emergent industry, by combining resources to provide educational resources to members and the public, conducting market research, enhancing credibility and trust, and advocating for their members. In Europe, the International ThermoWood® Association, which represents TMW producers and equipment manufacturers that use the ThermoWood® process, has been successful in advancing TMW in Europe by patenting their treatment processes, requiring standardization, auditing quality control, conducting life cycle assessment (LCA) on their products, certifying raw materials used, and conducting research and development activities [13].

Regulations

Developments such as the increasing concerns over illegal logging and the use of chemicals in wood treatments have created opportunities for the TMW industry. The 2008 amendment of the Lacey Act has increased enforcement of regulations related to trade of illegally sourced timber [14], with harsh penalties for those that knowingly or unknowingly allow illegally harvested timber to enter the supply chain. This increased enforcement has the potential to open market opportunities for domestically-sourced wood products, such as TMW, which shares some highly valued attributes with tropical hardwoods, such as a dark, rich color,

and enhanced durability [15]. Moreover, concerns for wood treatments involving potentially harmful chemicals have resulted in chemicals such as chromated copper arsenate (CCA) to be discontinued for residential uses in the U.S. [16], creating opportunities for chemical-free treatments, including thermal modification. However, it is worth noting that TMW is not recommended for ground contact use.

Technology

Nearly all TMW producers carry out the thermal treatment process in a different way, depending on the equipment used (Appendix 2 contains a list of manufacturers of thermal treatment equipment), species treated, the products' desired performance properties, and final uses, among other factors. The following list is a summary of the most common TMW processes used in Europe:

- *ThermoWood*[®] [13] is a thermal treatment process founded in Finland that dominates the TMW market in Europe. The *ThermoWood*[®] process may be used only by members of the International *ThermoWood*[®] Association, and heat-treats wood in the presence of steam with low oxygen content [17]. There are two *ThermoWood*[®] standard classes, *Thermo-S* and *Thermo-D*, which have different processes for emphasizing stability or durability depending on end use application of the material [13]. *Thermo-S* class heat-treated timber meets class 3 decay requirements and includes end uses as furniture or dry condition fixtures, while *Thermo-D* class meets class 2 decay requirements and may be used for outdoor applications [13]. A general overview of the *ThermoWood*[®] modification process can be found in Figure 7.
- *ThermoTreat 2.0* is a process that was developed by WTT (Wood Treatment Technology) [18] in Denmark. It uses a closed system hydrolysis process at high pressures but lower temperatures and takes approximately 12 hours to complete [18].
- The *Plato* process was developed in the 1980s in the Netherlands. It is a four-step process, which includes heating the wood under wet conditions, drying, heating the wood again, and curing the wood in dry conditions [19].
- *Retification* (*Retiwood*[®]) is a process developed by New Option Wood in France, which slowly heats up pre-dried wood in an atmosphere rich in nitrogen with a maximum 2% oxygen content [19].
- *Perdure* is another TMW process developed by New Option Wood. This process artificially dries fresh wood in an oven, then heats it up in a low-oxygen environment [19].
- *Oil Heat Treatment (OHT)* is a thermal modification process developed by the company Menz Holz in Germany. OHT heats wood in a closed-process, hot oil medium to provide good heat transfer [20].
- Another collection of thermal modification methods utilize heat and a vacuum. One company that uses this process is WDE-Maspell [21].

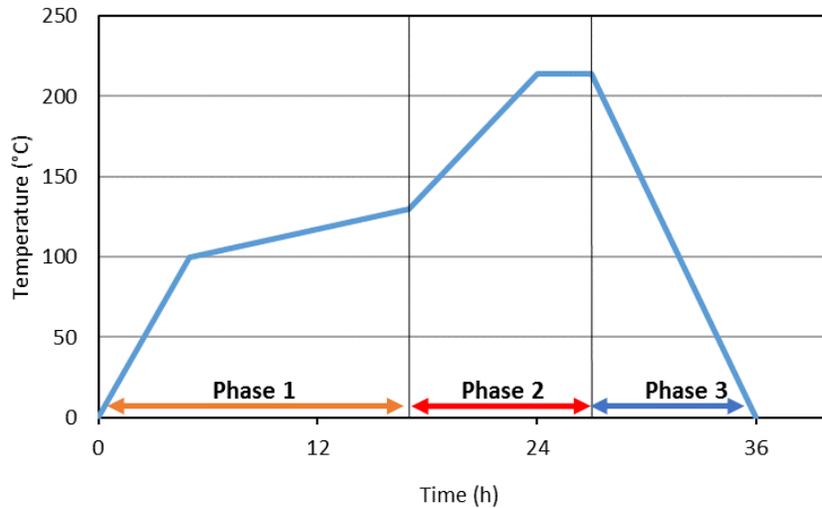


Figure 7. General overview of ThermoWood® thermal modification process [22].

While information is available about the processes used in Europe, there is very little published information about the thermal modification technology and processes used by U.S. TMW producers. Sandberg and Kutnar [17] reported at least one U.S. company using the ThermoWood® and Perdure processes, in addition to a unique process called the *Westwood* process, which they noted is a variation of the ThermoWood® process developed specifically for hardwood species.

Awareness and Perceptions

TMW is in its early stages of market development in the U.S., with just a few producers and distributors, and awareness among the general population very low [23]. At this stage, it is critical to increase awareness about the technology and develop positive perceptions about its performance benefits. Successful and visible projects utilizing TMW, like the University of Minnesota's Bell Museum of Natural History in St. Paul, Minnesota, will contribute to increased awareness and appreciation of TMW (Figure 8).



Figure 8. University of Minnesota's Bell Museum of Natural History, St. Paul, Minnesota, under construction. Exterior cover is thermally modified white pine. Photo credit: Omar Espinoza.

When TMW was first introduced to the U.S., its market growth was negatively affected by unsupported claims about its performance [7]. Consistent consumer perceptions are also made more difficult by the wide range of potential processing techniques for TMW, which result in different product characteristics, even for the same species and end use. These factors have contributed to consumer confusion [7] and highlight the need for a unified industry marketing strategy, which this study attempts to address.

A recent survey carried out as part of this study (see Professional User Research Summary- Results section) found that awareness is low among professional adopters, with 37% of respondents indicating very little or no awareness with TMW (Figure 2). However, a portion of this population seemed to have transitioned into the interest and evaluation stages of the product adoption since 22% of industry professionals surveyed for this study reported to be “Very familiar” with TMW (Figure 2) (more information on this can be found in the Professional User Research Summary- Results section). It is reasonable to assume the level of awareness among the general population is much lower, which is a major barrier preventing the TMW industry from growing [23]. Industry representatives interviewed for this report had a similar conclusion, citing a lack of knowledge on TMW, including technical information such as how to properly install TMW, as major barriers for their products’ adoption.

TMW Industry Marketing Practices

This section discusses the current marketing practices of TMW producers and distributors. The information is based on previous research by Espinoza et al. 2015 [23], the current research conducted by the authors, and industry member interviews conducted in July of 2017.

Size

At the time of writing, and based on internet research and consultation with experts, only around 13 firms currently produce or distribute TMW in the U.S. [23]. Five of these firms are located in the Midwest, three in the South, three in the Northeast, and two in the West. However, U.S. TMW producers generally agree that interest in thermal modification treatment is increasing, based on the amount of customer inquiries received [23], and there are a number of companies interested in entering the industry. All but one industry member interviewed for this study noted rapid sales growth, even exponential growth, of TMW products over the past five years.

While the current demand for and production of TMW in the U.S. is small, there is potential for considerable growth, if trends seen in Europe can be replicated, where production volumes of TMW have been increasing consistently since 2001. For example, the total annual production in Europe was around 130,800m³ in 2007 [24] and 280,000m³ in 2013 [25], a more than two-fold increase in less than six years. With the proper marketing strategy and concerted industry effort, similar growth could possibly be achieved in the U.S.

Distribution and Promotion

Results from interviews with U.S. manufacturers and distributors of TMW products [23] are useful to understand the U.S. supply chain of TMW. Manufacturers and distributors interviewed reported selling domestically to markets in many U.S. regions, and several companies reported exporting a significant share of their production to a wide variety of international markets. One TMW producer interviewed for this project noted that the U.S. is a great source of sustainably produced lumber, and TMW is approximately 5-10% lighter in weight than non-treated material, which can save money on shipping costs.

Distribution channels for TMW in the U.S. include lumberyards and distributors of building products, followed by manufacturers and contractors to a lesser extent (Table 3). Some companies also utilize landscape architects and retail lumberyards as distribution channels. TMW producers interviewed indicated selling exclusively to distributors and other business customers including sales representatives and architects. One company reported marketing directly through retail channel websites such as The Home Depot.

The most common promotional channels for TMW producers and distributors are company websites, followed by attendance at trade shows (Table 3). Some of the events attended by TMW producers and distributors include the biannual International Woodworking Fair (IWF) in Atlanta [26], WoodWorks events [27], and the Greenbuild International Conference and Expo [28]. However, during the data collection phase for this study, the Deck Expo in Baltimore, Maryland, no producers or distributors of TMW decking products were present.

Table 3. Current distribution and promotional channels used by TMW producers [23].

Distribution Channels	Promotional Channels
Distributors	Websites
Manufacturers	Trade Shows
Contractors	Trade Journals/Magazines
Architects	On-site Educational Events
Other	Installed Displays

Messaging

Durability and improved rot resistance, as well as the dark, rich color and attractive, exotic appearance of TMW are the attributes emphasized most often by TMW producers and distributors (Table 4). Other attributes highlighted by at least one U.S. TMW company include *Better Acoustic Properties*, *Locally Sourced*, *Lighter*, and *Not a Health Hazard*. In addition, several TMW producers indicated they are careful not to over-promise benefits, stressing that TMW is not a “maintenance-free” material. According to TMW producers interviewed for this project, using “environmental friendliness” in the companies’ messaging is more effective in some regions of the U.S. than others.

Table 4. Attributes emphasized by TMW producers [23].

Attributes Emphasized
Durability and improved rot resistance
Rich color, attractive or exotic appearance
Chemical-free, zero toxicity
Enhanced dimensional stability, lower hygroscopicity
Environmentally friendly
Competitive price compared to tropical
Machinability, sands and finishes easily

CURRENT STATE OF THE DECKING INDUSTRY

The information contained in the following sections comes mostly from two recent studies on decking industry advertisements in print magazines: Hamner, Hansen, & Tokarczyk (2012) [29] and McGraw, Smith, & Chen (2015) [30], as well as information from the recent study conducted by the authors of this report.

Messaging Practices in the Decking Industry

Between 1996 and 2006, a large increase in print advertisement frequency occurred in the decking industry [29]. Most of this advertising growth occurred after 2001 in response to WPCs entering the decking materials market as a substitute to solid wood products. Producers and distributors of naturally durable softwoods increased their number of advertisements by 300% during this period [29]. After 2006, this frequency fluctuated with the demand for decking products within the U.S. housing industry upturn and crash, with a more than 250% difference in the number of advertisements between the lowest and highest demand years [30]. From 2002 to 2014, WPCs were the most common material advertised in *Professional Deck Builder* magazine, making up 38% of all ads in that outlet [30]. The attribute promoted most frequently among all decking materials was *Aesthetics*, followed by *Durability* and *Color Option Availability* [30].

Participants

Consumers in the decking industry can be divided in two groups, intermediate consumers and end consumers. Intermediate consumers include deck specialists and contractors, wholesalers, retailers, distributors, manufacturers, and architects and designers. This group may have the greatest bargaining power over markets because they can influence purchasing decisions by end users [31], since deck specialists and contractors install over 80% of deck projects [32]. A previous study on architects and designers revealed that professional users are often involved in the selection process when choosing building materials, and have the potential to greatly influence the utilization of wood products [33]. In addition, it is easier to collect data on, and measure material selection of intermediate consumers compared to end consumers because of their exposure and experience with a wider variety of products.

The other group of consumers participating in the decking industry market is comprised of end users. They include homeowners, and sometimes renters, who are the final recipients of a product. A previous study found end consumers are responsible for specifying material type up to 30-50% of the time [32], making them less influential but still important to material selection. This group of consumers has recently become more influential because of the growth of the do-it-yourself (DIY) market [34].

Demographics

Demographic information was collected from this study and previous studies to create the profile of an average professional consumer in the decking industry. Participants in this study were mostly remodelers and deck specialists, and most firms were small, comprised of one to four people, which was also reflected in previous research [32, 35]. The most common materials used by this study's participants were WPCs and pressure treated lumber. There was a significant difference between participants who answered our survey in-person, at the 2016 Deck Expo in Baltimore [1], and those answering online, with the former reporting a larger percent of their projects being built with WPCs. Naturally durable materials and tropical hardwoods occupied third and fourth places in frequency of use, as indicated by respondents to our survey.

Some of the most important demographic takeaways from this study includes the information that reveals how preferences for TMW differ between demographic groups. Geographic location and profession were not overly important demographics for segmenting intermediate consumers, but industry members from the Western region of the U.S. and architects and designers currently view TMW most preferably. In addition, this study revealed the industry as a whole is still relatively unaware of TMW, with 37% of intermediate consumers reporting to have little or no familiarity with TMW (Figure 2). The environmental credentials of TMW can be enhanced by chain of custody forest certification, yet half of the respondents to this study reported being unfamiliar with forest certification. Over 485 million acres of forested land are certified by either the Forest Stewardship Council (FSC®) or the Sustainable Forestry Initiative (SFI®) worldwide, with much of that certification occurring in North America [36]. At least three U.S. TMW companies currently include forest certification in their promotional materials [37-39]. The data collected on industry familiarity with these two topics demonstrates there is considerable opportunity to raise awareness of both TMW and forest certification.

Demographic information of end consumers collected by previous studies revealed people aged 45-64 will experience a market share growth for decking that is considerably higher than other age groups, indicating more people in that age bracket will be building or remodeling decks. This older and more affluent segment of the population is generally willing to spend more money on amenities such as decks [40], which will be important to the decking industry over the next several decades. Another study found that as consumer age increased, so did acceptance for WPCs. As the end consumer profile shifts to reflect this dominant market share by older age groups, the lifetime of a deck and the hours of maintenance necessary for upkeep may become more important than decking material and price among these older consumers [41].

Buyer Motivation and Expectations

It is important to consider differences between intermediate and end user motivations and expectations. Previous consumer behavior, preferences, and perceptions research on decking materials has explored what attributes are most important to both groups of consumers.

Shook and Eastin [34] found price is not necessarily the dominant factor for professional consumers when selecting decking materials and that their perceptions of the decking materials available vary widely. The most important attributes for industry members who participated in the aforementioned study were *Long Life* and *Beautifully/Aesthetically Pleasing*. A study by

Eastin et al. 2005 [32] reported similar findings, suggesting industry members were more motivated by quality than price when selecting materials. Ganguly and Eastin [40], in another study, found *Longevity, Beauty, Consistent Material Quality, and Availability* to be the most important attributes and motivations of intermediate consumers.

Similarly, research on end users has revealed that they are also motivated more by quality than price. Eastin et al. 2005 [32] also explored end user perceptions and found homeowners are motivated by *High Quality, Durability, and Low-Maintenance*. Two additional studies on end consumers also found *Durability* and *Material* to be the two most important decking attributes [41, 42]. Another interesting finding from previous end consumer studies was that female end users are less sensitive to price, and are more interested in the environmental performance of products compared to men [41, 43]. These findings may represent an opportunity for producers and distributors of TMW, as this is a product made from a renewable material (wood) that which manufacture does not involve the use of chemicals and comes from sustainably managed forests.

Decking Industry Structure

The decking industry was a \$3 billion market in the U.S. as of 2011 [44] and was predicted to top \$4 billion by 2015 [45]. Around 4.2% of U.S. households add a deck to their house every year, resulting in over 3 million new decks being added to existing homes each year [40]. These figures have continued to stay strong, and in 2015, 23% of newly built single-family U.S. homes completed had a deck, which equaled approximately 149,000 new houses with decks [46] Each of the common decking materials available has its own industry makeup, with some sections of the market being fragmented into many small players and others being dominated by a few large companies. In the following sections, the characteristics of the industry for each of the major decking materials are discussed, as well as the perceptions for each material that were gathered as part of this project and presented in the Results-Perceptions about Decking Material Performance section.

Pressure Treated Lumber

Pressure treated lumber has been the dominant decking material since its introduction to the market in the 1970s, surpassing naturally durable softwoods [47]. However, pressure treated lumber has recently lost market share to alternative materials, falling to around 58% of the total demand for decking materials by 2010 [48]. Prices for pressure treated lumber decking are the lowest of all common decking materials (Table 5), which is likely one of the reasons it is still the most commonly used decking material. It is unlikely TMW will be highly competitive with pressure treated lumber until consumer demand for chemical-free products increases or regulations further restrict the use of chemicals. TMW and pressure treated lumber will probably occupy different market segments, at least initially, because of their price difference.

The pressure treated lumber industry is fragmented, comprised of many small to medium manufacturers and associations. The U.S. Census Bureau's manufacturer survey seemed to show a decline in the wood preservation industry (NAICS code: 321114), which includes pressure treated decking products. In 2008, there were 519 wood preservation business establishments with 13,432 employees, while in 2013 those numbers fell to 389

establishments and 8,287 employees, a 25% and 38% drop in number of establishments and employees, respectively [49]. In addition, previous research detected regional differences in the use of pressure treated lumber for decks, where 73% of decks in the Southeastern region of the U.S. were made of pressure treated lumber, but only 30% of decks in the Northwest and Southwest regions were made from this material [32].

Pressure treated lumber has traditionally been positioned as a low-cost decking material, but a study of decking product advertisements over a 12-year period, between 2002 and 2014, found the five attributes mentioned most frequently by pressure treated lumber producers were: *Environmental Friendliness* (81%), *Aesthetics* (56%), *Durability* (50%), *Strength* (38%), and *Cost* (38%) [30]. The same study also found pressure treated lumber producers utilized a “rational” appeal in 75% of their advertisements, which conveys a logical message to consumers about why a product fits their needs [30]. While the results of the study by the authors of this report found the perception of pressure treated lumber’s *Environmental Performance* and *Aesthetics* to be rather negative (Table 5), the attributes emphasized in the pressure treated lumber advertisements studied by McGraw et al. 2015 [30] most likely demonstrate an attempt by the industry to shift these negative perceptions. According to the results of our study, the perceived advantages of pressure treated lumber among professional consumers are the low cost and high availability of this material (Table 5), with three-quarters of respondents indicating that pressure treated is “Very affordable” or “Affordable,” and 90% perceiving it to be “Very easy to find” or “Easy to find.” An additional advantage of pressure treated lumber is that there are already many decks installed with this material, and homeowners may be less likely to switch materials when remodeling their current deck.

The results of the current study demonstrate that perceived weaknesses of pressure treated lumber include inferior aesthetics when compared to other materials (a “perception index” of 2.4 out of 5.0 for *Aesthetics* was calculated based on responses, with higher numbers indicating better performance, see Figure 5 in Professional User Research Summary- Results section). There is also a perception of pressure treated lumber having extensive maintenance requirements, (perception index of 2.6 out of 5.0 for *Need for Maintenance*) which may also be associated with high maintenance costs. Pressure treated lumber is perceived as having average *Environmental Performance* (2.9 perception index), which may be the result of the environmental issues surrounding the use of chromated copper arsenate (CCA).

In 2003, the wood treatment industry voluntarily stopped manufacturing CCA for residential uses, including decking [16]; but the perception of CCA as a harmful chemical treatment may have persisted after this discontinuation, and extended to the chemical treatments that were developed as replacements. In addition, consumers (professional and end users) may question the performance and effectiveness of the new alternative treatments, such as alkaline copper quaternary (ACQ), acid copper chromate (ACC), copper azole (CBA-A and CA-B), copper citrate (CC), copper dimethyldithiocarbamate (CDDC), and copper HDO (CX-A). All CCA-alternatives utilize copper as their primary biocide. The most common CCA alternative, ACQ, has special installation requirements, including the use of either hot-dipped galvanized copper or stainless steel fasteners to avoid corrosion [50]. These special installation requirements may have also added to the negative perception of pressure treated lumber.

Table 5. Comparison of decking material alternatives. Approximate price per linear foot information from Decks.com LLC [51]. Perceived advantages and disadvantages are results from the current study. More details can be found in Figure 5.

Material	Price per linear foot	Perceived Advantages	Perceived Disadvantages
Pressure Treated Lumber	\$0.75 - \$1.25	Cost and Availability	Maintenance and Aesthetics
Tropical Hardwoods	\$4.00 - \$5.00	Durability and Aesthetics	Maintenance and Cost
Naturally Durable Softwoods	\$1.25 - \$2.00	Aesthetics, Availability, and Environmental Performance	Maintenance
WPCs	\$3.00 - \$4.00	Maintenance, Durability, Aesthetics, and Availability	Cost
TMW	Not available	Durability, Aesthetics, and Environmental Performance	Cost and Availability

Tropical Hardwoods

Tropical hardwoods have gained popularity in the U.S. in recent decades, capturing a market share of 1% in 2006 [52] and 2-3% in 2010 [48]. Potential reasons for this growth are the appeal of tropical species' natural durability and aesthetics. Tropical hardwoods are comparatively more expensive than most other decking materials and occupy the upper end of the market. Common tropical hardwood species imported to the U.S. for decking are ipe (*Handroanthus spp.*), cumaru (*Dipteryx odorata*), and tigerwood (*Astronium graveolens*). Prices for TMW are competitive with tropical hardwood decking products, and these two materials will likely compete to capture a segment of the market for consumers who are not highly sensitive to prices.

Tropical hardwoods are imported to the U.S. from countries like Brazil, Peru, and Malaysia, among others [52], and have grown in popularity over the past 15 years. While there are many small importers of tropical hardwood decking materials, there are some big business players, such as the Iron Woods brand from Timber Holdings USA™ [53]. They sell nine different species of tropical hardwoods, with ipe being the most popular, and offer a 25-year warranty on their products.

Tropical hardwoods are generally marketed and positioned as being high quality, durable products with low maintenance requirements. An advantage of tropical hardwoods is their natural durability, which makes them highly resistant to decay and termites [54]. The most common tropical hardwoods commercialized for decking products are also high-density species (*ipe*, for example has a density of 64 lb./ft.³ at 12% moisture content, [55]), which correlates with high strength indicators and perception. In addition, an appealing aesthetic is perhaps tropical hardwoods' most positively perceived attribute (Table 5), with a perception index of 4.6 out of 5 for *Aesthetics* (see Figure 5). This positioning, which emphasizes aesthetics, durability, and maintenance requirements, was confirmed by a study of deck advertisements over a 12-year period between 2002 and 2014 [30]. McGraw et al. [30] found the five attributes mentioned most frequently by tropical hardwood producers and distributors, by percentage of advertisements, were: *Aesthetics* (86%), *Durability* (85%), *Maintenance* (71%), *Strength* (71%), and *Resistance to Biodegradation* (57%) [30]. The same study also found tropical hardwood producers and distributors utilized rational appeals in 100% of their advertisements, which convey a logical message to the consumer about why a product fits their needs [30].

Despite these positive attributes, one major weakness of tropical hardwoods is their high price, which limits this material to high-end uses and a relatively small market share. Also, the professional consumers that provided their input to this study seemed to perceive tropical hardwoods as having “average” maintenance requirements (Table 5) (tropical hardwoods had a perception index of 2.9 out of 5 for maintenance requirements, with 1 indicating very high maintenance requirements and 5 indicating very low maintenance requirements, using a weighted average perceptions index). Another challenge for tropical hardwoods is that certain consumers may have concerns about the legality or sustainability of timber harvested in some tropical countries. This has become a growing concern in recent years, with evidence supporting the claim that illegal logging causes a substantial amount of the deforestation in tropical countries [56].

Naturally Durable Softwoods

Domestic naturally durable softwood species such as western red cedar (*Thuja plicata*) and redwoods (*Sequoioideae spp.*) historically held a relatively constant market share, especially in the Western region of the country. The market share of these materials began to fall in the early 2000s due to market pressure from WPCs [40]; and as of 2010, they occupied around 12% of the decking market [48]. Prices for TMW are competitive with naturally durable softwoods [23], and these two materials will likely compete to capture a niche of the market for consumers who are not sensitive to high prices.

There are currently two major naturally durable softwood industry associations. The first is the Western Red Cedar Lumber Association [57], which owns the Real Cedar® brand name. This non-profit association represents 27 producers of Western red cedar products. On its website, this association emphasizes the low maintenance costs, dimensional stability, and aesthetically pleasing qualities of cedar decking. The second major industry association is the California Redwood Association, which has three producer members, all certified by the Forest Stewardship Council (FSC®), and located in California, including Humboldt Redwood™ [58], Big Creek Lumber [59], and Mendocino Forest Products Company® [60].

Decking products made with naturally durable softwood species (i.e. Western red cedar and redwood) have traditionally been positioned as a high-end, quality products that carry higher upfront costs but are worth their value. Producers and distributors of naturally durable softwoods usually emphasize the “natural look and feel” of their products, as well as the environmental advantages of a material sustainably harvested in U.S. forests. According to this study, perceived advantages of naturally durable softwoods among professional consumers include appealing *Aesthetics* and *Environmental Performance* (Table 5), with a perception index of 3.6 out of 5 for both *Aesthetics* and *Environmental Performance* (Figure 5). A 2014 life cycle assessment (LCA) study of redwood decking materials found that the amount of carbon stored in redwood decking, if emitted into the atmosphere as CO₂, is around ten times greater than the total CO₂ emissions from the manufacturing process [61]. A similar LCA in 2013 compared redwood decking to other materials and found that the global warming potential (GWP) for redwood was negative (-163 kg CO₂-eq), while non-recycled WPCs and recycled WPCs, both had positive GWPs (264 kg CO₂-eq and 144 kg CO₂-eq, respectively) [62]. For GWP, a negative value is desired, as it indicates a net decrease in atmospheric heat trapping potential. A positive GWP indicates a product has a net increase in atmospheric heat trapping potential. Another

advantage of naturally durable softwoods, as claimed by producers and distributors, is their ability to maintain cooler temperatures on sunny days, as well as their versatility to receive different colors and refinish.

This study found a perceived disadvantage of naturally durable softwoods to be high maintenance requirements (Table 5) (perception index of 2.2 out of 5). Another potential perceived disadvantage not detected by this study is limited availability of naturally durable softwoods, which was historically constrained to certain regions of the U.S.; however, these materials have recently become more widely available [40]. Also, naturally durable softwoods have perhaps the greatest photo degradation from sunlight of all major decking materials, especially when they are not properly maintained [63]. Lastly, although not as expensive as tropical hardwoods, naturally durable softwoods are in the higher range of price.

Wood-Plastic Composites (WPCs)

WPCs have recently been the fastest growing decking material, reaching a market share of 25% in 2010 since their introduction in the 1990s [48]. Prices for WPCs relative to TMW wood can vary considerably depending on product quality, with some products costing more than TMW and some being competitively priced with it. WPCs and TMW will likely be in direct competition in some market segments, along with tropical hardwoods and naturally durable softwoods.

WPCs have perhaps the most recognizable brand names of all decking materials among intermediate and end consumers, because of their intense marketing efforts and the 15-30 year warranties offered. A summary of three of the WPC industry's most dominant brands, according to The Decking Superstore® [64], follows:

- Trex® [65] has been the market leader of WPC products since the company's formation in 1996. The company's website emphasizes the recycled nature of their raw materials and the low maintenance requirements of their decking products.
- AZEK Building Products' TimberTech® brand of composite decking products [66] states that 73% of the raw materials for their products are recycled, and offer a warranty of 30 years for their products.
- Fiberon® manufactures the Veranda® brand of composite decking products [67] that are sold exclusively at The Home Depot® stores. They offer the shortest warranty at 15 years, and are made from over 80% recycled materials, according to the company website.

Since their introduction in the 1990s, companies producing and selling WPCs have aimed at positioning this product as a low maintenance, durable material that is environmentally-friendly due to a portion of their raw materials having recycled origins. A study of deck advertisements over a 12-year period between 2002 and 2014 found WPC producers use emotional appeals in 61% of their advertisements, which are intended to produce an immediate feeling that the customer would experience by purchasing the product [30]. The five attributes mentioned most frequently by WPC producers in their advertisements over the same period included: *Color Options* (55% of advertisements), *Aesthetics* (45%), *Warranty* (36%), *Maintenance* (29%), and *Moisture Resistance* (29%) [30]. Another aspect of WPC's positioning strategy is acknowledging the high upfront cost of their products, but claiming a lower cost over the products' lifetime (lower "ownership costs"), especially when considering the "high

maintenance costs” associated with solid wood decking products. WPC advertisements also highlight the innovation occurring in the WPC industry [29], using innovative terminology (“patent pending,” “new,” “improved,” “exclusive,” etc.) and/or imagery (“new product design,” “application options”). This focus on innovation differentiates the WPC industry from the traditionally conservative wood products industry and indicates an emphasis on customers. According to the results of this study, perceived advantages of WPCs among professional consumers includes low maintenance requirements, high durability, appealing aesthetics, and wide availability (Table 5) (the perception index calculated for these attributes was 4.2 for *Need for Maintenance*, 4.4 for *Durability*, 4.0 for *Aesthetics*, and 4.2 for *Availability*, with numbers closer to 5.0 indicating a perceived high performance).

This study found the main perceived disadvantage of WPCs among professional consumers was high cost (Table 5), with a perception index of 2.0 out of 5.0. Another potential weakness of WPCs is that some end consumers prefer the look and feel of solid wood products, and may be willing to trade the perceived higher maintenance costs of solid wood products for their quality and aesthetic advantages. A 2015 study exploring user perceptions of “naturalness” found users were quickly and easily able to recognize WPCs as significantly less natural than other wood products and gave them less favorable ratings for this attribute [68].

Since their introduction, WPCs have been aggressively marketed as having better performance and environmental qualifications than pressure treated lumber. However, a 2011 life cycle assessment (LCA) study comparing ACQ pressure treated lumber with WPCs found that pressure treated lumber’s environmental impacts were fourteen times lower for fossil fuel use, nearly three times lower for water use as well as greenhouse gas and smog emissions, and had almost half of the ecological toxicity impact of WPCs [69]. The amount of non-renewable resources and non-recycled content used in a WPC product directly affects its environmental impacts.

SWOT ANALYSIS OF THE THERMALLY MODIFIED WOOD INDUSTRY

A SWOT Analysis (Table 6) was conducted to identify the strengths, weaknesses, opportunities and threats to the TMW industry. This analysis is based on the information presented in previous sections, including a literature review of prior studies, data analysis from this research, and industry input from interviews conducted in July of 2017. It is a market planning method that can evaluate these four elements for the TMW industry by identifying the internal and external factors that are favorable or unfavorable to achieving industry objectives. Below is a definition for each of the four letters in the SWOT Analysis acronym, when considering TMW and/or the TMW industry.

- *Strengths*: Internal characteristics of TMW and/or the TMW industry that give it an advantage as an industry.
- *Weaknesses*: Internal characteristics of TMW and/or the TMW industry that place it at a disadvantage relative to others.
- *Opportunities*: External elements in the environment that may allow the TMW industry to build up its strengths.
- *Threats*: External elements in the environment that may pose potential problems or risks for the TMW industry.

Table 6. SWOT Analysis of Thermally Modified Wood (TMW). Items are sorted in order of importance and relevance, determined with industry input.

Strengths
<ul style="list-style-type: none"> • Non-toxic • Sustainable, when made with timber from sustainably managed forests • Thermal treatment gives wood a darker, exotic appearance • Improved durability compared to untreated material • Real, solid wood with authentic, natural appearance • Enhanced dimensional stability • Treatment is homogenous throughout the wood cross-section • Can be used indoors and outdoors • Less material needed long-term due to longer service-life • Durability, aesthetics, and price comparable to tropical hardwoods • Recyclable • Can use both hardwoods and softwoods
Weaknesses
<ul style="list-style-type: none"> • Low level of awareness among both intermediate and end consumers • Increased brittleness • Lack of process and quality consistency among different producers • Perception that TMW not widely available • Lack of product standards • Perception of high price relative to alternatives • Potential for waste due to wood splitting • Must be installed properly to account for potential dimensional changes after installation
Opportunities
<ul style="list-style-type: none"> • Increasing consumer preference for environmentally-friendly products • Growing concerns over use of chemicals in everyday products • Growing concerns for illegal logging, particularly in tropical countries • Potential market segment not highly sensitive to price (potential for high margins) • Ability to use underutilized and local timber species, such as aspen • Very high valued-added applications, such as musical instruments and gunstocks • Price competitive with imported tropical hardwoods • Growing preference for “low maintenance” materials for decking products • TMW association could combine resources to advance industry • Ability to utilize species affected by invasive species, such as ash • Growing export markets, especially for high-end solid wood products
Threats
<ul style="list-style-type: none"> • New to market, with established products such as WPCs, tropical hardwoods, and naturally durable softwoods

Strengths

The internal strengths of the TMW industry that give it an advantage over other materials include improved performance properties, such as an increased durability and dimensional stability. Thermal treatment also changes the chemical composition of the wood in a way that its acoustics resemble naturally aged wood, often prized for musical instruments. Additional enhanced properties of thermal modification treatment are noted in Table 7. The treatment, which is homogenous throughout the thickness of the wood (i.e., it is not just a surface treatment), also allows TMW to be used for indoor and outdoor applications. Many people also consider the dark color of TMW to be comparable to tropical hardwoods; this is often seen as an advantage in some applications, such as wood flooring. Another advantage of TMW is that it is a solid wood product, as many consumers prefer the authentic aesthetics of real wood. Because it is made of solid wood, TMW can be recycled or burned for energy; it is also a

sustainable product when harvested from properly managed forests. TMW is a versatile material that has the potential to utilize both hardwood and softwood species. Finally, it should be noted that TMW is a fairly new product in the U.S., which appeals to some customers simply because it is trendy and innovative.

Table 7. Some of the positive impacts on wood properties from thermal treatment.

Property	References
Reduced equilibrium moisture content: less swelling and shrinking due to moisture	[70], [71], [72], [73], [74], & [75]
Improved resistance to biological decay	[71], [76], [73], & [75]
Darkening of color throughout entire thickness, often resembling the look of tropical hardwoods	[77], [71], & [72]
Reduced emissions during use due to elimination of many volatile compounds	[72]
Improved dimensional stability	[70], [71], [76], [73], [74], & [75]

Weaknesses

The internal weakness of the TMW industry that put it at a disadvantage compared to other materials includes negative impacts on the wood properties from thermal treatment (Table 8). The thermal modification treatment does not eliminate common problems found in traditional solid wood products such as checking, color changes from sunlight exposure, and some moisture-induced dimensional changes. Low UV stability leads to graying of the wood when it is exposed to exterior environments, but there are coatings that can be applied to TMW to increase its UV stability which minimizes color change and graying. Another weakness of TMW is the low level of awareness among end users, as well as a perception of low availability among intermediate users. TMW is also currently more expensive than some other material alternatives, which limits it to certain segments of consumers. A lack of product performance standards and process and quality consistency among different producers is also potentially problematic. Finally, it is important for TMW to be installed properly to account for potential dimensional changes after installation. While TMW is more dimensionally stable than non-thermally-treated wood, it can still have some swelling due to moisture.

Table 8. Some of the negative impacts on wood properties from thermal treatment.

Property	Reference
Increased brittleness and cracking	[76]
Decreased mechanical strength, including reduced bending strength when subjected to static and dynamic loads	[19]
Spotted appearance on the surface due to exudation of rosin	[76]
Low UV stability, leading to graying of the wood when exposed to exterior environments	[76]

Opportunities

The external opportunities that the TMW industry may take advantage of include a competitive price with imported tropical hardwoods in a market segment that is not highly sensitive to price. There is also an opportunity to form an industry-focused TMW association to combine resources to grow the industry. In addition, consumer preferences are shifting towards environmentally friendly products and low maintenance materials. Consumer concerns are growing over use of chemicals in products and illegal logging, particularly in tropical countries. TMW has the potential to use underutilized local timber species such as aspen, as well as timber species that have been affected by invasive insect species, such as ash. Finally, there are currently growing export markets for high-end solid wood products, such as musical instruments and gunstocks, which are two product applications where TMW is used.

Threats

The external threats in the environment that may cause problems for the TMW industry include the newness of TMW products in the market and the already-established competition, such as WPCs, tropical hardwoods, and naturally durable softwoods. In addition, a threat to TMW in the past has been misleading/inaccurate claims made about its performance, particularly that it is a “maintenance-free” material.

MARKETING STRATEGY RECOMMENDATIONS

This section contains marketing strategy recommendations for the U.S. Thermally Modified Wood (TMW) industry that are based on primary and secondary data. Primary data consists of professional consumer perceptions, collected as a part of this research, which was described in detail in the results section. Secondary data includes previous research on the topic. The marketing strategy focuses on the U.S. TMW exterior decking products industry, including manufacturers and distributors; however, the recommendations presented are broad in scope and are useful for the TMW industry in general. Information in this section includes a value proposition, market segmentation, positioning, product and pricing information, and promotional and distribution recommendations. These suggestions were formed using data from previous studies, as well as the recent study conducted by the authors.

Value Proposition

TMW has the potential to regain some of the lost market share of solid wood decking products because it provides a chemical-free and sustainable alternative to competing materials. This research revealed professional consumers perceive TMW to have good *Durability, Environmental Performance, and Aesthetics*. These attributes will become increasingly preferred as consumers demand natural-looking and environmentally friendly products. TMW can be differentiated from pressure treated lumber by its chemical-free treatment. It can be differentiated from tropical hardwoods by the potential to utilize domestic/local timber from sustainably managed forests, while having similarly attractive aesthetics. Finally, the differences between TMW and WPCs that should be emphasized are the natural look and feel of solid wood, as well as superior environmental performance according to LCA studies.

Positioning

TMW is a chemical free treatment that improves the dimensional stability and decay resistance of wood species that would not normally be suitable for outdoor uses, and is aesthetically pleasing as a result of the treatment.

There are many benefits of TMW that are highlighted by positioning it as a chemical-free, solid wood product. Unlike WPCs and pressure treated lumber, it does not contain petrochemicals. When harvested from properly managed forests, wood is a sustainable and widely available resource in the U.S.

Some producers interviewed for this study consider that TMW should also be positioned as a “modified wood” product, including it with other modified wood products such as acetylated wood and furfurylated wood. By combining these products into a larger segment, it allows consumers to gain a better understanding of what TMW is.

In addition, TMW can potentially occupy similar market space as tropical hardwoods. Tropical hardwoods are heavy and sometimes difficult to work with, and their prices are volatile. One of the TMW producers interviewed noted that because there is not a high level of familiarity and knowledge about tropical hardwood species, this sometimes leads to confusion and in the

worst cases, using species with inadequate properties. Industry representatives also claimed that locally-sourced TMW can solve some of these issues.

Finally, it is important for the TMW community to develop a common positioning message as an industry. Many of the marketing issues with TMW have been a lack of inconsistent positioning and message about its performance.

Market Segmentation

Segmentation is a marketing technique that divides the market into groups of customers with common needs and characteristics, called market segments, and develops marketing strategies for each group, thus increasing customer satisfaction and market share in specific segments. Segmentation allows companies to use resources more effectively by targeting specific market segments and linking customer needs with product benefits, thus allowing companies to compete on factors other than price. The current study used responses from a survey on professional users of decking products to conduct a market segmentation exercise. Sawtooth Software [78] was used to identify three distinct groups of customers, based on their attitudes and preferences. Segments are identified by converting data into a “purchase probability,” which is understood as “utility effects.” These utility effects indicate the magnitude of consumer preference for each individual attribute level. Attribute levels with positive effects indicate it adds to the overall utility of the product, while attribute levels with negative effect indicate it “takes away” from the overall utility of the product. Importantly, the segments listed are an example of how the results from a market segmentation exercise can be utilized to formulate better strategies. Segmentation analysis is a way to section data by dividing participants into subgroups with different preferences and determining the part-worth utilities for each of those subgroups.

Segment 1

Segment 1 comprises 22% of the total sample, and two-thirds of this group described themselves as “Deck Specialists” or “Remodelers,” while no “Architects/Designers” were included in this segment (Table 9). This segment had a large percentage of respondents from smaller companies, with 55% working for businesses who employ 9 people or less. The most common locations where companies in this segment operated included the Northeast (41%) and Midwest (32%). This segment had the highest percentage of respondents who use WPCs for at least some of their projects (91%) and no respondents in this segment reported using TMW for their projects (Table 9). Segment 1 strongly preferred WPCs over other materials, with the highest “utility effect” compared to TMW, pressure treated lumber, and naturally durable softwoods. Members of this group consider *Material* the most important attribute, while they are least concerned with *Durability* and *Material Cost* of all three segments, and have the lowest preference towards environmental certification (Table 10). It is not anticipated that this segment can be effectively targeted by the TMW industry because of its strong preferences towards WPCs and weak preference for products with high environmental performance.

Segment 2

Segment 2 comprises 53% of the total sample and 77% of this group described themselves as “Deck Specialists” or “Remodelers,” with 89% indicating that at least some part of their companies’ business is in remodeling (Table 9). This segment had the largest number of respondents from smaller companies, with 63% working for businesses who employ 9 people or less (Table 9). Regions where companies in this segment operate include the Northeast (40%) and the South (21%). Familiarity with TMW was lowest in this segment, with 49% of members reporting little or no familiarity with TMW (Table 9). Importantly, of all segments, this group was least concerned with *Material* and placed the highest importance on *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification* (Table 10). Although this segment was more neutral on *Material* than the other two segments, respondents in this group did demonstrate the highest utility effect for TMW compared to other materials (Table 10). This segment had a higher sensitivity to price compared to the other two segments. This price sensitivity is consistent with Segment 2 having the highest number of members (70%) utilizing pressure treated lumber for at least some percentage of their products (Table 9).

Segment 2 is a largely price-sensitive group, comprised of members from small companies who frequently utilize pressure treated lumber, despite viewing it least preferentially among all materials included in the survey. Although this segment was the least aware of TMW overall, those members with some knowledge of TMW indicated the most positive perception of all three segments. For this reason, a positioning statement focused on this segment should aim to emphasize the similarities between pressure treated lumber and TMW, such as both being a solid wood material and enhanced resistance to biodegradation because of treatment. Then, TMW can be differentiated from pressure treated lumber by its sourcing of domestic species. Before this group begins to utilize TMW, it will be important to overcome the negative perception of TMW *Availability* and *Material Cost*. For this reason, this segment will likely be a secondary market segment to adopt TMW after Segment 3.

Segment 3

Segment 3 comprises 23% of the total sample and contains the largest percentage of “Wholesale/Retail/Distribution” and “Architect/Design” members of all three groups (Table 9). This group has the highest proportion of people with at least some percentage of their business in single-family new construction (78%), multi-family new construction (39%), and commercial construction (52%) (Table 9). Segment 3 reported having the most companies with operations across the entire U.S. (26%), and some international business (Table 9). In addition, 91% of Segment 3 members reported being “Very familiar” or “Somewhat familiar” with TMW and 13% use TMW for at least some percentage of their projects, which was the highest of the three groups (Table 9). This segment also had the lowest percentage of members using WPCs for at least some percentage of their projects (61%) (Table 9) and have the lowest utility for WPCs and pressure treated lumber among all three segments. *Material* was the most important attribute for this segment and they have favorable perceptions of tropical hardwoods and naturally durable softwoods, with a neutral perception of TMW (Table 10).

Segment 3 is comprised of wholesalers, architects, and designers who consider *Material* to be the most important attribute for decking products and prefer tropical hardwoods, followed

by naturally durable softwoods. A positioning statement that emphasizes the similarities between TMW and tropical hardwoods, such as similar aesthetics and price, will be important to increase market share of TMW among customers in this segment. Also, there is opportunity to gain market share in this segment by stressing the growing number of environmentally-conscious customers who are concerned with illegal logging in tropical countries, and suggesting TMW as an alternative to tropical hardwoods because of its non-toxic, recyclable, sustainable, and "local" nature. This group will unlikely be as affected by the negative perceptions of TMW having low availability and high costs as the other segments may be. For these reasons, this segment should be the first to be targeted.

Table 9. Demographic information for the three segments generated. For questions where more than one answer was allowed, percentages may add up to more than 100%.

	Segment 1	Segment 2	Segment 3
Relative Segment Size	22%	53%	23%
Respondent Profession			
Deck Specialist	41%	34%	13%
New Construction	14%	15%	13%
Remodeling	27%	43%	17%
Manufacturing	18%	8%	13%
Wholesale, Retail, Distribution	9%	13%	30%
Architect/Design	0%	6%	17%
Other	9%	11%	17%
Size of Company			
4 or fewer Employees	41%	55%	26%
5-9 Employees	14%	8%	13%
10-24 Employees	5%	11%	17%
25-49 Employees	36%	6%	26%
50-99 Employees	0%	9%	4%
100 or more Employees	5%	11%	13%
Type of Company Business			
Remodeling	86%	89%	74%
Single-Family New Construction	50%	68%	78%
Multi-Family New Construction	23%	26%	39%
Commercial	41%	34%	52%
Institutional	14%	11%	17%
Other	9%	9%	22%
Location of Company's Operations			
Midwest	32%	19%	30%
Northeast	41%	40%	30%
South	14%	21%	17%
West	5%	13%	13%
Entire U.S.	9%	13%	26%
Other	5%	8%	13%
Familiarity with TMW			
Very Familiar	23%	21%	30%
Somewhat Familiar	36%	30%	61%
Not very Familiar	36%	34%	9%
Haven't Heard of it	5%	15%	0%
Decking Materials Used			
Naturally Durable Softwoods	18%	45%	52%
Pressure Treated Lumber	45%	70%	30%
Tropical Hardwoods	18%	40%	65%
TMW	0%	4%	13%
WPC	91%	81%	61%
Plastic	41%	25%	26%
Other	5%	6%	4%

Table 10. Part-worth utilities for individual attribute levels rescaled to “zero-centered differences” for comparability.

	Segment 1	Segment 2	Segment 3	Overall Market
Relative Segment Size	22%	53%	23%	100%
Overall Attribute Importance				
<i>Material</i>	74%	15%	63%	28%
<i>Need for Maintenance</i>	8%	10%	5%	9%
<i>Durability</i>	4%	34%	7%	31%
<i>Material Cost</i>	8%	30%	16%	22%
<i>Environmental Certification</i>	7%	11%	9%	10%

Product

According to research, TMW has enhanced properties that makes it a suitable application for products such as decking, siding, flooring, pergola, and fencing products such as fence rails that do not come in direct ground contact. These enhanced properties include reduced equilibrium moisture content, improved resistance to biological decay, and improved dimensional stability [70, 76].

TMW also has desirable acoustical characteristics because it resembles the sound and structure of naturally aged wood, including reduced damping, sound velocity, “radiation ratio” and the sound properties of naturally-aged wood [79]; thus it may also be used for some musical instruments. Other applications include gunstocks [23], pool cues, saunas and other bathroom furnishings, entry doors, outdoor kitchen wood, and outdoor furniture as a replacement for the tropical wood teak. In addition, TMW may be utilized for specialty products by architects who are interested in the aesthetic appeal of the material.

These products can be made from a variety of hardwood and softwood species that have been thermally-treated. Common softwood species used for TMW include red pine (*Pinus resinosa*), southern yellow pines, and eastern white pine (*Pinus strobus*). Common hardwood species used for TMW include ash (*Fraxinus sp.*), yellow poplar (*Liriodendron tulipifera*), elm (*Ulmus sp.*), maple (*Acer sp.*), cherry (*Prunus sp.*), oak (*Quercus sp.*), sweetgum (*Liquidambar styraciflua*), and eucalyptus (*Eucalyptus sp.*) [23].

Price

There is currently limited information on TMW prices in the U.S., but producers interviewed by Espinoza et al. [23] indicated TMW is a high-end product and likely users will not be in a price-sensitive segment of the market. One producer of TMW noted that prices are comparable to tropical hardwoods and naturally durable softwoods and should be positioned as a high-quality product. One website currently lists prices of a TMW brand to be between \$2.56 and \$5.88 per lineal square foot, which places it within the approximate price ranges of tropical hardwoods and WPCs [80]. Industry members interviewed for this report stated that there is opportunity for TMW to compete with cedar in outdoor applications.

Results from this study indicate professional consumers currently perceive TMW prices to be high, but not as high as tropical hardwoods or WPCs (Figure 5). In addition, results from this study and previous research on professional consumer perceptions of decking attribute importance has consistently shown price is less important than attributes such as *Durability* and *Aesthetics* for the customers in which TMW would compete [32, 34, 40, 41]. For this reason,

price should not be a limiting factor in TMW success. Future research should explore professional consumers' willingness to pay for TMW to understand specific target price points for TMW producers.

Promotion

TMW should be promoted as a high-quality product by emphasizing its *Durability*, *Aesthetics*, and *Environmental Performance*. It can be positioned as a domestic alternative to tropical hardwoods because they share many attributes, including a dark, rich color. However, it will be important to distinguish TMW as domestically-sourced, which may appeal to consumers.

Promotional Goals

The promotional strategy for TMW should consider that awareness among both professional and end consumers is still relatively low, and these groups will most likely be unfamiliar with TMW's performance and attributes. It will be important for TMW industry promotion to include a mixture of stimulating demand to create awareness and increase knowledge, as well as enhance industry image through advertising, personal selling, and sales promotion, which includes displays at trade shows [81]. In addition, this research demonstrated that respondents who examined TMW decking samples in-person tended to develop positive perceptions about this material. This suggests the need to participate in trade shows and other events where products could be prominently displayed.

Promotional Mix

The most commonly used promotional channel for current TMW producers is through company websites [23]. If a TMW association is established in the U.S., a website promoting TMW with links to specific companies would be a powerful tool for consumers to learn more about the material and increase awareness. Another potential promotional tool for increasing awareness would be advertising in industry trade magazines targeted at industry professionals (such as *Professional Deck Builder*).

A promotional channel that would be beneficial to producers would be having a presence at expo and trade show events across the U.S. to increase awareness among professional consumers. Appendix 3 offers a list of expo and trade show events targeted at professional consumers that would be beneficial for TMW producers to exhibit their products.

Distribution

Channels of distribution allow for efficient product transport from producers to consumers and the development of these distribution channels will be essential to the market success of TMW. Results from this study indicate deck industry professionals currently believe TMW is not easily available. This lack of availability may be a primary reason the U.S. TMW industry has not expanded more rapidly. Given the small current size of the industry, establishing relationships with wholesalers and architects may be beneficial to increase awareness and make it easier to match expected product supply with demand from the target market.

The geographical coverage of current TMW producers includes five companies in the Midwest, three in the South, three in the Northeast, and two in the West [23]. This distribution of producers makes market potential in the Midwest easier, but results of this study indicate professional consumers in that region currently have the lowest preference for TMW.

CONCLUSIONS

Significantly more research has been conducted on the technical and performance aspects of TMW compared to its market potential. This research sought to address some of these gaps by identifying decking industry member perceptions of TMW using conjoint analysis, a marketing research tool used to understand how consumers make product selection decisions. A survey was administered to decking industry members using a computer-based questionnaire containing demographic, user perceptions, and conjoint analysis questions at a trade show event called the “Deck Expo” and online. This primary data was then analyzed and used along with secondary data from previous research to compile the recommendations in this marketing plan.

Key findings of this research support results from previous studies that a majority of decking industry members work for smaller companies, employing between one and four people. In general, respondents currently utilize a wide range of decking materials for their projects, but the two materials most frequently used are wood-plastic composites (WPCs) and pressure treated lumber. Over half of respondents are “Very familiar” or “Somewhat familiar” with TMW, but a considerable number also reported little to no familiarity with TMW, which suggests an opportunity for educating and informing this professional audience about TMW.

This research found *Durability* and *Aesthetics* to be the two most important attributes to professional consumers at this time, with *Cost of Materials* and *Environmental Performance* being less important. Overall, professional consumers surveyed for this research currently demonstrate a preference for WPCs and tropical hardwoods, and seem to have mixed perceptions of TMW. This is likely the result of unfamiliarity with TMW due to insufficient marketing efforts.

Three market segments were identified based on the results from this research. One of these segments is unlikely to readily adopt TMW but the other two segments have the potential to adopt TMW if effective marketing strategies are utilized to position the material correctly. The first of these two potential adopter segments is comprised of wholesalers, architects, and designers. They have the highest current familiarity with TMW and prefer tropical hardwoods more than all the other decking materials considered in this study. For this segment, it will be important to differentiate TMW as a more environmentally-friendly alternative to tropical hardwoods that has similar aesthetics and price attributes. The second of the two segments with potential for TMW adoption is comprised of remodelers who currently use pressure treated lumber for many of their projects, but show dissatisfaction with it compared to other decking materials. This segment currently has the lowest familiarity with TMW, so a positioning statement focused on this segment should aim to increase awareness of TMW while first emphasizing the similarities between pressure treated lumber and TMW, such as TMW’s solid-wood nature and its enhanced resistance to degradation as a result of treatment. TMW can be differentiated from pressure treated lumber by its potential sourcing from domestic forests and its improved dimensional stability.

Specific recommendations for positioning TMW were made, as well as suggestions on specific strategies for product, price, promotion, and distribution. An industry situational examination resulted in a SWOT Analysis for TMW (Strengths, Weaknesses, Opportunities, and Threats).

The data collection methods of the research that led to this marketing plan had limitations, including the potential for self-selection and regional bias. In addition, the data set used was not based on a randomized sample of the population of interest, which means that the conclusions from this study cannot be statistically generalized to the entire target population of professionals in the decking industry. Finally, this marketing plan is intended to benefit the U.S. TMW industry and its communities and does not make recommendations specific to individual companies.

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APPENDIX 1. THERMALLY MODIFIED WOOD PRODUCERS WORLDWIDE

Table 11. List of TMW producers worldwide by country. Information from: Feng [82] and Scheiding [83].

Country	Producer	Website
Austria	Eiterbichler Zipf	www.hotholz.at
	Mafi Holzverarbeitung GmbH	https://mafi.com/en
	Mirako	http://www.mirako.at/index.php/en/
	Stia AG	www.stia.at
	Thermoholz Aberger KG	www.thermoholz-aberger.at
	Tilo GmbH	www.tilo.at
Brazil	VAP Holzsysteme®	N/A
China	Dongli Wood Industry	http://www.020dongli.com/
	Jizhong Industry	http://www.shizhong.com/
	Nature International Group Ltd.	http://nature86.com
	ChenLu	http://www.chenlumuye.com
	LvZe	http://muguaban88.com
Canada	Bois Perdure	http://www.perdure.com/
	Kisis	http://www.kisistechnologies.com/
	Weston Premium Wood	http://westonpremiumwoods.com/
Czech Republic	X-Hotwood	http://www.x-hotwood.com/
	FHS Frisch (bei Plzen)	N/A
	TimelessTimber	N/A
Denmark	Celloc	http://celloc.dk/
	Moldrup Systems Pte Ltd	http://www.moldrup.com/
Estonia	Brenstol Oü	http://thermory.com/
	HaServ Oü reola	http://www.haserv.ee/et/
	Priit Pütt Oü	http://www.hardwood.ee/en/
	Thermoarena Oü	http://thermoarena.com/
Finland	Sahakuutio Oy	http://www.sahakuutio.fi/fi/etusivu/
	Heinolan Ruskopuu Oy	http://www.ekoaspen.com/etusivu
	HJT-Holz Oy	http://www.hjt-holz.com/thermoholz/
	Metsä Wood	http://www.metsawood.com/
	Oy Lunawood Ltd	http://www.lunawood.com
	Stora Enso Wood Products	www.storaenso.com
	SWM-Wood Oy	http://www.swm-wood.com/en/swm-wood-2/
	Suomen Lämpöpuu Oy SLP	http://www.suomenlampopuu.com/en/
	UPM Kymmene Oyi	http://www.wisaplywood.com/fi/Pages/Default.aspx
France	Eurochêne	http://www.eurochene.com/
	Ducerf	http://www.ducerf.com/
	CRITT Bois	http://www.crittbois.com/
	BOISBMT	http://www.dumoulin-bois.fr/
	KIT FORET	N/A
	Stabilprocess	http://fr.stabilprocess.com/
	Retiwood	N/A
	Jouen Frères	http://www.jouen-freres.fr/
	Sivalbp S.A.	http://www.sivalbp.fr/
Germany	MHD Menz Holz Design GmbH	N/A
	Holzindustrie Templin	http://www.hitemplin.com/
	Firstwood GmbH	http://www.firstwood.de/index.php
	Holzbodenwerk Krottenthaler	http://www.holzbodenwerk.de/

Country	Producer	Website
Germany	Timura Holzmanufaktur GmbH	http://www.timura.de/
	BES Bad Essener Säglwerk	http://www.bad-essener-saegewerk.de/
	OWI GmbH	http://www.owi-lohr.de/
	JEP HARDWOOD FLOORING	http://www.jep-parkett.de/
Italy	Florian Legno	http://www.florianinc.com/en/
	WDE Maspell	http://www.wde-maspell.com/
Japan	Koshii & Co. Ltd.	http://www.koshii.com/
Latvia	TermoWood Ex	http://www.termowoodex.com/
Lithuania	UAB Volunta Parket Vilnius	http://www.voluntaparket.lt/
Netherlands	Elder-oak	https://www.elder-oak.com/
	Firmolin Technologies Ltd	http://www.firmolin.com/index.php/nl-nl/
	Platowood	http://www.platowood.com/
New Zealand	Tunncliffe's	http://www.tunncliffes.co.nz/
Norway	Marnar Bruk Royal	http://marnarbruk.no/
Poland	TARTAK Stephen	http://www.tartakstefan.pl/v2/index.php
Portugal	Atlantic Wood	http://atlanticwood.pt/
	Palsar	http://www.palsar.eu/
Romania	J.F. Furnir SRL, Brasov	http://www.jffurnir.com/en/
Russia	Sudoma Sawmill	http://en.sudomasawmill.com/
Slovenia	Silvaprodukt	http://en.silvaprodukt.si/
Spain	De Buena Madera	http://www.grupo-gamiz.com/
	Thermogenik	http://www.thermogenik.com/index.php
Sweden	Heatwood	http://www.heatwood.se/en/
	Thermoplus AB	N/A
Switzerland	Balz Maschinen AG	http://www.balz-holz.ch/
	ETS Röthlisberger SA	http://www.corbat-holding.ch/
Turkey	NovaWood	http://www.novawood.com/
	Arin Orman	http://www.arin.com.tr/
	NasWood	http://www.nasreddingroup.com/
U.K.	Brimstonewood	http://www.brimstonewood.co.uk/
U.S.	Thermory USA	http://www.thermoryusa.com/home
	EcoVantage	http://www.ecovantagewood.com/
	Bailey Wood Products	http://www.baileywp.com/
	Cambia	http://www.cambiaaewood.com/
	Arbor Wood Co.	http://arborwoodco.com/
	Northland Forest Products	http://www.northlandforest.com/
	Pakari	http://www.pakaritmd.com/
Superior ThermoWood®	N/A	

APPENDIX 2. MANUFACTURERS OF THERMAL TREATMENT EQUIPMENT

Table 12. Most common brands of thermal modification kiln providers in North America and Europe that provide both "open" (non-pressurized) and "closed" (pressurized) systems.

Company/Brand Name	Type of System	Country of Origin	Website
Jartek	Open (ThermoWood®)	Finland	http://www.jartek.fi/main-page
Luxhammer	Open (ThermoWood®)	Finland	http://www.luxhammar.com/
Valutec	Open (ThermoWood®)	Sweden	http://www.valutec.ca/
Mahild Drying Technologies	Open	Germany	http://www.mahild.com/index.php/en/
MEC Torrefaction	Open	Canada	http://www.mectorrefaction.com/company.html
Westwood	Open	United States	http://www.westwoodcorporation.com/
WTT	Closed	The Netherlands	http://www.wtt.dk/products/thermo-treatment
FirmoLin Technologies	Closed	The Netherlands	http://www.firmolin.com/index.php/en/
Huber Holz	Closed	Austria	http://huber-holz.at/

APPENDIX 3. LIST OF INDUSTRY-FOCUSED TRADE SHOWS AND EXPOS

American Institute of Architects (AIA) Conference of Architecture

- About: Every year, the AIA Conference on Architecture attracts thousands of architects and design professionals—a collection of talented and visionary individuals who are dedicated to improving the quality of life for all people in all communities.
- Upcoming Dates and Venue: Javits Center, New York, NY. June 21st-23rd, 2018.
- Website: <http://conferenceonarchitecture.com/>

Construction Super Conference

- About: The Construction SuperConference, now in its 32nd year, is recognized as the preeminent construction conference developed for mid- to senior-level professionals who work in any of the legal and commercial construction markets. Impactful plenary sessions and compelling panel discussions from top legal, consulting, and leaders of construction companies bring to the forefront challenging issues and new insights into the legal, business, and economic challenges and opportunities in today's construction industry. Participants will walk away with invaluable information and resources to assist them in meeting today's challenges. The conference will showcase many notable and expert in-house and outside construction counselors and consultants who will take up the many challenges of advising construction industry participants in a challenging economy. The program design of the conference allows ample opportunity to meet and network with representatives from the leading construction firms and the industry's top construction attorneys.
- Upcoming Dates and Venue: The Encore at Wynn- Las Vegas, NV. December 4th-6th 2017.
- Website: <http://www.constructionsuperconference.com/>

DeckExpo

- About: Remodeling Show | DeckExpo | JLC LIVE (R|D|J) is an annual trade-only residential construction mega-event that provides remodelers, deck builders, and other industry professionals with a vibrant exhibit hall filled with nearly 300 products and services from leading industry manufacturers, a strong educational conference program with business and job site training, and networking events every day of the event. Among the hundreds of exhibitors, the exhibit hall features LIVE installation clinics presented by leading industry professionals, interactive, hands-on workshops, and instructional exhibitor-led product demonstrations. Forge new relationships with product manufacturers on the exhibit hall floor, fellow construction professionals in the educational conference sessions, and during social functions like the Welcome Party, NAHB event, and other less formal get-togethers during the week.
- Upcoming Dates and Venue: Music City Center- Nashville, TN. October 25th-27th, 2017.
- Website: <https://remodelingdeck.com/>

East Coast Builders Conference (ECBC)

- About: The East Coast Builders Conference is today's residential building, remodeling and construction industry "must attend" conference event offering meaningful education that will help you enhance and advance the future for your company, shareholders, employees and your clients. Featuring educational tracks on Building, Remodeling, Design, Business and Kitchen and Bath, the ECBC sessions within these tracks will take a deep dive into current topics, such as Aging in Place, Technology, Legal, Subs & Trades and Marketing. Can't make it for a full day? Don't worry, watch our website as we will be adding mini educational sessions that will take place throughout the Exposition days! Join us at the ECBC in Atlanta, the only educational offering on the East Coast that offers you the opportunity to expand your knowledge, share your ideas, learn from your peers and help shape the future of the industry
- Upcoming Dates and Venue: Cobb Galleria Centre- Atlanta, GA. May 4th-5th, 2017.
- Website: <http://ecbcshow.com/>

FENCETECH

- About: The American Fence Association has been serving the fence, deck, railing and security industry since 1962. AFA is the largest and most comprehensive resource in the industry for the latest developments, tools, materials, standards, trends and discounts. FenceTech showcases products like aesthetic appearance of modern fence products, wood fence materials and accessories, gate operators & access control, security fence and access control, stainless steel cable, rod, mesh, and specialty products etc. in the Industrial Products, Security & Defense industries.
- Upcoming Dates and Venues: Phoenix Convention Center- Phoenix, AZ. February 5th-9th, 2018.
- Website: <http://www.americanfenceassociation.com/fencetech/>

Greenbuild International Conference and Expo

- About: "All In" encompasses the breadth of the sustainability and green building movement. Capturing all people, all sectors, all industries, all buildings, all cities and so much more, this theme welcomes everyone to grow as green building champions, and to do so at Greenbuild. When we come together at Greenbuild, we are one community of professionals, advocates and practitioners, students and teachers, designers and builders, and everything in between. We are all in. We invite people from every walk of life, from all over the globe, to learn with us and to help elevate green building principles and practices to the next level. "All In" also describes the depth of commitment we feel to our community and to our mission. We leave no stone unturned in our pursuit of what's next — new technology, new ideas and new ways forward. We are dedicated to transforming the market and changing the way the people all over the world experience buildings. We are all in.

- Upcoming Dates and Venue: Boston Convention and Exhibition Center- Boston, MA. November 8th-10th, 2017. McCormick Place (West Building)- Chicago, IL. November 14th-16th, 2018. Georgia World Congress Center- Atlanta, GA. November 20th-22nd, 2019.
- Website: <https://greenbuildexpo.com/>

International Builders Show™ (IBS)

- About: The International Builders' Show is organized by the National Association of Home Builders (NAHB) and is the largest light construction building industry tradeshow in the United States.
- Upcoming Dates and Venue: Orange County Convention Center- Orlando, FL. January 9th-11th, 2018.
- Website: <https://buildersshow.com/Home/>

International Woodworking Fair (IWF)

- About: The International Woodworking Fair is one of the top woodworking trade shows in the world for the furniture manufacturing, architectural woodwork, custom and general woodworking industries. Companies exhibiting at IWF include manufacturers, suppliers and retailers from the wood, plastic and related material processing industries. This premium trade show attracts thousands of visitors looking for the best technologies, supplies and products to support their ventures.
- Upcoming Dates and Venue: Georgia World Congress- Atlanta, GA. August 22nd-25th, 2018.
- Website: <http://www.iwfatlanta.com/>

Pacific Coast Builders Conference (PCBC®)

- About: Dedicated to advancing the art, science and business of housing, PCBC is the largest homebuilding tradeshow representing the west coast region. Launched in 1959 as a small educational conference at the Sheraton Palace Hotel in San Francisco, PCBC is now an annual two-day conference, product display and business exchange and is open to anyone professionally involved in the building industry, including builders, developers, architects, remodelers, designers, contractors, dealers/distributors and suppliers/manufacturers. In the past, PCBC was an acronym for "Pacific Coast Builders Conference". Over time the name became an inaccurate reflection of the audience, as the show now draws attendees from all over the United States, Canada, Mexico and more than 25 other countries. Today the show is known simply as PCBC. PCBC alternates each year between San Francisco and San Diego and has been endorsed as the official show of Leading Builders of America (LBA), whose membership includes 20 of the largest publicly and privately held homebuilders in the nation.
- Upcoming Dates and Venue: Moscone Center- San Francisco, CA. June 26th-28th, 2018 and May 28th-30th, 2019.
- Website: <http://www.pcbc.com/>

Sunbelt Builders Show™

- About: The Sunbelt Builders Show™ is one of the largest building industry events in North America and is owned and operated by the Texas Association of Builders. The award-winning Show draws thousands of residential construction industry professionals from the United States, Canada and Mexico to more than 200 exhibit booths. Additionally, the Show features special networking events, keynote speakers, quality educational sessions and a solid sales and marketing atmosphere. Imagine an event powerful enough to lead an industry and reshape communities across the region. Imagine a gathering of thousands of residential construction professionals from every sector of the housing industry. Every year, more than 2,000 leaders in single and multi-family building, remodeling, land development, finance and management come together to share the latest information, exchange ideas, and foster lasting personal and professional relationships.
- Upcoming Dates and Venue: Hilton Anatole- Dallas, TX. August 2nd-3rd, 2017.
- Website: <http://www.sunbeltbuildersshow.com/home>

Woodworks™: Wood Products Council

- About: WoodWorks offers a wide range of in-person and online training opportunities, from Wood Solutions Fairs that include concurrent seminars and a trade show, to half-day workshops, lunchtime seminars and webinars.
- Website: <http://www.woodworks.org/events-calendar/upcoming/>

APPENDIX 4. RESOURCES

Natural Resources Research Institute (NRRI)

- About: Focuses on delivering research solutions to balance the economy, resources, and environment for resilient communities. Possesses unique Thermally Modified Wood R&D capabilities.
- Address: 5013 Miller Trunk Hwy Duluth, MN 55811
- Website: <https://www.nrri.umn.edu/>
- Email: nrriinfo@d.umn.edu
- Phone: (800) 234-0054 and (218) 778-2694

Forest Products Management Development Institute (FPMDI)

- About: Seeks to increase knowledge of wood products production and use, and associated issues strategies, and technologies on the part of forest products industry employees, key forest products consumer groups, and those involved in shaping national and regional forest policy.
- Address: Kaufert Lab 2004 Folwell Ave. St. Paul, MN 55108
- Website: <http://fpmdi.bbe.umn.edu/>
- Email: oaespino@umn.edu

U.S. Forest Service Forest Products Laboratory

- About: Mission is to identify and conduct innovative wood and fiber utilization research that contributes to conservation and productivity of the forest resource, thereby sustaining forests, the economy, and quality of life.
- Address: Forest Products Laboratory One Gifford Pinchot Drive Madison, WI 53726
- Website: <https://www.fpl.fs.fed.us/index.php>
- Email: mailroom_forest_products_laboratory@fs.fed.us
- Phone: (608) 231-9200